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How does engaging with nature relate to life satisfaction? Demonstrating the link between environment-specific social experiences and life satisfaction

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ABSTRACT

The natural environment contributes to human wellbeing in a variety of ways, including providing outdoor recreation venues and underpinning cultural practices. Understanding whether the diversity of human-nature experiences significantly relate to overall subjective wellbeing, however, is rarely explored. Using results from 4418 respondents to an online survey conducted in Washington's Puget Sound region, we describe the relationship between overall life satisfaction and diverse metrics of how people engage with the natural environment. We found that eleven of the thirteen tested metrics had a small but positive correlation to overall life satisfaction and specific groupings of environment-specific social indicators were internally reliable constructs that predicted life satisfaction. These included: Sense of Place, Outdoor Activities, Good Governance, Social and Cultural Activities, Psychological Well-being, and Resource Access. This research empirically demonstrates that a variety of mechanisms for engaging the natural environment significantly contribute to overall subjective wellbeing.

1. Introduction

Over the past several decades, environmental psychologists and other social scientists have explored the link between the natural environment and various dimensions of human wellbeing. For example, research has demonstrated that interacting with natural environments results in physiological and perceived stress reduction (Ulrich et al., 1991; Tyrväinen et al., 2014; Irvine, Warber, Devine-Wright, & Gaston, 2013). Being in nature also has positive impacts on emotional wellbeing (Bratman, Hamilton, Daily, & Gross, 2015; Marselle, Irvine, & Warber, 2013; White, Alcock, Wheeler, & Depledge, 2013a, 2013b), cognitive performance (Keniger, Gaston, Irvine, & Fuller, 2013), and affective connection and identity (Hinds & Sparks, 2008). Socially, research has shown that natural vegetation can reduce crime (Kuo & Sullivan, 2001) and enhance social connections (Sullivan, Kuo, & DePooter, 2004; Weinstein et al., 2015). Still lacking in this social-ecological research, however, is clarity on the specific types of interactions that are most important for delivering benefits, and how this importance varies by demographic attributes (Keniger et al., 2013).

Human wellbeing depends not only on objective metrics such as health and economic status, but on a variety of subjective experiences that vary by individual (Diener, Lucas, Schimmack, & Helliwell, 2009; Kahneman, 1999). While the linkages between ecological conditions and objective wellbeing have been more frequently studied (e.g., drinking water and air quality), linkages between various aspects of engaging the natural environment and overall subjective wellbeing are theorized yet rarely validated (except, for example; Wolsko & Lindberg, 2013). One of the most common ways of capturing a subjective assessment of wellbeing is through metrics such as Life Satisfaction (National Research Council, 2013). Substantial research has identified global predictors of life satisfaction, including one's personal characteristics and social context (Kahneman, 1999). For example, Gallup's global study identified the five primary predictors of life satisfaction as the quality of one's social and community relationships, financial and physical status, and job satisfaction (Rath & Harter, 2010). Demographically, women tend to be more satisfied with life whereas life satisfaction shows a U-shaped trend as one increases in age (Pew

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Research Center, 2014). Life satisfaction also has a positive logarithmic correlation with income, demonstrating only marginal returns in life satisfaction after reaching a certain level of household income (Deaton, 2008). Other demographic factors, such as marriage status and education level have smaller, but also significant positive correlations to life satisfaction (Pew Research Center, 2014).

While diverse ways of engaging with the natural environment have been shown to contribute to various objective and subjective metrics of human wellbeing, the relative ability of these interactions to predict life satisfaction, a globally comparable metric of subjective wellbeing, is still unclear (Russell et al., 2013). In the realm of psychological connection to nature, studies that have looked at one's Connection to Nature Scale (CNS) and one's attitude toward the natural world with the New Ecological Paradigm (NEP) have found that CNS, but not NEP, correlates to overall life satisfaction (Capaldi, Dopko, & Zelenski, 2014; Mayer & Frantz, 2004). While the correlation with CNS was found to be small (~0.20), it was similar in magnitude to other demographic factors such as marriage and education. Other psychological variables, such as mental distress, have also been shown to be linked with life satisfaction when one lives near green spaces (White et al., 2013a). These findings held true even after controlling for income, employment, marital status, physical health, and housing type.

The latter suggests that proximity to and physical engagement with natural environments is particularly relevant to life satisfaction. MacKerron and Mourato (2013) broadly explored this question, finding that self-reported happiness was greater for those visiting any type of natural environment. This study focused on the more affective measure of happiness, though, rather than the evaluative measure of overall life satisfaction. Better studied is the positive relationship between life satisfaction and outdoor activity, particularly in North America (Edginton, DeGraaf, Dieser, & Edginton, 2005, pp. 978). There are still questions as to the specific mechanisms by which outdoor activity contributes to life satisfaction (e.g., engaging in activity or fulfilling needs such as autonomy), but it seems that most outdoor activity experiences correlate to life satisfaction (Mert, Zurnaci, & Akgun, 2015; Sugiyama & Thompson, 2005).

Environmental governance has also been identified in qualitative studies as having an impact on human wellbeing (Lankford et al., 2010). Environmental governance describes the process by which decisions are made, quantifying characteristics such as trust, transparency, and legitimacy (Lemos & Agrawal, 2006). While the research on general governance, specifically trust in local and state institutions and assessment of performance, has found mixed relationships to life satisfaction (Hlepas, 2013; Jakubow, 2014), much of the variation is predicted by country-level differences in governance rather than individual determinants. Specific to the natural environment, it appears that the link between life satisfaction and environmental governance is often made indirectly either through general governance inquiries or the quality of the natural environment (e.g., Silva, de Keulenaer, & Johnstone, 2012), but not the specific focus on environmental governance itself.

This research sought to identify the relative importance of diverse nature-oriented experiences on one's overall life satisfaction assessment. We did so by quantifying the relationship between wellbeing and six common mechanisms by which nature influences human wellbeing based on prior qualitative research (Biedenweg, 2016). When a diversity of residents from the Puget Sound, WA were asked, “How does the natural environment contribute to your wellbeing?”, the consistent responses included that it provided opportunities for outdoor activity and access to wild food; that engaging with it improved psychological health, enhanced their sense of place, and contributed to important cultural or social activities; and that the process of managing the natural environment substantially influenced their wellbeing (Biedenweg, 2016). We acknowledge that each of these constructs represents different types of interactions with nature, ranging from direct contact to the ability to influence its management. Yet, the literature also supports the premise that each of these constructs has an impact on life satisfaction, suggesting that the natural environment could play very different roles in influencing subjective wellbeing. This study confirms diverse the diverse human-nature interactions as unique constructs, tests the strength of each construct's relationship to wellbeing in a multivariate analysis, and statistically explores their relative significance to life satisfaction across a large, place-based population.

2. Methods

2.1. Context

Our research was conducted in the Puget Sound region of Washington State, USA where over 3.7 million inhabitants live within urban cities (Seattle and Tacoma), rural communities, and 18 Native American territories (Puget Sound Institute, 2015). The natural environment includes the 12,000 km^2 Puget Sound watershed with rocky and sandy intertidal zones, mountainous coniferous forests, and large, fertile floodplains. Coordinating the recovery of this degrading social-ecological system is the task of Washington State's Puget Sound Partnership (Partnership) (Puget Sound Partnership, 2014). As part of the process, indicators have been selected to monitor progress, including metrics of human wellbeing as they relate to the natural environment (Biedenweg, 2016). These indicators were developed over three years through interviews and workshops with about 300 local residents, social scientists and policymakers in which participants responded to the prompt “how the natural environment contributes to my wellbeing”.

