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Does Subjective Health Affect the Association between Biodiversity and Quality of Life? Insights from International Data

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Abstract Global health may depend upon biodiversity (BD) for well-being, but evaluation is challenging, as cross-cultural data is scarce. International models of the association between biodiversity (BD) and quality of life (QoL), examined whether subjective health is a mediating factor. The biophilia hypothesis was evaluated. Multi-

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Level Mediation Analysis modelled adult data ($N = 3511$) from 15 countries. Subjective QoL was assessed in six WHOQOL SRPB domains, and subjective health rated. Four area-independent indicators of plant and animal BD were estimated. Poverty (HDI education) was a covariate. Biodiversity was strongly, positively associated with QoL, but subjective health was not a significant mediator in any model. Although spiritual QoL showed best fit, confirming the hypothesis, social, psychological, and independence models were also significant. From nine spiritual components, QoL from hope and optimism showed the strongest model. Furthermore, only hope correlated moderately, positively with BD in mammals, and ferns. This is the first major international study in this field. When judging QoL in relation to BD, people do not take into account whether their health is good or poor. The exclusive biophilia focus on spiritual QoL is unwarranted, deserving a broader multi-dimensional approach. Global policy and the Millennium Ecosystem Assessment are addressed.

Keywords Quality of life · Health · Biodiversity · Evaluation · Wellbeing · Biophilia

Background

The diversity of living things is threatened by environmental impact and human population growth, so studies are needed to understand complex problems connected with climate change. Habitat destruction, chemical pollution, trafficking of invasive alien species and climate change, show little signs of slowing, so contributing to high extinction rates of global and local species (Butchart et al., 2010; Tittensor et al., 2014). Conserving biodiversity (BD) is therefore urgent (Chivian & Bernstein, 2004; Hough, 2014), but knowledge is incomplete about how it links with health and well-being. Recent optimism about rapidly resolving this problem has emerged from new debates on planetary health (Rodin, 2014) which is defined as: "*The health of human civilisation, and the state of the natural systems on which it depends*" (Whitmee et al., 2015).

Many conservation measures involve protecting land and natural resources from exploitation that generate short-term economic growth, so conserving BD can have immediate costs involving trade-offs against well-being and health (McShane et al., 2011; Robinson, 2011). As geographic locations with the richest BD are often less developed economically (Hough, 2014), tension between conservation and development raises equity issues for decision-makers (Parmesan & Skevington, 2010; Parmesan et al., 2009). Conserving BD involves choosing between different economic and political actions that affect personal interests, and may involve ethics. Arguments favoured by conservationists mostly employ utilitarian reasoning, as wild nature conservation is viewed as a win-win situation where benefits ultimately exceed costs (Pierce & Moran, 1994; Ulrich, 1986). As cost-benefit analysis can arise from conservation actions, access to accurate estimates of both is vital, so quality measurement tools are important. It is difficult to determine BD's economic value in terms of its present and future contributions to ecosystem goods and services (Costanza et al., 1997). This is because it involves distant projections, and assumptions about discount rates and the consequences of failing to protect BD from future events like climate change. When justified this way, projects can fall short on expectations (McShane et al., 2011). As implementing conservation measures ultimately depends on popular

sentiment and political will, inadequate justification of expenditure based on results from these types of measures is problematic for the future of BD.

Yet when asked whether BD should be conserved, lay-people believe it holds value (Kellert, 2009), but economic approaches do not work well when applied to emotions about BD (e.g. where monetary value is attached to BD experience). In contrast, E. O. Wilson's "biophilia" hypothesis indicates that people appreciate a biodiverse environment due to an 'inherent preference' for, and affinity with nature (Kellert & Wilson, 1993; Wilson, 1984). As Wilson's hypothesis specifies that spiritual quality of life (QoL) is enhanced by BD, this position does not require reference to secondary assessment of BD's value. An alternative approach would be to investigate spiritual quality of life (QoL) in diverse world locations, with their biodiversity densities. It is plausible that health accounts for some of this association, as health and well-being are closely linked in the literature (e.g. (Mc Dowell & Newell, 1996, Chapter 9). However this model has not been examined with global cross-cultural data. This is important because such evidence could affect international policy-making in both conservation and planetary health fields.

Several factors have impeded progress to date. First, methodological and theoretical exchanges between conservation/environment and health/well-being fields have been limited (Lercher, 2003; Sandifer et al., 2015), until the advent of planetary health (Rodin, 2014). Second, there is weak consensus about how to define key concepts like well-being, QoL, health, mental health, and their subjective and objective dimensions. These terms are often used interchangeably, as though the concepts and their respective measures are synonymous (e.g. in the Millennium Ecosystem Assessment (MEA) (Hough, 2014; Millennium Ecosystem Assessment, 2005; Robinson, 2011; Sandifer et al., 2015). Opaqueness has in turn obscured the process of selecting a suitable measure for policy evaluation or research (Camfield & Skevington, 2008).

