

Biocultural approaches to well-being and sustainability indicators across scales

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Monitoring and evaluation are central to ensuring that innovative, multi-scale, and interdisciplinary approaches to sustainability are effective. The development of relevant indicators for local sustainable management outcomes, and the ability to link these to broader national and international policy targets, are key challenges for resource managers, policymakers, and scientists. Sets of indicators that capture both ecological and social-cultural factors, and the feedbacks between them, can underpin cross-scale linkages that help bridge local and global scale initiatives to increase resilience of both humans and ecosystems. Here we argue that biocultural approaches, in combination with methods for synthesizing across evidence from multiple sources, are critical to developing metrics that facilitate linkages across scales and dimensions. Biocultural approaches explicitly start with and build on local cultural perspectives — encompassing values, knowledges, and needs — and recognize feedbacks between ecosystems and human well-being. Adoption of these approaches can encourage exchange between local and global actors, and facilitate identification of crucial problems and solutions that are missing from many regional and international framings of sustainability. Resource managers, scientists, and policymakers need to be thoughtful about not only what kinds of indicators are measured, but also how indicators are designed, implemented, measured, and ultimately combined to evaluate resource use and well-being. We conclude by providing suggestions for translating between local and global indicator efforts.

Complex global environmental challenges call for innovative, multi-scale, and interdisciplinary approaches to research-based policy and action^{1,2}. Monitoring and evaluation are central to ensuring these approaches are effective^{3–5}. Developing accurate indicators and relevant success criteria to assess the local outcomes of sustainability management actions, and linking them

to broader national and international policy targets, remains a key challenge for resource managers, policymakers, and scientists².

What indicators we decide to measure and how we measure them impact the people and activities that are included in or affected by a given initiative. Efforts to evaluate well-being or resource use that are developed solely on regional or global scales may leave out

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indicators critical for local systems. They may discount, mischaracterize, or ignore place-based values, worldviews, and knowledge systems^{6–8}. Culturally grounded perspectives are missing from many medium- and large-scale efforts developed by governments and other institutions that aim to implement sustainable resource management and monitor goals and targets^{9,10}. Disconnects can result in miscommunication, misdirected resources, and policies that fail to inspire appropriate action¹¹. More worryingly, assessments that lack a place-based cultural context can be harmful to communities, leading to loss of control over place, knowledge, or resources^{12,13}. Many types of knowledge and knowledge system — from ways of knowing that reflect in situ, local, place-based cultural values (recognizing that ‘culture’ is dynamic⁸) to externally derived information from ex situ researchers or policymakers — can contribute to understanding and managing systems sustainably^{14–16} (Fig. 1). We use local,

place-based, and in situ interchangeably to represent culturally grounded actors such as local or Indigenous peoples who manage cultural and biological resources and to differentiate from actors — be they local or external to a community — who are not familiar with the cultural practices of a place. We recognize individuals can be local in some contexts and external in others, and in a particular location people self-define with different ‘communities’ at different times.

We suggest that different knowledge systems, and the indicators that emerge from these systems, can exist in one of three states:

- As separate systems (Fig. 1a)
- As interacting but conflicting systems with externally derived sustainability indicators that may be culturally inappropriate at local levels (Fig. 1b)
- As synthesized knowledge systems (Fig. 1c)