2.2. Survey content

Thirteen survey questions were selected to represent the Partnership's indicators for monitoring human wellbeing associated with Puget Sound restoration (Appendix A). Respondents were asked to self-assess their experience using categorical scales with five response options. Questions included the frequency of: outdoor recreation in winter (from less than 1 time per month to almost everyday), outdoor recreation in the summer (same), enjoying the outdoors with family (same), feeling inspired while out in nature (almost never to almost always), feeling stress relief while in nature (same), and engaging in stewardship or community activities (never to at least once per week). The questions also solicited an assessment of ability to access wild local resources (never to almost every day during harvest season), trust in policymakers and scientists to manage natural resources (almost never to almost always), and statements on attachment and identity to the Puget Sound area (strongly disagree to strongly agree). Additionally, each respondent received a standardized life satisfaction asking, “In the past year, how satisfied have you been with your life as a whole” with five response options from extremely dissatisfied to extremely satisfied.

Additionally, age, gender and economic status for each respondent were automatically collected by the Internet-based survey tool in two different ways. Individuals on mobile devices (approximately 92% of our respondents) were required to register and record basic demographic data before participating in the survey. For those who accessed the survey while web browsing on their computer, their demographics were inferred using IP addresses and

web histories, rather than asking them as survey questions (Table 1). Because the inferred demographic data were probabilistic measures, the increased noise could attenuate potential differences (e.g., if some women were categorized as men and some men were categorized as women, this would pull the group estimates closer together). This would ultimately result in more conservative estimates of between-group differences, however; potential errors in demographic measurement would not drive significant results. In fact, the representativeness and accuracy of our chosen platform compares favorably with probabilistic and nonprobabilistic panel Internet surveys (McDonald, Mohebbi, & Slatkin, 2012).

We limited demographic data collection to these factors due to space limitations (see below). This was justified because prior surveys found income and age to be most predictive of life satisfaction and other potential demographic covariates (such as marital status or health) to be about equal to variables on interaction with nature. One additional covariate (length of residence in the region) was added because research has found that the results of interacting with nature (such as sense of place) can vary significantly by time in place (Lewicka, 2010).

2.3. Multiple matrix internet survey

Whereas traditional surveys apply a large number of questions to a relatively small population (or else require significant funding and resources), we implemented a multiple matrix survey design (Gonzalez & Eltinge, 2007; Thomas, Raghunathan, Schenker, Katzoff, & Johnson, 2006) that divided the complete questionnaire into question subsets that were administered to unique subsets of the total respondent sample. Using the correlational structure of observed responses in concert with demographic data for each respondent, we were able to develop a probabilistic estimate for empty–unasked–cells (Raghunathan & Grizzle, 1995).

This approach has theoretical benefits in addition to the obvious practical benefits of money and completion time. First, while shorter surveys inherently provide less information, the debatable quality of information provided by longer surveys can negate the presumed informational advantage. Long surveys, for example, can encourage poor answering behavior, differential approaches to questions as the survey progresses, and other unintended consequences (Herzog & Bachman, 1981; Johnson, Sieveking, & Clanton, 1974; Kraut, Wolfson, & Rothenberg, 1975; Shields & To, 2005). Moreover, because longer surveys are more burdensome, they can decrease response rates and thereby potentially increase non-response bias (Burchell & March, 1992; Groves, Singer, & Corning, 2000).

Aside from these theoretical considerations, at the time of survey implementation our project was committed to testing a web-based platform (Google Consumer Insights – GCS) that was more economical and facilitated high response rates for the region. GCS, however, could only implement surveys with 10 questions or fewer. One reason for the restricted length is to enable higher response and completion rates (McDonald et al., 2012). Since we had 15 unique questions in total, this meant that a multiple matrix design was necessary. All survey designs are subject to a budget constraint, and thus the number of responses and the length of each response present a co-maximization problem. The multiple matrix approach offered a way to survey a larger number of respondents and probabilistically infer structurally missing data points (i.e., questions that were not asked of a given respondent).

Table 1
Inference Methods for Demographic Data for 8% of respondents.

Variable	Inference method
Location	nearest city based upon IP address
Urban Density	census tract data associated with inferred location
Income	census tract data associated with inferred location
Gender	Google-associated web history
Age Group	Google-associated web history

2.4. Microsurvey structure

Each microsurvey (a.k.a. block) contained six questions (Appendix B). The first two questions were fixed for every block: life satisfaction and length of residence. That left 13 questions to fill the remaining 4 places within the microsurveys. We set the criteria that each question should only be used once within a single block and that the order in which the four questions were asked did not matter. This resulted in 715 potential combinations for the microsurveys. We chose to develop 24 different microsurveys, which allowed us to observe many different combinations of questions while still obtaining a high number of responses per microsurvey. This meant that we needed to identify an optimal set of 24 different combinations from amongst the 715 choices.

Multiple matrix designs work best when there is strong correlation between questions such that responses to one question can more reliably predict responses to another question (Raghunathan et al., 1995; Gonzalez and Eltinge, 2007). Rather than go about the design randomly, we chose to generate a potentially more effective design by pilot testing the full set of 15 questions with 40 undergraduate students. We analyzed the correlation between their responses and developed a sampling algorithm to minimize the correlation between questions asked within the same micro-survey and maximize the correlation between questions not asked within the same survey. This maximized predictive power for the missing responses in the multiple matrix design. The sampling algorithm constrained potential designs in terms of how many times a given question was asked across all microsurveys (to ensure that every question was asked a sufficient number of times), how many times pairs of questions appeared together within a block (so that correlation between every question pair could be observed), and then sampled from the population of these acceptable designs to identify the design that would minimize error resulting from the imputation.

2.5. Survey implementation

We contracted GCS to produce approximately 180 responses for each microsurvey (such that each question would have at least 1000 responses) from respondents across the Puget Sound. GCS primarily services marketing research; however, it has also been found an effective tool to survey the general public for research (Santoso, Stein, & Stevenson, 2016), including public thinking about oils spill risks and oils spill practices (Bostrom et al., 2015), exercise and health (Thomas, Kyle, & Stanford, 2015), and energy efficient lighting (Gerke, Ngo, Alstone, & Fisseha, 2014).

Surveys were administered to respondents with IP addresses that were located within the target zipcode prefixes from 980 to 985. GCS recruited respondents from the population of users for Google's web-based and mobile products. The basic framework of GCS is that web publishers sign up with GCS to host surveys that serve as a "wall" to content access; Google then pays these publishers for hosting Consumer Surveys (McDonald et al., 2012). Two advantages of this approach are that surveys are non-intrusive (since respondents were going to answer survey questions of one form or another) and reciprocal (in that respondents receive benefits in exchange for their participation). As a result, GCS has an average 16.75 percent response rate, as compared to a 1% average for most Internet surveys (Lavrakas, 2010), 7–14% for telephone surveys (Pew Research Center, 2011), and 15% for Internet panels (Gallup 2012 as cited in McDonald et al. (2012)). The demographic

data of potential respondents was inferred in real time to allocate respondents across surveys in such a way as to optimize the sampling across demographics (McDonald et al., 2012).