Standardized measures of QoL with quality data, were developed by a cross-cultural collaboration originating at the World Health Organisation (WHO) Geneva. The WHO defines subjective quality of life as: '*An individual's perception of their position in life, in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns*' (The WHOQOL Group, 1994). The WHO Quality of Life Spirituality, Religion and Personal Beliefs assessment (WHOQOL SRPB) was developed to investigate spiritual QoL and health in multiple cultures world-wide, through an internationally agreed protocol designed to generate equivalent, culturally-adapted, language versions (The WHOQOL SRPB Group, 2006). Compatible QoL assessment for diverse cultures living in very different environments will be crucial to reliably evaluating the relative success of conservation projects globally, for example, in the Millennium Ecosystem Assessment (MEA) due in 2020.

A recent systematic review concluded that high BD is associated with good health (e.g. mental, cardiovascular), and health-related activities (e.g. exercise) (Lovell et al., 2014). In addition, an extensive body of evidence shows that subjective QoL is positively linked to subjective health (e.g. (Fallowfield, 1990; Hyland, 1992; Staquet et al., 1998). Although each of these two pathways has been separately confirmed, cross-cultural tests of them are limited. It is also not known whether these two pathways would be reconfirmed if assessed together using cross-cultural data. In addition, and more importantly, the empirical association between BD and QoL remains largely

unexplored within an international context. Assessing these three pathways together within one single integrated model is the main aim of the current research. In particular we focus on whether subjective, self-reported health could have a significant mediating effect on the BD-QoL pathway. Do people in this situation make judgements about their subjective QoL with reference to the status of their health? This is also theoretically interesting as health is not currently a formal component of the biophilia model. Moreover where health has been studied, 'objective' indicators (e.g. mortality; life expectancy, body weight), not subjective measures, are commonly applied. The present study progresses the field towards establishing the 'universality' of a fully integrated model, and the findings are strengthened by using international data.

In Fig. 1, the biophilia hypothesis predicts that BD will be positively associated with spiritual QoL. The reverse direction is neither logical nor theoretically grounded. The hypothesis also implies that the fit of the spiritual model will be stronger than for any other QoL domain. Consequently, the model of spiritual QoL is compared with the five others available in the WHOQOL SRPB. Where domain models were either significant, or expected to be significant, facets comprising that domain were also separately modelled, to explore the detail. In addition, we examined whether selected taxonomic indicators from plant and animal BD were positively correlated with spiritual qualities of life.

Methods

Sample and Procedure

Commensurate with Declaration of Helsinki principles, approval for the international study was obtained by the WHO Division of Mental Health and Substance Abuse from

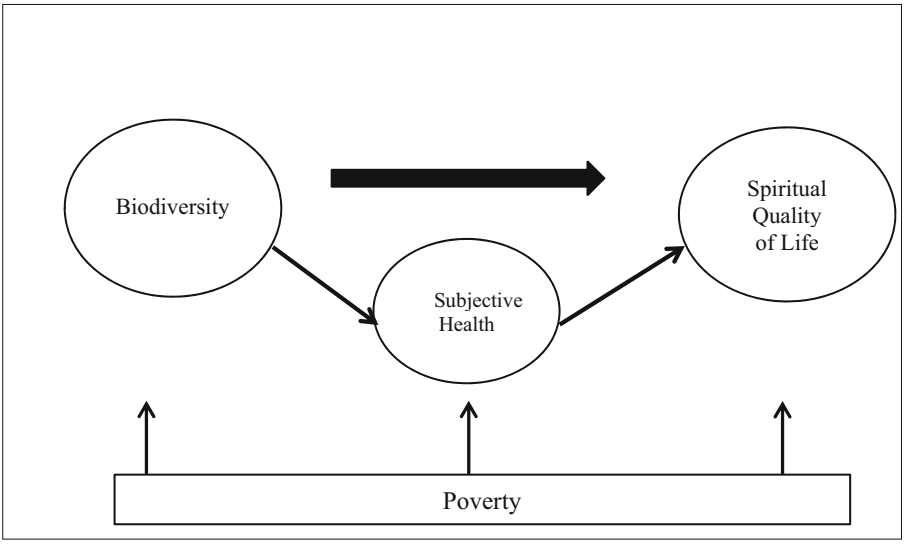

Fig. 1 A model to examine whether the association between Biodiversity and Spiritual Quality of Life is mediated by Subjective Health (with poverty as a co-variate)

the Ethics committee of the World Health Organisation, Geneva. All participating centres also obtained local ethical approval.

