

Humans and Nature: How Knowing and Experiencing Nature Affect Well-Being

Roly Russell,¹ Anne D. Guerry,² Patricia Balvanera,³
Rachelle K. Gould,⁴ Xavier Basurto,⁵ Kai M.A. Chan,⁶
Sarah Klain,⁶ Jordan Levine,⁶ and Jordan Tam⁶

¹The Sandhill Institute for Complexity and Sustainability, Grand Forks, British Columbia V0H 1H9, Canada; email: roly@sandhillinstitute.org

²Natural Capital Project, Woods Institute for the Environment, Stanford University, Seattle, Washington 98115; email: anne.guerry@stanford.edu

³Centro de Investigaciones en Ecosistemas, Universidad Nacional Autónoma de México, Morelia, Michoacán, 58350 Mexico; email: pbalvanera@cieco.unam.mx

⁴Emmett Interdisciplinary Program in Environment and Resources, Stanford University, Stanford, California 94305; email: rachelle@post.harvard.edu

⁵Duke Marine Lab, Nicholas School of the Environment, Duke University, Beaufort, North Carolina 28516; email: xavier.basurto@duke.edu

⁶Institute for Resources, Environment and Sustainability, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada; email: kaichan@ires.ubc.ca, s.klain.ubc@gmail.com, levine.jordan.s@gmail.com, jordan.tam@gmail.com

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Abstract

Ecosystems provide many of the material building blocks for human well-being. Although quantification and appreciation of such contributions have rapidly grown, our dependence upon cultural connections to nature deserves more attention. We synthesize multidisciplinary peer-reviewed research on contributions of nature or ecosystems to human well-being mediated through nontangible connections (such as culture). We characterize these connections on the basis of the channels through which such connections arise (i.e., knowing, perceiving, interacting with, and living within) and the components of human well-being they affect (e.g., physical, mental and spiritual health, inspiration, identity). We found enormous variation in the methods used, quantity of research, and generalizability of the literature. The effects of nature on mental and physical health have been rigorously demonstrated, whereas other effects (e.g., on learning) are theorized but seldom demonstrated. The balance of evidence indicates conclusively that knowing and experiencing nature makes us generally happier, healthier people. More fully characterizing our intangible connections with nature will help shape decisions that benefit people and the ecosystems on which we depend.

Contents

| | |
|---|-----|
| 1. INTRODUCTION | 474 |
| 2. CONCEPTUAL ORGANIZING FRAMEWORK | 475 |
| 2.1. Our Approach: Biases and Boundaries | 475 |
| 2.2. Channels of Human Experience with Ecosystems | 476 |
| 2.3. Constituents of Well-Being | 478 |
| 3. THE STATE OF THE ART: LINKING NATURE EXPERIENCE TO WELL-BEING | 478 |
| 3.1. Physical Health | 479 |
| 3.2. Mental Health | 480 |
| 3.3. Spirituality | 482 |
| 3.4. Certainty, and Sense of Control and Security | 483 |
| 3.5. Learning and Capability | 484 |
| 3.6. Inspiration and Fulfillment of Imagination | 485 |
| 3.7. Sense of Place | 486 |
| 3.8. Identity and Autonomy | 487 |
| 3.9. Connectedness and Belonging | 489 |
| 3.10. Subjective Well-Being | 490 |
| 4. FUTURE PERSPECTIVES | 491 |
| 4.1. Where Could We Go from Here? | 492 |
| 5. CONCLUSIONS | 493 |

Ecosystem: a system formed by biotic elements (living things) and abiotic elements (including water, nutrients, energy) and the interactions among them

Well-being: people's capacity to be and do well in life, and achieve a state of health, happiness, or prosperity

1. INTRODUCTION

People need ecosystems. Implicit and explicit recognition of this simple fact has inspired a great deal of research in an effort to improve outcomes for people and the ecosystems on which we rely (1). Significant effort has been directed at understanding the wide range of benefits that ecosystems provide to people in order to facilitate sound decision making accounting for the connections between ecosystems and people (e.g., 2–4). Failing to incorporate these benefits (although we assess both benefits and costs, we use the term benefit for

simplicity because benefits are most common) into decision making is jeopardizing the design and implementation of the resulting strategies because those strategies are often disconnected from what really matters to many people (5).

Ecosystems contribute to human well-being in various ways. Ecosystems provide the necessary resources of food, water, shelter, and energy. Also, they regulate the conditions (e.g., temperature, water quality) in which people live, work, and play and, most fundamentally, underpin the basic processes (e.g., primary production) and cycles (e.g., carbon cycle, water cycle) that support life. These types of “ecosystem services”—provisioning, regulating, and supporting (1)—have received the majority of research attention. Ecosystems, however, also contribute culturally and psychologically determined benefits to people that are crucial to human well-being (e.g., References 6–9). These “cultural ecosystem services” represent intangible dimensions of the links between people and ecosystems that are psychological, philosophical, social, and spiritual and are at the very core of human preferences and values. Incorporating these intangibly derived benefits into decision making is thus at least as important as incorporating the more tangible ones. Although assessing comprehensive suites of nonmaterial services from ecosystems is difficult using traditional methods, characterization of these intangibles is both possible (10) and critical to the development of a fuller understanding of human connections to ecosystems.

The psychologically and culturally mediated connections between people and natural systems have long been studied by anthropologists, sociologists, psychologists, and geographers. Cultural ecology, political ecology, and cultural anthropology have assessed the ways in which culture interfaces with environmental conditions, and indeed, this more holistic relationship between people and their surroundings has always been a keystone of anthropological inquiry (e.g., identity, sense of place, cultural domains) (6, 11–13). In addition, specific culturally mediated benefits provided by ecosystems, such as recreation (14–16), scenic

beauty (e.g., Reference 8), effects of ecosystems on physiological health (e.g., References 17 and 18), and mental health (19, 20), have been quite intensively studied (21) but usually independent of one another. Thus, further synthesis of the intangible links between nature and human well-being is needed.

Here, we synthesize the available empirical literature regarding the contributions of ecosystems (or nature) to human well-being via nonmaterial connections. It is our hope that this can facilitate the explicit incorporation of these connections into decision making. Although clearly the terms nature and ecosystems differ in numerous ways that have been problematized extensively elsewhere (e.g., Reference 22), we use them as equivalents to encompass the epistemological approaches of different disciplines. We first propose a conceptual framework to organize the literature by (a) delineating the channels of experience through which people associate with ecosystems and (b) suggesting how those channels link to various constituents of human well-being. Then, we survey the literature and assess our current understanding of the role of nonmaterial connections from ecosystems to human well-being. Finally, we highlight gaps in the literature and suggest future research that might begin to fill those gaps.

2. CONCEPTUAL ORGANIZING FRAMEWORK

There is a pervasive, visceral understanding that our nonmaterial connections to ecosystems provide rich benefits, but systematically analyzing these connections must be done at the interface of disciplines as disparate as behavioral science, philosophy, art, medicine, anthropology, history, and ecology. A conceptual framework that enables the organization and integration of these wide-ranging dimensions is a critical initial step in their synthesis.

Here, we propose that nonmaterial connections to ecosystems are realized through different channels of experience and contribute to different constituents of well-being. We first lay out our conceptual background and define

the different channels and constituents. Then, although we recognize the strong linkages between and among the four channels of experience and the 10 constituents of well-being, we endeavored to dissect the literature into individual interactions between them to better map the current state of knowledge. For studies that applied to many options, we chose the channel-constituent pair that seemed most relevant.

2.1. Our Approach: Biases and Boundaries

Three ground-clearing efforts are necessary before we move forward: The first addresses our use of the complex and diverse term nature; the second addresses the character of this undertaking; and the third addresses the predominately Western and positivistic worldview that underpins this review.

First, definitions and concepts of nature are exceptionally diverse, and treatments of this subject fill volumes. Here, we use the term nature very broadly. We focus on the flow of benefits from nature/ecosystems to people; our conceptualization of nature encompasses both living and nonliving components of ecosystems (including human-modified environments). It ranges from the most pristine areas in Antarctica to a few trees in an urban street (and the birds, mammals, insects, and other life they harbor), and it includes forests and coral reefs as well as diverse or simplified agroecosystems and domestic animals. We exclude nonliving human-built environments, though these environments can, and often do, serve as the matrix within which nature affects people. In this review, we have artificially separated nature from humanity. Ultimately, nature and humanity are truly inseparable; nature cannot be defined in a way such that it does not also include humanity or some of its work. Accordingly, our analysis is partial and static. A more complete analysis would include the multitude of ways that nature and humans interact and evolve over time, but such an analysis is beyond the scope of this article.

