Title Evaluating connection to nature and the relationship with conservation behaviour in children.

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Key words

Assessment, connection, monitoring, evaluation, Connection to Nature Index

Abstract

'Connection to nature' is a multidimensional trait thought to be important for developing positive conservation behaviours, and strengthening people's connection to nature has become the focus for many conservation activities. A connection to nature may be developed through repeated engagement with nature, and experiences during childhood are thought to be particularly significant. However, many children today are considered to have a low connection to nature, presenting a critical challenge for the future of nature conservation. Several instruments have been developed for measuring connection to nature. These instruments are important for establishing current levels and thresholds of connection and evaluating efforts to improve connection, yet the

23 way the instruments and the derived scores relate to the term 'connection' frequently used in
24 conservation discourse has, so far, been overlooked. In this study, we interrogate Cheng et al's
25 (2012) Connection to Nature Index (CNI) and develop a refined "gradient of connection" based on
26 the instrument structure, proposing boundaries of low (below 4.06), mild (between 4.06 and 4.56)
27 and strong (over 4.56) connection that are relevant for conservation activities. Furthermore, we
28 show how the suggested boundaries relate to self-reported conservation behaviours with a high
29 probability of performing behaviours (> 70%) only reached at strong levels of connection. Our data
30 show that, in agreement with current perceptions, the population of UK children surveyed have a
31 low connection to nature and are unlikely to be performing many conservation behaviours. This
32 demonstrates how the index can be used to measure and evaluate connection in populations in a
33 way that will enhance future conservation efforts.

1. Introduction

The term 'connection to nature' is frequently used to describe aspects of our attitude towards nature, primarily representing the affective element of the human-nature relationship along with cognitive and behavioural components (Cheng & Monroe, 2012; Kals & Müller, 2012; Kals, Schumacher, & Montada, 1999; Mayer & Frantz, 2004; Tam, 2013). One route to conservation success requires changing human behaviour (Schultz, 2011) and, although attitudes are not the only factor that may influence behaviour (Kollmuss & Agyeman, 2002), a strong connection to nature is thought to be an important driver to promote positive conservation behaviours, be they pro-nature (Richardson, Cormack, McRobert, & Underhill, 2016) or pro-environmental behaviours (Collado, Corraliza, Staats, & Ruíz, 2015; Frantz & Mayer, 2014; Geng, Xu, Ye, Zhou, & Zhou, 2015; Hinds & Sparks, 2008; Richardson & Sheffield, 2017). Connection to nature is considered to be critical for the future of nature conservation as people with little connection to nature are less likely to be concerned by, and act against, its disappearance (Kareiva, 2008; Miller, 2005; Soga & Gaston, 2016; Swaisgood & Sheppard, 2011). Increasing urbanisation, in conjunction with increasing amounts of technology for entertainment, means that people are spending less time in the outdoors, in nature (Kareiva, 2008; Pergams & Zaradic, 2008; Soga & Gaston, 2016). The reduction in contact with nature is considered one of the reasons why people are often unengaged with current conservation issues (Miller, 2005). For example, surveys state 68% of the UK population is unaware or unconcerned about biodiversity loss (Defra, 2016). Increasingly, attention is being paid to connecting people to nature, exemplified by the inclusion of statements on connecting people in the UK government 25 year plan for the environment (Defra, 2018). Increasing people's connection to nature has become a goal for many conservation projects and organisations, under the assumption that there is a level of 'connected' that means a person will be more likely to act positively for conservation throughout their lifetime. To assist evaluation of projects, to inform debate, activities and research, and to demonstrate effective use of limited conservation resources there is a need to

define and clarify what is meant by the term 'connected', and to help provide evidence on whether improving nature connection leads to greater success in achieving conservation goals.

Much commentary and research around connection has focussed on children (Louv, 2008; Miller, 2005). The widely held perception is that today's children are deprived of contact with nature and are disconnected (Louv, 2008; Miller, 2005; Soga & Gaston, 2016). We rely on the current generation of children for future conservation action, as connecting children to nature aims to assist their development into adults that enjoy nature-based activities and are motivated to behave positively towards the environment (Asah, Bengston, & Westphal, 2012; Miller, 2005). However, more clarity is required about how to define a connected child and what this means for conservation (Cheng & Monroe, 2012; Zylstra, Knight, Esler, & Le Grange, 2014).

While specific target behaviours may be linked with particular attitudes, research has shown that, in the UK, identities are related to more general pro-environmental behaviour across different domains (Gatersleben, Murtagh, & Abrahamse, 2014). Connection to nature is a measure of people's relationship with nature, their values and identity and, therefore, widely hypothesised to be indicative of general pro-conservation behaviours across different contexts. Connection to nature is a subjective and multi-dimensional construct, describing affective aspects of an individual's emotional relationship with nature, influenced by cognitive and behavioural components (Tam, 2013; Zylstra et al., 2014). Connection to nature depicts an individual's enduring relationship to nature and their perception of belonging to a wider natural community (Cheng & Monroe, 2012; Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009; Zylstra et al., 2014), variously expressed as involving feelings of freedom and safety (Kals et al., 1999), sense of identity (Olivos & Aragonés, 2011; Schultz, 2002), enjoyment, oneness, empathy and responsibility (Cheng & Monroe, 2012; Kals et al., 1999; Olivos & Aragonés, 2011).

Studies on connection to nature in children have found that connection encompasses such dimensions as a sense of enjoyment, membership of the natural world, oneness or kinship, empathy

and responsibility that individuals may feel with or towards nature (Cheng & Monroe, 2012; Ernst & Theimer, 2011). The pathway from connected child to connected adult is not clear but there is evidence that childhood nature experience leads to adulthood connection (Wells & Lekies, 2006), with interactions with nature, peers and learning environments being significant (Prévot, Clayton, & Mathevet, 2016; Stevenson et al., 2014). For example, research on American and Norwegian adults with environmental careers revealed an interest in nature that developed with repeated nature experience, from playing to more structured learning, in comparison to those in non-nature careers (Chawla, 1999; James, Robert, & Carin, 2010) while, in New Zealand, nature-based recreation in early years increases the likelihood of participation as an adult (Lovelock, Walters, Jellum, & Thompson-Carr, 2016).