The WHOQOL SRPB was completed by 3511 adults (>18 years) living in 15 countries (2001–2002). The predominant religious orientation is shown in brackets: *Africa* - Kenya ($n = 240$; Christian); *Americas* - Argentina ($n = 225$; Catholic), Brazil ($n = 253$; Catholic), Uruguay ($n = 250$; Christian); *Asia* - India ($n = 241$; Hindu/ Muslim), Japan ($n = 43$; Zen Buddhist), Malaysia ($n = 240$; Muslim), Thailand ($n = 188$; Buddhist); *Middle East* - Egypt ($n = 240$; Muslim), Israel ($n = 265$; Jewish), Turkey ($n = 225$; Muslim); *Europe* - Italy ($n = 102$; Catholic), Spain ($n = 239$; Catholic), Lithuania ($n = 239$; Catholic), UK ($n = 277$; spiritual/ atheist).

The study protocol recommended recruitment in a wide range of geographical locations; these were different for each country. Pragmatic convenience sampling accessed participants from urban, suburban and rural environments. In UK, for example, rural participants were least accessible, so supplementary recruitment was conducted in a Welsh rural environment centre, a country GP practice, and using the phone directory (O'Connell and Skevington 2010).

An internationally agreed quota sampling design ($2 \times 2 \times 2$) targeted equal groups for gender (male/female), health status (sick/well), and age band (≤ 45 years or ≥ 45 years), within each country. The age-range of the total sample was 16–90 years; 46% were ≥ 45 years. The final sample included 51.5% ($n = 1806$) women ($M_{age} = 42.4$ years), and 48.4% ($n = 1701$) men ($M_{age} = 42.4$ years). During recruitment, 43% self-reported current illness, and the most prevalent diseases and conditions were: heart problems (15%), high blood pressure (13%), depression (9%), arthritis (9%), cancer (7%), and HIV (4%) (The WHOQOL SRPB Group, 2006). The international sample contained: agnostics, atheists, Buddhists, Zen Buddhists, Christians, Hindus, Jews, Muslims, and indigenous beliefs (e.g. animism). In each centre, spiritual, religious and personal beliefs (SRPB) were recruited in proportion to a national sampling frame developed from local statistical data (The WHOQOL SRPB Group, 2006). For example, UK census statistics showed that 27% religious, 53% spiritual, and 16% atheist participants should be recruited. British religious groups were subdivided into Trinitarian churches (Protestant, Catholic, Anglican), non-Trinitarian churches (e.g. Mormon, Jehovah's Witness), and other religions (Muslim, Sikh, Hindu, Jew), so these were targeted in the ratio of 14:1:2 (O'Connell and Skevington 2010).

Measures

Quality of Life Assessment

The WHOQOL SRPB is a multi-dimensional, multi-lingual, subjective QoL measure. It was developed using an advanced cross-cultural methodology to improve equivalence between language versions, so that comparison between cultures would be more reliable and valid (Skevington et al. 2004; Bowden and Fox-Rushby 2003). This instrument demonstrates good psychometric properties, and is standardised for international use (The WHOQOL SRPB Group, 2006). The WHOQOL SRPB contains 132 items, rated on 5-point (Likert) interval scales. The items assess 33 facets of QoL, being scored in one of six QoL domains: spiritual, environmental, psychological, social relations, physical and independence. The spiritual QoL domain contains nine facets

assessing outcomes from spiritual, religious and personal beliefs (SRPB). (One facet is confusingly labelled 'spirituality'.) The WHOQOL instruments are endorsed as suitable for environmental use and conservation research (Lercher, 2003). In the present sample, internal consistency reliability (Cronbach's alpha) was very high for 128 specific items in the WHOQOL SRPB (alpha = .967). Item substitution procedures showed that not one item detracted from overall internal consistency reliability.

Self-Reported Health

Subjective health status was self-assessed on a 5-point rating scale, from 1 (*very poor*), to 5 (*very good*). This additional, independent question is administered with the WHOQOL SRPB.

Other Indicators

An international pool of indicators drawn from the literature was scrutinised to identify potential covariates for the proposed model. The inclusion criteria were: the concept adopted, the scale of application, data availability, and development status. A measure was shortlisted if it had: (i) a concept that could influence the model, relevant to the objectives; (ii) available data for 2001–2002, matching the timing of the WHOQOL SRPB survey; (iii) data for the 15 countries participating in this study.

Biodiversity To conduct the present study, a generic, multi-dimensional assessment of BD density was needed. First, we searched the literature to select a suitable measure or indicator, using keywords. Three researchers agreed the inclusion/exclusion criteria. Headings based on the research question were also agreed, so that information could be tabulated as it was extracted from selected publications. One researcher (SD) assessed all selected papers; these were then independently evaluated by two others (SR & SS). After adjustments and disagreement resolution, the research team made the final decisions. Indicators were excluded when: (i) data was unavailable for participating countries (e.g. The Living Planet Index); (ii) the concept was outside the scope of the research (i.e. biosphere demands (e.g. The Ecological Footprint), ecosystem integrity, river fragmentation, extinction threat (The Red List)); (iii) BD data was limited to particular world region(s), not world-wide (e.g. The Global Wild Bird Index is focussed on Europe); (iv) BD was assessed for habitats not present in every participating country (e.g. marine BD); (v) BD was assessed for one habitat only (e.g. forests).