Ecosystem services: ecosystems' contributions to human well-being, e.g., provisioning services, regulating services, cultural services, and, underpinning them all, supporting services

Cultural ecosystem services: ecosystems' contributions to human well-being mediated through nonmaterial processes (e.g., the mind or culture)

Material/nonmaterial: adjectives describing benefits and harms where materiality is defined by a physical (e.g., food, fiber, fuel, bodily harm) or monetary nature

Natural/nature: all living and nonliving components of ecosystems described in an expansive though not exhaustive way, excluding nonliving human-built environments

Empirical: derived from or verifiable by experience or experiment

Constituents of well-being: the range of human needs that when satisfied contribute to well-being

Second, we recognize the Herculean (and, if misinterpreted, Quixotic) task we set for ourselves with this effort. Given the psychologically, evolutionarily, culturally, and ecologically embedded character of the rich and varied connections between humans and nature, it is impossible to provide an exhaustive review. Instead, we aim to identify those facets of the relationship that have received substantive research attention and to highlight those that remain poorly captured and characterized in the research literature. We focus on the empirical (and mainly peer-reviewed) demonstrations of effects on well-being of changes or differences in elements of nature. A notable, if undesirable, consequence of this choice is the omission of many empirical and rich ethnographic or historical approaches. Our intent is to recognize the many approaches to empirically documenting the nonmaterial relationships between humans and nature and to gather and organize some of this diverse literature (again, with the notable exception of ethnographic and historical approaches) in one review to yield a more complete picture. We hope to identify gaps in the literature, clarify fruitful avenues for future research, and provide a compilation that serves as a useful foundation for others to build upon.

Third, our approach is limited by our chosen conceptual perspective and thus by the methods we employ: We emphasize research that focuses on measurable end points or is positivistic. We recognize that there are many different “ways of knowing.” With the aim of comparing and contrasting different literatures in a defensible and replicable manner, we chose to focus on empirical work in scientific journals. Although we do include some books and book chapters, the literature we use here is biased toward papers in peer-reviewed journals written in English (see our methods in the **Supplemental Material**; follow the **Supplemental Material link** from the Annual Reviews home page at <http://www.annualreviews.org/>). Our incorporation of books and book chapters, which are often used to report research based on phenomenological and constructivist epistemologies, is more limited. Anthropological and

ethnographic narratives—arguably the most empirical and holistic assessments of these human-nature relationships—are not cleanly compatible with our focus on nonmaterial benefits as demonstrated by ecosystem change or difference. This constraint results in a literature available for review that is skewed toward the individualist, psychological, clinical, experimental, and reductionist studies, and away from more holistic narratives and the anthropological and sociological disciplines. In sum, this perspective and these methods bias our results toward reductionist, psychological, and Western perspectives.

2.2. Channels of Human Experience with Ecosystems

People experience ecosystems in a variety of ways. We pick berries, fish in the sea, imagine wild places, listen to birds singing, bury our dead in the earth, and celebrate harvest with our families and communities. While recognizing that we fall sick to pathogens and can be harmed by toxic plants and dangerous animals, we focus our review on nonmaterial benefits from ecosystems. In turn, our thinking is rooted fundamentally in our directly lived experience with the world and thus with our surrounding environment (whether it be built or natural).

Growing insights on the full range of human interactions with ecosystems have been gained from the empirically supported theory of embodied cognition. According to embodied cognition theory (e.g., References 23–25), all of our more complex, abstract, or culturally specific concepts are creative recombinations of physical experiences we have with the world around us (e.g., seeing and interacting with tangible objects, moving our bodies through space, or correlating phenomena such as size and weight). This implies that the way in which we interact with our environment helps guide how we think and who we are—and thus impacts the core of our well-being. We use this basic insight from embodied cognition—that interaction with the environment affects human well-being—to structure our review. To build a

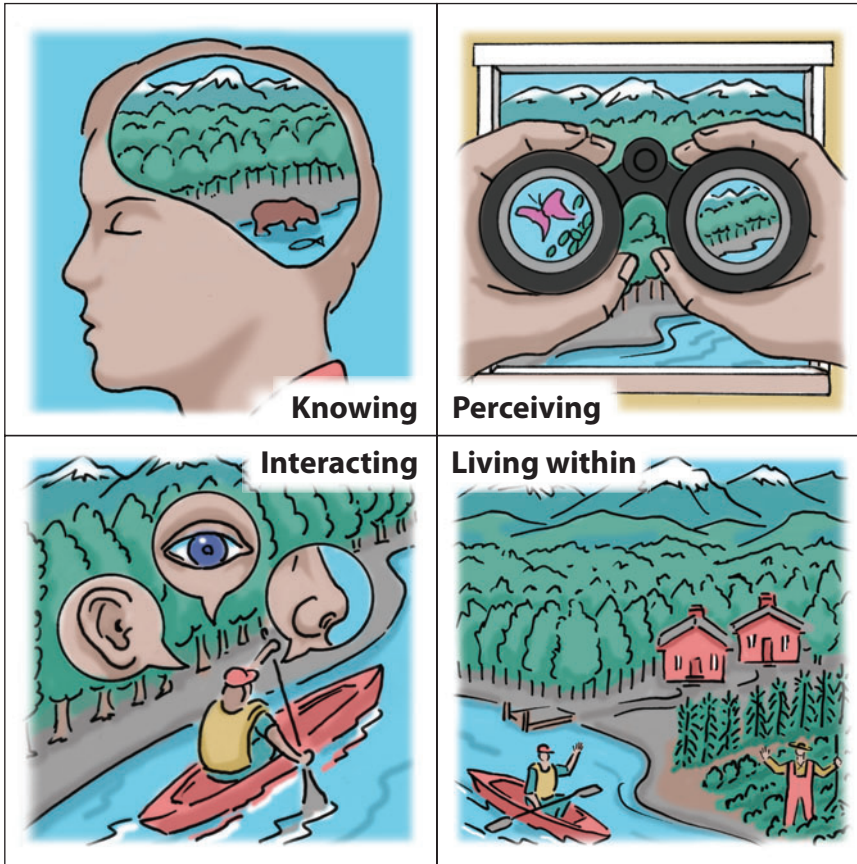


Figure 1

Four channels of human interactions with ecosystems: (a) knowing, thinking about an ecosystem or just the concept of an ideal ecosystem; (b) perceiving, remote interactions with ecosystem components; (c) interacting, physical, active, direct multisensory interactions with ecosystem components; and (d) living within, everyday interactions with the ecosystem in which we live.

frame with which to organize the wide-ranging literature reviewed here, we first categorize human interactions with nature and then categorize aspects of well-being.

We propose that benefits derived from non-material interactions with ecosystems may be obtained through four different channels of human experience (one of many possible typologies) (**Figure 1**). Building from the connection between interaction with the environment and human well-being articulated by embodied cognition, we sought to articulate categories of people's interactions with nature. We suggest that these channels incorporate all of the ways

in which people experience nature, consciously or subconsciously, yet do not pretend that they are truly separable or mutually exclusive. Indeed, multiple channels can be, and often are, experienced by a person at any one point in time. The four channels are (a) knowing, the metaphysical interactions that arise through thinking about an ecosystem, its components, or the concept of an ideal ecosystem, in the absence of immediate sensory inputs (e.g., imagining a polar bear hunting, thinking about a favorite place); (b) perceiving, remote (i.e., neither proximate nor tangible) interactions with ecosystem components, often associated

Channels of human experience: the different ways in which humans interact with the world around them

Intangible connections: capabilities, experiences, relationships, and other social or psychological (thus cultural) nonmaterial mediators of ecosystems' contribution to well-being

with visual information alone (e.g., viewing a mountain, watching a nature video); (c) interacting, physical, active, direct multisensory interactions with ecosystem components (e.g., catching a fish, building a sandcastle, touching moss, smelling nearby pine trees, gardening), which may be cursory and may involve other people; and (d) living within, the everyday, repetitive, pervasive, voluntary, or involuntary interaction with the ecosystem in which one lives (e.g., living in a forested area, near an urban park, or by the seashore). The unique aspects of contributions mediated by social interactions in nature (e.g., bonding through shared hunting experiences, celebrating an important ceremony outdoors) are poorly differentiated theoretically from other interactions with nature, so we have included research specific to social interactions in nature within the interacting channel. These four channels are interrelated in many ways. Viewing, for example, is often a basis for knowing; living within nature encompasses all other channels but also stimulates new kinds of relationships. One specific example is that interacting by fishing to make a living contributes to knowing. We arrange them from the most remote from an ecosystem to the most intimately connected.

2.3. Constituents of Well-Being

Well-being can be understood as a complex and synergistic function of several components; when these constituents are combined, the state of the whole person emerges. Components of human well-being have perhaps most famously been articulated by Maslow (26) in his hierarchy of needs, which includes physiological needs as well as needs for esteem, belonging, and safety. Although the idea that these needs are ordered in such a hierarchy is now viewed as inaccurate, evolutionary psychological theory and evidence suggest that these broad categories remain generally relevant and have functional explanations (27). Reviewing the literature of human needs, Tay & Diener (28) identified similar though nominally different categories, but to these, they add status, competence, and autonomy.

Others have added the needs for identity, creation, leisure, and understanding (29), as well as purpose and personal growth (30).