Connection to nature has correlated positively with human health and wellbeing variables, both physical and psychological (Richardson, Maspero, et al., 2016; Soga & Gaston, 2016; Zelenski & Nisbet, 2014; Zylstra et al., 2014), indicating there may be personal benefits to be gained from experiencing nature. Behaviour change theory suggests positive or negative emotions can be an important factor in determining behaviours, so it is necessary to address emotions in order to elicit desired behaviours (Cane, O'Connor, & Michie, 2012). The emotional aspect of the human relationship with nature is indeed considered a factor affecting pro-environmental behaviour (Kollmuss & Agyeman, 2002) and some studies have shown that environmental attitude, and an emotional affinity to nature, link to positive behaviours (Frantz & Mayer, 2014; Geng et al., 2015; Kals et al., 1999). For example, Collado et al. (2015) showed that environmental attitude mediated the relationship between frequency of nature contact and positive environmental behaviour for children in urban and rural environments in Spain, while in China contact with nature increased children's willingness to conserve wildlife (Zhang, Goodale, & Chen, 2014) and US students with greater connection to nature use less electricity (Frantz & Mayer, 2014). Furthermore, there is evidence that childhood experiences of camping, hiking, playing in woods or picking flowers is positively related to protective environmental behaviours in adults (James et al., 2010; Wells &

110 Lekies, 2006). The positive relationship between connection to nature and conservation behaviour
111 suggests that increasing the level of connection in the population, particularly in children, could
112 encourage more conservation behaviour, the desired outcome for conservation success.

113 A number of instruments are available to measure connection to nature, which give a connection
114 score for the individual (Zylstra et al., 2014). Instruments include, for example, the Connection to
115 Nature Scale (Mayer & Frantz, 2004), the Nature Relatedness scale (NR and short-form NR-6; Nisbet
116 & Zelenski, 2013; Nisbet, Zelenski, & Murphy, 2009) and Inclusion of Nature with Self (INS; Schultz,
117 2002), Environmental Identity scale (Clayton & Opotow, 2003), Emotional Affinity to Nature scale
118 (Kals, Schumacher, & Montada, 1999) and the Connection to Nature Index (CNI; Cheng & Monroe,
119 2012). Commonalities between instruments reveal a broad all-encompassing construct, with
120 divergence between the various measures and analyses due to the different emphasis on affective,
121 cognitive or behavioural components (Bragg, Wood, Barton, & Pretty, 2013; Tam, 2013; Zylstra et al.,
122 2014). In addition to differences in the aspect of connection being measured, there are differences
123 between instruments in how scores are calculated, so, what do these score mean and what scores
124 are required to catalyse conservation behaviours? In this study we investigate whether it is possible
125 to objectively determine conservation-relevant scores based on the instrument's structure.

126 Apart from the CNI, instruments have been developed for use with adults rather than children. A
127 comparison between three instruments, the CNI, INS and NR-6, revealed the CNI to be the most
128 preferred measure for children, demonstrating high internal consistency and being the measure
129 both easiest to comprehend and preferred by 8-12 year old respondents (Bragg et al., 2013).
130 Although this scale has been used in a number of studies, firstly, little is known about how the
131 instrument scores relate to the concept of being connected enough to be concerned about
132 conservation issues, or secondly, how scores relate to performing positive conservation behaviours.
133 This research had 2 aims: Aim 1) to determine an objective scale of connection to nature, as
134 measured by the CNI, which makes the instrument more relevant to conservation outcomes, and

Aim 2) to examine the relationship between our level of connection and self-reported conservation behaviours, separated into environment and nature behaviours, among children. Specifically, for Aim 1) we defined a connected child as one that would respond to the instrument statements more frequently in the positive than negative, and hypothesised therefore that a threshold for connection can be established by determining when children are more likely to be positive about nature than neutral or negative, then for Aim 2) we hypothesised that increasing connection in school children would correlate with increasing self-report performance of positive conservation behaviours. Finally, we relate the responses given to the CNI with self-report behaviours in order to analyse whether our criteria for connection developed in Aim 1 can identify those acting for conservation.

2. Methods

2.1. Determining connection

For Aim 1) we investigated the CNI score distribution. For the first step we examined the distribution of all possible CNI scores to determine levels of connection to nature based on a CNI score. The CNI is a 16-item index (Table 1) with each item rated on a 5-point Likert scale from Strongly Disagree to Strongly Agree and subsequently scored 1-5. An overall CNI score is calculated as the mean of the 16 scores. Higher overall CNI scores represent greater connection to nature. The CNI range and distribution was calculated from all combinations of responses to the 16 items. There are 4845 possible combinations of 1-5 scores for the 16-item CNI, resulting in overall CNI scores ranging from 1 to 5 in increments of 0.0625. There is only one way of achieving a CNI score of 1 or 5 but there are 177 combinations that lead to a CNI score of 3, the distribution mean.

For the second step, we examined the relationship between overall CNI scores and frequency of positive responses (Agree /Strongly Agree) to each of the 16 items. For a criterion-based approach to determine connection we assumed that a positive response to an item was an indication of a connection to nature. A statistical norm-based approach was considered but given the current perception of low connection to nature among children (Louv, 2008; Miller, 2005), norm-based

boundaries would not necessarily reflect a level of connection that met conservation definitions, and would be necessarily arbitrary and subjective. Instead, we proposed the following criteria: low connection was when negative/neutral answers were predominant in the responses; mild connection to nature would be demonstrated by a child giving positive responses more frequently (at least nine positive responses), and strong connection was defined as when a child responded "Strongly Agree" most frequently (at least nine times). In line with the multi-dimensional and subjective character of the connection to nature construct, this analysis does not interrogate responses to individual items but defines connection based on the overall score.

2.2. Connection and Behaviour

For Aim 2) we collected real data from UK-based school children. Data for this study were collected from 775 children aged 10-11, in 15 schools in central England over three months during 2015. Schools were recruited through opportunity sampling of schools dispersed across the East Midlands region in the UK. The schools ranged in their extent of designated nature areas on the school grounds and dedicated clubs to gardening and nature preservation. For example, one school had an outdoor education practitioner who promoted outdoor education and forest schools, whilst children there could also work towards John Muir Awards and the RSPB's Wildlife Action Awards. As part of a larger study on children's lives and nature experience, the children were asked to respond to the CNI and to 13 questions about their pro-conservation behaviour. Tinsley and Tinsley (1987) suggest a ratio of 5 - 10 respondents per item, therefore the sample size of the study (n = 775) was regarded sufficient. In addition to the overall CNI score, the CNI provides information on four subscales (Cheng & Monroe, 2012): enjoyment, empathy for wildlife, sense of oneness and sense of responsibility. CNI and subscale scores for each individual were calculated from the relevant items. In this study the CNI was found to have a high internal reliability score (Cronbach's $\alpha = .84$), similar to that obtained in previous research ($\alpha = 0.87$: Cheng & Monroe, 2012).