One remaining concern was the extent to which the GCS target population— Internet users— reflected the overall US population. As Internet use becomes increasingly ubiquitous, this problem is lessening, but as of 2011, an extensive Pew Foundation study found that Internet users were on average younger, more educated, and of higher income than the general population (Duggan & Brenner, 2012). It is important to note that this issue is not unique to Internet surveys; phone and mail surveys have similar challenges. Nevertheless, we used post-stratification weights based upon the most recent American Community Survey (ACS) to weight responses in accordance to the sample population.

3. Data

3.1. Response rates and representation

Response rates were measured by dividing the number of completed surveys over the number of "impressions." An impression occurred when a user viewed the first survey question. Since our design implemented 24 different microsurveys, there are 24 different response rates ranging from 36% to 51%, with a median of 43%. In total, of the 10,291 individuals who viewed any of the 24 microsurveys, 4418 completed all 6 questions, for an overall response rate of 43%.

In terms of overall representativeness of the regional population, our survey population is younger and earns a higher income than the overall population. To account for this, we used post-stratification survey weights generated from the most recent ACS data in order to ensure that responses are properly weighted to reflect subregion demographics. One caveat is that we received very few responses from those age 55 or older, making post-stratification undesirable; we elected to focus on adults under the age of 55 for the entire data set. While another alternative here would be to conduct raking on each of the marginal distributions of our dataset, we determined that post-stratification presented a simpler methodology, while allowing us to be forthright with our readers that our survey was generally ineffective at reaching Puget Sound populations over the age of 55.

3.2. Multiple imputation

A key component of our process was to impute missing responses produced by the multiple matrix survey design. Because respondents were not asked every question, we used multiple imputation (Rubin, 2009) to estimate responses based on observed responses and the available demographic data. The basic premise of multiple imputation is that missing data can be simulated by sampling from the predictive distribution of the missing value (Reiter & Raghunathan, 2007); these samples generate many simulated complete data sets. We conducted a large number of separate iterations, within which each missing data point was assigned a value drawn from a probabilistic distribution of potential values for the given point to produce a distribution of complete data sets. The point and variance estimates from the simulated distribution of imputed data sets were then combined to facilitate statistical inference via complete-data methods (Rubin, 2009).

One advantage of our research design relative to other multiple imputation applications is that we can be confident that data were, in fact, missing completely at random (Carpenter & Kenward, 2013). In our case, likely responses for unasked questions were not expected to differ in substantive, unobserved ways from observed responses because respondents were randomly assigned to a subset of questions. Missing data points thus do not indicate refusal to respond or neglect on the part of the respondent to answer the question. The primary implication of this is that the observed data can be considered representative of the sample population.

4. Analysis and results

4.1. Individual indicators significantly but minimally correlate to life satisfaction

To get a basic understanding of how each indicator related to life satisfaction, we examined the correlation between each of the 13 questions and the life satisfaction variable. Because both the independent variables and the dependent variable were ordinal data, standard correlation metrics such as Pearson's product-moment correlation were inappropriate (Chen & Popovich, 2002). Instead, we used bivariate polychoric correlation which assumes that the observed ordinal responses are the manifestation of normally distributed continuous latent variables (Choi, Peters, & Mueller, 2010; Olsson, 1979).

For estimation, we used a joint maximum likelihood approach involving two simultaneous processes. First, the observed ordinal data were linked to the continuous latent variable by identifying thresholds, or cut points, that distinguished ordinal categories (Choi et al., 2010). We estimated thresholds for each variable based upon the one-way marginal frequency of that variable. Second, correlation was estimated on these thresholds using maximum likelihood estimation (see Olsson, 1979). The standard errors used to evaluate the significance of each correlation estimate are the estimated covariance of the correlation and thresholds.

Eleven of the thirteen indicators had a statistically significant

Table 2
Bivariate correlation values comparing survey responses with life satisfaction responses.

Polychoric correlation w/Life satisfaction	
Q3: Attachment to Puget Sound region	0.100***
Q4: Identification with Puget Sound region	0.139***
Q5: Inspired by time spent outdoors	0.107***
Q6: Stress reduced by time outdoors	0.092***
Q7: Frequency of winter outdoor recreation	−0.007
Q8: Frequency of summer outdoor recreation	0.054**
Q9: Frequency of wild local resource gathering	0.089***
Q10: Ability to access desired wild local resources	0.021
Q11: Participation in community activities related to local environment	0.075***
Q12: Participation in environmental stewardship and restoration activities	0.052**
Q13: Time spent with family outdoors	0.038*
Q14: Trust in policymakers to protect the environment	0.165***
Q15: Trust in scientific experts to protect the environment	0.152***

*p < 0.05; **p < 0.01; ***p < 0.001.

Table 3
Ecosystem management outputs and outcomes hypothesized to increase wellbeing (with corresponding survey questions).

F1: Psychological benefits from time spent in the outdoors
Q5: Inspired by time spent outdoors
Q6: Stress reduced by time outdoors
F2: Outdoor recreational activities
Q7: Frequency of winter outdoor recreation
Q8: Frequency of summer outdoor recreation
Q13: Time spent with family outdoors
F3: Environmentally related social and cultural events
Q11: Participation in community activities related to local environment
Q12: Participation in environmental stewardship and restoration activities
F4: Access to wild local resources
Q9: Frequency of wild local resource gathering
Q10: Ability to access desired wild local resources
F5: Sense of place
Q3: Attachment to Puget Sound region
Q4: Identification with Puget Sound region
F6: Trust in environmental governance
Q14: Trust in policymakers to protect the environment
Q15: Trust in scientific experts to protect the environment

bivariate correlation with life satisfaction (Table 2). Only five of these indicators, however, had a positive correlation to subjective wellbeing of 0.1 or above: trust in scientific experts, trust in policymakers, identification with the Puget Sound region, inspiration drawn from spending time outside in Puget Sound, and attachment to the region. No indicator has a significant negative correlation with subjective wellbeing.

These correlation values were small in magnitude, which was expected. Considering the role that significant life factors such as community, income, and physical health play in human wellbeing, it would have been surprising if a factor such as "trust that scientists are doing what is best for the environment" or "identifying with the Puget Sound region" demonstrated a large correlation with life satisfaction. Thus, while bivariate correlation was a good starting point for analyzing the survey results, we continued our analysis using multivariate methods to analyze how key indicators work in concert with a limited set of demographic variables to mitigate the relationship between environmentally-oriented social indicators and life satisfaction.

4.2. Individual indicators correlated into distinct factors

While most bivariate correlations between indicators and life satisfaction were small in magnitude, many of the indicators strongly correlated with one another, reflecting their close relationships. The survey was actually designed with particular constructs in mind, such that sets of questions were intended to provide data regarding particular avenues through which ecosystem management outputs and outcomes are hypothesized to be associated with wellbeing (Table 3). These six constructs were developed based on categories of wellbeing provided by the initial participants of the human wellbeing project. Thus, while many of the questions could belong in a different construct (such as stewardship), these are the groupings most commonly identified by laypeople.