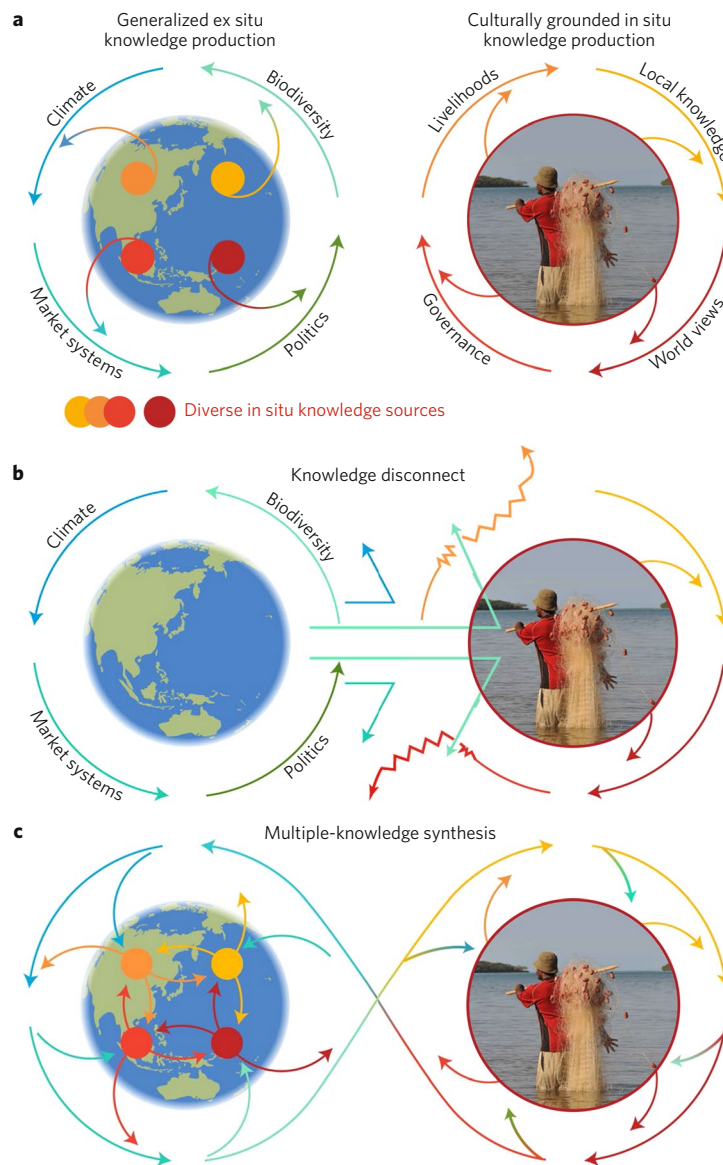


Fig. 1 | Ex situ and in situ knowledge production and synthesis. **a**, Ex situ and culturally grounded in situ perspectives generate different but complementary knowledge systems that can guide sustainable resource management. **b**, Policy and management driven by ex situ perspectives: approaches that are primarily driven by ex situ perspectives often deliver knowledge in ways that disrupt or conflict with in situ worldviews and well-being, thereby limiting potential for positive interplay between ex situ and in situ knowledge systems. **c**, Policy and management recognizing local perspectives: approaches recognizing and respecting in situ as well as ex situ knowledge systems can lead to more effective syntheses and enduring on-the-ground impact. Credit: photograph, Nicolas Pascal, Blue finance.

Understanding biocultural approaches

Here we argue that biocultural approaches are critical to understanding social-ecological systems and the development of locally relevant indicators. Biocultural (or ecocultural as per ref. 17) approaches are those that explicitly start with and build on place-based cultural perspectives — encompassing values, knowledges, and needs — and recognize feedbacks between ecological state and human well-being^{18–22}. These approaches, in combination with methods for synthesizing across evidence from multiple sources^{23,24}, can also help to develop the indicators that are required to meet current complex challenges²⁵. Exchange between in situ and ex situ actors facilitates identification of crucial problems and solutions that are currently missing from many regional and international framings of sustainability^{21,22,26}. We suggest that methods that synthesize across culturally grounded and generalized knowledge from multiple sites (Fig. 1c) can foster greater human adaptive capacity and ecological resilience. In doing so, these methods may be more effective than those that rely on a priori frameworks for information synthesis^{7,8,27,28}.

Historical, political, and economic forces have resulted in a disproportionate representation and power of people and institutions in the West/global North in shaping ‘global’ or ex situ knowledge, policy, and norms²⁹. Yet place-based actors are critical to guide the implementation and monitoring of natural resource management for ethical and practical reasons^{13,30}. Indigenous peoples and other in situ communities manage lands and seas that hold significant portions of the planet’s biodiversity³¹ and carbon stocks³². In addition, place-based communities have generated creative resilient responses to global pressures, despite experiencing outsized impacts from them^{33,34}.