Building upon these taxonomies, we use 10 constituents of well-being to structure our synthesis of the literature documenting the intangible connections between nature and human well-being. We do not intend these as a theoretical framework for well-being theory, the creation of which is beyond our purview, but rather a framework with which to organize the literature. The 10 constituents we use span the spectrum of critical dimensions of human well-being:

1. Physical health
2. Mental health
3. Spirituality
4. Certainty and sense of control and security
5. Learning/capability
6. Inspiration/fulfillment of imagination
7. Sense of place
8. Identity/autonomy
9. Connectedness/belonging
10. Subjective (overall) well-being

Admittedly, these categories are imperfect, and the lines between them are often blurred. For example, the subjective well-being category is a composite that can represent elements of all other categories. Because there is a large literature devoted to this emergent property, we decided to include it as a distinct category. Despite their imperfections, we posit that these categories serve the purpose of binning the literature to illuminate how different types of interaction with the environment affect well-being. We provide further information on our definitions of each category at the beginning of each numbered section below.

3. THE STATE OF THE ART: LINKING NATURE EXPERIENCE TO WELL-BEING

Ecosystems contribute to nonmaterial well-being in all manner of complex ways, which might seem to defy comprehensive or structured understanding. Here, we show how

these diverse contributions from ecosystems to human well-being can be understood and organized as addressing components of well-being through channels of nature experiences. By reviewing representative examples of research that addresses each experiential channel within each constituent of well-being, we provide one perspective on organizing and synthesizing this dramatically interdisciplinary literature. Through this framework, we also isolate apparent gaps in our scholarly understanding of these intangible human-nature relationships.

For a more thorough exploration of the literature reviewed herein, see **Supplemental Table 1** at <http://www.annualreviews.org/>.

3.1. Physical Health

Here, we focus on studies that used at least one physiological metric (e.g., heart rate or blood pressure) to report the contributions of nature to physical health, specifically, how changes or differences in nonhuman organisms and/or ecosystems result in changes or differences in physical health. Given the inextricable links between physical health and mental health, some of the studies described below could have been categorized in mental health and vice versa.

3.1.1. Knowing. We found no empirical research documenting the connection between knowledge of nature and physiological health as provided by intangible connections (provision of medical remedies via knowledge of traditional ecological knowledge would classify as material connections to ecosystems and thus be excluded from this review).

3.1.2. Perceiving. Evidence abounds that views of natural ecosystems have positive physiological effects (20). In one clinical example (31), subjects are exposed to either a window with a natural scene, a plasma TV screen with an image of the same natural scene, or a brick wall. Viewing the real scene through the window led to more rapid recovery of heart rates after exposure to low-level stress than

the plasma screen representation, and in turn the plasma screen subjects recovered more rapidly than did those viewing the brick wall (31). Correspondingly, prison inmates with a view of adjacent farmland had fewer demands on the prison health care system than did prisoners with a view of the prison courtyard (32).

3.1.3. Interacting. Physiological benefits from more intimate connections with nature have also been documented. For example, contact with animals shows health benefits; patients recovering from acute myocardial infarction who had pets were healthier than their counterparts without pets (33), and pet ownership is associated with reduced incidence of allergies (34). Furthermore, proximity to green spaces has been correlated with longevity of the elderly (35, 36). Exercise in a natural environment has been shown to provide some positive benefits relative to synthetic environments, but less so for physiological measures than for measures of emotions (37).

3.1.4. Living. A large volume of research assesses the relationship between physical health and living in predominately natural versus built environments, although many such connections are ultimately explained by tangible causal pathways and thus outside of the purview of this review [e.g., recent research that biodiversity around where people live correlates positively with human microbiotic diversity and may contribute to greater immunological tolerances (38)]. Loss of trees to the emerald ash borer in the United States increased county-level mortality related to cardiovascular and lower-respiratory-tract illness (39), a complex causal pathway but not obviously based on delivery of tangible ecosystem goods.

Residents of neighborhoods with more green space tend to have better self-reported health after controlling for many significant sociodemographic characteristics (40, 41). In a similar study, Mitchell & Popham (42) found that the relationship became insignificant in high-income neighborhoods. Although

differences in morbidity rates are highly correlated with socioeconomic factors, proximity of homes to green space may lessen these differences through the provision of exercise and stress reduction opportunities in populations potentially less inclined or less able to engage in such activities (43).

Ecological degradation has been empirically associated with degradation of both physical health (e.g., respiratory or mosquito-borne illnesses) and mental health (e.g., depression) (39, 44, 45), though not consistently. Conceptual models of how human health depends upon ecosystem health (and vice versa) are being developed, but this connection is generally ascribed to tangible connections, for example, documented links between infectious disease transmission and ecological degradation (46). Evidence of bidirectional links between human health and ecosystems has inspired calls for healthcare systems to address access to, and the health of, natural settings to adequately nurture human health (20, 47–50).

3.1.5. Summary. Connections between physical health and natural systems are frequently described (51), and empirical evidence unequivocally indicates that various forms of nature experience result in positive physiological health responses. This literature has generally focused on the benefits of viewing nature for recovery or for medical care, the benefits of interacting with individual animals for various measures of health and longevity, and the pathways by which living in more natural environments improves self-reported health and allergy sensitivity and reduces disease burden. One potential reason for the relative abundance of research in this area is the predominance of positivistic assessment in clinical research. However, these studies frequently assess impacts on isolated components of physical health rather than on comprehensive human health. Teasing apart the direct and indirect (e.g., through increased exercise), and similarly the material and nonmaterial, effects of ecosystems on physical health remains an outstanding knowledge gap and challenge.

3.2. Mental Health

In this section, we focus on richly supported contributions of ecosystems to indicators of mental health, understood broadly to include cognitive performance, self-reported stress, and emotional well-being. For the purposes of this review, a semantic rather than a substantive distinction is made to isolate ecosystems' contributions to mental health (again focusing on change or difference in mental health resulting from or correlating with biophysical change or differences), despite both the blurred divisions between mental and physical health and the extensive evidence of a strong connection between the two. We are keenly aware that many impacts of nature on other constituents of well-being may manifest themselves in part through evidence of changes to mental health. Numerous insightful reviews explore nature experience and mental health (19, 20, 52).

3.2.1. Knowing. Anecdotal evidence about the mental health benefits of knowing that nature exists are frequently acknowledged (53, 54), yet empirical evidence of this connection is poorly documented. Knowledge of belonging to a community or something greater than oneself through nature is argued to be a plausible cause of the broader positive psychological benefits of nature (55).

3.2.2. Perceiving. Views of nature have been repeatedly associated with improved mental health and reduced stress levels (17, 56–58). Studies of the workplace found that a view of natural elements (e.g., plants) helped buffer the impact of job stress (lowering employees' intentions to quit and marginally improving general well-being) (57) and were associated with greater employee satisfaction with work, reductions in perceived stress, greater life satisfaction, increased patience, and better health (56). This effect may be well enough recognized, even if subconsciously, that offices lacking windows providing views of natural scenes more extensively use nature proxies such as indoor plants and photographs (59, 60). Driving

on roads in natural settings as opposed to urban settings has been documented to reduce driver stress (as monitored by physiological parameters such as blood pressure and electrodermal activity) and to increase the ability to cope with future stress (61), even when the suite of potential confounding variables (e.g., abundance of safety-related cues) is considered.

The empirical literature studying the role of proximity to, views of, and time spent in green space is bountiful and provides robust indications that green space has a positive influence on mental well-being. Although these effects certainly also involve more intimate channels of interaction with nature, we primarily summarize them here. Among apartment tenants, views of more natural environments (relative to views of built environments) led to increases in well-being and greater residential satisfaction (17), in addition to increases in self-discipline (62). Views of nature may also have educational benefits, increasing the capacity for attention as shown through objective performance measures and subjective self-reported metrics (42, 63).

3.2.3. Interacting. Time spent in natural systems has a documented positive effect on human mental health. A review of the empirical literature addressing the relationship between visits to natural settings and recovery from mental fatigue by Kuo (64) showed that 14 of the 16 reviewed studies showed one or more statistically significant effects. In previous studies, there has been a hypothesized negative effect of urbanity on health (e.g., relationships driven by differences in pollution, exercise, and cultural practices producing anxiety and stress); the studies reviewed by Kuo imply that this urbanity effect may be better explained by the availability of proximate green space than by other drivers. The relationship between perceived health and green space was found across all levels of urbanity, without significant distinction between natural green space and agricultural green space.

Urban dwellers have been shown to exhibit better concentration, focus, and reduced fatigue and irritability upon spending time in a natural

environment (65). Ottosson & Grahn (66), in a study exploring recovery from crisis (e.g., a death or severe loss), concluded that experiencing nature promotes restoration better than do other inputs studied (such as taking a walk, and interacting with friends). The same authors have noted in other research that the benefits of visiting natural spaces may be disproportionately larger for those who are ailing the most; for example, elderly people with a particularly low “psychophysiological balance” (defined as general helplessness, frequency of hospital visits, and low tolerance of other people) are the most positively affected by a visit to a garden as measured by heart rate and blood pressure changes (67); although these are physical effects, they are intricately connected to mental state. Hartig & Staats (68) studied college students to explore the potential restorative effects of a walk in a natural setting and found that, although natural settings were restorative in all the studied situations, the effect was larger when subjects were in a more fatigued condition.