Thus, we used a confirmatory polychoric factor analysis model to validate the latent constructs of interest as a function of related survey questions. Confirmatory factor analysis (CFA) assumes that there are particular dependencies among observed variables (the survey questions) and latent variables of interest (in this case, ecosystem management outputs and outcomes shown in Table 3) (Bartholomew, Steele, Moustaki, & Galbraith, 2008). The relationship between each individual variable and a given factor is expressed by factor loadings, which reflect the correlation between a given variable and a given factor.

We included the thirteen variables shown in Table 2 (not including life satisfaction, since we ultimately wanted to examine how the factors related to life satisfaction). Fig. 1 presents a path diagram with standardized factor loadings that show how each variable is associated with a given construct. Factor loadings can be interpreted similar to correlation; the loading for a given variable on a factor reflects the extent to which that factor accounts for the variable. Model identification can be problematic where there are only two indicators for a given factor, particularly when the two indicators are not themselves both strongly related. In this case, however, the strong standardized loadings for each factor speak to the validity of measuring each construct by the designated survey questions.

We fit the CFA model using the *lavaan* package in R (Rosseel, 2012); for ordered categorical data, this package facilitates a diagonally weighted least squares estimation strategy with robust standard errors. With sample sizes greater than 200 (in this case, $N > 3000$), the chi-square test is almost always significant by virtue of sample size alone (Barrett, 2007). Thus, we fit the Root Mean Square Error of Approximation (RMSEA) statistic (which is an absolute fit index comparing the model to a perfectly fitting model) for the model with a 90% confidence interval of 0.051–0.059. A RMSEA statistic of 0.05 is typically considered to represent a "good fitting" model (with 0.01 being "excellent" and 0.08 being "poor") (MacCallum, Browne, & Sugawara, 1996). A second goodness-of-fit statistic, the Tucker-Lewis incremental fit index (Tucker & Lewis, 1973) was 0.973 for the CFA model with robust standard errors; this is above the 0.95 cutoff which is traditionally considered the floor for well-fitting models (Barrett, 2007).

4.3. Factors predicting life satisfaction

Although the rank order of the life satisfaction potential responses clearly matters (e.g., somewhat satisfied is of higher rank than extremely dissatisfied on the life satisfaction scale), the categories do not have meaningful quantitative differences. To estimate the relationship between each factor and life satisfaction, we used a structural equation model (SEM) that combined the confirmatory factor analysis with an ordered logit regression.[1] Traditionally, analyses of life satisfaction appear to be robust with an ordinary least

[1] Unlike a typical structural equation model, in which the dependent variable is also a latent variable modeled as a function of several manifest variables, since there is only one variable used to measure the outcome variable of interest (life satisfaction), the regression component of the structure equation model is an ordinal logit regression on reported life satisfaction.

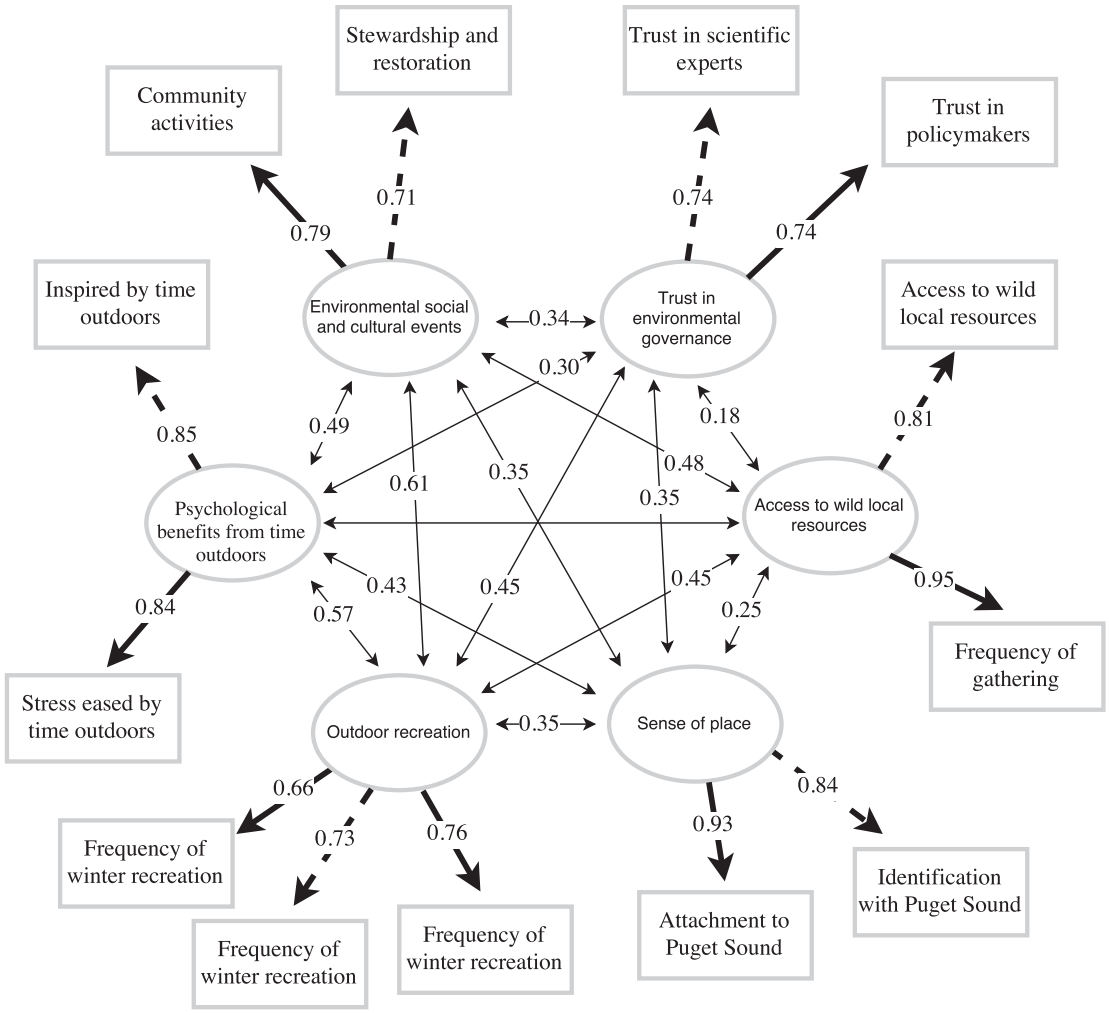

Fig. 1. Path diagram with confirmatory factor analysis standardized loadings. Dashed lines represent the default fixed parameter.

squares model in lieu of an ordered logit specification (i.e., assuming each category represents a 1 unit increase in the dependent variable) (Ferrer-i-Carbonell & Frijters, 2004; van Praag & Ferrer-i-Carbonell 2004). However, we believe that using an ordered logit model provides more clearly interpretable results because it uses maximum likelihood estimation to model the probability of being above or below a given category threshold. Each coefficient reflects the percentage change in the odds of being in a higher category given a one-unit change in the explanatory variable.