In the absence of a suitable generic BD indicator, we then calculated BD density for all countries where QoL data was available, using an area-independent index based on EARTHTRENDS quotients for species richness (S) in 2002 (World Resources Institute, 2007). This index is commonly used in ecological studies, being acknowledged as a fundamental BD metric (Gaston, 1996). Four taxonomic divisions of plants (conifers, ferns), and animals (birds, mammals) were selected as examples of non-overlapping, taxonomically coherent categories. These categories contain macroscopic organisms that are readily observable by casual observers of the natural environment. Thus "plants" was excluded, because it comprises organisms from very diverse taxonomic affiliations which would likely be perceived quite differently by most observers (e.g. trees, herbaceous

plants); also plants would have included two of our selected categories. Amphibia and insects were excluded as usually, they are not easily observed. Only terrestrial species were included, not marine and freshwater species where awareness could be limited to professionals, or aquatic life amateurs (e.g. catching fish to eat). Here S, is the species number in a defined area. As S varies systematically with the area sampled, it is adjusted for country area by regressing S against country area for all countries. The data is fitted to the eq. $\mathbf{S = cA^z}$, and c and z values are calculated for the whole data set. By assuming that the value of the exponent z would be constant for each country, the residual value of S per unit area was calculated for every country. Values range from 0 (low), to 100 (high), in these quotients. The four indicators selected are prominent and established global features of BD.

Poverty Poverty could be an important explanatory variable in the BD model, as countries in tropical regions typically report lower annual income (GDP), higher deprivation levels, poorer health and higher BD, than outside the tropics (e.g. (Hough, 2014). International poverty indicators considered included: the Human Development Index (HDI) (United Nations Development Program (UNDP), 1990) and its successor, the HDR, Human Poverty Index, Gini Index and Poverty Line (developing countries only). Excluded indicators: (i) evaluated conglomerated concepts, not single concepts, and (ii) showed missing data (as listed above). Only the HDI satisfied the inclusion criteria, and of its three sub-dimensions, educational level is an established proxy for poverty. Furthermore the highest level of education obtained correlates positively with many QoL dimensions (Skevington & the WHOQOL Group, 2010).

Analysis Plan

Multilevel Mediation Analysis (MLMA) was performed on the WHOQOL SRPB cross-cultural data (Stata v.13.1) (Krull & MacKinnon, 2001). Variations in QoL were examined within culture-specific clusters (countries), where correlated MLMA takes similarity into account. Independent variables are not required, and missing data is well tolerated. The model accounted for BD being constant within each culture/country (a level 2 group variable), and QoL measurement for every adult (a level 1 individual variable). The mediating variable was self-reported health status provided by each individual, who also completed QoL data. Country educational level (HDI) was the proxy for poverty and a covariate in each model. Three separate random intercept models were estimated, and parameters combined, generating estimates of direct and indirect, or mediated effects (product of coefficients). Summed direct and indirect effects give the total effect of BD on QoL.

We examined the association between BD and QoL, modelling a QoL domain or facet as the dependent variable in each case, and including subjective health as an intermediary mediational variable. Where particular domains were expected and confirmed, or discovered to be significant, component facets within that domain were also independently modelled, to explore the detail. Three mixed models are regressions, each estimated by restricted maximum likelihood: (i) QoL on BD, and HDI; (ii) subjective health on BD, and HDI, and (iii) QoL on subjective health, BD, and

HDI. Each analysis was 'boot-strapped' with 1000 independent replications, to produce boot-strap standard errors and bias-corrected 95% confidence intervals. Where confidence intervals contain zero, this shows that the effect is not significant (5% level).

For facet models, a subset of full data was first analysed containing participants without any missing values. As sex-life and 'spirituality' facets showed more missing data than others ($n = 3428$), they were first excluded from the analysis, then a complete case analysis (sex-life ($n = 3425$), 'spirituality' ($n = 3263$)) was conducted.

Since data analysis in the present study is considered secondary, confidence intervals for multiple tests were not adjusted. The entire set of results is presented to allow for a complete interpretation.

Bivariate associations between BD level in the four taxonomic indices, and nine spiritual QoL facets were tested. Adjusted for number of analyses, and number of countries, an a priori power test indicated that a moderate Pearson correlation coefficient of $r > .514$ would be significant, so this criterion was adopted.

Results

Does Subjective Health Explain any of the Association between Biodiversity and Quality of Life?

