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Can people be sentinels of sustainability? Identifying the linkages among ecosystem health and human well-being

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Abstract

Human well-being depends on the health of ecosystems, but can human well-being also be an indicator of ecosystem health, and perhaps even sustainability? Research shows that ecosystem health and human well-being are often mutually reinforcing, whether in the direction of wellness and sustainability or poverty and degradation. However, while well-being is increasingly recognized as an important consideration when managing ecosystems, human needs and activities are often still thought of only in terms of their negative impacts on ecosystems. In this essay, we explore the proposition that there can be a mutually constitutive relationship between people's well-being and the health of ecosystems, and discuss what such a relationship would mean for expanding the use of human well-being indicators in ecosystem-based management. Specifically, we discuss two areas of theory: ecosocial theory from social epidemiology and the marginalization–degradation thesis in political ecology; collectively, these provide a justification, in certain circumstances at least, for thinking of well-being as not just an add-on in natural resource management but as an indicator of ecosystem health and a prerequisite of social-ecological sustainability. We conclude with a discussion of future research needs to further explore how human well-being and ecosystem health interact.

Key words: ecosystem health, human health, well-being, resilience, social-ecological systems, social justice, sustainability, win–win ecology

Introduction

In ecology, "sentinel" describes a species whose health is closely linked with the conditions of its habitat. These species are often thought of as an indicator of ecosystem health or as an early warning of ecosystem change. The sentinel concept is used to a similar end in public health: "sentinel surveillance" describes the monitoring of human populations that are known to be at particular risk for some health problem, as a way to anticipate emerging epidemiological patterns (World Health Organization 2015). These two examples illustrate the versatility of the word "sentinel", which generally describes a sentry or guard, but also can be used to refer to the act of keeping watch, as well as the position from which watch is kept (Oxford English Dictionary 2016). With these various meanings in mind, we explore here whether the sentinel concept has a similar place in sustainability science: specifically, whether people can be sentinels of sustainability, and not just in the important sense of being active guards or stewards (Chapin et al. 2011), but also in the spirit of the examples above, where

people's own health and well-being provide either an indicator of sustainability or an early warning of emerging environmental problems.

Human health and well-being[1] are now regularly recognized by scientists and policymakers as essential considerations in the effective management of natural resources (Millennium Ecosystem Assessment 2005; Agyeman 2008; Coulthard 2012; Biedenweg et al. 2016). This is a noteworthy shift in mainstream environmental thinking, which has long assumed that human activities are inherently harmful to the environment, and that environmental conservation and sustainability therefore require some trade-off or cost to society (Smith and Wishnie 2000; Dagget 2005; Kates 2011). Kates (2011), for example, lists "what are the principal tradeoffs between human well-being and the natural environment?" as the fourth of seven top questions in sustainability science (p. 19450). Yet, in the last few decades, research in multiple areas has shown that win–win solutions, where human activities promote biodiversity and people and ecosystems thrive together, are both possible and preferable from the perspectives of social justice and sustainability (Coughenour et al. 1985; Ostrom et al. 1992; Agyeman et al. 2002; Rosenzweig 2003; Dagget 2005; Sayre 2006; Chappell and LaValle 2011; Padoch and Pinedo-Vasquez 2010; Robson and Berkes 2011; Hicks et al. 2013; Augustine and Dearden 2014; Zheng and Wang 2014). Among natural resource-dependent communities in particular, there is much evidence that social and environmental outcomes are often mutually reinforcing, whether in the direction of wellness and sustainability or disease and degradation (Cao et al. 2009; Loring and Gerlach 2009; Nayak et al. 2014; Sandifer et al. 2015; Amberson et al. 2016; Duffy et al. 2016).

Building on this literature, the question we explore here is whether, and in what circumstances, human well-being can serve as an indicator of ecosystem health, and perhaps also of social-ecological sustainability. This is a provocative premise; we live at a time when human health outcomes are the best that they have ever been, at least for some segments of the world's population, and arguably at the cost of global environmental problems such as biodiversity loss and climate change (Stanley 1995; Raudsepp-Hearne et al. 2010; Sachs 2015). This is known as the environmentalists' paradox, and it is caused, at least in part, by the advent of globally scaled technologies that allow people to be disconnected from the ecosystems on which they rely (Sundkvist et al. 2005; Hornborg 2009; Raudsepp-Hearne et al. 2010). However, provocative concepts such as "affluenza", "nature deficit disorder", and "ecologically unequal exchange" have been proposed in the last decade that illuminate the societal tradeoffs and injustices that make first-world affluence possible and force us to challenge how we account for the apparent, but perhaps illusory, gains to human health and flourishing in the Anthropocene (Louv 2006; Hamilton 2009; Hornborg 2009).