Building upon this evidence, methods for nature-based therapy (e.g., wilderness, horticultural, and animal-assisted therapy) have demonstrated success in healing patients who previously had responded poorly to other treatment (see Reference 20 for a thorough review); the assumed primary mechanism behind the success is a positive effect of nature on mental well-being. Immersion in nature has also been shown to have positive influence on levels of generosity and caring (69), another potential mechanism for the success of such therapies.

3.2.4. Living. Everyday exposure to natural elements is linked to mental health. Homes surrounded by more green space have been associated with an increased ability of residents to cope with subjectively and personally defined major issues (64). Also, Wells & Evans (70) documented a negative relationship between psychological distress in children and “naturalness” of the home environment (as indicated by a score summarizing views from the home, yard materials, and abundance of houseplants), even after taking socioeconomic status

into account. Nearby nature also buffered the effects of stressful life events on the children's level of psychological distress (70). One study found that homes surrounded by more greenery (e.g., trees and grass) are associated with reduced internal family conflict (71). A more recent study demonstrated a positive effect of vegetation on the personal well-being of city dwellers and weak positive associations of well-being with species richness and bird abundance (72). Deep interconnections have been found between mental well-being and living in close relationship with animals. Numerous studies document the positive effects of pets and interactions with pet animals, such as therapy dogs, on both mental and physical health (73–75).

3.2.5. Summary. The empirical literature unequivocally identifies strong relationships between nature and mental health (19, 20). Extensive evidence demonstrates the multiple effects that viewing, interacting with, and living in natural environments can have: reducing stress, increasing patience, increasing self-discipline, increasing capacity for attention, increasing recovery from mental fatigue or from crisis and from psychophysiological imbalance. These effects were associated with natural settings generally (e.g., green space or biologically diverse ecosystems) and individual animals (e.g., pets).

3.3. Spirituality

Many accounts of well-being include a constituent that encompasses perceived connections to others and otherworldly forces that go beyond what is generally considered within physical and mental health. Even though the role of ecosystems and nature in contributing to such spirituality is not always expressed as providing benefits, it is nevertheless the case that losses or degradation of ecosystems or natural objects can trigger negative impacts on this component of well-being. The distinction among the impacts through the alternative channels of experience on spiritual health is much less clear, but we highlight major differences.

3.3.1. Knowing. Although the bulk of the peer-reviewed literature may indicate otherwise, it is important to note that spiritual benefits deriving from the existence of nature are not limited to indigenous populations. A broad-ranging study on emerging forms of nature-based spirituality in modern US society found that both groups and individuals see ecological processes as sacred (76), and more local studies in British Columbia (77) and Hawai'i (R.K. Gould, N.M. Ardoin, U. Woodside, N. Hannahs, T. Satterfield, G.C. Daily, paper in preparation) have found that diverse respondents express deep and varied spiritual connections to ecosystems.

Sacred sites abound in numerous—possibly even all—religions. An individual's knowledge of the continued existence and preservation of personally or culturally relevant sacred natural sites can, in many cases, be linked directly to that individual's sense of spiritual well-being (78). Examples of how spiritual well-being can be tied to natural sites include the Makah people of the northwestern United States who have complex aspects of their spiritual well-being tied to the ability to engage in whale hunting (79), and the people of Meghalaya, India, who “believe that the Sylvan deities would be offended if trees are cut and twigs, flowers, fruits, etc. are plucked [from sacred groves]” (80, p. 563). Ecological degradation can constitute cultural or spiritual loss that alters and often contributes to the impoverishment of cultures even if degradation of a given resource does not significantly impact ecosystem function (81, 82).

Various ecosystem components (including a wide range of plants, animals, and minerals) are key elements in the diverse practices (with spiritual overtones or ramifications) of many indigenous cultures, including ceremonies (e.g., Reference 83). Spiritual ceremonies often involve key elements from the ecosystem as central features. For instance, ceremonies dedicated to the jaguar (and dependent on the knowledge of its existence), which is central to the Nahuatl cosmology, are still practiced today in some areas of southern Mexico (84).

3.3.2. Perceiving. Documentations of the connections between perception of nature and spiritual well-being are sparse. McDonald (85) documented environmentalists' perception of a vital force while in nature, often mediated by the perception of natural forms or phenomena, such as steelhead salmon or salt marshes.

3.3.3. Interacting. There are many studies on the spiritual benefits of wilderness experiences in Western cultures. Interviews of wilderness users in California's Eldorado National Forest (86) found that most interviewees acknowledged the spiritual value of the wilderness. Similarly, there is evidence that the experience of camping in natural settings is, at least in part, a spiritual process for many people (87, 88). According to one study, a majority of wilderness visitors seek the spiritual values or benefits of wilderness (89). A review of empirical research on exposure to nature and well-being (90) surmises that such spiritual/transcendent experiences provide greater self-confidence, sense of belonging, and clarity about "what really matters." Ashley (91) identified a feeling of connection and interrelationship with other people and nature as the primary defining characteristic of wilderness spirituality.

3.3.4. Living. Evidence of the impact on spirituality of living with access to natural systems and components is thin. One study (92) surveying urban dwellers documents that many city dwellers' personal ties to urban forests and trees often approach a spiritual involvement and provide many of the spiritual connections often attributed to wilderness experiences.

3.3.5. Summary. The literature provides a rich set of examples of the importance of sacred places and the wilderness experience for the spirituality of some individuals and groups: Spiritual values are commonly tied to ecosystems or elements of ecosystems (e.g., Reference 6). Although resource management efforts must recognize materially based ecological connections or risk unexpected outcomes, it has been argued that "[i]gnoring the psychological and

spiritual connections between humans and the natural world can result in equally nasty surprises" (93, p. 29). Nonetheless, empirical insights into the role that ecosystems play in this relationship beyond wilderness experiences and sacred places remain scarce. This stems, in part, from the particularly complex nature of positivistic assessments of spiritual health. It is also influenced by the Western philosophical bias in the academic literature; this bias underrepresents perceived spiritual connections to nature (94).

3.4. Certainty, and Sense of Control and Security

In practice, the effects of nature on this component of well-being (certainty, control, and security) are often measured through (lessened or heightened) feelings of fear or insecurity, representing only a narrow circumscription of the whole constituent.

3.4.1. Knowing. Little empirical research exists, but the available information we found indicates that merely knowing about nature, natural phenomena, and the state of ecosystems may be associated with feelings of insecurity or lack of control in Western cultures. As an example, natural disasters (tornadoes and hurricanes) were ranked (eighteenth) among the top 20 most common fears of school-age Americans (from second to twelfth grade) (95). Furthermore, greater knowledge about the system can be associated with increased awareness of or concern for the state of the system (96). Aldo Leopold's statement that the cost of an ecological education is to "live alone in a world of wounds" (97, p. 165) is an example thereof.

3.4.2. Perceiving. Significant literature indicates connections between perceiving natural elements and feelings of fear. Obsessive fear of natural elements is common on the basis of visual (or sometime auditory) interactions with natural elements, such as snakes, spiders, wasps, moths, blood, thunder, and feathers (98), and almost all specific phobias are directly

or indirectly associated with natural objects (99). Such phobias covary with fears of animals that are often considered disgusting (but not harmful), such as maggots (100). The more general study of affective responses of people to natural landscapes and other objects is reviewed in other sections of this article, specifically in the realms of health, both physical and mental, and is represented by relevant studies numbering in the hundreds (8, 101).

3.4.3. Interacting. Fear of natural elements is a very real and adaptive aspect of interacting with nature, particularly in rural places. Human-wildlife conflicts affect millions of people globally (102) and can have severe impacts on well-being. In India, for example, one person per day is killed by an elephant, and significant associated mental health impacts of human-elephant conflicts have been documented (103).

Surveys of farmers and fishers conducted in Alaska and Florida (two states in which some residents have increasingly encountered climate-driven changes) show that personal exposure to climatic change greatly increases concern and willingness to take action (indicating sense of control), potentially implying that their sense of security is informed—and threatened—by their interactions with natural elements through their work (104, 105).

The literature on “peak experiences” (i.e., intense situations inspiring transcendental or joyful states) indicates that nature-based activities that test the limits of skill and capability, such as mountain climbing or white-water rafting, are associated with a heightened sense of control and can produce transcendent experiences (106, 107); the ability of these natural contexts to challenge one’s sense of control enables this euphoria. Similarly, the environment enables engagement in activities that satisfy competency needs (e.g., being an accomplished skier), as discussed in the Identity and Autonomy section below.