Multi-Level Mediation Analysis (MLMA) confirmed that BD was significantly, positively associated with QoL, supporting the prediction in Fig. 1. After accounting for health status, the direct effect remained significant in four of the six domains. *No significant evidence was found in any domain model to support the prediction that subjective health has a mediating effect on the BD-QoL association.* The results are shown in Table 1 by the 95% confidence intervals for indirect effects which contain zeros. Together these results demonstrate that subjective health cannot be confirmed as a mediating variable in the hypothesised pathway.

The model for spiritual QoL with BD showed the strongest fit of all six QoL domains in Table 1 and these results confirmed the positive direction of association predicted by the biophilia hypothesis. Although social QoL and psychological QoL models were also significant and strong, the fit for both is only slightly weaker than spiritual QoL. Independence and physical QoL models also showed significant direct effects, but a weaker fit, although significant results for both domains were not predicted. However for physical QoL, the overall effect was also non-significant, so further weakening physical QoL results. Contrary to prediction based on the study context, direct and overall effects were non-significant for the environment domain in Table 1.

> The findings confirm the biophilia hypothesis which states that spiritual QoL is specifically the most important QoL dimension in relation to BD. However this highly multi-dimensional measure also showed that social, psychological, and independence domains do make important contributions to the overall outcome of better QoL, and this is a new finding.

Table 1 Mediation analysis on WHOQOL SRPB Domains, showing effect estimates (bootstrap standard errors), and 95% bias-corrected confidence intervals

	Outcome					
	Total Effect		Direct Effect		Indirect Effect	
	Estimate (boot SE)	95% bcCI	Estimate (boot SE)	95% bcCI	Estimate (boot SE)	95% bcCI
Physical	3.02 (1.68)	−0.19, 6.30	3.37 (1.54)	0.39, .49*	−0.35 (0.89)	−2.11, 1.32
Psychological	9.22 (1.41)	6.43, 11.85*	9.44 (1.35)	6.74, 2.11*	−0.22 (0.55)	−1.26, 0.88
Independence	5.95 (1.96)	2.15, 9.81*	6.36 (1.73)	3.06, .85*	−0.41 (1.04)	−2.53, 1.54
Social	9.79 (1.44)	6.76, 12.32*	9.96 (1.42)	6.93,12.60*	−0.17 (0.42)	−1.03, 0.67
Environment	0.61 (1.34)	−1.88, 3.18	0.75 (1.31)	−1.86, 3.23	0.14 (0.36)	−0.80, 0.62
Spiritual	10.60 (1.35)	7.90, 13.12*	10.71 (1.34)	8.08,13.37*	−0.11 (0.27)	−0.61, 0.44

boot SE = boot-strap standard error; 95% bcCI = 95% bias-corrected Confidence Interval; *$p < .05$

Which Facet Components Contribute Most to Domain Models of Quality of Life?

Nine facets of spiritual QoL were modelled to examine their contributions to the spiritual domain, and direct effects were found significant for seven models. As before, no facet models of spiritual QoL showed that subjective health was a significant mediating variable. A positive direction for each of the seven models confirms that high BD is associated with multiple good spiritual qualities of life. Quality of life relating to hope and optimism showed the strongest model fit, then ranked in order: faith, meaning and purpose in life, inner strength, spirituality, inner peace, wholeness & integration (see Table 2). These spiritual facets elaborate QoL outcomes within the biophilia hypothesis, and largely confirm it.

As psychological and social QoL models were strong, and conservation studies suggest these are important domains, we also modelled their component facets. Significant models for all three social facets were found: sex-life, personal relations, and social support. Four out of five psychological facets also showed significant, positive models. Most important among these was self-esteem, followed by cognitions, positive feelings and negative feelings (see Table 2). Again, in every psychological and social model, subjective health was not a significant mediator.

Although the domain model for environmental QoL was non-significant, in the light of the context, its eight facets were modelled to examine internal variations. Six environmental QoL facet models showed significant direct effects; not one showed that subjective health was a significant mediator (see Table 2). Of these, four models showed positive associations with BD, with the best fit for perceived access to health and social care, then physical environment, opportunities for recreation and leisure, and home environment. In contrast significant, negative relationships were found in two models on perceived financial resources, and physical safety and security (Table 2). These results indicate that high BD is associated with perceptions that financial resources are poor, and the physical environment is unsafe and insecure. These were the only two negative significant associations among all domain and facet models tested in the present study.

