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## **Biocultural approaches to well-being and sustainability indicators across scales**

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105

106 Abstract

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

127

128 Introduction

129 Complex global environmental challenges call for innovative, multi-scale, and  
130 interdisciplinary approaches to research-based policy and action<sup>1,2</sup>. Monitoring and  
131 evaluation are central to ensuring these approaches are effective<sup>3-5</sup>. Developing  
132 accurate indicators and relevant success criteria to assess the local outcomes of  
133 sustainability management actions, and linking them to broader national and  
134 international policy targets, remains a key challenge for resource managers,  
135 policymakers, and scientists<sup>2</sup>.

136

137 What indicators we decide to measure and how we measure them impact the people  
138 and activities that are included in or affected by a given initiative. Efforts to evaluate  
139 well-being or resource use that are developed solely at regional or global scales may  
140 leave out indicators critical for local systems. They may discount, mischaracterise,  
141 or ignore place-based values, worldviews, and knowledge systems<sup>6-8</sup>. Culturally  
142 grounded perspectives are missing from many medium and large-scale efforts  
143 developed by governments and other institutions that aim to implement sustainable  
144 resource management and monitor goals and targets<sup>9,10</sup>. Disconnects can result in  
145 miscommunication, policies that fail to inspire appropriate action, and misdirected  
146 resources<sup>11</sup>. More worryingly, assessments that lack a place-based cultural context  
147 can be harmful to communities, leading to loss of control over place, knowledge, or  
148 resources<sup>12,13</sup>. Multiple types of knowledge and knowledge systems – from ways of  
149 knowing that reflect in-situ, local, place-based cultural values to externally derived  
150 information from ex-situ researchers or policymakers – can contribute to  
151 understanding and managing systems sustainably<sup>14-16</sup> (Fig. 1). We use local, place-  
152 based, and in-situ interchangeably to represent culturally grounded actors such as  
153 local or Indigenous peoples who manage cultural and biological resources and to  
154 differentiate from actors – be they “local” or “external” to a community – who are  
155 not familiar with the cultural practices of a place.<sup>a</sup>

156

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

- 159 ● as separate and independent reinforcing systems (Fig. 1a),
- 160 ● as interacting but conflicting systems with externally derived sustainability  
161 indicators that may be culturally inappropriate at local levels (Fig. 1b), or
- 162 ● as synthesised knowledge systems (Fig. 1c).

163

164 INSERT FIGURE 1

165

166 Understanding biocultural approaches

167 Here we argue that biocultural approaches are critical to understanding social-  
168 ecological systems and the development of locally-relevant indicators. Biocultural

169 (or ecocultural as per Thaman 2000<sup>17</sup>) approaches are those that explicitly start  
170 with and build on place-based cultural perspectives – encompassing values,  
171 knowledges, and needs – and recognise feedbacks between ecological state and  
172 human well-being<sup>18–22</sup>. These approaches, in combination with methods for  
173 synthesising across evidence from multiple sources<sup>23,24</sup>, can also help to develop the  
174 indicators that are required to meet current complex challenges<sup>25</sup>. Exchange  
175 between in-situ and ex-situ actors facilitates identification of crucial problems and  
176 solutions that are currently missing from many regional and international framings  
177 of sustainability<sup>21,22,26</sup>. We suggest that methods that synthesise across culturally  
178 grounded and generalised knowledge from multiple sites (Fig. 1c) can foster greater  
179 human adaptive capacity and ecological resilience. In doing so, these methods may  
180 be more effective than those that rely on a priori frameworks for information  
181 synthesis<sup>7,8,27,28</sup>.

182 Historical political and economic forces have resulted in a disproportionate  
183 representation and power of people and institutions in the West/Global North in  
184 shaping “global” or ex-situ knowledge, policy, and norms<sup>29</sup>. Yet place-based actors  
185 are critical to guide the implementation and monitoring of natural resource  
186 management for ethical and practical reasons<sup>13,30</sup>. Indigenous peoples and other in-  
187 situ communities manage lands and seas that hold significant portions of the  
188 planet’s biodiversity<sup>31</sup> and carbon stocks<sup>32</sup>. In addition, place-based communities  
189 have generated creative resilient responses to global pressures, despite  
190 experiencing outsized impacts from them<sup>33,34</sup>.