The SEM allowed us to control for the limited set of demographic characteristics, geographic sub-region, and other exogenous covariates to isolate the relationship between life satisfaction and each factor (Fig. 2). This technique had two primary advantages: (1) Instead of using predicted individual factor scores as exogenous covariates in the ordered logit model, we actively modeled the relationship between the latent factor variables and the dependent variable (life satisfaction); and (2) the structural equation specification also models covariance amongst the latent factors (Bartholomew et al., 2008).

The regression portion of the model still relied on an ordered logit specification, which estimates the probability of being in a given category versus any lower-ranking category. The model coefficients were then interpreted just as in a logit model, where each coefficient refers to an additive change in the log odds. To ease interpretation, we exponentiated these coefficients to produce a multiplicative effect on the odds ratio. Thus, a coefficient greater than one shows a positive effect and a coefficient less than one shows a negative effect (Table 4). As with the CFA model above, the model was estimated via a diagonally weighted least squares (DWLS) estimation strategy with robust standard errors (Rosseel, 2012). The RMSEA statistic has a 90% confidence interval of 0.032–0.036, well below standard goodness-of-fit ceilings (MacCallum et al., 1996). Likewise, the Tucker-Lewis incremental fit index (Tucker & Lewis, 1973) is 0.957, again evidencing that the model suitably fits the data.

Table 4 presents estimated model parameters, using a 95% confidence interval for statistical significance. Each coefficient is interpreted as having a multiplicative effect on the odds of being in a higher response category. For instance, the lower bound of the 95% confidence interval for males predicts that a male has a 7% decrease (odds * 0.93) in the odds of being in a higher category, and the upper bound predicts a 7% increase (odds * 1.07) (thus, the male variable is insignificant since this interval contains 1.00, which has no effect on the odds since odds * 1.00 = odds).

Income was expected to exhibit diminishing marginal utility, which is typically addressed by log-transforming income. However, our survey results provide income ranges rather than actual income. To account for the expected positive, but diminishing, relationship between income and life satisfaction, we assigned each

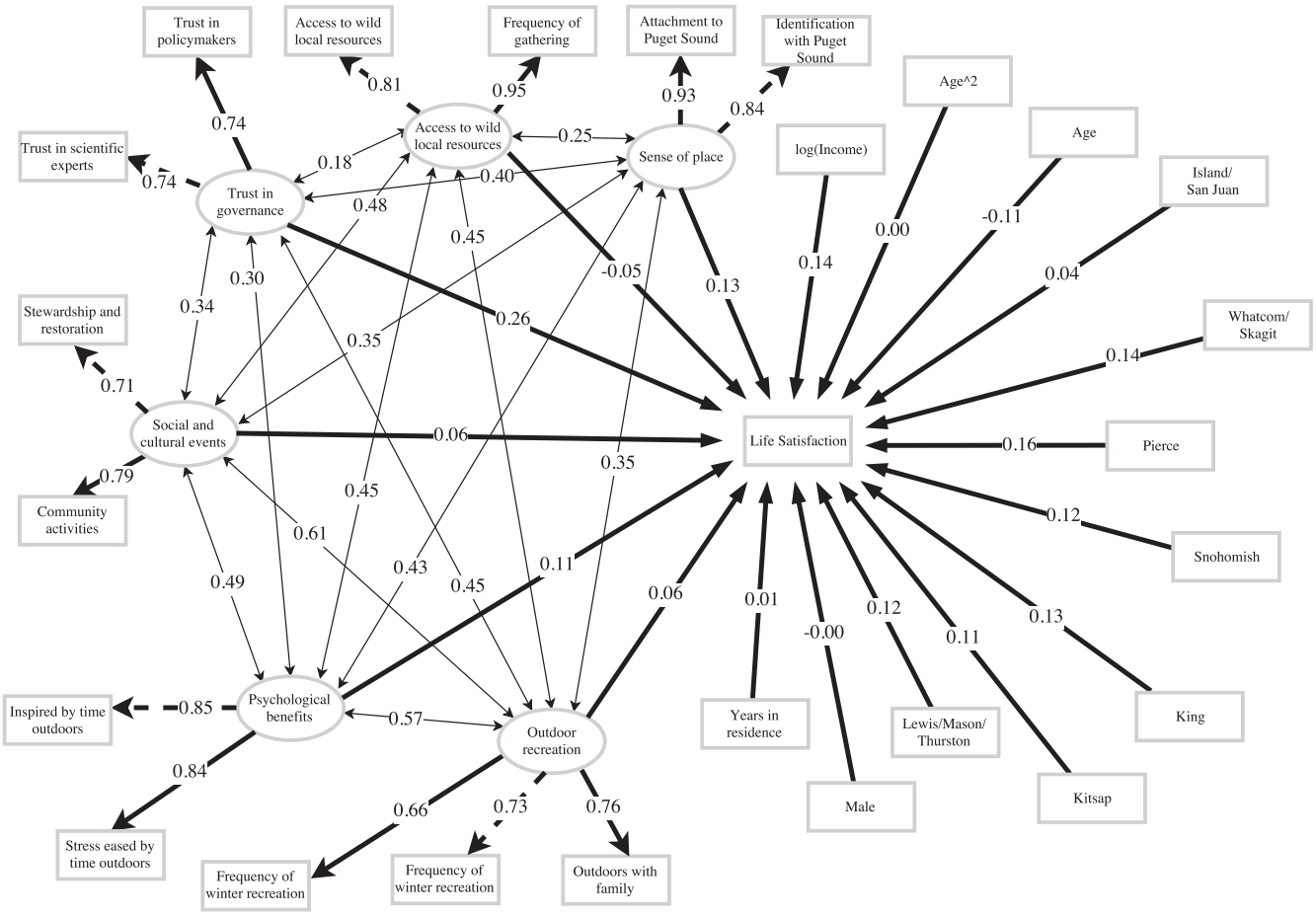

Fig. 2. Structural equation model results for predictors of life satisfaction.

Table 4
Predictors of life satisfaction.

Human-environmental wellbeing indicators	(95% CI)	
F1: Psychological benefits from time spent in the outdoors	1.08	1.22
F2: Outdoor recreational activities	**1.00**	**1.18**
F3: Environmentally related social and cultural events	**1.00**	**1.19**
F4: Access to wild local resources	**0.89**	**0.99**
F5: Sense of place	**1.12**	**1.24**
F6: Trust in environmental governance	**1.35**	**1.53**
Local sub-region	(95% CI)	
Island, San Juan	0.97	2.31
King	**1.06**	**2.14**
Kitsap	**1.02**	**2.07**
Lewis, Mason, Thurston	**1.08**	**2.20**
Pierce	**1.00**	**1.98**
Snohomish	0.99	1.98
Whatcom, Skagit	**1.12**	**2.24**
Demographic covariates	(95% CI)	
Male	0.93	1.07
Income	**1.16**	**1.28**
Age	0.95	1.02
Age^2	1.00	1.00
Years of residence in Puget Sound	1.00	1.00
Conditional intercepts	(estimate)	
Extremely dissatisfied|Somewhat dissatisfied	1.44	
Somewhat dissatisfied|Neither satisfied nor dissatisfied	3.18	
Neither satisfied nor dissatisfied|Somewhat satisfied	4.31	
Somewhat satisfied|Extremely satisfied	13.64	

Parameter estimates where the posterior bounds do not encompass one (prior to rounding) are shown in boldface; the boldface reflect parameters for which the model shows a strong non-negligible effect (since baseline odds * 1 = odds). Items in bold are statistically significant.

observation to the middle value of the income range in which it was placed (e.g., $25,000 to $50,000 is assumed to be $37,500), and then fit the resultant variable with a logarithmic transformation. Net of all other variables, moving up one income bracket increases the odds of reporting strong life satisfaction by 16%–28%.