3.4.4. Living. Abundant empirical evidence linking the proximity of buildings to nearby vegetation has shown reduced levels of fear,

crime, aggression, and violence, but the evidence was not unequivocal (64, 108). As discussed above, there is extensive evidence that exposure to green spaces reduces the negative effects from stressful events (e.g., Reference 109). However, a higher quantity of nearby vegetation increases fear and fear of crime in some contexts (110).

Conservation of resources theory proposes that a loss or threat of loss to an individual’s personal or psychosocial resources produces harmful psychological outcomes, which might be interpreted as a symptom of loss of security that carries over to impacts on other well-being components (111). Natural disasters have produced some of the most dramatic instances of resource loss. For example, resource loss was shown to be the best predictor of generalized psychological distress and post-traumatic stress following Hurricane Andrew’s landfall in 1992 (111). Yet, in all these cases, the specific role of nature cannot easily be dissected from the negative effects of such disasters on infrastructure, food availability, and economic income. For example, it has been shown that in coastal systems, nearshore habitats, such as reefs, marshes, and dunes, can significantly reduce the damage caused by sea-level rise and storms (112, 113), but we found no studies examining how this protective role changes people’s perceptions of safety.

3.4.5. Summary. Within this category, the balance of costs and benefits of interacting with nature is unusual in that the bulk of the reviewed literature addresses the ways in which natural systems degrade well-being through a lack of control and security, and through fear. These effects are often results of experiences with more uncontrolled nature.

3.5. Learning and Capability

Information, understanding, learning, and acquired capability are critical parts of the human experience and contributors to well-being (114). Drawing much of the work in this category together, attention restoration theory

(115) postulates that nature provides a restorative environment that renews focus and aids attention, presumably resulting in improved cognition. The theory is well supported empirically (116, 117) and likely provides the mechanism for much of the literature summarized below.

3.5.1. Knowing. Although the evidence is more narrative than quantitative, the abundant examples of documented biomimicry (e.g., design modeled on or imitating biological organisms or systems) speak to the prevalence of this relationship: Knowledge of natural systems enhances human capabilities (118). Ecological and biological systems serve as inspiration for technological development and entire fields of research and design [e.g., cellular automata, artificial immune systems, neural networks, interactive evolutionary computation, complex adaptive systems, ecodesign, and biophilic design (119–123)].

3.5.2. Perceiving. Exposure to images of natural systems seems to enhance learning, even of unrelated material. Specifically, it has been shown experimentally that viewing pictures of nature as opposed to urban environments is positively linked with the restoration of directed attention (116, 117). Views of nature also increased capacity for attention as shown through objective performance measures and subjective self-reported metrics (63).

3.5.3. Interacting. Interacting with nature appears to enhance learning more strongly than simply seeing it. Kaplan & Berman (124) reviewed 13 studies that assessed real or virtual nature contact and psychological response metrics. As described therein, these studies all supported a positive impact of nature exposure (being in, seeing, and interacting with nature) on attention restoration. For example, walking in nature compared to walking in urban environments was positively linked with the restoration of directed attention (116). Mayer et al. (55) showed demonstrable effects of exposure to the natural environment on both attention capacity and self-awareness. They also found

that the effects were stronger with real exposure compared to simulated exposure from videos of nature. Studies reviewed by Taylor et al. (125) documented facilitated knowledge transfer and greater academic achievement in groups taught in outdoor contexts versus in indoor classrooms. In addition, an increased capacity for attention in children who have “greener” play spaces has been documented (126).

Recent experimental evidence shows a measureable cognitive advantage (improvement of higher-level cognitive skills) derived from sustained exposure to nature (127). The authors noted that, pragmatically, whether the effects are driven by increased nature exposure or decreased technology exposure is moot given that they are so strongly inversely related in real-world contexts.

3.5.4. Living. We are not aware of empirical research that specifically addresses how living within natural settings contributes to enhancing learning and cognitive abilities.

3.5.5. Summary. Although the literature documenting the cognitive contributions of interaction with nature is significant within the mental health realm, as documented above, the broader contributions of interaction with nature to learning and cognition are more sparsely documented. The literature reviewed does show a clear theorized and sometimes empirically supported relationship wherein interactions with nature provide a significant benefit to human cognition.

3.6. Inspiration and Fulfillment of Imagination

The capacity to be inspired is part of what makes us human. With this in mind, we explored the literature documenting the diverse ways in which natural systems affect inspiration, creativity, and imagination.

3.6.1. Knowing. Knowledge, understanding, and the mystery of nature have been philosophically and logically argued to lead to fulfillment

of imagination (8, 128–130). Wilson articulates this nicely: “Humanity is exalted not because we are so far above other living creatures, but because knowing [other living creatures] well elevates the very concept of life” (128, p. 22). This kind of connection, however, is particularly difficult to document empirically.

Simply knowing of the existence of particular natural elements (also known as “existence value”) is the important fulfillment of imagination for some. Many surveys across different cultures demonstrate perceived existence value by identifying that 70–90% of survey respondents believe that natural ecosystems have a right to exist independent of any benefit to humanity (131). We found no appropriate literature documenting the connection between existence value and creativity.

3.6.2. Perceiving. Abundant evidence indicates that viewing nature can provide creative inspiration [e.g., the work of Kellert et al. (132)], but anecdotal evidence of this relationship is more abundant than empirical literature of mechanisms involved. Also see Reference 133 and citations in the knowing channel of the cognitive constituent above (118–123)

3.6.3. Interacting. Empirical work documenting how interactions with nature may affect creativity is unexpectedly scant [see the exceptions within the environmental education literature (e.g., Reference 134)]. The volume of anecdotal literature regarding this connection, however, is enormous, as is the diversity of creative products (e.g., poetry, painting, dance, music, architecture, science) that clearly take inspiration from interaction with nature or time spent in natural systems (e.g., Reference 132).

One interesting survey in the Catalan Pyrenees points to fulfillment through interacting with natural elements. Of all the services (e.g., provisioning food) that home gardens provide to households, the intangibles are considered most important. Survey respondents most valued the activity of gardening as a hobby; the heritage value of home gardens; their enjoy-

ment of aesthetics; a place for education or research; a connection to spiritual feelings; creating and enhancing social networks; and the use of gardens in folklore, art, and design (135).

Taylor et al. (136) showed that more green vegetation is linked to more creative play in children. Analysis of a school yard that had some asphalt replaced by more natural elements documented more positive social relationships among children and more creative play (137). Empirical studies have documented a connection between diverse playgrounds and more creative play, and natural environments are argued to generally afford diverse playground opportunities (138–140).

3.6.4. Living. Disciplines such as archaeology and cultural anthropology highlight examples of nature-based inspiration, but assessments identifying the relative contributions of nature versus other factors are unavailable.

3.6.5. Summary. The ways in which one can conceive that natural systems provide people with creative inspiration are legion. Imprints of this connection between people and natural systems can be seen in art, poetry, literature, dance, music, science, architecture, medicine, and more. However, despite these rich and obvious ties, few peer-reviewed studies explicitly and empirically parse out the inspirational power of nature. The other ways of knowing mentioned above (art, architecture) may provide a more compelling exploration of the relationship, yet the peer-review and the scientific processes provide consistent ground rules for exploring this realm. This is fertile ground for further work.

3.7. Sense of Place

People are part of ecosystems, and the connection to a physical place in the world can be an important component of well-being for many. Connection to nature can contribute to the development of a sense of place, which in turn can promote the formation of people’s “ecological identity” (141). To explore this theme,

we looked for indications of the ways in which specific ecological characteristics of a place, such as ecosystem condition, contribute to the development of a sense of place in people.

3.7.1. Knowing. People get attached to places for many reasons, but only some reasons directly pertain to the biophysical characteristics of the place (142). Memory of a place, or how it once was, also reflects place attachment. A sense of place is linked to spiritual connections with an ecosystem, and both can change as ecosystems change. Place-based myths or identity changes as the physical environment changes and no longer supports this connection (143–145).

3.7.2. Perceiving. No research that we are aware of specifically addresses visual or other remote exposure to places and empirically assesses how this contributes to sense of place.

3.7.3. Interacting. Interacting with nature tends to increase people's attachment to place and their willingness to act to defend or protect those places. Scannell & Gifford (146) analyzed Canadian residents' behavior and showed that natural rather than the civic aspects of place attachment predicted pro-environment behavior. As individuals partake in nature-based activities, values concerning the wellness of these places tend to rise (147). For example, being active in restoration efforts increased attachment to local natural places (148), and community gardeners are anecdotally shown to be more connected to place (149).

Many researchers (e.g., References 140, 150, and 151) believe that engaging children in various outdoor experiences will facilitate relationships and develop a sense of place, in turn developing attachment to local environments and their communities. However, empirical work for this is limited. Sense of place research recognizes the critical roles that social dynamics and interactions play in the human-nature relationship (152). Environmental features and place character were roughly equally important for social reasons (family and friends) in one sur-

vey of attachment to place (153). Among Inuit people, it has been shown that feelings of place attachment were negatively affected by disruption of hunting, fishing, foraging, trapping, and traveling, as well as by climate change-induced ecological degradation (154).