Accordingly, researchers are now beginning to look beyond simple relationships among social and ecological outcomes, in search of a more nuanced understanding (Horwitz and Finlayson 2011; Ang and Passel 2012). Below, we discuss these issues through the lenses of two areas of theory—embodiment theory from social epidemiology and the marginalization–degradation (M–D) thesis from political ecology. Collectively, we argue that these theories provide a compelling justification for the use of human well-being indicators, in certain circumstances at least, in the assessment of ecological health and for the identification of situations where incentives exist for people to enact unsustainable strategies. Further, we argue that if we can come to understand the social and ecological circumstances in which human well-being and ecosystem health outcomes are mutually reinforcing, we can use this knowledge to guide the development of policies and management strategies that enable people to

[1]Hereafter, we simply refer to "human well-being", recognizing that health in a solely biomedical sense is part and parcel of well-being, and reflecting a trend in the health literature to define health broadly (e.g., Engel 1977; House 2001; Clark 2005).

reconnect with local ecosystems, in pursuit of more healthful communities and sustainable environmental practices.

Background

Numerous frameworks exist for describing and defining human well-being, ranging in focus from the individual to the nation, and hailing from such diverse disciplines as anthropology, ecological economics, Indigenous studies, rural sociology, social epidemiology, and veterinary medicine (e.g., Wilkinson 1991; Nussbaum and Sen 1993; Gasper 2004; Clark 2005; Gough and McGregor 2007; Diener 2009; Loring and Gerlach 2009; Wildlife Conservation Society 2009; White 2010; Britton and Coulthard 2013; Donatuto et al. 2014; Biedenweg et al. 2016). A full review of these frameworks is outside the scope of this essay (see Gasper (2004); Weeratunge et al. (2014)); what is important for the present discussion is that despite their differences, many well-being frameworks share a general philosophy of linking social, psychological, biophysical, and ecological domains[2] (Millennium Ecosystem Assessment 2005; Armitage et al. 2012; Coulthard 2012). Frameworks in this vein generally identify three dimensions of well-being: (1) a material dimension (i.e., people's needs for life and safety); (2) a psychological and spiritual dimension (i.e., people are happy and enriched culturally and spiritually, and psychologically resilient to adversity); and (3) a social or relational dimension (i.e., people are secure, collaborative, empowered, and able to respond collectively to problems) (Engel 1977; White 2010; Britton and Coulthard 2013). Well-being is also thought of as blending both subjective and objective dimensions: objective well-being entails readily observable outcomes such as wealth or health status, but these tell only part of the story (Costanza et al. 2009; Duraiappah 2011); subjective well-being, which focuses on people's own definitions of and feelings regarding their wellness, is likewise an important consideration (Wolsko et al. 2006; Gough and McGregor 2007).

Ecosystem health is also a concept with multiple uses and interpretations (Grumbine 1994; Slocombe 1998). Generally speaking, ecosystem health is a metaphor for describing the state of an ecosystem in respect to some criteria that have been identified as desirable (Rapport et al. 1998). Like well-being, ecosystem health entails three dimensions, and healthy ecosystems are those that maintain (1) a characteristic organization (i.e., biodiversity and structural arrangements); (2) high levels of vigor (i.e., productivity); and (3) resilience (i.e., ability to recover from some perturbation) (after Rapport et al. 1998). Also like well-being, ecosystem health blends objective and subjective aspects: biodiversity and productivity, for example, can be measured in relatively straightforward ways, but ecosystems can have numerous possible stable states, and which of those ought to be prioritized over others is a subjective and inherently societal matter. Thus, the concept of ecosystem health has been debated by some as being too subjective for use in scientific pursuits (i.e., what is desirable according to *whom*?) (Suter 1993; Stanley 1995; Fitzsimmons 1999; Lackey 2001; Kueffer and Larson 2014). Nevertheless, ecosystem health's uptake in a variety of applied sciences, including the human health sciences, has been extensive (e.g., Su et al. 2010; Costanza 2012; Halpern et al. 2012; Wilcox et al. 2012).