There are a number of ways of acting positively for the environment and nature that can be considered to be conservation (Clayton, 2012). We distinguished two groups of behaviours: pro-environmental behaviours being more general behaviours around resource use and energy saving, and pro-nature behaviours as activities focussed on wildlife-oriented actions that mentioned identifiable groups such as birds or insects. Five and eight questions on behaviours relevant to children were asked for pro-environmental and pro-nature behaviours respectively. An individual's pro-environmental behaviour was measured using five items previously employed by Collado and Corraliza (2015) gauging whether children carry out environmental behaviours such as switching off lights to save energy (Table 2). Children responded using a 5-point Likert scale, ranging from 1 (completely disagree) to 5 (completely agree). The pro-environmental behaviour measure was found to have fair internal reliability ($\alpha = 0.74$), identical to the original study (Collado & Corraliza, 2015). Probability of an individual undertaking pro-nature behaviour was assessed through dichotomous responses to eight items (Table 2). As a suitable previously used set of questions could not be identified, the questions were developed for the study through collaboration between RSPB staff and psychology researchers at the University of Derby. The questions were devised to ask young children about a range behaviours they could be reasonably expected to be performing to benefit nature, and that may benefit specific wildlife groups, or their membership of wildlife-related organisations. The questions have also been used successfully in further research (Richardson, Cormack, et al., 2016). The Kuder-Richardson 20 formula for binary variables shows the pro-nature items have reasonable internal reliability (KR20 = 0.60).

Research met University of Derby Research Ethics Committee standards and adhered to the British Psychological Society ethical guidelines. Permission was obtained from the school's head teacher, with each school expressing an interest to take part informed that the school would receive thank you gifts from the RSPB. Consent letters were sent to parents of the participants through the school, outlining the purpose of the research, giving them the opportunity to request that their child did not

complete the questionnaire and detailing the child's right to withdraw their data for one month after completion.

Questionnaires, numbered to ensure respondent anonymity, were handed out to each year 6 class (10-11yr olds) in register order then the researcher was introduced and briefly outlined the questionnaire and process. Children were told that their parents had given consent for them to take part and were informed of their right to stop at any stage. They were assured that their responses were confidential and that there were no wrong answers, and thus not a test.

Questionnaires were completed in the classroom. The majority of year 6 children who participated were able to comprehend the questions without any problems, although some sought clarifications and assistance with details, for example ethnic group. In some schools there was support from a teaching assistant, although the responses were the children's own. Once all children in a class had completed the questionnaire, they were collected and the children were thanked. Children were then provided with a research debrief informing them the questionnaires were for the RSPB, who were looking at the relationship between children's engagement with nature, their well-being and behaviour and their participation had earned some rewards for their school.

2.3. Are the CNI and connection criteria a valid measure for identifying likelihood of conservation behaviour?

The probability data on children's pro-nature behaviour was used to classify children as positive actors for conservation at two levels: firstly at a conservative >0.5, then at a more stringent >0.70. Receiver Operating Characteristic (ROC) curves and the Area Under the Curve (AUC) were calculated in order to determine the quality of the CNI, and thresholds proposed in this study, as a test to discriminate between individuals more and less likely to act positively for conservation. ROC curves are based on the relationship between sensitivity (proportion of true positives) and specificity (proportion of true negatives) that a test identifies at different test scores. The AUC value ranges

from 0 to 1 and gives a measure of how well a test performs as opposed to chance (AUC=0.5). Šimundić (2009) recommends the AUC can be used to classify tests as: bad (0.5-.06), sufficient (0.6-0.7), good (0.7-0.8), very good (0.8-0.9), and excellent (0.9-1.0). This process was repeated for the pro-environmental probability data using the same probability levels of >0.5 or >0.7 to indicate those acting positively for conservation.

2.4. Data analysis

All data analyses were conducted in R (R Core Team, 2016). For Aim 1) examination of the mean CNI distribution and distribution of positive scores in relation to CNI were carried out using built-in R functions (Crawley, 2007).

For Aim 2) initial data examination revealed that 50 individuals had not fully completed the CNI, so these individuals were excluded, leaving a sample size of 725. Mean and median CNI and subscale scores were examined in relation to gender and school. A further eight individuals gave incomplete responses to the pro-nature items and the final sample size for pro-nature analyses was 717. Six individuals did not complete the pro-environmental items so the final sample size for these analyses was 719.

To examine whether more connected individuals undertake more pro-nature behaviours, we modelled the probability of pro-nature behaviour in relation to CNI score using binomial logistic regression (Zuur et al., 2009). The dataset was split into a training and a test set with respect to the pro-nature response data, using random number allocation balanced by schools and gender (train, females = 175, males = 184; test, females=170, males = 188). We constructed a generalized linear mixed model (GLMM) with logit link using the glmer function in the R package lme4 (Bates et al., 2015). The full model included CNI, gender, Days Out Per Week (DOPW; a self-report measure of how many times the child had been outside in the last seven days) and school. School was included as a random effect, as was an observation level random effect as the data were overdispersed.

In order to examine the pro-environmental behaviour relationship with CNI, pro-environmental items were dichotomised, with non-positive responses (1, 2, 3) = 0 and positive responses (4, 5) = 1. Our assessment that the neutral answer (3) was non-positive was based on the assumption that this response implied no commitment to carrying out that action. The train and test subsets were balanced across schools and genders (train, females = 190, males = 172; test, females = 159, males = 198). A GLMM with logit link was constructed, with the full model including explanatory variables of CNI, gender, DOPW and school.

The ROC analyses were carried out using the pROC package in R (Robin et al., 2011). ROC curves and AUC values were calculated on the children's data collected under the assumption that individuals were acting for conservation when their behaviour probability score was >0.50. Confidence intervals and median specificity and sensitivity values around the specific threshold CNI values were subsequently calculated from 2000 bootstrap replicates.

3. Results

3.1. Determining connection

The results of the analysis of CNI scores for Aim 1 revealed the instrument's score distribution. Examination of the frequency of positive answers in any individual CNI response set shows that CNI scores of up to 4.00 can be obtained by answering positively to only 50% of the statements which is the lowest score that can be achieved by responding positively to all 16 questions (Figure 1a). Similarly, at a CNI score of 4.50, at least eight responses will have been "Strongly agree" (Figure 1b), while above 4.8125 there are no "Strongly disagree" responses, and at over 4.8750 there are only neutral or positive responses.

Using our definitions of connection to nature (see Methods) low connection is <4.06, mild connection at 4.06≥CNI<4.56, when at least nine answers will have been positive, and strong connection at CNI ≥ 4.56, when at least nine answers were "Strongly Agree". However, it is clear

281 from the distribution of “Agree” and “Strongly Agree” answers that the definitions may be met at
282 lower CNI scores, so a gradation of connection, rather than strict boundaries is recommended. The
283 gradation is represented by the grey scale background in Figure 2.