Scholarship and stories stemming from participatory action research³⁵ and ethnobiology (for example, research into traditional ecological knowledge; TEK) have documented local capacity to respond to stresses³⁶. In particular, participatory and community-led resource management approaches have shown that working within place-based social and cultural contexts has the potential to capture connections and drivers of behaviour, such as variation in communal versus individual property rights, that external framing of a system might miss^{11,37,38}. However, it is increasingly recognized that local institutions are nested within complex multi-level governance systems³⁹. While best practices have been widely developed for community-based governance approaches, new theories and methods are needed to link local goals with sustainable management outcomes that are critical to global policy objectives^{10,40,41}.

Biocultural approaches to indicator development

International efforts to address complex global concerns (for example, landscape fragmentation or food security) increasingly recognize the importance of feedbacks among social and ecological processes, and that human well-being is linked to ecosystem states and processes^{42,43}. For instance, the recently developed Sustainable Development Goals, stemming from the Millennium Ecosystem Assessment³, theoretically support planning, tracking, and reporting that integrate across social and ecological systems⁴⁴. International assessments, such as those emerging from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), incorporate these concepts, although not without some definitional challenges^{45,46}.

One theory that provides guidance in linking between local and global resource management is social-ecological systems (SES) theory⁴⁷. SES theory provides a priori frameworks for understanding social and ecological feedbacks that characterize the settings within which humans exist and impact policy^{25,48}. However, while SES approaches help to conceptualize interactions between elements of a system, they may neglect or under-emphasize the importance of cultural values, beliefs, and worldviews to sustainable resource management. For instance, vulnerability assessments identify

system weaknesses and emphasize what communities and individuals lack^{34,48,49}. This can inadvertently erode local perceptions of well-being and direct blame towards place-based communities, thus fostering a framing of helplessness^{50,51}. Furthermore, SES approaches that rely on ex situ values such as the importance of material goods can be problematic. For example, an Amerindian village that had only one television for the whole village had a quality of life indicator measurement below that of other villages where individual families had their own televisions⁵². However, watching one television together was considered *mex* by the inhabitants. *Mex* is a local concept of well-being as ‘beauty’, valuing not just aesthetics but extended, strong, and peaceful social relations⁵³.

Although related conceptually to SES, biocultural approaches differ in that they explicitly start with the specific human practices, local knowledge and cultural beliefs that influence and are influenced by the land- and seascapes of which human communities are a part^{19,36,54}. All biocultural approaches are social-ecological in nature, but not all social-ecological approaches frame interactions from locally relevant cultural perspectives. There is a fundamental difference between theoretical conceptions of interactions between social and ecological elements of a system (which externally framed SES can accomplish effectively) and culturally grounded understandings of what factors drive a system (an explicit goal of all biocultural and some SES approaches).

In relation to indicator development for sustainable resource management, biocultural approaches present opportunities that can address some of the challenges (Fig. 1b) by creating space for metrics that facilitate cross-scale linkages. Effective biocultural approaches to indicator development have a number of characteristics. First, they begin with an understanding of locally grounded questions and institutions that communities use when interacting with or managing resources. A clear awareness of who is included in the community, what criteria constitute community membership, diverse opinions within the community, and on what scale and by whom decisions are being made is key⁷. As with development of any indicator, clarity on agency — indicators for what and for whom, chosen by whom, analysed by whom, resulting in actions decided on by whom — is essential³⁵.

Second, the indicators developed are deeply relevant to people’s cultural way of life (Table 1). They encompass cultural values and worldviews that shape people’s understandings of their roles within and responsibilities to their environment^{56,57}. For instance, within the Reimaanlok national framework for the establishment of community-based conservation areas in the Marshall Islands, traditional knowledge holders guide the selection of targeted resources and threats as well as the mapping of sacred places^{18,54}.

Third, the ways in which the indicators are measured and monitored are coordinated with existing livelihood strategies or social activities of the people involved in the monitoring^{58,59}. For example, the Lutsel K’e Dene First Nation identifies the health of fish based on observations carried out during and immediately after fishing, such as fatness of fish, colour and texture of the flesh, and health of organs⁶⁰.

Fourth, biocultural approaches to indicator development are enacted with the explicit intention of using the collected knowledge to guide action of interest to communities^{57,61,62,63}. The International Partnership for the Satoyama Initiative, for instance, supports communities in social-ecological production landscapes and seascapes to develop a variety of social, cultural, and biological indicators to facilitate local management⁶³.