191 Scholarship and stories stemming from Participatory Action Research<sup>35</sup> and  
192 ethnobiology (e.g., research into Traditional Ecological Knowledge - TEK) have  
193 documented local capacity to respond to stresses<sup>36</sup>. In particular, participatory and  
194 community-led resource management approaches have shown that working within  
195 place-based social and cultural contexts has the potential to capture connections  
196 and drivers of behaviour, such as variation in communal versus individual property  
197 rights, that external framing of a system might miss<sup>11,37,38</sup>. However, it is  
198 increasingly recognised that local institutions are nested within complex multi-level  
199 governance systems<sup>39</sup>. While best practices have been widely developed for  
200 community-based governance approaches, new theories and methods are needed in  
201 order to link local goals with sustainable management outcomes that are critical to  
202 global policy objectives<sup>10,40,41</sup>.

203

#### 204 Biocultural approaches to indicator development

205 International efforts to address complex global concerns (e.g., landscape  
206 fragmentation, food security) increasingly recognise the importance of feedbacks  
207 among social and ecological processes, and that human well-being is linked to  
208 ecosystem states and processes<sup>42,43</sup>. For instance, the recently developed  
209 Sustainable Development Goals, stemming from the Millennium Ecosystem  
210 Assessment<sup>3</sup>, theoretically support planning, tracking, and reporting that integrate

211 across social and ecological systems<sup>44</sup>. International assessments, such as those  
212 emerging from the Intergovernmental Science-Policy Platform on Biodiversity and  
213 Ecosystem Services (IPBES), incorporate these concepts, though not without some  
214 definitional challenges<sup>45,46</sup>.

215 One theory that provides guidance in linking between local and global resource  
216 management is social-ecological systems theory<sup>47</sup> (hereafter called SES). SES  
217 provides a priori frameworks for understanding social and ecological feedbacks that  
218 characterise the settings within which humans exist and impact policy<sup>25,48</sup>.  
219 However, while SES approaches help to conceptualise interactions between  
220 elements of a system, they may neglect or under-emphasise the importance of  
221 cultural values, beliefs, and worldviews to sustainable resource management. For  
222 instance, vulnerability assessments identify system weaknesses and emphasise  
223 what communities and individuals lack<sup>34,48,49</sup>. This can inadvertently erode local  
224 perceptions of well-being and direct blame toward place-based communities, thus  
225 fostering a framing of helplessness<sup>50,51</sup>. Furthermore, SES approaches that rely on  
226 ex-situ values such as the importance of material goods can be problematic. For  
227 example, an Amerindian village that had only one television for the whole village  
228 had a quality of life indicator measurement below that of other villages where  
229 individual families had their own televisions<sup>52</sup>. However, watching one television  
230 together was considered “mex” by the inhabitants. “Mex” is a local concept of well-  
231 being as “beauty”, valuing not just aesthetics but extended, strong, and peaceful  
232 social relations<sup>53</sup>.

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

243 In relation to indicator development for sustainable resource management,  
244 biocultural approaches present opportunities that can address some of the  
245 challenges (Fig. 1b), by creating space for metrics that facilitate cross-scale linkages.  
246 Effective biocultural approaches to indicator development have a number of  
247 characteristics. First, they begin with an understanding of locally grounded  
248 questions and institutions that communities use when interacting with or managing  
249 resources. A clear awareness of who is included in the community, what criteria  
250 constitute community membership, diverse opinions within the community, and on  
251 what scale and by whom decisions are being made is key<sup>7</sup>. As with development of  
252 any indicator, clarity on agency – indicators for what and for whom, chosen by  
253 whom, analysed by whom, resulting in actions decided upon by whom – is

254 essential<sup>55</sup>.

255 Second, the indicators developed are deeply relevant to peoples' cultural way of life  
256 (Table 1). They encompass cultural values and worldviews that shape peoples'  
257 understandings of their roles within and responsibilities to their environment<sup>56,57</sup>.  
258 For instance, within the Reimaanlok national framework for the establishment of  
259 community-based conservation areas in the Marshall Islands, traditional knowledge  
260 holders guide the selection of targeted resources and threats as well as the mapping  
261 of sacred places<sup>18,54</sup>.