Similarly, the life satisfaction literature age has a U-shaped relationship, such that middle aged people are on average less satisfied than are younger or older people. As the survey provided age ranges, rather than numeric age, we again assigned observations to the midpoint of the range (e.g., 25 to 34 becomes 29.5), and fit age as a quadratic term. Table 4 shows the result for both age as a category and the quadratic age-squared. We found that neither format of age had significant influence on life satisfaction within our population.

For the subregion adjustments, the reference category is the Clallam County-Jefferson County subregion. This region has the lowest life satisfaction values on average, and thus the adjustments for all other subregions generally shows a strong increase in the odds of a respondent reporting that she was extremely satisfied with her life (Table 4). The predicted increase was statistically significant at the 95% confidence level for five of the seven other subregions, and significant at the 90% confidence level for the remaining two subregions.

Controlling for the demographic characteristics and location, all six human-environmental wellbeing factors were predictors of life satisfaction. A one standard deviation increase in psychological wellbeing from time spent outdoors increased the odds of life satisfaction by 8–22%. Net of all other variables, a one standard deviation increase in outdoor recreational activities was associated with between a 0 and 18% increase in the odds of being above

baseline satisfaction. A one standard deviation increase in participation in community activities related to the natural environment was associated with a 0%–19% increase in the odds of responding above baseline life satisfaction. Sense of place and trust in environmental governance were among the strongest predictors of life satisfaction, corresponding to 12–25% and 34–52% increases in the odds of responding above baseline life satisfaction for a one standard deviation increase.

Access to wild local resources (tangible goods such as shellfish or mushrooms), however, had an opposite effect as the other factors. We found that a one standard deviation increase in access to wild local resources decreased the odds of an individual responding that they were above baseline wellbeing by between 1 and 11%.

5. Discussion

We sought to understand whether stakeholder-identified indicators of wellbeing statistically correlated to a global metric of subject wellbeing. Using a survey-based instrument to elicit ratings of the social-ecological indicators and overall life satisfaction, we found that eleven of the thirteen indicators had a statistically significant association with overall life satisfaction. As these indicators had previously been identified as important in qualitative interview settings, this finding was not noteworthy, but was important to confirm at this large scale. More importantly, we found that the diverse metrics of engaging with the natural environment statistically factored into six unique categories and, controlling for a limited set of demographics, all were significantly related to life satisfaction.

The fact that Psychological benefits from time spent in the outdoors, Outdoor recreational activities, Environmentally related social and cultural events, and Sense of place had significant, positive relationships to life satisfaction is well supported in the literature. Various cultures have been shown to be dependent on the health of the natural environment (Atkins, Simmons, & Roberts, 1998; Donatuto, Grossman, Konovsky, Grossman, & Campbell, 2014) and it has been assumed that cultural maintenance is critical to overall life satisfaction and mental health, particularly in resource-based communities (Clarke, 1991). Engaging in physical activity is widely recognized as contributing to physical and mental wellbeing, and the added benefit of being outdoors contributes to stress reduction and cognitive restoration (Bratman, Hamilton, & Daily, 2012; Kaplan & Kaplan, 1989). Sense of place is usually defined as assigning meaning and attachment to a physical space and/or social community (Williams & Stewart, 1998) and has been explored as both a predictor of environmentally responsible behaviors (Ardoin, 2014) and a contributor to health and quality of life (Eyles & Williams, 2008; Hinds & Sparks, 2008). Lastly, environmental governance has been found to affect people's life satisfaction by both enhancing the quality of the natural environment and ensuring people's sense of control and social justice (Foo, Martin, Polsky, Wool, & Ziemer, 2014). Because this was the highest correlate to life satisfaction in our sample, simply ensuring the provision of tangible benefits is not enough for human wellbeing; the process by which decisions are made about managing and distributing services is critically important.

The negative relationship between access to wild local resources and life satisfaction is also noteworthy given the importance of local foods in the prior interview-based study (Biedenweg, 2016; Biedenweg et al., 2014). However, our finding that access to local foods decreases wellbeing is net of other factors such as location, age, and income. To clarify this result further, we explored the