Biocultural approaches build on community-based and participatory methods by more explicitly taking a systems perspective, which emphasizes feedbacks between ecological and cultural elements in a system. The types of indicators created through biocultural approaches can capture both the ecological underpinnings of a cultural system and the cultural perspectives of an ecological

Table 1 | Examples of United Nations Sustainable Development Goal (SDG) indicators and additional or alternative indicators stemming from biocultural approaches

Issue	Relevant SDG	Example of externally driven metric(s)	Discussion	Examples of indicators derived from biocultural approaches
Food security	Goal 2: “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”.	Indicator 2.1.2: “Prevalence of moderate or severe food insecurity in the population, based on the food insecurity experience scale (FIES)”. FIES sample question: “During the last 12 months was there a time when your household ran out of food because of a lack of money or other resources?” ¹⁰²	Some Pacific island countries have strong cultural obligations to provide family/guests with food ¹⁰³ . Standardized vulnerability-framed questions about food security may not generate accurate data due to cultural reluctance to admit to food shortages. Biocultural framing would emphasize local knowledge and definitions of resource systems, and innovation for resilience.	(1) Percentage of households in the community that report having a stable food supply throughout the year. Food supply can be subsistence-based, bought, or a result of exchange. (2) Average length of time after a disaster for which households in the community have access to an emergency supply of culturally valued food.
Quality education	Goal 4: “Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all”.	Indicator 4.1.1: “Proportion of children and young people: (a) in grades 2/3; (b) at the end of primary; and (c) at the end of lower secondary achieving at least a minimum proficiency level in (i) reading and (ii) mathematics, by sex”.	Inclusion of place-based ecological knowledge can increase local ownership of school curricula, strengthen management practices and build identity for pupils ¹⁷⁰⁴ .	Vitality (that is, rate of retention over time) of ecological knowledge and practice, vitality of transmission pathways for information about land and sea, innovation in ecological knowledge systems ⁹⁵ .
Access to fresh water	Goal 6: “Ensure availability and sustainable management of water and sanitation for all”.	Indicator 6.3.2: “Proportion of bodies of water with good ambient water quality”.	The Maori worldview does not distinguish between the spiritual health and ecological state of water sources. Some water sources are considered sacred, or <i>tapu</i> . An indicator such as ambient water quality is incomplete in its ability to assess Maori values including the role of particular locations in creation stories, use in access routes and the ability for a site to be used by future generations ⁸³ .	The Maori-based cultural health index for streams includes: (1) site status (for example, traditional significance); (2) the intangible and tangible value of a site; and (3) stream health measures that were developed through participatory processes ⁸³ .
Sustainable tourism	Goal 8: “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”.	Indicator 8.9.1: “Tourism direct gross domestic product (GDP) as a proportion of total GDP and in growth rate”.	GDP is often not measurable or meaningful at the local level. Further, a biocultural framing could capture whether tourism activities are beneficial for place-based communities and supportive of traditional culture ¹⁰⁵ .	Relative contribution of local tourism revenues within average annual household income as generated from culturally appropriate marketing or demonstration/presentation of traditional knowledge and customary practices (for example, guided interpretive hikes by respected elder; visitor use of traditional navigation).
Protection of marine resources	Goal 14: “Conserve and sustainably use the oceans, seas and marine resources for sustainable development”.	Indicator 14.5.1: “Coverage of protected areas in relation to marine areas”.	Measuring marine protected area (MPA) coverage does not account for effectiveness of MPA location, design, or management ¹⁰⁶ . Percentages are insufficient metrics of sustainability. Moreover, this metric may exclude locally managed marine areas, which often lack legal status but incorporate place-based practice ¹⁰⁷ . For example, in Hawai‘i, the community-based subsistence fishing areas sets rules based in traditional resource management without the complete closures that might result in a loss of place-based practice ^{33,108} .	(1) Are common marine resources managed sustainably, through locally supported customary management systems? (2) The Micronesia protected area management effectiveness scorecard is designed to measure stakeholder engagement, local knowledge and other aspects of effective protected area management at the community level, although it can also be scalable to national and regional levels ¹⁰⁹ .