Theoretical linkages

There are clear linkages among the three dimensions of ecosystem health and those of human well-being (**Table 1**). Ecosystem productivity is relevant to people's material well-being, through

[2]Some well-being literature makes a distinction between *hedonic* well-being, which equates well-being with "thin" needs such as happiness and pleasure, and *eudaimonic* well-being, which emphasizes "thick" needs such as the social relationships and environmental circumstances that enable a person to thrive and self-actualize (Nussbaum and Sen 1993; Ryan and Deci 2001; Dean 2010). The approach we adopt here reflects the latter philosophy. As Ryan and Deci (2001) note, this philosophical debate is unlikely to be reconciled.

Table 1. Linking human well-being and ecosystem health.

Human well-being	Ecosystem health	Notes	Impoverished state (Fig. 1)
Material	Vigor	Human communities benefit from vigorous natural resource systems. Likewise, when people's "thick" needs for well-being are met (Dean 2010), incentives to overharvest resources are reduced.	Ecosystems with low vigor are "rigid", or unlikely to change; people, likewise, can be constrained or "locked in" when they lack the resources to innovate or change.
Relational	Structure	People rely on families, neighbors, and social relations at multiple scales for their well-being. Likewise, when people pursue respectful relationships with non-human biological forms, local knowledge and stewardship likely improves.	Ecosystems lacking structural health are "eutrophic"—productive but low in diversity or complexity; likewise, when relational well-being is low, people are isolated, regardless of material and psychological well-being.
Psychological	Resilience	These third dimensions both involve how the system in question copes with disturbance over time, though in human well-being frameworks this dimension is not just reactionary, but reflects human agency through such additional considerations as self-actualization and life satisfaction.	Ecosystems that are complex and vigorous but lack resilience are "brittle", in that they are readily disrupted; this can cause psychological stress, and human and social systems are likewise fragile when they lack the psychological resilience to cope with such challenges.

the access and availability of food and other ecosystem services (Millennium Ecosystem Assessment 2005). Likewise, ecosystem organization is linked to relational well-being, through the nature and quality of people's relationships with each other and also with nonhuman biological forms. The latter are a noteworthy and explicit consideration in many Indigenous world views and systems of ethics (Rose 1999; Anthony 2013). Finally, psychological, social, and ecological resilience are also often tightly linked (Adger 2000; Davidson 2010; Almedom 2015): people can draw resilience from ecosystems during times of stress, and they can also impart their own resilience to ecosystems through active stewardship and an ability to adapt when ecosystems are in crisis.

Despite the obvious linkages, it is important to recognize that the various disciplinary approaches noted above place different degrees of emphasis on the role of the environment in determining well-being outcomes. Environmental health research, for example, clearly identifies environmental factors as important determinants of people's objective well-being (Egger et al. 2004; Clark 2005; Brulle and Pellow 2006). Well-being research with Indigenous peoples and other members of small natural resource-dependent communities has likewise shown that environmental factors contribute to both subjective and objective well-being outcomes (Picou et al. 1992; Markstrom and Charley 2003; Pollnac and Poggie 2006; Samson and Pretty 2006; Wolsko et al. 2006; Donatuto et al. 2014; Weeratunge et al. 2014; Amberson et al. 2016). However, as noted earlier, well-being by some objective measures has improved at a global level while ecosystem health problems have also increased (Millennium Ecosystem Assessment 2005; Raudsepp-Hearne et al. 2010); likewise, work in psychology has found that people are rather adaptive to environmental circumstances, and as such, can feel well in a wide range of circumstances, including those that would be considered to be objectively poor (Diener 2009; Diener and Ryan 2009; Rath and Harter 2010). These differences likely relate to the definitions or philosophies of well-being adopted by these different research programs (Waterman 2007), and also the cultural and socioeconomic context in which the research was developed and implemented (Henrich et al. 2010). We return to these apparent contradictions below where we discuss caveats to our argument.

Given the complexities and subjectivities of both concepts, an explicit theoretical and methodological basis for linking and operationalizing them in initiatives for ecosystem management and community

sustainability is essential (Reed et al. 2006). Generally, our argument is situated within social-ecological systems theory, which posits inherent, but often complex feedback and interactions among social and ecological phenomena (Bennett 1996; Berkes and Folke 2000). Building on this theoretical platform, we discuss here two additional areas of theory that offer insights into the nature of the linkages among human well-being and ecosystem health.