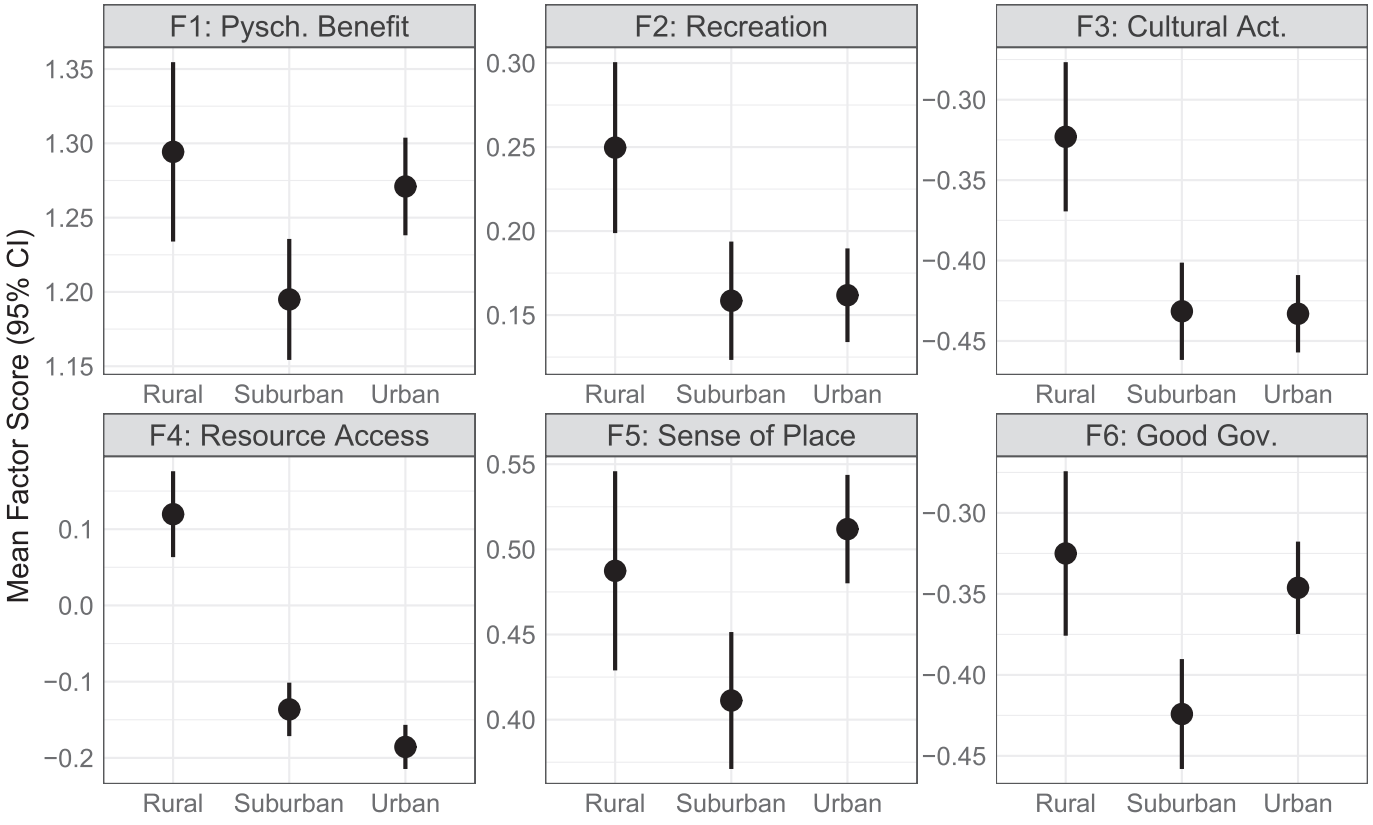

Fig. 3. Factor values by residential density. Y-axis values represent factor scores; each bar represents the 95% confidence interval for the mean factor score for three different populations: rural (Rur), suburban (Sub), and urban (Urb).

possible interaction between available demographic characteristics and resource access by comparing the predicted factor scores from the SEM model across these characteristics.

Fig. 3 shows the factor estimate confidence intervals based on the urban density of respondents. While most confidence intervals overlap, it is of note that rural residents in most cases have the highest mean factor scores across multiple factor categories, including resource access, outdoor recreation and participation in environmentally related cultural activities. This means that rural residents responded more positively to the questions associated with these factors than residents from urban and suburban areas. The most distinct influence of urban density, however, was with the resource access factor.

Based on these subgroup estimates and the fact that five of seven subregions had significantly higher wellbeing than Clallam County, which is one of the most rural Puget Sound counties, it appears that the resource access factor encapsulates rural residents who at least in part rely upon resource access for subsistence. In other words, it is possible that once psychological benefits, outdoor recreation, stewardship, sense of place and governance are controlled for, resource access is reduced to a subsistence variable and that food access for the purposes of culture or recreation are partially captured elsewhere. In these conditions, we may not expect that the ability to access resources as frequently as necessary would increase wellbeing because needing to access local resources is likely associated with other personal and social factors that significantly worsen wellbeing.

This hypothesis is supported by our findings in regards to income. While in the full model we found that increases in income increase life satisfaction, we also found that increases in income were associated with increases across all factors, with the notable exception of resource access and sense of place (Fig. 4). For resource access in particular, individuals in the highest income bracket have scores that are more negative on average than all lower income brackets. With regards to the sense of place factor, there is no obvious association across income levels.

An important application of this finding is that policy efforts to improve local food access may improve wellbeing through a variety of other factors, but local food access in and of itself tends to be highest for individuals who already have lower wellbeing. Improving food access, for example, may lead to improvements in culture, recreation, and or psychological wellbeing, but people who *need* more access to local resources are those who may for many other reasons report low wellbeing. However, as individuals move beyond the most basic needs, the additional benefits (F1,F2,F3,F5,F6) can result in improvements to wellbeing. We recognize that this interpretation is tenuous because the generic nature of the question does not allow us to know which resources people referred to and that our results are potentially specific to Puget Sound, where most rural communities are highly dependent on healthy natural resources.

6. Conclusion

Demonstrating that diverse mechanisms for engaging the natural environment correlate to a globally accepted metric of life satisfaction provides insight to the relationship between the natural environment and human wellbeing. This study confirmed that there are unique categories of engaging with the natural environment, and that these categories significantly predict overall life satisfaction when some demographic variables are held constant. The fact that these categories are unique, meaning that responses to

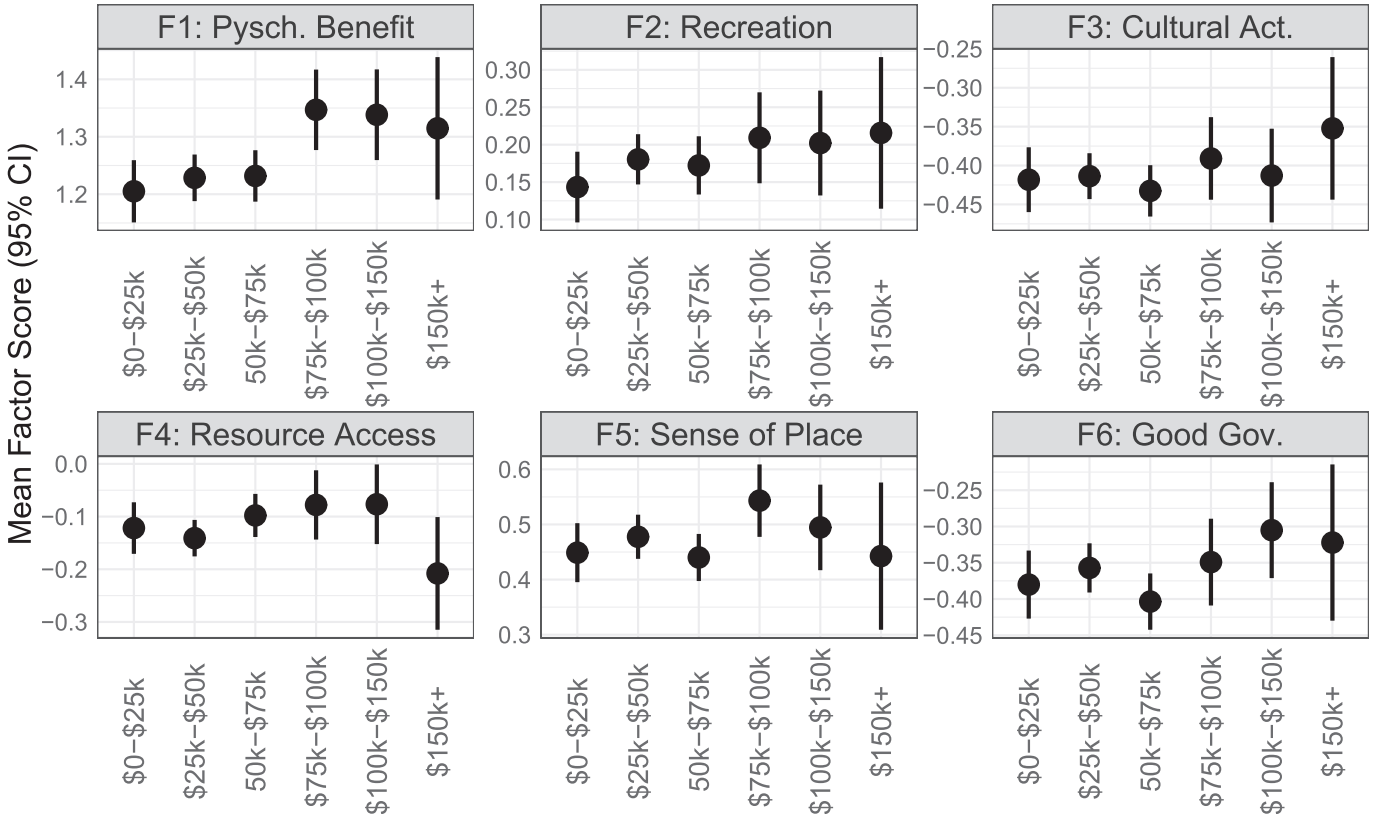

Fig. 4. Factor values by income group. Y-axis values represent factor scores; each bar represents the 95% confidence interval for the mean factor score for different income groups (n = 4418).

questions representing one attribute were more correlated to each other than to questions representing other attributes, is important for theory as well as practice. Specifically, these results highlight five categories of engaging the environment (F1: Psychological benefits from time spent in the outdoors, F2: Outdoor recreational activities, F3: Environmentally related social and cultural events, F5: Sense of place, F6: Trust in environmental governance) as having a positive impact on human wellbeing. A fifth category, Access to wild local resources (F4), was found to be negatively associated with wellbeing— a result which should be explored further in ecosystem wellbeing studies. We also recognize that these are not comprehensive groupings of engagement, as they depended entirely on the metrics we chose to explore as a result of local input on the drivers of their wellbeing related to the natural environment. Thus, future studies should explore additional potential ways that engaging the natural environment can contribute to subjective wellbeing.