Continued

Table 1 | (continued)

Issue	Relevant SDG	Example of externally driven metric(s)	Discussion	Examples of indicators derived from biocultural approaches
Protection of terrestrial resources	Goal 15: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss".	Indicator 15.5.1: Red List index.	Red listing evaluation may not reflect local abundance of culturally important species. For example, a highly culturally important species that is in steep local decline, but stable nationally or globally, would not be identified. Similarly, globally or nationally threatened species that are of local cultural importance may be locally thriving due to sustainable management. Red listing can then have negative local consequences. Alternative metrics could reflect the status of local forest resources as well as interest in maintaining cultural practices.	How long does it take to collect forest resources for cultural practices and how has the amount of time to complete this harvest changed since elders in the community were young?

state, and thus can highlight interactions and feedbacks between humans and their environment. For example, a social indicator may encompass social or cultural practices that in turn explain an observed phenomenon in the population dynamics of a species. A social indicator such as 'trend in percent of elders or parents transmitting traditional knowledge to children' could explain why a harvested species has healthy populations, because intergenerational transmission of TEK regarding the impact of harvest of individuals at different life stages facilitates effective population management. Similarly, biological trends and processes — such as dynamics or status of totem species — may underpin local visions of well-being because people's perceptions of well-being are tied to the health of their totem.

Many cultural aspects are known to affect adaptive capacity⁶⁴ and yet are often deemed intangible and thus potentially unmeasurable⁶⁵. Consequently, many assessments rely on indicators that are easier to quantify, compare, aggregate, and communicate across scales and arenas, but that may miss out on feedbacks or critical variables at the local level that biocultural approaches could illuminate (Table 1). As noted in ref. ⁶⁶, conservation and sustainability efforts frequently approach social-cultural aspects as if they are assessing biodiversity: by creating lists of stakeholders, documenting spatial data on land/sea use, and converting these into relative costs. These approaches overlook the complex psychological and cultural reasons behind management action or inaction. Indicators can and should measure the perceptions of the effect of ecological change on well-being, as these perceptions can drive behaviour more than factors collected via empirical data on change⁴¹. Perceptions impact local support (or lack thereof) for management action. Recognition of the role of perceptions within the context of different worldviews is critical to understanding connections and disconnections between international, national, and local framing of problems and successes^{41,67–69}.

An emerging literature has begun to identify innovative methods to address the challenges of capturing cultural aspects of a system, when the creation of metrics is deemed helpful or necessary by all parties in a consultation⁶⁵. For instance, challenges in developing indicators of intangible elements of a system can in part be resolved through the use of ethnographic interviewing techniques that elucidate how the values, beliefs, and experiences of individual people affect their understanding of that system⁶⁵. As one example, in exploring the impact of western Lesotho's Metolong Dam on local inhabitants, researchers used audiovisual and global positioning system technology along with interview and group discussion notes to

document 'intangible culture' as expressed through the relationships between landscape features and cultural histories and narratives⁷⁰.

Overall, indicators need to be meaningful and applicable to practice at local levels, and should be situated within a context of feedbacks between interconnected ecological and cultural components of a system. Given these complex factors, biocultural approaches can assist in developing grounded, accurate, appropriate, and relevant indicators.

Managing cross-cultural indicator development

Biocultural approaches can be undertaken by Indigenous and other place-based communities without engaging with ex situ entities⁷¹. These communities might not use the term biocultural to describe their approach, as for them it is a lived experience. Furthermore, biocultural approaches are not exclusively used in the context of Indigenous communities or in the 'global South'. High Nature Value farming and other European biocultural initiatives highlight the use of biocultural approaches in non-Indigenous settings⁷². However, as communities across the globe face internal and external environmental and economic pressures, they have increasingly engaged with ex situ actors in knowledge exchange and co-creation of indicators^{21,23,73}. The process of co-creation of indicators across groups can help to frame questions and solutions that span scales⁷ and ensure that indicators are relevant to users⁷⁴ (Fig. 1c). Collaborations that seek to understand and embrace the complexity and interrelated nature of different worldviews can lead to improved conservation and management outcomes^{75–78}.