3.7.4. Living. As Berry (155) proclaims in relation to the agricultural landscape he lives within, "What I stand for is what I stand on" (p. 207). Much sense of place research focuses on residents—those who live within an ecosystem. However, living in natural systems does not consistently provide positive associations with sense of place; individuals carry both positive and negative associations with a nearby places (as demonstrated for Great Salt Lake, Utah) (152). Similarly, positive sense of place associated with living near a natural environment does not always depend on understanding of the ecological processes or goods delivered from that place (152).

3.7.5. Summary. More than for other categories of well-being components, we found substantial effort devoted to understanding how socializing within natural systems contributes to place attachment. Most of the sense of place literature documents the more intimate channels of interaction, with less literature addressing knowing and perceiving, and more addressing interacting and living within. It is unclear what if any unique attributes might distinguish the place-attachment power of natural space relative to man-made space (e.g., ecological place meaning versus social or architectural) (151), perhaps in part because the biophysical characteristics of places have received less scholarly attention than the individual/psychological component of person-place relationships (156), and because of the challenge of dissociating nature-related effects of space from other effects (see Reference 157).

3.8. Identity and Autonomy

Experiences in nature forge identity for a great many people around the world. Indeed, the

cultural variation in the depth of this relationship (i.e., the role of nature in producing purpose or identity) confounds empirical estimation because of the Western construct of a distinction between nature and culture imposed upon the rest of the world (7, 158, 159). For much of the world—for example the Gimi of Papua New Guinea, who have no notion of division of nature and culture because the forests are manifestations of their ancestors—nature is part of their identity to a great degree, and thus, articulating this connection becomes rather nonsensical (9, 160, 161). To highlight the literature that exists, we adopt the Western notion and explore the connections between nature and identity below, acknowledging that there are cultural contexts well explored by social sciences wherein nature-identity relationships are so fundamental that reductionist approaches are inappropriate.

3.8.1. Knowing. It has been suggested in a number of fields that identity is intertwined with ecosystems. Because direct interaction with those systems may not be critical, we address those relationships here. The relationship between identity and landscape has been theorized as critical and has been discussed in hundreds of academic publications. For example, the debate surrounding the connection between the land and the Nez Perce of Idaho has been argued to be akin to a debate about ethnic survival (162). Kazakh communities in western Mongolia define Kazakhness in terms of the ecological environment of the mountains and use music to associate with this identity and place (163). Music is used to associate with both identity and place in other locations as well (164).

3.8.2. Perceiving. No empirical research that we are aware of explicitly assesses the role of remotely observing nature in forming a sense of identity or purpose, although visual elements of a landscape can be critical for a person's identity and sense of place, for example, the sacred groves discussed above.

3.8.3. Interacting. The identity-landscape connection is made perhaps most frequently in studies of indigenous peoples, and this connection manifests largely through interacting with the landscape (165–167; R.K. Gould, U. Woodside, N.M. Ardoin, N. Hannahs, T. Satterfield, & G.C. Daily, paper in preparation). As one example, Stairs (165) put forth the idea of “ecocentric identity”—that is, that identity encompasses human, animal, and material—and claimed that the Inuit have this form of identity. Dorais (168) noted that without going to the land for hunting, fishing, and trapping, “Inuit would not be Inuit any more” (p. 299). This concept of ecocentric identity conforms to identity theory that states that identity is formed by people's actions (169), such as hunting, fishing, or other cultural activities that could be integrally rooted in ecosystems. For example, turtle hunting among the Meriam of Torres Strait, Australia, involves individuals engaging in a social hunting process that involves no direct material benefit to themselves (170). Similarly, among the Nez Perce Native Americans traditional subsistence activities are the primary means of accumulation, maintenance, or loss of intangible symbolic capital (e.g., trust, prestige) (162). A long-term study on the “lobster gangs” of Maine—the fishermen who jointly manage the common-pool resource of Maine's lucrative lobster fishery—has also touched on the identity-related aspects of a fishing way of life; this work suggests that conserving fishing resources conserves the lobstermen's identity (171). There is a tendency to prioritize the unique connection that indigenous people have with their land and waters; additional empirical work might explore identity-ecosystem linkages in a broader range of cultural contexts.

The connection between nature and identity can also be mediated by particular species. The cultural keystone species concept was coined for species that people interact with so strongly (e.g., through hunting, fishing, or gathering) that the species help define a people (for example, salmon for the First Nations in the Pacific Northwest in North America) (82).

Nonhuman animals in some contexts—such as in agriculture—may play a significant role in forging personal identity (172, 173).

In Alaska's Bristol Bay, Kelty & Kelty (174) used identity theory from social psychology to examine and explain the relationship between people and the environment. They found that the biggest (self-reported) potential impacts of an unsustainable fishery were "loss of connection with the natural environment in the area (76%) and reductions in overall yearly income (74%). The next most affected outcomes of a collapsed fishery included negative effects on life satisfaction (62%), relationships with others important to [respondents] (57%), and way of life (56%)" (174, p. 340). When asked why the salmon fishery was important, most respondents mentioned complex webs of lifestyle, culture, tradition, and connections with family and environment, and 78% of respondents "agreed that fishing is 'an important part of who they are as a person'" (174, p. 341).

On the community level, it has been argued that community autonomy and self-sufficiency decreases with increasing urbanization (175). A study of nonindigenous "timber towns" in the inland US Northwest found that people in these more-isolated and autonomous communities rated their communities higher on quality of life than did people in less-isolated locations (176).

3.8.4. Living. There is a wealth of empirical anthropological and ethnographic work on the identity-landscape link as it relates to living within. The identity of many cultures is strongly linked to their ecosystems; we do not purport to capture this massive literature here. For instance, work with the Popolucas of central western Mexico found that they linked their identity to the rainforest within which they live (177), and work with the Gimi in Papua New Guinea found that their identity was tied to their forests (160). Displacing agrarian people from their land has been shown worldwide to have predicted negative influences on their identity (178–181).

The issue of autonomy is frequently discussed with respect to aboriginal concerns in terms of indigenous self-determination in which land, and rights to land, often play central roles. Hunting, fishing, and gathering are part, at times a critical part, of autonomy for indigenous groups (170, 182).

3.8.5. Summary. Identity is clearly tightly linked to the attributes of the landscape and to activities performed within nature. Most of the evidence surrounding the contribution of nature to forging identity is associated with interacting in nature and encompasses living within nature. Positive impacts of interactions with nature have been documented on the identity of individuals as well as those of communities. These links have most often been shown for indigenous cultures, largely in the context of anthropological studies, but also apply to nonindigenous people. Environmental degradation and displacement of people from their lands has been shown to negatively affect their identity and autonomy.

The relationship between identity and the natural environment has been characterized (183) as having three categories, two of which are tightly linked to socializing within nature: experiencing nature as individuals (a person and the nonhuman environment); experiencing nature in social and community contexts (where the social community matters but is not central to the identity); and experiencing nature as members of social groups (wherein the group identity is central, e.g., in a rangeland conflict between ranchers and environmentalists).

3.9. Connectedness and Belonging

Social connections and the sense of belonging to a larger community (184), as well as connections with nature (185, 186) and with life at large (see 187), are all positive correlates of well-being and are mostly interrelated. One example of the latter relationship is described in the biophilia hypothesis (8, 128), positing that people have a biologically based need to affiliate with and feel connected to the broader natural world (life and life-like

processes). An eco-physiologist's extension of this argument suggests that meeting this need for a connection with nature has psychological benefits (188). Another manifestation of this constituent is the contribution of nature to social connectedness (social capital and cohesion, or a general sense of belonging) (189).

3.9.1. Knowing. Natural settings (e.g., water, greenery) are in a category most often identified in association with places identified as favorites by adults (190), although not by children (191), even if they are not visited frequently. Similarly, nature is underrepresented in association with an unpleasant place (192). There are indications that natural locations are robustly identified as favorite places across cultures (192).

3.9.2. Perceiving. We did not identify any appropriate research on this topic that met our inclusion requirements.

3.9.3. Interacting. People's connection to nature is built by experiences, and these, in turn, predict aspects of people's well-being. Students who took a walk in a natural setting reported stronger feelings of connectedness to nature after the walk than students who walked in urban settings; those with stronger connectedness to nature scores tended to have greater abilities to reflect on a life problem, better capacities for attention, and more positive affects (feelings or emotions) (55). The most significant influential factor in predicting individuals' connection to nature was the amount of time people spent outdoors (193).

Connectedness can be to a physical place or to an animal. Many farmers have deep emotional ties to the animals they work with; this complex relationship and the "emotional and ethical entanglements of human-animal relations" (194, p. 100) involve clear connections to the well-being of the humans involved (some are discussed above in the sections on Physical Health and Mental Health). Strong emotional connections between farmers and their animals produce documented health benefits, and human and livestock health are interrelated in complex ways (195).