284 *3.2. Connection and Behaviour*

285 For Aim 2, the CNI distribution of the 725 children was left-skewed (D’Agostino skew = -0.66, z=-
286 6.72, P<0.00; Figure 2) with a median score of 4.06 and mean of 4.00 (s.d. ± 0.55). Given the skewed
287 data, the median is a more appropriate measure of central tendency. There was a significant
288 difference between genders with a higher median CNI score for girls (4.19, mean = 4.14) than boys
289 (3.94, mean = 3.88) and a significant difference between schools (two-way ANOVA: gender,
290 $F_{(1,709)}$=46.62 P<0.00; school, $F_{(14, 709)}$=2.67 P<0.00). Furthermore, gender and school differences
291 could be seen in the four subscales (in order Enjoyment, Empathy, Oneness, Responsibility : Gender,
292 $F_{(1,709)}$=53.01 P<0.00, $F_{(1, 709)}$=31.30 P<0.00, $F_{(1, 709)}$=15.16 P<0.00, $F_{(1, 709)}$=10.52 P<0.00; School, $F_{(1,}$
293 $_{709)}$=3.16 P<0.00, $F_{(1, 709)}$=1.65 P=0.06, $F_{(1, 709)}$=3.13 P<0.00, $F_{(1,709)}$=1.91 P=0.02).

294 Differences between genders and schools were observed in pro-nature behaviours. Girls were more
295 likely than boys to answer positively (median positive answers, girls = 4, boys = 3; anova gender
296 $F_{(1,701)}$=21.82 P<0.00, school $F_{(14,748)}$=3.27 P<0.00) with seven boys and eight girls answering all
297 positively, while 21 boys and eight girls answered negatively to all pro-nature items. No gender
298 difference was seen in positive response to pro-environmental behaviour items, however the school
299 difference persisted (median positive answers, girls = 3, boys = 3; Anova, gender, $F_{(1,703)}$=0.66 P=0.42;
300 school, $F_{(14,703)}$=3.87 P<0.00). The datasets generated during the current study are available from the
301 corresponding author on reasonable request.

302 With the GLMM for pro-nature behaviour, single-term deletions showed that gender and DOPW did
303 not improve the model. Inspection of the residuals indicated that this model was valid and model
304 results show that the probability of positive response to the behaviour statements increased with

increasing CNI score (Figure 3; Table 3). The model was used to fit predicted scores to the test data set and comparison between fitted and observed test data showed that the regression coefficient was not significantly different from 1 ($y = 1.02x-0.021$, adjusted $R^2=0.34$, $t=0.27$ $P=0.79$) indicating good model prediction.

For the GLMM of pro-environmental behaviours, single term deletions showed that CNI, school and gender were significant terms within the model but DOPW did not improve the model so was removed. The final model shows an increasing probability towards positive answers to environmental statements, with a slight difference between genders (Figure 4; Table 3). Using the model to fit predicted scores to the test data set showed the regression coefficient was not significantly different from 1 ($y=0.903x-0.04$, adjusted $R^2=0.35$, $t=-1.47$ $P=0.14$).

3.3. *Are the CNI and connection criteria a valid measure for identifying likelihood of conservation behaviour?*

For pro-nature behaviours there were 508 children with probability of pro-nature behaviour of 0.5 or less, so less likely to be performing the behaviours, and 209 children with probability >0.50. Not all children with a low CNI had low probability of pro-nature behaviour or with a high CNI score had high probability but ROC curve analysis indicates whether the CNI is a justifiable discriminatory tool for behaviours. The ROC curve has an AUC = 0.77 which indicates CNI is a good indicator of likelihood of behaviour (Šimundić, 2009) i.e. that whether children are perfoming behaviours or not can be assessed by their CNI score. At a "connected" threshold value of CNI=4.06, median specificity=0.57 (so 57% of children below the threshold had a probability below 0.5 and were true negatives, while 43% of children below the threshold had a probability over 0.5 and were false negatives) and median sensitivity = 0.79 (79% of children with CNI above threshold had a probability over 0.5 – true positives while 21% were children with CNI above the threshold but probabilities below 0.5 - false positives). At a higher "connected" threshold value of CNI=4.56 the median specificity=0.89 and median sensitivity = 0.40, so more true negatives were correctly classified but fewer true positives.

Raising the bar for the probability of pro-nature behaviour to >0.70 resulted in 621 children not acting for nature and 96 acting for nature with the CNI still demonstrating good discriminatory ability (AUC=0.79). At the "connected" threshold value of CNI=4.06, median specificity=0.47 and median sensitivity = 0.83 while at the higher "connected" threshold value of CNI=4.56 the median specificity=0.85 and median sensitivity = 0.51.

For the pro-environmental probability data, there were 346 children with probability ≤0.5 and 373 >0.5. Again, the AUC = 0.77 which indicates CNI is good test (Šimundić, 2009). At the threshold value of CNI=4.06, median specificity=0.61 and median sensitivity = 0.72. At the threshold value of CNI=4.56 median specificity=0.92 and median sensitivity = 0.29. When the bar for behaviour was raised to a probability of >0.70, there were 509 children below that probability and 210 above that probability with the CNI being classified as a very good test (AUC=0.80). At the threshold value of CNI=4.06, median specificity=0.54 and median sensitivity = 0.77 while at the threshold value of CNI=4.56 median specificity=0.91 and median sensitivity = 0.43.

4. Discussion

Due to the multidimensional nature of connection, defining connected children is subjective. Measures of connection are influenced by the focus on affective, cognitive or behavioural components and the instrument used (Tam, 2013; Zylstra et al., 2014). We have established, under Aim 1, a gradient of connection and general thresholds for determining a connected child as measured by the CNI, a commonly used measure of children's connection to nature (Bragg et al., 2013; Cheng & Monroe, 2012). The range of identical CNI scores that arise from different response combinations means it is difficult to completely separate children that are predominantly positive from those more frequently giving neutral/negative responses. Consequently we propose a relevant gradient of connection. Our results demonstrate that low connection results in a CNI score of 1 to around 4.06, mild connection is around 4.06, rising to strong connection at around 4.56. Under Aim 2, our sample of 725 children from 15 UK schools showed the population had a median CNI score of

4.06 and mean of 4.00, which shows that, on our gradient of connection, the majority of children were positioned around low and mild connection. The ROC analysis showed that the CNI had good discriminatory ability to differentiate between those more likely to act positively for conservation or not. Analysis around our suggested threshold of 4.56 correctly classifies the majority with low probabilities as more poorly connected and, thus, provides a good target for CNI scores in children.