Ecosocial theory

The first area of theory, ecosocial theory from social epidemiology, offers a strong case for using human well-being outcomes in the evaluation of ecosystem health. Ecosocial theory provides a set of principles for understanding how health relates to, and is influenced by, biological, ecological, and societal factors (Krieger 2001, 2005). The core principle in ecosocial theory is the embodiment thesis, which describes:

> [H]ow we literally incorporate, biologically, the material and social world in which we live, from conception to death; a corollary [of embodiment] is that no aspect of our biology[3] can be understood absent knowledge of history and individual and societal ways of living. (Krieger 2001, p. 672)

Embodiment suggests, in other words, that we are living artifacts of our social and natural environs and exposures. Three claims follow from the embodiment thesis that are particularly pertinent to the discussion at hand (adapted from Krieger 2005):

1. People's well-being tells stories about the conditions of their existence.
2. People's well-being tells stories that often—but not always—match their stated accounts.
3. People's well-being tells stories that they cannot or will not tell, either because they are unable, forbidden, or choose not to.

If the embodiment thesis is accurate, the implications for using indicators of human well-being in the evaluation of environmental conditions are numerous: if we can come to understand the various pathways by which environmental circumstances become encoded in our bodies and other aspects of our well-being, we can look to these outcomes for evidence of environmental problems that might not be caught via traditional monitoring. Also, given the second and third considerations above—that well-being, and perhaps objective well-being in particular, can reveal information that people cannot—there may be potential to use well-being indicators alongside local knowledge and observations of environmental conditions as a way to offset the observational biases and shifting baselines that can be encountered in cases of long-term environmental change and degradation (Pauly 1995; Papworth et al. 2009). In other words, changes in people's well-being may provide a record of long-term environmental changes to which people have otherwise become accustomed.

The marginalization–degradation thesis

It is well-known that a reinforcing pattern can emerge among environmental degradation and societal marginalization (Brashares et al. 2004; Cao et al. 2009; Robbins 2012; Nayak et al. 2014; Harrison et al. 2015). In the political ecology literature, this relationship is known as the marginalization–degradation (M–D) thesis (Robbins 2012). The M–D thesis holds that the societal marginalization of a group of people, whether because of socioeconomic inequities or because powerful

[3]Krieger uses the language of biology and bodies in her work; reiterating the point made in a previous footnote, we are adapting the language to match the more holistic, biopsychosocial paradigm that underpins well-being research today.

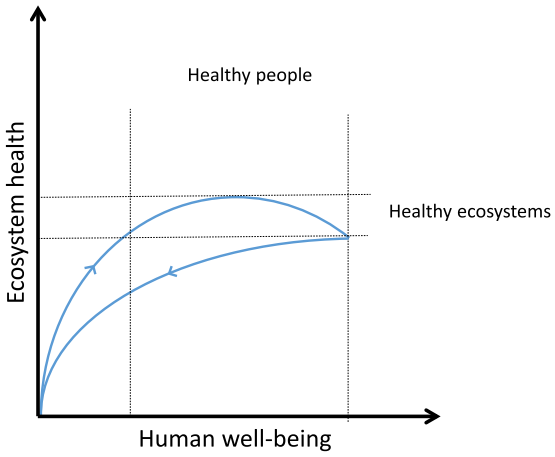

Fig. 1. A schematic combining ecosystem health and human well-being. The shape of the curve is hypothetical and could take many other forms; here, the shape reflects the positive feedback loop of the M–D thesis. Dashed lines identify hypothetical ranges within which ecosystems and people are healthy. The upper curve shows that it is possible to grow social benefits at the expense of environmental outcomes but without passing below an ecosystem health threshold; the rightmost inflection point and lower curve illustrates the assertion that if human activities ultimately do compromise ecosystem health, social benefits will begin to recede. Modified from Loring (2016) (licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0)).

actors are able to degrade the ecosystems on which they rely, creates a scenario in which people will act in ways that further degrade local environments, for example, hunting or fishing illegally. A positive feedback loop is involved, whereby the ensuing environmental degradation furthers inequity and marginalization, and thus further incentivizes local environmental degradation as people struggle to meet their short-term needs. The specific aspects of marginalization that motivate people to act in such ways, whether conditions of material poverty, societal or political factors, or matters of cultural identity and prestige, are not always straightforward (McCay 1981; Duffy et al. 2016), though the root drivers of marginalization are generally situated in broader structural and societal issues of inequity and unequal exchange (Hornborg 2009). As such, the pattern of the M–D thesis is informative and deserves scrutiny within the context of management for conservation and sustainability (Duffy et al. 2016; Loring 2016).