For example, in coastal British Columbia, a collaborative team of Heiltsuk First Nation youth and leadership and ex situ scientists placed Heiltsuk observations of grizzly bear (*Ursus arctos*) in the context of *Gvi'ilas* — customary law in which bear behaviour is recognized as a voice to guide decision-making about whole ecosystems — to undertake basic bear studies. In this project, the Heiltsuk framed the research questions and led the partnership to carry out data collection and communicate the findings to the broader community. The research relied both on population and landscape genetics and on Heiltsuk ways of knowing. As it was embedded in Heiltsuk governance structures, the research led to changes in bear management objectives, sanctions on trophy hunting and outlines for a multi-nation grizzly bear sanctuary under formal co-management frameworks⁷⁹.

Elucidating culturally grounded understandings requires time and skills, to translate between different types of knowledge and scales of governance^{21,80}. Collaborators need to observe and listen carefully, and be open to the validity and deep complexity of other

ways of knowing⁸¹. They must also have skills to identify indicators embedded in numerous cultural forms⁵⁹. Indigenous indicators may be integrated within social contexts that are unfamiliar to ex situ scientists^{12,82}, or that may seem disconnected from environmental management but are inextricably linked for in situ actors. These forms may include stories, songs, ceremonies, oral histories, and what ex situ actors might view as ‘art’^{21,75,82,83}. Including information from different knowledge systems can provide a more complete picture for decision-making^{84,85}. For instance, oral histories from Hawai’i informed the development of local indicators of environmental and climate change. These include distribution of pan-Pacific, culturally important trees that were once widespread as described by place names and legends, but are now sparse due to landscape transformations and climate change effects⁸⁶.

Cross-cultural knowledge sharing and collaborations require understanding of how to manoeuvre through the diversity of expectations, perceptions, and viewpoints within and across communities. Knowledge from different sources may initially seem incompatible⁸⁷. Overcoming this requires ex situ actors to take the time to understand the local context for these knowledges and not dismiss them⁸⁸. With biocultural approaches, the social-cultural context for local knowledge is key, as is explicit recognition of the producers and holders of knowledge. Knowledge extraction without this context and attribution can disempower local knowledge holders and undermine that knowledge’s transformative potential for management¹⁰. Ethnographic research has a key role to play in understanding the politics and process of how knowledge arises and is translated between different groups, and how that can inform decision-making^{82,87}.

Cross-cultural navigation also involves recognizing different perspectives on the type and depth of knowledge that is sufficient for characterizing critical dimensions of a system for management. For example, both in situ and ex situ actors and managers may have only a partial vision of the larger system. In New Ireland, Papua New Guinea, in situ actors might know the micro-scale behavioural ecology of sandfish (*Holothuria scabra*), but they do not necessarily know the behavioural ecology of species that are intimately connected to the sandfish in the larger system⁸⁹; ex situ actors might know the large-scale dynamics of those reef species in the western Pacific but may not understand the micro-system dynamics of single reef sites (P.W., unpublished observations). Individuals who are steeped in local cultures but have worked or studied, for instance, in international settings can help with ensuring successful co-creation processes⁹⁰. Effective two-way communication between ex situ and in situ actors can facilitate policies that leverage the power of both locally relevant knowledge that has evolved within a place and larger-scale generalizable knowledge^{21,26}.

Such collaborative cross-cultural work comes with a number of challenges. Involving numerous sources of knowledge can increase potential for conflict, and enhanced complexity can overwhelm decision-makers and scientists⁹¹. Other points that must be considered include the range of beliefs and biases people bring to an endeavour, competitive funding environments, organizational structures driven by external value systems, timelines for reporting that favour efficiency and speed, ethical issues regarding the dissemination and use of co-produced knowledge, and the arbitrary nature of classifying different types of knowledge²⁴. Some of these issues can be overcome if researchers approach cross-cultural work with strategies aimed at fostering true partnerships with in situ groups. Research has shown that when initiatives include diverse actors across all stages, local users are more likely to sustain those initiatives^{13,24,55}. Building in enough time and appropriate conditions for iterative reflection in selection of indicators is critical, as is consideration of rights, representation, and power dynamics^{13,55,92}. The social process of engagement, of working together to reflect on and choose indicators, is a key ingredient of successful indicator

development and the discussion itself may lead to improved outcomes. An initiative is more likely to produce practical, actionable knowledge when researchers understand and leverage the interactive nature of knowledge- and decision-making⁹³. When synthesizing different knowledges, approaches that are iterative, collaborative, and include methods to evaluate validity and reliability can be helpful²⁴, as are strategies that use validation processes internal to each system to ensure that the highest calibre knowledge is available for consideration^{23,73}.