When set against our gradient of connection, the real data used in this research support current perceptions of general disconnection from nature within young people (Louv, 2008; Miller, 2005; Soga & Gaston, 2016). Specifically, 335 children (46%) had low connection (scores below 4.06) and only 128 (18%) had a strong connection (over 4.56). In accordance with this perception, results from the evaluation of environmental education programs in the US show that the majority of students would be considered to have low connection to nature, with only two of 14 groups having a mean CNI over 4.06 (Ernst & Theimer, 2011). In comparison, a study in the UK that surveyed children who were members of a wildlife group or who were present at nature reserves, showed they have a mean CNI score of 4.41$\pm$ 0.39 s.d., indicating mild to strong connection (Bragg et al., 2013). These results support our conclusion of a meaningful gradient of connection, as it detects differences between groups in nature and in the classroom, and that direct engagement with nature is necessary to promote connection.

Encouragingly, the children in this study displayed the hypothesised positive relationship between CNI score and the probability of carrying out pro-conservation behaviours. A positive relationship between connection and pro-environmental behaviours has been seen in previous work (Collado et al., 2015; Frantz & Mayer, 2014; Kals et al., 1999; Zylstra et al., 2014). However, the predicted probability of carrying out pro-nature behaviours did not reach more than 0.5 until the CNI score was over 4.19 (mild connection). Similarly, the predicted probability of undertaking pro-environmental behaviours did not exceed 0.5 until around 4 (3.81 for boys, 4.13 for girls). Even at the maximum connection score of 5, the probability of performing pro-nature behaviour was only

380 0.70 and pro-environmental behaviour 0.82 or 0.89 for girls and boys respectively. Overlaying our
381 gradient for connection with the modelled probability of pro-nature or pro-environmental
382 behaviours, shows that the probability of children with low connection performing pro-nature and
383 pro-environmental behaviours is under 0.5 (Figure 5). The positive correlation between connection
384 and self-reported behaviour supports the notion that the strength of an individual's connection to
385 nature is linked provides a motivation for conservation behaviour, supporting the idea that activities
386 that connect children to nature are, therefore, critical for future conservation success. Conservation
387 requires evidence-based connection activities (e.g. Richardson, Cormack, et al., 2016; Richardson &
388 Sheffield, 2017) that move beyond activities focussed on knowledge of, identification of, and simple
389 contact with nature (Lumber, Richardson, & Sheffield, 2017). However, even high levels of
390 connection to nature, as indicated by the CNI, do not guarantee children will be acting positively for
391 conservation, perhaps unsurprisingly given that attitude is not the only factor affecting behaviour
392 (Kollmuss & Agyeman, 2002).

393 There are a few limitations to this research that would benefit from further investigation. In setting a
394 definition for connection, we have assumed that a broadly positive response set is preferable to the
395 more variable or extreme responses, but our definition of strong connection uses the demarcation
396 of nine "Strongly Agree" responses. Willingness to give an extreme response is affected by factors
397 such as gender, culture and education (Batchelor & Miao, 2016) that are not linked to connection to
398 nature, so our second definition may be unduly penalising some people. Furthermore, individual
399 items were not interrogated. It may be that particular CNI items are more linked to behaviour than
400 others, so a high response for particular items may be preferable rather than overall connection
401 score. A more detailed analysis of the CNI items may reveal the relationship between particular
402 items and behaviour, or it may be preferable to develop a new instrument that focuses on the
403 determinants of conservation behaviour rather than connection to nature. Furthermore, only a small
404 set of potential behaviours was used, which could conceivably misrepresent children who do other
405 activities. However, a list of desired conservation behaviours could be so lengthy that investigating

406 anything more than an individual's general relationship between connection and behaviour becomes
407 intractable. The sample itself is not without its limitations. The data is cross-sectional, with self-
408 report behaviours, so the causal relationship between connection and behaviour is not explicit.
409 These data do not provide information on whether improving connection would alter individual
410 behaviour, but that the two variables are positively correlated. Additionally, the majority of
411 participants identified themselves as white, with a small proportion identifying Black, Asian and
412 Minority Ethnic (BAME) groups. Given that observations in the UK show individuals from BAME
413 communities are less likely to engage with natural environments (Hunt, Stewart, Burt, Dillon, & Joy,
414 2016), further validation of the thresholds need to be undertaken with a more representative
415 sample.

416 Despite the limitations, the analyses presented do provide some interesting directions for future
417 research. There was a gender difference in connection with girls having a higher median connection
418 score than boys, which would place the female population in the mild connection zone while boys
419 predominantly had low connection. The gender differences in connection and behaviour is an area
420 worthy of further study as, in an intriguing contrast, boys were more likely to report carrying out
421 pro-environmental behaviours. The pro-environmental behaviours were measured through a
422 previously designed set of questions, the results from which did not mention any difference in
423 gender (Collado & Corraliza, 2015). However, a tendency towards a gender divide in connection
424 among UK children has been noted before (Bragg et al., 2013). Given gender differences in
425 connection and tendency to more extreme scores (Batchelor & Miao, 2016), it may be that gender-
426 specific measurement of connection, with gender-relevant statements or scoring systems could be
427 useful in the future. The variation in connection and behaviour between schools is also of interest.
428 An analysis, not presented here, indicated no relationship between CNI scores and greenspace
429 surrounding the schools, however, there could be differences related to teacher's willingness to
430 engage outside (Dyment, 2005), the greenspace in the school catchment area or socio-economics of
431 school intake. All these factors may influence behaviour in the local community and school pupils.

The fact that variation was seen at school level, which were similarly located, may indicate cultural and social variation could influence responses and affect comparison between scores among more widely separated populations. Connection to nature, and the relationship with conservation, may be very variable between communities and cultures.

5. Conclusion

For researchers and practitioners interested in nature connection in children, this paper has determined that CNI results are best viewed as indicating a gradient of connection to nature, that the CNI discriminates well between those demonstrating conservation behaviours and therefore high CNI scores (>4.56) are associated with conservation benefits. Therefore this work has implications for any programme that seeks to facilitate pro-conservation behaviours by enabling children to form a connection with nature through an evidence-based approach. This scale, along with our gradient of connection, may be useful in assessment of population baselines on connection to nature and evaluating the progress that programmes may make. Furthermore, connection to nature has been shown to have a positive relationship with conservation behaviour, which adds to the weight of evidence that connecting children to nature is important for the future of conservation (Louv, 2008; Miller, 2005; Swaisgood & Sheppard, 2011).

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586

587 **Figure Captions**

588 **Figure 1. Positive responses to the Connection to Nature Index (CNI).** The frequency of positive
589 responses by overall CNI score, for each of the 4845 possible combination of responses to the CNI.
590 Individual graphs show frequency of a) “Agree” and “Strongly Agree” and b), “Strongly Agree”.