With respect to the present argument, the M–D thesis is complementary to the embodiment thesis in that it completes a conceptual loop for positing a mutually constitutive relationship between well-being and ecosystem health (**Fig. 1**). That is, the embodiment thesis helps us understand how human outcomes are influenced by environmental outcomes, and the M–D thesis shows how those human outcomes may encourage people to behave in ways that further stress local environments. The M–D thesis also supports the argument that environmental problems are often rooted in societal problems and, therefore, can be solved by attending to these social issues. If social policy and action is taken to address marginalization, the incentives that lead people to behave in ways that degrade ecosystems can be reduced.

Discussion

Coulthard (2012) argues that human well-being is an important consideration in natural resource management because it can help managers to understand people's motivations, and also to anticipate the impacts of changes on local people. Our goal with this essay is to extend this proposition even further: if the theoretical ideas we propose here are sound, then not incorporating well-being indicators in environmental management is at best a missed opportunity; at worst, it is an omission that will lead us to mistake some systems as being sustainable when in fact there are ongoing societal injustices that will undermine sustainability in the long run (Loring 2013). A corollary to this premise is that healthy and empowered people and communities are surely in a far better position to steward the ecosystems on which they rely than those who are marginalized.

One important caveat to our argument is that the strength of the proposed relationship among human well-being and ecosystem health is likely dependent on how tightly people are linked with their proximate environments (Sundkvist et al. 2005). As noted above, research on well-being does not always find environmental factors to be a principle determinant. In part, this is likely because many people around the world rely heavily on ecological subsidies from far-off places (Hornborg 2009). Likewise, there are other societal determinants of health, such as structural inequities and historical legacies (e.g., colonialism in North America) that can cause well-being in small communities to be poor, even if ecosystems remain relatively healthy (Kawagley 1995; Stephenson 1995; House 2001). Yet, our argument is not that there is *always* a mutually constitutive relationship among human well-being and ecosystem health, but that there *can be*, and that this should be considered an opportunity for making natural resource systems on both local and global scales more sustainable. Indeed, some Indigenous communities are strengthening their cultural and ecological relationships with local land and seascapes as a way to heal from the biophysical and psychosocial impacts of colonialism and also take more control over local ecosystem health (e.g., Hassel 2006; Augustine and Dearden 2014). The premise is that when people are closely connected to their land and seascapes, not only does their potential for stewarding those resources improve (e.g., Kloppenburg et al. 1996; Sundkvist et al. 2005; Berkes 2010), but they also become the literal embodiment of local environmental health. Communities that fit this criteria of being tightly linked with their proximate environments may thus fit the bill as "sentinel communities", in the sense that their health and well-being can provide early warning for emerging environmental problems, and also in that they are best position to be stewards of local land and seascapes (e.g., Berkes 2010).

One additional challenge to the sentinel community concept is that in many cases, local sustainability problems are not caused by locals, but are driven by global markets and large, multinational actors whose actions are depleting and degrading resources in ways that local people are ill-equipped to defend against (Acheson 2015). That is, for every person whose well-being is on the beneficial side of ecologically unequal exchange, there are people and places who must bear these costs. These large-scale problems can seem intractable, but global awareness is shifting regarding these kinds of problems, with certifications and labels such as the Marine Stewardship Council, the Forest Stewardship Council, and Fair Trade coffee providing examples of solutions that, while not perfect, are steps in the right direction. Our argument here further justifies the explicit inclusion of local well-being in such programs as an essential prerequisite for certifying some product or natural resource management system as sustainable.

Because environmental health and human well-being are such complex phenomena, we admit that more research is necessary to determine the extent to which frameworks for well-being can offer indicators that are useful for environmental monitoring. One prerequisite is that a strong theoretical basis is necessary for making ecosystem health and human well-being operational through indicators (**Fig. 2**), and this is a challenge that we have attempted to address above. As noted, there already exists a plethora of academic frameworks for describing human well-being; what we need now are empirical investigations, ideally done in partnership with local communities, that test and build on these frameworks to further our theoretical understanding of the links (both real and potential) between environmental and societal outcomes. That is, we need to more fully explore the premise depicted in **Fig. 1**—that healthy people espouse healthy ecosystems, and vice versa. While seductive, if the premise is to be informative in terms of looking to local communities as sentinels of sustainability, we need more information on the pathways of causation, including the different possible shapes that the relationship might take, and the cross-scale interactions through which global drivers and processes create local consequences. Getting started, objective well-being indicators (e.g., incidence of disease and nutritional status) may provide low-hanging fruit for exploratory research, but local subjective understandings of well-being should be pursued as well, as neither is capable of telling the whole story.