Table 2 Mediation analysis on WHOQOL SRPB Facets, showing effect estimates (bootstrap standard errors), and 95% bias-corrected confidence intervals

	Outcome					
	Total Effect		Direct Effects		Indirect Effects	
	Estimate (boot SE)	95% bcCI	Estimate (boot SE)	95% bcCI	Estimate (boot SE)	95% bcCI
Pain and Discomfort	−8.34 (2.17)	−13.06, −4.31*	−7.93 (2.05)	−12.60, − 4.07*	−0.41 (0.91)	−2.29, 1.30
Energy and Fatigue	10.38 (1.96)	6.41, 13.94*	10.78 (1.83)	7.20, 14.23*	−0.39 (0.88)	−2.20, 1.23
Sleep and Rest	7.27 (2.31)	2.88, 12.01*	7.66 (2.22)	3.21, 11.77*	−0.38 (0.86)	−2.17, 1.16
Positive Feelings	10.17 (1.85)	6.58, 13.59*	10.45 (1.75)	7.05, 13.79*	−0.27 (0.61)	−1.52, 0.85
Thinking, Learning, Memory, Concentration	11.03 (1.74)	7.65, 14.30*	11.22 (1.70)	7.97, 14.40*	−0.19 (0.43)	−1.07, 0.61
Self-Esteem	14.00 (1.87)	10.09, 17.46*	14.20 (1.81)	10.58, 17.83*	−0.20 (0.44)	−1.10, 0.62
Body Image	3.02 (2.09)	−1.07, 6.95	3.24 (2.01)	−0.59, 7.08	−0.22 (0.49)	−1.24, 0.66
Negative Feelings	8.24 (2.17)	4.17, 12.63*	8.54 (2.09)	4.50, 12.60*	−0.30 (0.68)	−1.73, 0.93
Mobility	3.51 (2.27)	−1.43, 7.83	3.89 (2.15)	−0.47, 8.06	−0.38 (0.85)	−2.14, 1.18
Activities of Daily Living	7.66 (2.05)	3.48, 11.29*	8.06 (1.90)	4.18, 11.61*	−0.40 (0.90)	−2.27, 1.24
Dependence on Medication and Treatment	1.34 (2.80)	−4.13, 6.59	1.97 (2.64)	−3.37, 6.80	−0.64 (1.42)	−3.49, 1.99
Working Capacity	12.39 (2.45)	7.61, 1.83*	12.80 (2.29)	8.24, 16.95*	−0.41 (0.92)	−2.31, 1.25
Personal Relations	9.99 (1.80)	6.67, 13.53*	10.19 (1.77)	6.86, 13.68*	−0.20 (0.44)	−1.11, 0.60
Social Support	5.56 (1.95)	1.78, 9.39*	5.66 (1.95)	1.90, 9.48*	−0.10 (0.24)	−0.60, 0.32
Sex life[a]	14.18 (2.05)	10.14, 18.10*	14.41 (1.99)	10.43, 18.00*	−0.22 (0.59)	−1.45, 0.83
Physical Safety and Security	−8.02 (1.79)	−11.50, − 4.52*	−7.85 (1.76)	−11.32, −4.33*	−0.17 (0.39)	−0.96, 0.56
Home Environment	3.72 (1.90)	0.34, 7.36*	3.84 (1.89)	0.49, 7.43*	−0.12 (0.27)	−0.68, 0.37
Financial Resources	−16.56 (2.21)	−20.81, 11.94*	−16.38 (2.19)	−20.39, − 11.97*	−0.19 (0.42)	−1.02, 0.59
Access to Health and Social care	8.16 (1.95)	4.42, 12.00*	8.25 (1.95)	4.46, 12.06*	−0.09 (0.20)	−0.53, 0.25
Opportunities for Information and Skills	2.95 (1.89)	−0.70, 6.74	3.12 (1.87)	−0.46, 6.88	−0.16 (0.37)	−0.94, 0.51
Opportunities for Recreation and Leisure	6.46 (2.03)	2.25, 10.27*	6.68 (1.97)	2.56, 10.45*	−0.22 (0.49)	−1.27, 0.67

Table 2 (continued)

	Outcome					
	Total Effect		Direct Effects		Indirect Effects	
Physical Environment	7.86 (1.76)	4.42, 11.32*	7.97 (1.74)	4.52, 11.32*	−0.11 (0.24)	−0.61, 0.31
Transport	1.05 (2.13)	−2.92, 5.27	1.23 (2.13)	−2.66, 5.51	−0.18 (0.41)	−1.06, 0.55
Spirituality[b]	13.27 (2.01)	9.15, 16.93*	13.41 (2.01)	9.55, 17.45*	−0.14 (0.36)	−1.09, 0.33
Spiritual connection	4.15 (2.44)	−0.50, 9.05	4.17 (2.44)	−0.49, 9.12	−0.02 (0.06)	−0.24, 0.04
Meaning and Purpose in life	14.89 (1.75)	11.36, 18.20*	15.03 (1.72)	11.52, 18.24*	−0.14 (0.31)	−0.78, 0.44
Awe and wonder	−6.46 (1.83)	−10.04, − 2.90*	−6.35 (1.82)	−9.74, 2.66	−0.11 (0.25)	−0.62, 0.36
Wholeness and integration	10.92 (1.86)	7.11, 14.51*	11.06 (1.83)	7.30, 14.78*	−0.14 (0.32)	−0.80, 0.44
Inner strength	13.66 (2.10)	9.84, 17.72*	13.76 (2.09)	10.08, 17.89*	−0.11 (0.24)	−0.61, 0.34
Inner peace	11.50 (1.99)	7.65, 15.42*	11.69 (1.96)	7.90, 15.65*	−0.19 (0.42)	−1.08, 0.58
Hope and optimism	18.09 (1.80)	14.73, 21.63*	18.27 (1.75)	14.92, 21.77*	−0.19 (0.42)	−1.07, 0.59
Faith	15.27 (2.21)	10.96, 19.50*	15.26 (2.21)	10.96, 19.51*	0.00 (0.05)	−0.12, 0.08