591 **Figure 2. UK children on the gradient of connection.** The distribution of CNI scores for 725 children
592 aged 10-11, from 15 UK schools. Grey scale background and top axis identifies the proposed gradient
593 of connection to nature.

594 **Figure 3. Probability of performing nature behaviours.** Results of mixed effect logistic regression of
595 pro-nature behaviour v. CNI score. Solid line shows model predicted values and dots are observed
596 data from 382 individuals.

597 **Figure 4. Probability of performing environmental behaviours.** Results of mixed effect logistic
598 regression of pro-environmental behaviour v. CNI score. Solid line shows model predicted values for
599 males, dashed line shows model predicted values for females and dots and circles are observed data
600 from 378 individuals.

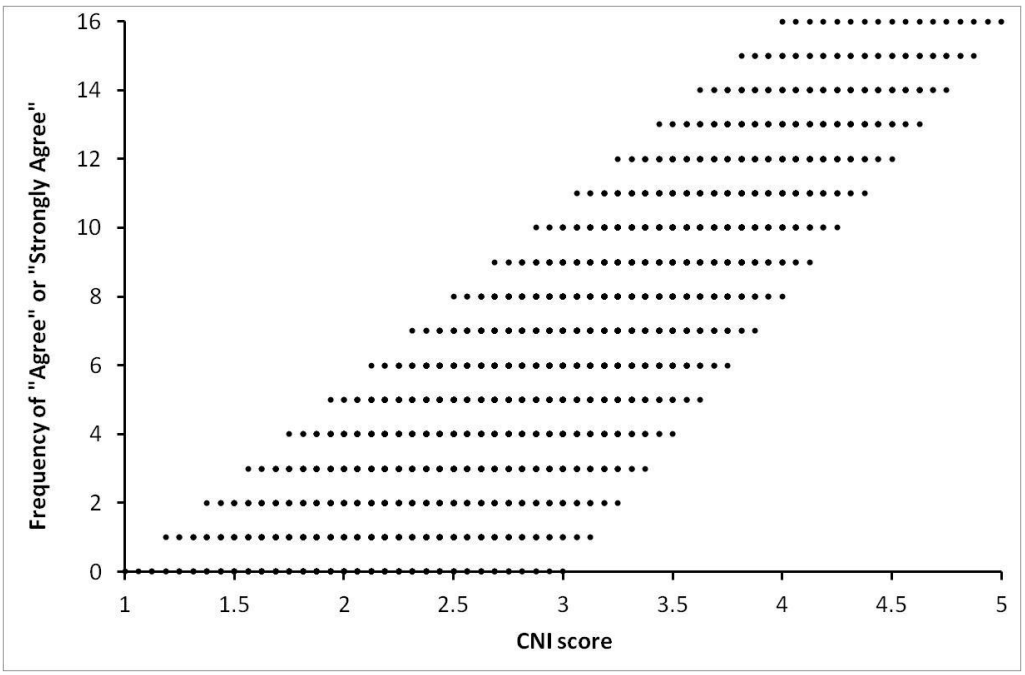
601 **Figure 5. How the probability of performing pro-conservation behaviours relates to connection to**
602 **nature.** Grey scale background shows the gradient of connection from low to mild and strong, solid
603 black line shows the probability of pro-nature behaviour, light grey lines show the probability of
604 pro-environmental behaviour dashed = girls, solid = boys.