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Appendix A. Survey questions

Q2: The University of Washington would like to learn about your relationship to the natural environment. How many years have you lived in the Puget Sound region?

Q1: In the past year, how satisfied have you been with your life as a whole?

Mark only one oval.
- Extremely dissatisfied
- Somewhat dissatisfied
- Neither satisfied nor dissatisfied
- Somewhat satisfied
- Extremely satisfied

Q3: I am attached to the Puget Sound region.

Mark only one oval.
- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

Q4: I identify with the Puget Sound region.

Mark only one oval.
- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

Q5: In the past year, how often have you felt inspired when spending time in nature?

Mark only one oval.
- Almost never or never
- Some of the time (about a third)
- About half of the time
- Most of the time (about two-thirds)
- Almost always or always.

Q6: In the past year, how often has spending time in nature helped you reduce stress?

Mark only one oval.
- Almost never or never
- Some of the time (about a third)
- About half of the time
- Most of the time (about two-thirds)
- Almost always or always.

Q7: This past winter, how often did you engage in outdoor recreational activities (such as walking, kayaking, or skiing)?

Mark only one oval.
- Rarely or never (less than 1 time per month)
- About 1–3 times per month
- About 1 time a week
- Several times per week (about 3 times a week)
- Almost every day (at least 5 times a week)

Q8: This past summer, how often did you engage in outdoor recreational activities (such as walking, kayaking, or gardening)?

Mark only one oval.
- Rarely or never (less than 1 time per month)
- About 1–3 times per month
- About 1 time a week
- Several times per week (about 3 times a week)
- Almost every day (at least 5 times a week)

Q9: In the past year, how often did you gather or hunt wild local resources (such as fish, berries, shellfish, mushrooms, or deer)?

Mark only one oval.
- Never
- Rarely (once or twice during the season)
- Occasionally (several times during the season)
- Regularly (most of the season)
- Constantly (almost every day during the season)

Q10: If you like to gather or hunt wild local resources (such as fish, berries, or deer), how often are you able to access as much as you'd like?

Mark only one oval.
- I don't like to gather or hunt
- Rarely (less than 30% of the time)
- Sometimes
- Usually (more than 70% of the time)

Q11: In the past year, how often did you participate in a cultural activity celebrating the environment? (such as a salmon ceremony, a harvest festival, or an environmental film festival)

Mark only one oval.
- Never
- Rarely (at least once or twice)
- Occasionally (at least three or four times)
- Regularly (at least once a month)
- Constantly (at least once a week)

Q12: In the past year, how often did you participate in environmental stewardship activities (such as removing invasive plants or environmental monitoring)?

Mark only one oval.
Never
Rarely (at least once or twice)
Occasionally (at least three or four times)
Regularly (at least once per month)
Constantly (at least once per week)

Q13: In the past year, how often did you spend time outdoors with your close friends or family?

Mark only one oval.
Rarely or never (less than 1 time per month)
About 1–3 times per month
About 1 time a week
Several times per week (about 3 times a week)
Almost every day (at least 5 times a week)

Q14: How much of the time do you think you can trust local policymakers to protect the Puget Sound?

Mark only one oval.
Almost never or never
Some of the time (about a third)
About half of the time
Most of the time (about two-thirds)
Almost always or always.

Q15: How much of the time do you think you can trust scientific experts to protect the Puget Sound?

Mark only one oval.
Almost never or never
Some of the time (about a third)
About half of the time
Most of the time (about two-thirds)
Almost always or always.

Appendix B. Block designs

Set questions.
Q1: How satisfied are you with life.
Q2: How long have lived in Puget Sound.

Table B1
Block designs paired with Q1 and Q2

Block 1 (N = 186):	Block 2 (N = 177):	Block 3 (N = 195):
Winter Activities	Winter activities	Cultural Activities
Cultural Activities	Local Resource Access	Trust Scientific Experts
Local Resource Gathering	Summer Activities	Stewardship Activities
Local Resource Access	Stewardship Activities	Local Resource Access
Block 4 (N = 185):	Block 5 (N = 182):	Block 6 (N = 188):
Trust policymakers	Winter activities	Inspiration
Stress reduction	Local Resource Access	Attachment
Attachment	Attachment	Local Resource Gathering
Inspiration	Outdoors with family	Stress Reduction
Block 7 (N = 177):	Block 8 (N = 177):	Block 9 (N = 176):
Outdoors with Family	Attachment	Local Resource Gathering
Cultural Activities	Inspiration	Summer Recreation
Trust Scientific Experts	Outdoors with Family	Stress Reduction
Winter Recreation	Cultural Activities	Trust Scientific Experts
Block 10 (N = 180):	Block 11 (N = 184):	Block 12 (N = 186):
Outdoors with Family	Trust Scientific Experts	Trust Scientific Experts
Cultural Activities	Stress Reduction	Summer Recreation
Local Resource Gathering	Winter Recreation	Identify
Stress Reduction	Outdoors with Family	Trust local policymakers
Block 13 (N = 182):	Block 14 (N = 179):	Block 15 (N = 190):
Trust Scientific Experts	Stress Reduction	Identity
Trust Local Policymakers	Winter Recreation	Attachment
Winter Recreation	Cultural Activities	Trust Local Policymakers
Local Resource Access	Attachment	Stewardship Activities
Block 16 (N = 179):	Block 17 (N = 178):	Block 18 (N = 178):
Inspiration	Inspired	Summer Recreation
Identity	Summer Recreation	Trust Scientific Experts
Local Resource Gathering	Trust Scientific Experts	Local Resource Gathering
Attachment	Trust Local Policymakers	Local Resource Access
Block 19 (N = 180):	Block 20 (N = 179):	Block 21 (N = 183):
Trust local policymakers	Identity	Inspiration
Summer Recreation	Environmental Stewardship	Summer Recreation
Outdoors with Family	Stress Reduction	Local Resource Access
Local Resource Access	Cultural Activities	Environmental Stewardship
Block 22 (N = 175):	Block 23 (N = 193):	Block 24 (N = 185):
Identity	Trust local policymakers	Identity
Trust Local Policymakers	Identity	Inspiration
Stewardship Activities	Attachment	Local Resource Gathering
Outdoors with Family	Outdoors with Family	Stewardship Activities

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