262 Third, the ways in which the indicators are measured and monitored are  
263 coordinated with existing livelihood strategies or social activities of the people  
264 involved in the monitoring<sup>58,59</sup>. For example, the Lutsel K'e Dene First Nation  
265 identify the health of fish based on observations carried out during and immediately  
266 after fishing, such as fatness of fish, colour and texture of the flesh, and health of  
267 organs<sup>60</sup>.

268 Fourth, biocultural approaches to indicator development are enacted with the  
269 explicit intention of using the collected knowledge to guide action of interest to  
270 communities<sup>57,61,63</sup>. The International Partnership for the Satoyama Initiative, for  
271 instance, supports communities in social-ecological production landscapes and  
272 seascapes to develop a variety of social, cultural, and biological indicators to  
273 facilitate local management<sup>63</sup>.

274 Biocultural approaches build on community-based and participatory methods, but  
275 more explicitly take a systems perspective, emphasising feedbacks between  
276 ecological and cultural elements in a system. The types of indicators created through  
277 biocultural approaches can capture both the ecological underpinnings of a cultural  
278 system and the cultural perspectives of an ecological state, and thus can highlight  
279 interactions and feedbacks between humans and their environment. For example, a  
280 social indicator may encompass social or cultural practices that in turn explain an  
281 observed phenomenon in the population dynamics of a species. A social indicator  
282 such as "trend in percent of elders or parents transmitting traditional knowledge to  
283 children" could explain why a harvested species has healthy populations, because  
284 intergenerational transmission of TEK regarding the impact of harvest of individuals  
285 at different life stages facilitates effective population management. Similarly,  
286 biological trends and processes – like dynamics or status of totem species – may  
287 underpin local visions of well-being because peoples' perceptions of well-being are  
288 tied to the health of their totem.

289 Many cultural aspects are known to affect adaptive capacity<sup>64</sup> and yet are often  
290 deemed intangible and thus potentially unmeasurable<sup>65</sup>. Consequently, many  
291 assessments rely on indicators that are easier to quantify, compare, aggregate, and  
292 communicate across scales and arenas but that may miss out on feedbacks or  
293 critical variables at the local level that biocultural approaches could illuminate  
294 (Table 1). As Biggs and colleagues<sup>66</sup> note, conservation and sustainability efforts

295 frequently approach social-cultural aspects as if they are assessing biodiversity: by  
296 creating lists of stakeholders, documenting spatial data on land/sea use, and  
297 converting these into relative costs. These approaches overlook the complex  
298 psychological and cultural reasons behind management action or inaction.  
299 Indicators can and should measure the perceptions of the effect of ecological change  
300 on well-being, as these perceptions can drive behaviour more than factors collected  
301 via empirical data on change<sup>41</sup>. Perceptions impact local support (or lack thereof)  
302 for management action. Recognition of the role of perceptions within the context of  
303 different worldviews is critical to understanding connections and disconnections  
304 between international, national, and local framing of problems and successes<sup>41,67-69</sup>.

305 An emerging literature has begun to identify innovative methods to address the  
306 challenges of capturing cultural aspects of a system, when the creation of metrics is  
307 deemed helpful or necessary by all parties in a consultation<sup>65</sup>. For instance,  
308 challenges in developing indicators of intangible elements of a system can in part be  
309 resolved through the use of ethnographic interviewing techniques that elucidate  
310 how the values, beliefs, and experiences of individual people affect their  
311 understanding of that system<sup>65</sup>. As one example, in exploring the impact of western  
312 Lesotho's Metolong Dam on local inhabitants, researchers used audiovisual and GPS  
313 technology along with interview and group discussion notes to document  
314 "intangible culture" as expressed through the relationships between landscape  
315 features and cultural histories and narratives<sup>70</sup>.

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

### 321 Managing cross-cultural indicator development

322 Biocultural approaches can be undertaken by Indigenous and other place-based  
323 communities without engaging with ex-situ entities<sup>71</sup>. These communities might not  
324 use the term biocultural to describe their approach, as for them it is a lived  
325 experience. Furthermore, biocultural approaches are not exclusively used in the  
326 context of Indigenous communities or in the "Global South". High nature value, low-  
327 intensity farming and other European biocultural initiatives highlight the use of  
328 biocultural approaches in non-Indigenous settings<sup>72</sup>. However, as communities  
329 across the globe face internal and external environmental and economic pressures,  
330 they have increasingly engaged with ex-situ actors in knowledge exchange and co-  
331 creation of indicators<sup>21,23,73</sup>. The process of co-creation of indicators across groups  
332 can help to frame questions and solutions that span scales<sup>7</sup> and ensure that  
333 indicators are relevant to users<sup>74</sup> (Fig. 1c). Collaborations that seek to understand  
334 and embrace the complexity and interrelated nature of different worldviews can  
335 lead to improved conservation and management outcomes<sup>75-78</sup>.