605

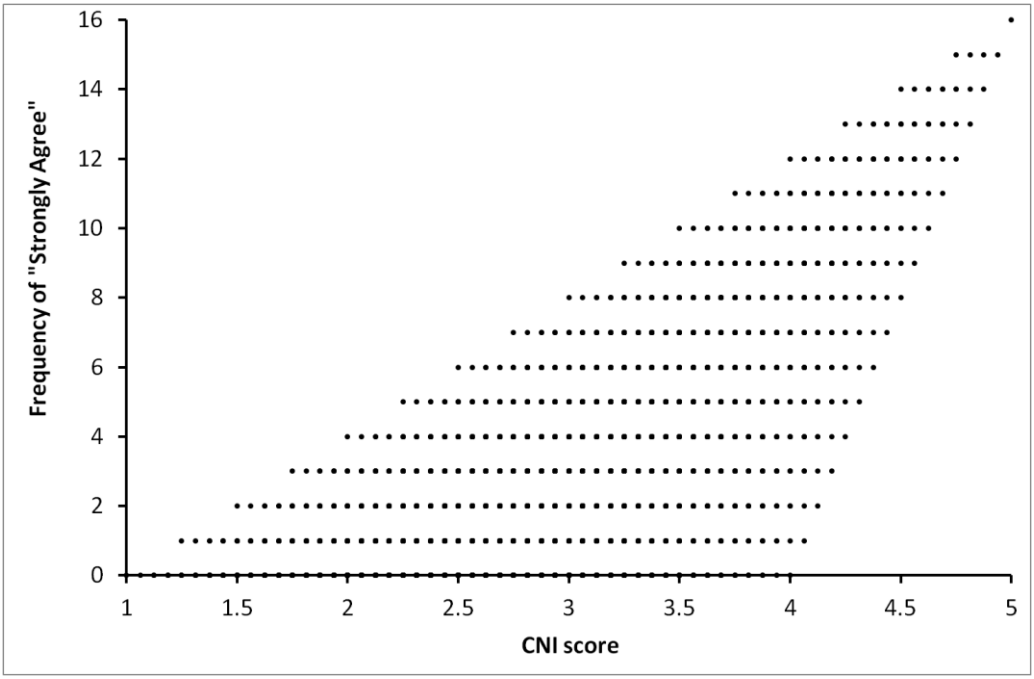
Figures

Figure 1

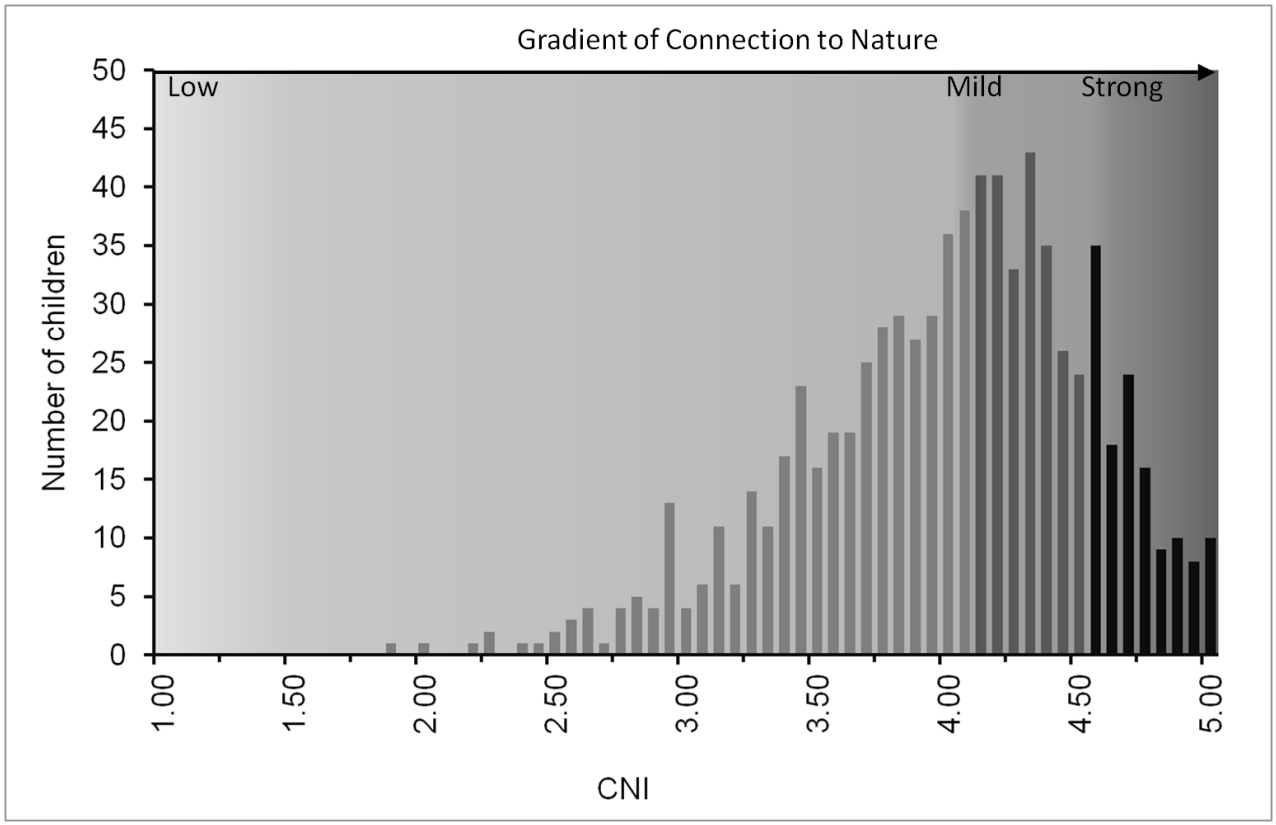
a)



b)

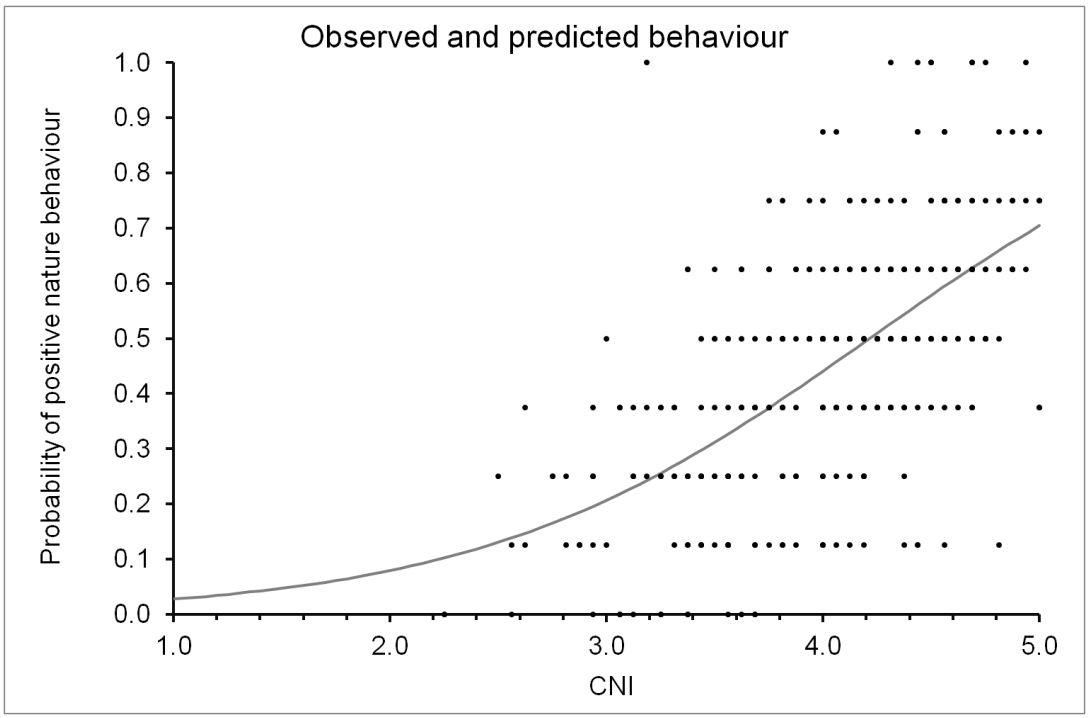


612 Figure 2



613

614 Figure 3



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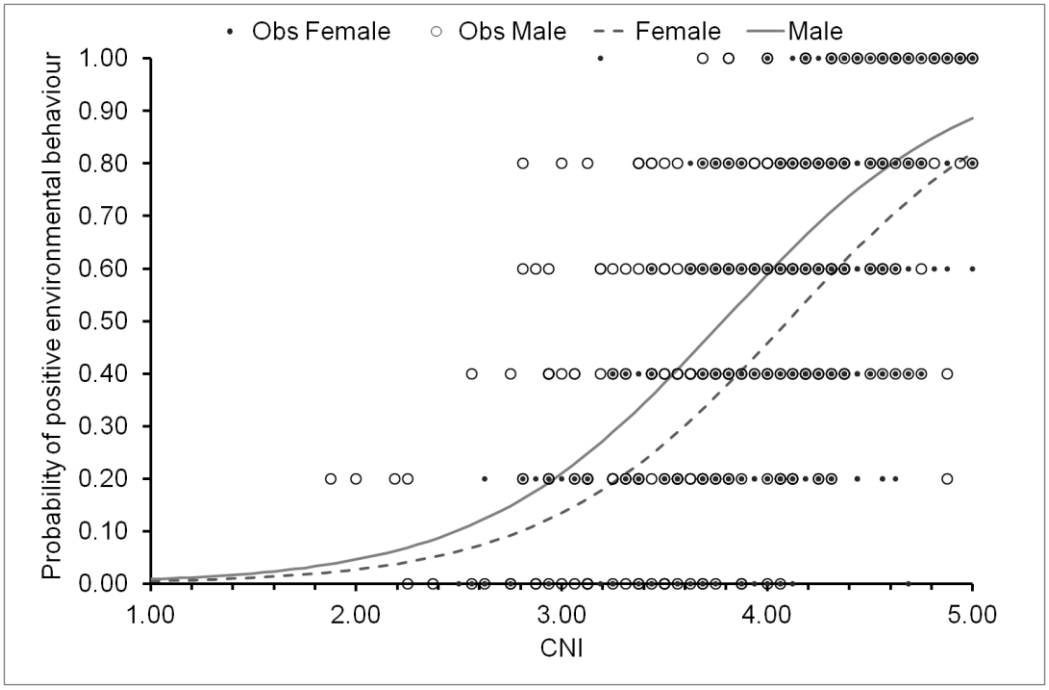
616 Figure 4