Boot SE = boot-strap standard error; 95% bcCI = 95% bias-corrected Confidence Interval. [a] $N = 3425$. [b] $N = 3263$

*$p < .05$

Does Biodiversity in Plants and Animals Correlate with Spiritual Qualities of Life?

Biodiversity densities for the four selected plant and animal taxonomic divisions were correlated with QoL in nine spiritual facets, and a multiple tests criterion applied. Good QoL from hope and optimism correlated moderately and significantly with high BD in mammals ($r = .56$), and in ferns ($r = .60$). No significant correlations were found for BD in conifers or birds, or for any remaining spiritual QoL facets.

Discussion and Conclusions

Subjective QoL and subjective health survey data was collected from 3511 adults world-wide, and modelled in relation to national biodiversity levels, controlling for poverty. Four of the six WHOQOL SRPB domain models confirmed positive associations between BD and QoL. However in every model, no evidence was found to support the view that subjective health is an important mediator in this pathway. These findings lead to the conclusion that not only is high BD strongly associated with good QoL, but that this occurs regardless of whether people perceive their health to be good or poor. When judging their QoL in relation to BD, they do not take into account the status of their health. Information collected in 15 countries provides the most extensive cross-cultural study on this issue, to date.

Theory underpinned the modelling of the biophilia hypothesis, strengthening conclusions in a field where theory is rarely applied. The hypothesis specifically predicted that higher BD leads to good spiritual QoL (Kellert & Wilson, 1993; Wilson, 1984), and we confirmed this strong association. Furthermore, when compared with five other QoL domains, the spiritual domain was strongest, strengthening the original hypothesis. Assessing spiritual QoL as part of the hypothesized mechanism was previously hampered by the absence of a suitable generic, international tool, but the WHOQOL SRPB now makes this possible and offers a novel application. Despite its age, biophilia remains theoretically interesting, although alternative mechanisms like biosynergy, or the mutual enrichment of life, have been proposed (Rose, 2011). The findings reported could contribute to establishing a biophilia theory.

Models of social relations QoL and psychological QoL were almost as strong as the spiritual result, so together these findings point to the psycho-socio-spiritual benefits of living in highly biodiverse environments, as suggested by some conservation studies (e.g. (Cervinka et al., 2012)). Quality of life related to high levels of independence flags up a fourth QoL domain that is significantly associated with high BD. We therefore conclude that the exclusive focus on spiritual QoL within the biophilia hypothesis is unduly narrow, and unwarranted. The findings show that the original, specific theoretical emphasis on spiritual QoL should now be broadened to embrace social, psychological and independence dimensions. Although the biophilia hypothesis per se was confirmed with international data, simultaneously these findings show that BD has multiple QoL outcomes, not one.

The present approach enabled three pathways to be investigated within one single integrated model. This was made possible by building on previous studies showing individual bivariate connections between combinations and permutations of BD,

health, and well-being concepts. In addition, this global cross-cultural data derived from one common instrument, enabled a more holistic model to be tested. An important observation is that health was assessed as part of this model. Unusual in conservation work, health was here assessed from a subjective, not an objective perspective. This may be rare because large scale face-to-face surveys are costly, and challenging to implement. The present study consistently found that subjective health did not influence the BD-QoL pathway for any important QoL domains, contrasting with previous claims about the impact of objective health measures. This result therefore makes a new contribution to a field where conclusions are still considered equivocal (e.g. Hough, 2014; Lovell et al., 2014). Future research could compare the performance of objective and subjective health indices, within this mediation model.

Hope and optimism was the strongest part of spiritual QoL associated with BD. Furthermore hope was the only spiritual quality that strongly associated with any selected taxonomic categories; in this case, the BD of mammals, and ferns. Hope theory suggests that high hope reflects human capacities to conceptualise clear goals, and develop specific strategies to reach them, so hope functions as a potential agent of change (Lopez et al., 2004). As good QoL from hope and optimism is associated with higher BD, individuals with very hopeful QoL might be most likely to change minds and behaviour on issues like climate change. Other methods could be used to further examine whether good QoL from hope and optimism is key to the love of nature described as biophilia.