Gardening has been found to contribute to building social capital and social networks while simultaneously reducing stress and encouraging nurturing characteristics (Reference 47 and the studies therein). There is also evidence that socializing in nature promotes social cohesion: Examples from northwestern North America include changes to subsistence strategies and the ensuing changes to social cohesion in those communities (196, 197). Socializing outdoors is crucial to many people [e.g., in Latin America (198)].

3.9.4. Living. Natural places can enhance connections between people, and the connections between people and nonhuman animals can enhance human well-being. For example, residents in areas with more green space or trees have greater social cohesion and sense of community (199, 200). Similarly, proximity to natural environments with high cultural values (values categorized as serene, wild, lush, spacious, and cultural) is positively related to neighborhood satisfaction in Sweden (201).

3.9.5. Summary. Direct interactions with nature have been shown to positively contribute to a sense of connection to nature and connection to community. Interacting with nature (via socializing or living within nature) contributes to social connectedness. Both connections with nature (187) and social connections (184) have been shown as correlates of general well-being and to be interlinked (the connection to nature also correlates positively with having meaning in one's life (reviewed in Reference 187)).

3.10. Subjective Well-Being

Subjective well-being represents self-reported assessments of overall individual well-being. Holistic well-being and happiness are complex synergistic combinations of many components and represent an emergent characteristic that is unpredictable from the component parts. In this section, we review literature that explicitly addresses these emergent characters of well-being, given that thus far this review has documented pertinent links between

natural systems and specific components of happiness or general well-being (e.g., increased well-being through reduction in stress caused by views of nature).

3.10.1. Knowing. Mayer & Frantz (185) placed connectedness to nature (see section above) in a broad context, documenting that connectedness to nature appeared to be as important of a contributor to subjective well-being as are more traditional variables associated with subjective well-being (such as marriage, education, and income). Multiple studies (55, 185, 189) demonstrate that connectedness to nature significantly predicts the participants' degree of life satisfaction and overall happiness and perspective-taking ability. See also work by Iceland and collaborators (202), described below.

Research in the United Kingdom concluded that concern for the state of the ozone layer was negatively correlated with subjective well-being, yet concern for species loss was positively correlated with subjective well-being (203); they interpreted this as an example of the hypothesis that people derive psychological benefits from caring about other species (8).

3.10.2. Perceiving. As documented in more detail under the constituents of physical health above, visual exposure to nature can increase general satisfaction (17).

3.10.3. Interacting. Little research explores specifically how interactions with nature influence general well-being beyond component elements already reviewed. Matsuoka & Kaplan (204) reviewed the literature relating landscape design to well-being and, in conclusion, reiterated the strong linkages between the two. Similarly, being in natural environments has been shown to improve mood in a general sense (186, 205), and a positive correlation has been shown between the well-being of green space users and the species and habitat richness of those spaces (206).

In the Puget Sound region of Washington, representatives of 12 key stakeholder groups (business associations, environmental groups, county governments, etc.) nearly unanimously

identified categories titled “recreation & tourism” and “ethics & existence values” as among the highest importance of all material and intangible connections to nature (202).

3.10.4. Living. There is a great deal of literature that identifies the mechanisms through which living in nature contributes to specific constituents of well-being but little from the broader perspective of holistic well-being. Surprisingly, given a profusion of confounding factors, course-grained global analyses indicate that there is a detectable relationship between the state of nature in a nation and subjective well-being (207).

On a state-to-state scale, people are generally willing to sacrifice employment income and pay a for a greater cost of living for cultural ecosystem services provided by inland waterways, public stewardship of federal lands, and access to national parks (208). Pecuniary state-to-state differences (i.e., wages, rent, cost of living) can be correlated to a set of nonpecuniary variables (e.g., local climate, national park attendance, presence of an ocean coastline)—a methodology entitled compensating differentials—demonstrating that densely populated and industrialized states score consistently lower in ranked quality-of-life variables than less densely populated rural western states (208, 209).

3.10.5. Summary. Subjective well-being is an encompassing category that includes all the various constituents of well-being, thus rigorously identifying such relationships is more challenging than it may be for certain individual constituents (described above). As a result, empirical evidence of the impacts of interactions with nature on this encompassing category is scarce, hindering wider generalizations.

4. FUTURE PERSPECTIVES

Empirical research on the connections between nature experiences and constituents of human well-being is uneven. The amount of literature available, the generality of the results, the

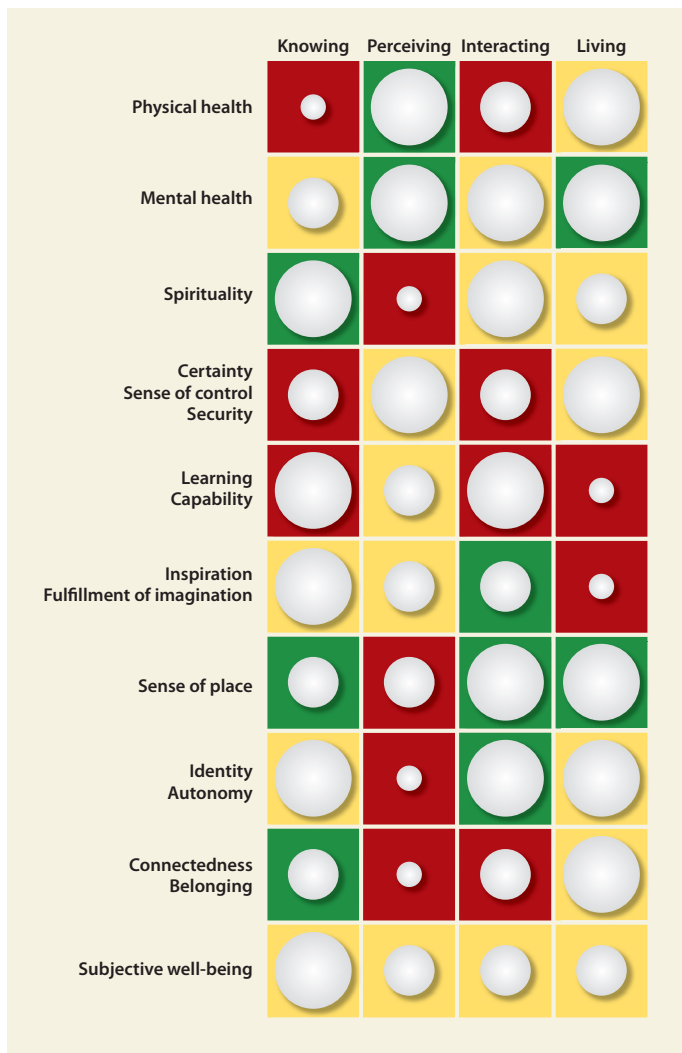


Figure 2

A synthesis of the overall quantity and generalizability of relevant empirical literature. The size of the circle in each cell indicates the amount of research, with small circles indicating minimal research and large circles indicating plentiful research. The generalizability of the research available is represented by cell shading: Red indicates that most research focuses on very specific aspects of the channel-constituent pair, and green indicates broadly applicable research.

primary discipline and thus typical way of knowing, and the nature of the evidence itself vary dramatically for different constituents (see **Figure 2** and **Supplemental Table 1**).

Some of these human-nature connections have been covered extensively, have shown consistent results across ecosystems and cultures,

and were supported by empirical tests of hypotheses. These include the benefits to physical health derived from perceiving nature; those to mental health derived from perceiving, interacting, and living in nature; and those to spiritual health derived from knowing nature. In addition, the benefits of interacting with nature to inspiration, and the benefits of knowing about and interacting with natural systems to the development and reinforcement of sense of place, are well documented.

The roles of nature experiences in influencing many aspects of human well-being are still poorly documented. For example, the benefits of living in nature on learning and inspiration, or the links between identity, self-sufficiency, and belonging with perceiving nature, are poorly documented in the mainly positivistic literature we reviewed. As discussed in the State of the Art section above, many of these relationships are hypothesized to be important and remain to be more thoroughly documented.

Is it worth searching for evidence of these under-studied contributions of nature to human well-being? We believe so. Part of the complication is that the data-rich narratives, for example, ethnographies, are often difficult to condense into succinctly communicated or quantitative insights regarding the relationship and are thus omitted from decision making. Indeed, the rich literature available in books was not included here, albeit a source of some of the most robust information on these topics. Nonetheless, in the same way that the past decade has witnessed unprecedented advances in understanding the biophysical and economic benefits people obtain from ecosystems, the coming decade could substantially advance knowledge, scholarship, and discourse by documenting the impacts of less tangible connections between people and ecosystems on well-being.

4.1. Where Could We Go from Here?

This review is a first attempt at synthesizing the complexity of the impacts of nature on human well-being via nonmaterial connections.

This endeavor has highlighted many of the challenges involved: (a) the large number and sometimes incommensurable methodologies of disciplines that must be united, (b) the biased nature of available sources, and (c) the extremely varied nature of the evidence itself given vastly different biophysical and cultural contexts.