336 For example, in coastal British Columbia, a collaborative team of Heiltsuk First  
337 Nation youth and leadership and ex-situ scientists placed Heiltsuk observations of  
338 grizzly bear (*Ursus arctos*) in the context of Gvi'ilas – customary law in which bear  
339 behaviour is recognised as a voice to guide decision-making about whole  
340 ecosystems – in order to undertake basic bear studies. In this project, the Heiltsuk  
341 framed the research questions and led the partnership to carry out data collection  
342 and communicate the findings to the broader community. The research relied both  
343 on population and landscape genetics and on Heiltsuk ways of knowing. Since it was  
344 embedded in Heiltsuk governance structures, the research led to changes in bear  
345 management objectives, sanctions on trophy hunting, and outlines for a multi-nation  
346 grizzly bear sanctuary under formal co-management frameworks<sup>79</sup>.

347 Elucidating culturally grounded understandings requires time and skills, to translate  
348 between different types of knowledge and scales of governance<sup>21, 80</sup>. Collaborators  
349 need to observe and listen carefully, and be open to the validity and deep complexity  
350 of other ways of knowing<sup>81</sup>. They must also have skills to identify indicators  
351 embedded in multiple cultural forms<sup>59</sup>. Indigenous indicators may be integrated  
352 within social contexts that are unfamiliar to ex-situ scientists<sup>12,82</sup> or that may seem  
353 disconnected from environmental management but are inextricably linked for in-  
354 situ actors. These forms may include stories, songs, ceremonies, oral histories, and  
355 what ex-situ actors might view as “art”<sup>21,75,82,83</sup>. Including information from different  
356 knowledge systems can provide a more complete picture for decision-making<sup>84,85</sup>.  
357 For instance, oral histories from Hawai'i Island informed the development of local  
358 indicators of environmental and climate change. These include distribution of pan-  
359 Pacific, culturally important trees that were once widespread as described by place-  
360 names and legends, but are now sparse due to landscape transformations and  
361 climate change effects<sup>86</sup>.

362 Cross-cultural knowledge sharing and collaborations require understanding of how  
363 to maneuver through the diversity of expectations, perceptions, and viewpoints  
364 within and across communities. Knowledge from different sources may initially  
365 appear incompatible<sup>87</sup>. Overcoming this requires that ex-situ actors take the time to  
366 understand the local context for these knowledges and not dismiss them<sup>88</sup>. With  
367 biocultural approaches, the social-cultural context for local knowledge is key, as is  
368 explicit recognition of the producers and holders of knowledge. Knowledge  
369 extraction without this context and attribution can disempower local knowledge  
370 holders and undermine that knowledge's transformative potential for  
371 management<sup>10</sup>. Ethnographic research has a key role to play in understanding the  
372 politics and process of how knowledge arises and is translated between different  
373 groups and how that can inform decision-making<sup>82,87</sup>.

374 Cross-cultural navigation also involves recognising different perspectives on the  
375 type and depth of knowledge that is sufficient for characterising critical dimensions  
376 of a system for management. For example, both in-situ and ex-situ actors and  
377 managers may have only a partial vision of the larger system. In New Ireland, Papua

378 New Guinea, in-situ actors might know the micro-scale behavioural ecology of  
379 sandfish (*Holothuria scabra*) but they do not necessarily know the behavioural  
380 ecology of species that are intimately connected to the sandfish in the larger  
381 system<sup>89</sup>; ex-situ actors might know the large-scale dynamics of those reef species in  
382 the Western Pacific but may not understand the micro system dynamics of single  
383 reef sites (PW n.d.). Individuals who are steeped in local cultures but have worked  
384 or studied, for instance, in international settings, can help with ensuring successful  
385 co-creation processes<sup>90</sup>. Effective two-way communication between ex-situ and in-  
386 situ actors can facilitate policies that leverage the power of both locally relevant  
387 knowledge that has evolved within a place and larger-scale generalisable  
388 knowledge<sup>21,26</sup>.