Previous research lends tangential support to findings on ferns, as it shows the benefits of green spaces to health and wellbeing (e.g. (Lee & Maheswaan, 2010; Van den Berg, 2017; Van den Berg et al., 2016)). Depending on mammals for survival has spiritual properties for some cultures (e.g. reindeer herds for Canadian Cree Indians (Parmesan et al., 2009)) and more broadly, animal relations offer a 'universal' source of well-being (Nussbaum, 2000). What is not directly established is whether mammals and ferns attract particular human attention over other taxonomic categories, although plausibly they could function as implicit benchmarks of BD change. Other taxonomic categories may also be markers of hope and optimism QoL, but testing them all was beyond the scope of the current research. Retaining an international research perspective is essential in this field, as attention focussed on certain categories can be culture-bound (e.g. UK interest in birds), rather than universal.

The present study has several limitations. First, national not local BD estimates were analysed, so this may have accuracy implications, especially in highly diverse countries like Brazil. Although some participants would know about BD locally, gathering individual perceptions of BD would improve global research. Second, like most studies in this field, cross-sectional data was analysed which cannot confirm causation between BD, QoL and health. Nevertheless boot-strapped MLMA improved confidence in conclusions, over simple correlation. Had we detected significant mediation effects for health, issues of causality would have generated more concern. However consistently positive findings in this study offers a departure point for more complex designs (e.g. longitudinal), to better test causality. Third, as modelling conventions require building a simple BD and QoL model, then adding a health mediator and adjusting for poverty, new candidate variables can now be added to increase complexity, and better approximate to reality. Fourth, national samples could be structured to target equal subgroups of people living in rural, urban and suburban environments.

Other observations can be made. The context led us to expect that environmental QoL would be associated with BD, but this was not confirmed. However by examining the components, we found that half of the environmental QoL facets showed significant positive models, commensurate with expectation. Two negative models were equally interesting, as poor QoL derived from insufficient money to meet a person's needs, and feeling unsafe and insecure, were associated with higher BD. This occurred even though poverty had been adjusted to account for low GDP, and greater deprivation in the tropics where the highest BD occurs (Hough, 2014). It is therefore plausible that both life qualities are linked to objectively poor material conditions ((Chambers, 2003); p170), so underscoring the need to compare subjective and objective indictors. These results signal that environmental QoL may be especially responsive to poverty impact, rather than flagging a potential measurement problem for this internationally validated environmental QoL domain (Skevington & Epton, 2018), but this should be monitored. We recommend that self-assessed poverty is routinely collected alongside subjective QoL and health, in future environment and conservation studies.

Second, a rich multi-dimensional profile of WHOQOL SRPB dimensions offers a fine-grained QoL analysis that could assist conservationists with evidence-based decisions. Its protocol enables new equivalent language versions to be developed that have been culturally-adapted and translated, and could be used by cultures threatened with environmental disasters (e.g. from El Nino). Community members with high hope and optimism QoL could be readily identified, and may be best suited to addressing BD challenges locally. The WHOQOL-BREF was suitable for use in environmental policy and practice (Lercher, 2003), but by extending spiritual QoL in the WHOQOL SRPB, the latter can improve evaluation of environmental QoL. A shorter 33-item WHOQOL SRPB BREF was recently standardised for community population surveys (Skevington et al. 2012), and would be useful in this field.

In conclusion, research on the relationship between BD, health and QoL (United Nations Environment Program and WCMC 2011) can contribute to understanding some complexities of planetary health. Although researchers have assumed that conserving BD has intrinsic QoL costs that trade-off against conservation benefits (McShane et al., 2011), technically improved estimates of utility will be needed to justify previous equivocal results, and address these issues (e.g. (Faith et al., 2010)). The present study offers the first theory-driven international model, with evidence showing consistently strong, positive associations between BD and QoL on several dimensions. It is not influenced by whether a person perceives their health to be good or poor. Such findings support our original thesis based on lay-beliefs, that to experience BD is intrinsically valuable. The findings also indicate that world-wide, people consistently value BD for reasons unconnected with the services it provides, so the results assist on-going public debates about conservation policy.

The findings contribute to debates about the relationships of 'well-being' to ecosystem services (MEA, 2005). In 2020, global, empirical information obtained from a state of the art multidimensional, multi-lingual QoL measure, could be invaluable to decision-makers who need to know not just whether well-being targets were met in communities facing conservation dilemmas, but exactly which well-being dimensions were improved. Without subjective data, governments will not be able to conclude whether global 'wellbeing' targets set for 2020, were achieved.

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