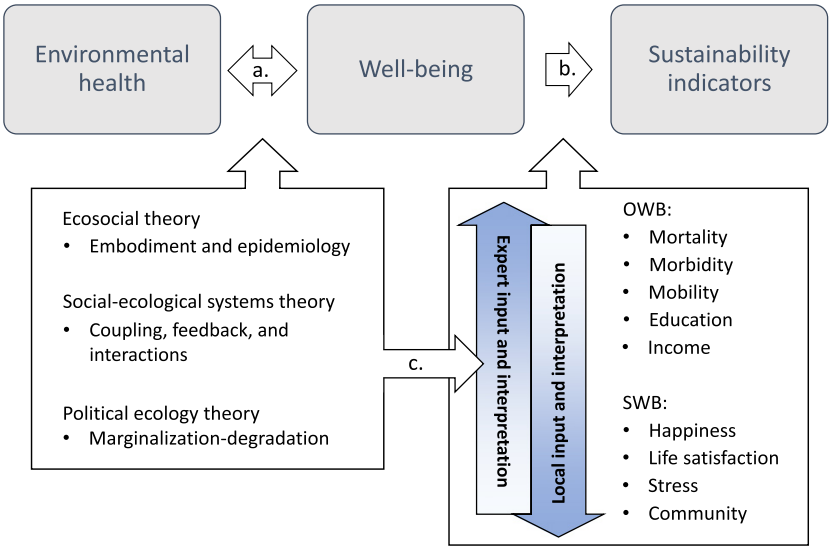

Fig. 2. Indicators serve to operationalize complex theoretical concepts. On the left side (*a*), theories are listed that identify reciprocal linkages among the environment and well-being; on the right side (*b*), frameworks for well-being offer specific indicators for informing assessments of ecosystem health and sustainability. Note that a mix of subjective and objective well-being indicators (SWB and OWB) is likely important, along with a combination of local (bottom-up) and expert (top-down) interpretations.

Methodologically, it is essential that this research proceed in a collaborative and decolonized manner, such that the colonial and first world biases that continue to challenge research in areas such as psychology and sustainability can be avoided (Smith 1999; Reed et al. 2006; Henrich et al. 2010). Local and traditional knowledge, in particular, is likely an important source of information about the linkages among human and environmental health outcomes (Wolsko et al. 2006; Raymond et al. 2010; Alessa et al. 2015), and local knowledge research offers additional methodological insights for the kind of work we are proposing here (e.g., Huntington 1998). New research could investigate people's own understandings of how their well-being functions in relationship to the natural world. What aspects of their well-being and ecosystem health do people prioritize for protection and improvement? What dependencies among the two domains do people see? It seems unlikely that local people will cognitively parcel their well-being into the same categories that typify the various academic frameworks discussed above; as such, qualitative research that seeks to uncover people's *emic*, or personally held cognitive models of well-being and ecosystem health, will help both scientists and policymakers to better understand the place-based nature of these phenomena. Such work may also illuminate new and promising strategies for intervention on social and environmental problems.

The various challenges discussed above notwithstanding, we believe that there is clear potential for integrating sentinel communities into sustainable environmental management, and for thinking about how we can use the notion of being sentinels as a vision for healing the human-nature divide and reorienting our relationships with the natural world in places where livelihoods and ecosystems are currently disconnected. Doing so would be a step beyond that of just being stewards, because we would be making own personal stakes in the matter explicit. Discursively, adopting this language would also be a noteworthy step toward replacing the "Anthropocene" paradigm of how people interact with ecosystems, which is characterized by impacts, tradeoffs, and paradoxes, to a "post-Anthropocene" paradigm of sustainability based instead on pursuing connections, mutualisms, and win–win scenarios.

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Author contributions

Conceived and designed the study: PAL, MSH, HN. Drafted or revised the manuscript: PAL, MSH, HN.

Competing interests

The authors have declared that no competing interests exist.

Data accessibility statement

All relevant data are within the paper.

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