Bridging global and local policy and management

If we are to monitor and evaluate sustainable resource use and well-being effectively, we need mechanisms that allow for translation between place-based contexts and other scales, including layers of local and regional government. Thus, in addition to being thoughtful on all scales about what kinds of indicator we measure and who is doing the measuring, we need robust, transparent processes to guide how indicators are designed, implemented, analysed, combined or compared, and incorporated into decision-making processes. Global efforts should also explicitly consider why and how to standardize, despite the ease of comparing and aggregating standardized information. Indicators capturing information in exactly the same way regardless of local context may not be meaningful. Conversely, measures that are developed on local scales and reflect specific place-based values may not easily translate to other locales or to national and international policy by the very nature of their specificity⁸².

There are several non-exclusive ways to bridge the gaps between local and global indicators. For instance, it may be possible to group complementary indicators under a particular dimension, such as governance, that is meaningful on local as well as global scales. Place-based communities could choose from these indicators to suit their cultural and biological setting^{43,94}. This type of system has already been designed. The vitality index of traditional environmental knowledge (VITEK) is a locally appropriate, globally applicable index that can be used to measure, assess, and compare local ecological knowledge transmission. VITEK defines broad domains of TEK for the overall index, but the actual questions used as indicators are adapted locally⁹⁵. Tools such as the Mauri model provide a flexible process by which communities can quantify their perceptions of the long-term viability of different well-being dimensions and develop benchmarks tailored to local settings⁹⁶; while the indicators relate to a specific location, the indicator groupings and methods for scoring the results are fixed, facilitating comparability across communities⁵⁴.

In addition, provincial and national level agencies have an important role to play. National initiatives such as the Melanesian well-being index standardize and quantify well-being using culturally appropriate metrics⁹⁷. Similarly, in Latin America, emerging well-being concepts such as *Buen Vivir* (‘living well’) use culturally grounded quantitative approaches⁹⁸. One of the earliest efforts to quantify holistic well-being, Bhutan’s gross national happiness index, focuses on non-economic development measures and has received much global attention, although these efforts have also been critiqued in relation to exclusion of minority groups⁹⁹. National level understanding of local systems and patterns can lead to better tracking of whether or not global targets are being met and enable policy development and action on the ground to address local issues meaningfully. Initiatives that work with national governments to develop indicator strategies for international conventions, such as the Convention on Biological Diversity’s (CBD) National Biodiversity Strategic Action Plan process and the Biodiversity Indicator Partnership, or to assess the current status of biodiversity, such as IPBES^{45,46}, could help ensure that culturally grounded indicators are developed and used.

Joint efforts in implementation of existing international conventions, such as between the CBD and the United Nations Educational, Scientific and Cultural Organization's Convention for the Safeguarding of the Intangible Cultural Heritage, could lead to shared indicators of progress that would better address combined cultural and biological elements on the local scale. These efforts could also promote information sharing, bridge organizational concerns, and integrate specialized knowledge and actions across multiple scales and sectors¹⁰⁰.

Conclusion

Global targets such as sustainability and well-being are best addressed through multi-level governance¹⁰⁰, and we argue that biocultural approaches can create space for meaningful local metrics while supporting cross-scale application. Future work could find ways to compare results from biocultural approaches to indicator development with those that did not include cultural aspects or feedbacks between humans and their environments, to see if outcomes differ. In addition, more work needs to be done regarding methods for synthesizing across multiple knowledge systems and identifying ways to maintain the richness of local narratives to counter reductionist approaches in decision-making^{75,101}. While great strides are being made in better articulating methods for collaboration and not just participation^{13,26,30}, this remains an ongoing challenge. We believe that by integrating local perspectives and values into global scale indicator development efforts, biocultural approaches can both facilitate development of metrics more appropriate for in situ communities and support the innovative approaches to research-based policy and action necessary to confront complex environmental challenges.

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Competing interests

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