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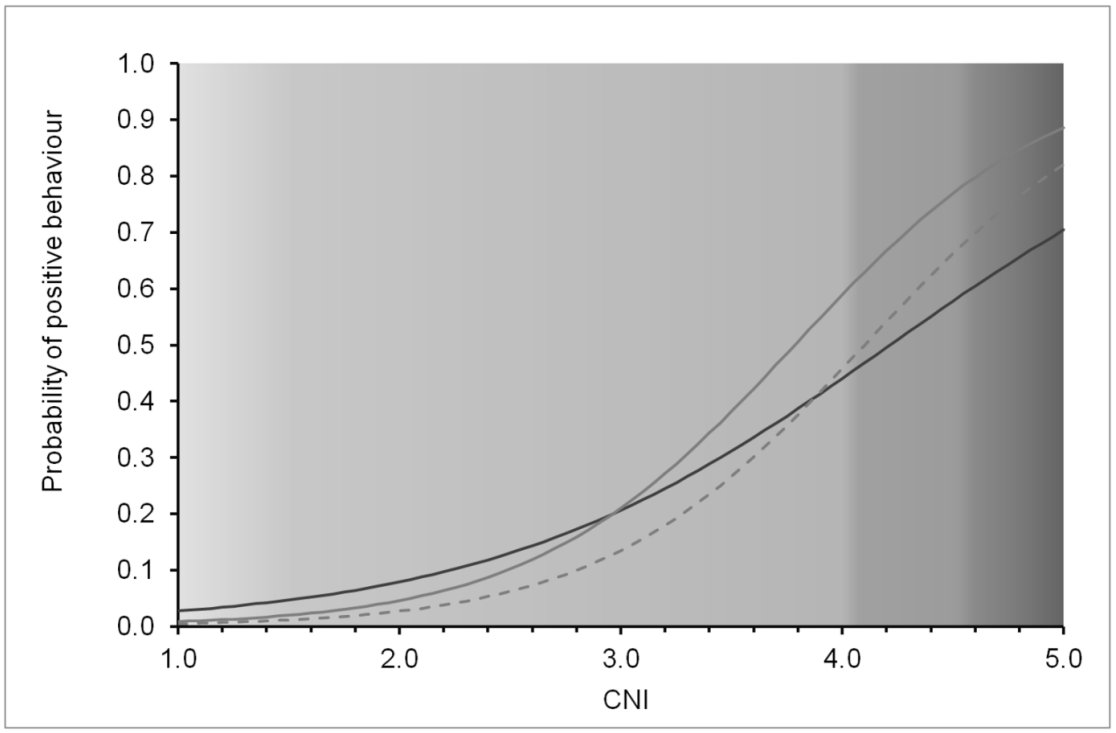
618 Figure 5



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620

621 **Tables**

622 Table 1: *Connection to Nature Index* (Cheng & Monroe, 2012). A 16-item scale developed to measure
623 connection to nature in children. Item responses are Strongly Disagree, Disagree, Neither agree or
624 disagree, Agree, Strongly Agree.

Subscale	Questions included within the subscale
Enjoyment of nature (7 items)	I like to hear different sounds in nature
	I like to see wild flowers in nature
	When I feel sad, I like to go outside and enjoy nature
	Being in the natural environment makes me feel peaceful
	I like to garden
	Collecting rocks and shells is fun
	Being outdoors makes me happy*
Empathy for creatures (4 items)	I feel sad when wild animals are hurt
	I like to see wild animals living in a clean environment
	I enjoy touching animals and plants
	Taking care of animals is important to me
Sense of oneness (3 items)	Humans are part of the natural world
	People cannot live without plants and animals
	Being outdoors makes me happy*
Sense of responsibility (3 items)	My actions will make the natural world different
	Picking up trash on the ground can help the environment
	People do not have the right to change the natural environment

625 *item is attributed to two subscales.

626

627 Table 2: *Pro-conservation behaviours*. Children were asked to respond to the following statements
628 on their current behaviour. For the pro-environmental behaviours children were asked to respond
629 on a five point Likert scale from completely agree to completely disagree. For the pro-nature
630 behaviours children were asked whether they do them or not.

Behaviour group	Items
Pro-environmental (Collado & Corraliza, 2015)	1. I carry out activities to protect the environment
	2. To save water, I use less water when I take a shower or bath
	3. In school, I talk to my teachers and peers about the importance of doing things to protect the environment (e.g. recycling)
	4. At home I help to separate (rubbish) and to recycle
	5. To save energy I switch off the electrical appliances when I am not using them
Pro-nature	1. I put food out to feed garden birds
	2. I make homes for nature at school or in the garden (e.g. bugs, hedgehogs)
	3. I put insects stuck inside, safely outside
	4. I grow flowers and plants that birds and insects will like
	5. I take part in events to help nature (e.g. Big Garden Bird Watch)
	6. I pick up litter to help nature have a better home
	7. I am a member of a wildlife or nature group at school
	8. I am a member of a wildlife or nature group outside of school (e.g. RSPB, Wildlife Trust etc.)

631

632 Table 3: Estimates and results from the generalized linear mixed models examining the relationship

633 between behaviour and connection to nature.

	Estimate	Std. error	Variance	Std. dev	z	P
Pro-nature behaviour						
ID			0.06	0.24		
School			0.00	0.05		
Intercept	-4.67	0.33			-13.96	<0.00
CNI	1.11	0.08			13.62	<0.00
Pro-environmental behaviour						
ID			0.26	0.51		
School			0.06	0.24		
Intercept	-7.02	0.57			-12.35	<0.00
CNI	1.72	0.13			12.80	<0.00
Gender (Male)	0.54	0.13			4.27	<0.00

634

635