Further explorations of differences among cultures, biophysical contexts, and gender for these intangible links are needed. A systematic assessment of the wide literature available on these issues would be a significant advancement. Indeed, different cultures experience nature in different ways, and explorations of individual cultures and their experience of nature would highlight nuances that could not be captured at the cross-cultural level summarized here. For example, we sought to include both positive and negative impacts on well-being. However, except in a few categories (e.g., sense of control and security), we found that most of the literature on intangibles we reviewed identified positive impacts of nature on human well-being. However, tropical ecosystems rich with hazardous species may be more likely to evoke fear and thus be associated with decreases in well-being. And not only do different geographies and different cultures affect one's experience of nature, gender too affects the way humans interact with and experience nature.

Documenting culturally and psychologically mediated benefits derived from nature will require the same bold approach used in the past decade in the broader field of more tangible ecosystem services: one characterized by various trials, some unfruitful and some providing great insights. Rather than limiting such synthetic research to the biophysical and economic sciences, the search needs to encompass and unite the wide range of evidence (and types of evidence) available in the social sciences and the humanities. Sources of information may include archeological, ethnographic, linguistic, historic, and current sociological information, as well as more creative positivistic analysis of, for example, popular music, children's literature, or current oral traditions. Epistemological approaches need to transcend those

heavily based in single modes (e.g., quantitative biophysical ecosystem assessment, clinical psychological trials, or narrative anthropological monographs) and include those based on synthesizing knowledge obtained from a wide variety of sources and approaches (21) and uniting the deep knowledge held across the numerous germane disciplinary traditions.

5. CONCLUSIONS

The nonmaterial connections between people and their environment are strong, cosmopolitan, and necessary for human well-being, as repeatedly indicated by the studies reviewed herein. These contributions of nature experiences to human well-being can be difficult and sometimes impossible to quantify. Yet we ignore the critical, pervasive, and wide-ranging contributions of ecosystems to well-being mediated by nonmaterial relationships at our peril. It is our hope that this review serves as a challenge to the academic community to engage in better synthetic assessment of these relationships so fundamental to human well-being.

Some facets of this expansive body of knowledge are richly studied and are conducive to understanding through a reductionist empirical Western lens (e.g., nature exposure and physiological health), whereas other equally vital aspects of human well-being (e.g., identity, spirituality) are inherently difficult to assess with these methodologies given the different cultural conceptualizations and the biases involved. These facets of the relationships are thus poorly represented in the scientific literature. Equally, certain fields of discourse have highly distinct epistemologies (for example, the role of narrative in ethnography as contrasted to clinical trials in psychology), which creates complications for effective broad interdisciplinary synthesis.

This enterprise—reviewing the scientific literature for all sorts of documentation of the intangible connections between people and their ecosystems—could be conceived of as a fool's errand. Yet, we never presumed to complete an exhaustive review of the literature nor

presumed that academic literature is even the best place to find evidence of these connections. Rather, we hope that we have succeeded in weaving together disparate strands of evidence to yield a less incomplete picture of the myriad ways in which natural systems contribute to well-being in intangible ways and in highlight-

ing some places where the literature appears to fall short of capturing the richness of human connections to nature. Better documentation of these rich relationships between nature and well-being, and the complex benefits people draw from nature, ought to result in more effective decision making.

SUMMARY POINTS

1. On the whole, though not always, nature makes people happier and healthier via our nontangible connections to ecosystems.
2. These connections to ecosystems have long been studied in many disciplines, yet the incommensurability of different ways of knowing associated with this disciplinary diversity has hindered holistic review, synthesis, and explicit inclusion of these connections in decision making.
3. The positive effects of nature on physiological health and mental health have been unequivocally documented.
4. The strong positive effects of nature on identity and spirituality are robustly demonstrated for indigenous groups but poorly documented for other cultures.
5. The effects of nature on learning, cognition, and inspiration are often assumed and occasionally documented but have not been systematically assessed.
6. The literature on security and control highlights a preponderance of the negative contributions of nature, producing feelings of fear and lack of control.
7. The sense of place and connectedness has been moderately often shown to benefit from interactions with nature, mostly through direct experiences.

FUTURE ISSUES

1. To extend the boundaries of existing scholarship, we need new approaches for knowledge synthesis. Peer-reviewed quantitative assessments, narrative ethnographies, and other disciplinary methods must be united by synthetic approaches that respect and synergistically combine diverse ways of knowing.
2. Further research is especially needed to clarify the benefits of living in nature on learning and inspiration, and the links between identity, self-sufficiency, and belonging with perceiving nature.
3. Our knowledge could be advanced by studies with an encompassing perspective that assesses how the different constituents of well-being benefit from nature through the different channels of experience as well as through their complex interactions.
4. Archeological, ethnographic, linguistic, historic, and current sociological information, as well as the analysis of music, literature, and current oral traditions, should be further incorporated in the assessment of contributions of ecosystems to people's well-being.

5. The explicit incorporation of nontangible benefits from ecosystems into decision making is needed to ensure the sustainability and well-being of future generations.

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Contents

| | |
|---|-----|
| Introduction | v |
| Who Should Read This Journal? | vii |
| I. Earth's Life Support Systems | |
| Environmental Tipping Points <i>Timothy M. Lenton</i> | 1 |
| Regional and Global Emissions of Air Pollutants: Recent Trends and Future Scenarios <i>Markus Amann, Zbigniew Klimont, and Fabian Wagner</i> | 31 |
| Pyrogeography and the Global Quest for Sustainable Fire Management <i>David M.J.S. Bowman, Jessica A. O'Brien, and Johann G. Goldammer</i> | 57 |
| II. Human Use of Environment and Resources | |
| A Global Assessment of Manufacturing: Economic Development, Energy Use, Carbon Emissions, and the Potential for Energy Efficiency and Materials Recycling <i>Timothy G. Gutowski, Julian M. Allwood, Christoph Herrmann, and Sahil Sabni</i> | 81 |
| Life-Cycle Assessment of Electric Power Systems <i>Eric Masanet, Yuan Chang, Anand R. Gopal, Peter Larsen, William R. Morrow III, Roger Sathre, Arman Shehabi, and Pei Zhai</i> | 107 |
| Methods and Models for Costing Carbon Mitigation <i>Jayant Sathaye and P.R. Shukla</i> | 137 |
| On the Sustainability of Renewable Energy Sources <i>Ottmar Edenhofer, Kristin Seyboth, Felix Creutzig, and Steffen Schlömer</i> | 169 |
| Smart Grids <i>Peter Palensky and Friederich Kupzog</i> | 201 |
| Water Conservation: Theory and Evidence in Urban Areas of the Developed World <i>David Saurí</i> | 227 |
| Agricultural Biotechnology: Economics, Environment, Ethics, and the Future <i>Alan B. Bennett, Cecilia Chi-Ham, Geoffrey Barrows, Steven Sexton, and David Zilberman</i> | 249 |

| | |
|---|-----|
| Recent Advances in Sustainable Buildings: Review of the Energy and Cost Performance of the State-of-the-Art Best Practices from Around the World <i>L.D. Danny Harvey</i> | 281 |
| Smart Everything: Will Intelligent Systems Reduce Resource Use? <i>Jonathan G. Koomey, H. Scott Matthews, and Eric Williams</i> | 311 |
| State of the World’s Nonfuel Mineral Resources: Supply, Demand, and Socio-Institutional Fundamentals <i>Mary M. Poulton, Sverker C. Jagers, Stefan Linde, Dirk Van Zyl, Luke J. Danielson, and Simon Matti</i> | 345 |
| Global Environmental Change and Human Security <i>Karen O’Brien and Jon Barnett</i> | 373 |
| III. Management, Guidance, and Governance of Resources and Environment | |
| Actionable Knowledge for Environmental Decision Making: Broadening the Usability of Climate Science <i>Christine J. Kirchhoff, Maria Carmen Lemos, and Suraje Dessai</i> | 393 |
| Market Instruments for the Sustainability Transition <i>Edward A. Parson and Eric L. Kravitz</i> | 415 |
| Methods and Global Environmental Governance <i>Kate O’Neill, Erika Weintal, Kimberly R. Marion Suiseeya, Steven Bernstein, Avery Cohn, Michael W. Stone, and Benjamin Cashore</i> | 441 |
| Humans and Nature: How Knowing and Experiencing Nature Affect Well-Being <i>Roly Russell, Anne D. Guerry, Patricia Balvanera, Rachelle K. Gould, Xavier Basurto, Kai M.A. Chan, Sarah Klain, Jordan Levine, and Jordan Tam</i> | 473 |
| IV. Integrative Themes | |
| Preindustrial Human Impacts on Global and Regional Environment <i>Christopher E. Doughty</i> | 503 |
| Indexes | |
| Cumulative Index of Contributing Authors, Volumes 29–38 | 529 |
| Cumulative Index of Article Titles, Volumes 29–38 | 533 |
| Errata | |

An online log of corrections to *Annual Review of Environment and Resources* articles may be found at <http://environ.annualreviews.org>