389 Such collaborative cross-cultural work comes with a number of challenges.  
390 Involving numerous sources of knowledge can increase potential for conflict, and  
391 enhanced complexity can overwhelm decision-makers and scientists<sup>91</sup>. Other points  
392 that must be considered include the range of beliefs and biases people bring to an  
393 endeavor, competitive funding environments, organizational structures driven by  
394 external value systems, timelines for reporting that favor efficiency and speed,  
395 ethical issues regarding the dissemination and use of co-produced knowledge, and  
396 the arbitrary nature of classifying different types of knowledge<sup>24</sup>. Some of these  
397 issues can be overcome if researchers approach cross-cultural work with strategies  
398 aimed at fostering true partnerships with in-situ groups. Research has shown that  
399 when initiatives include diverse actors across all stages, local users are more likely  
400 to sustain those initiatives<sup>13,24,55</sup>. Building in enough time and appropriate  
401 conditions for iterative reflection in selection of indicators is critical, as is  
402 consideration of rights, representation, and power dynamics<sup>13,55,92</sup>. The social  
403 process of engagement, of working together to reflect on and choose indicators, is a  
404 key ingredient of successful indicator development and the discussion itself may  
405 lead to improved outcomes. An initiative is more likely to produce practical,  
406 actionable knowledge when researchers understand and leverage the interactive  
407 nature of knowledge-making and decision-making<sup>93</sup>. When synthesising different  
408 knowledges, approaches that are iterative, collaborative, and include methods to  
409 evaluate validity and reliability can be helpful<sup>24</sup>, as are strategies that use validation  
410 processes internal to each system to ensure that the highest calibre knowledge is  
411 available for consideration<sup>23,73</sup>.

#### 412 Bridging global and local policy and management

413 If we are to monitor and evaluate sustainable resource use and well-being  
414 effectively, we need mechanisms that allow for translation between place-based  
415 contexts and other scales, including layers of local and regional government. Thus,  
416 in addition to being thoughtful at all scales about what kinds of indicators we  
417 measure and who is doing the measuring, we need robust, transparent processes to  
418 guide how indicators are designed, implemented, analysed, combined or compared,  
419 and incorporated into decision-making processes. Global efforts should also

420 explicitly consider why and how to standardise, despite the ease of comparing and  
421 aggregating standardised information. Indicators capturing information in exactly  
422 the same way regardless of local context may not be meaningful. Conversely,  
423 measures that are developed at local scales and reflect specific place-based values  
424 may not easily translate to other locales or to national and international policy by  
425 the very nature of their specificity<sup>82</sup>.

426  
427 There are several non-exclusive ways to bridge the gaps between local and global  
428 indicators. For instance, it may be possible to group complementary indicators  
429 under a particular dimension, such as governance, that is meaningful at local as well  
430 as global scales. Place-based communities could choose from these indicators to suit  
431 their cultural and biological setting<sup>43,94</sup>. This type of system has already been  
432 designed. The Vitality Index of Traditional Environmental Knowledge (VITEK) is a  
433 locally-appropriate, globally-applicable index that can be used to measure, assess,  
434 and compare local ecological knowledge transmission. VITEK defines broad  
435 domains of traditional ecological knowledge for the overall index, but the actual  
436 questions used as indicators are adapted locally<sup>95</sup>. Tools such as the Mauri Model  
437 provide a flexible process by which communities can quantify their perceptions of  
438 the long-term viability of different well-being dimensions and develop benchmarks  
439 tailored to local settings<sup>96</sup>; while the indicators relate to a specific location, the  
440 indicator groupings and methods for scoring the results are fixed, facilitating  
441 comparability across communities<sup>54</sup>.

442 In addition, provincial and national-level agencies have an important role to play.  
443 National initiatives such as the Melanesian Well-being Index standardise and  
444 quantify well-being using culturally appropriate metrics<sup>97</sup>. Similarly, in Latin  
445 America, emerging well-being concepts such as Buen Vivir (“living well”) use  
446 culturally grounded quantitative approaches<sup>98</sup>. One of the earliest efforts to quantify  
447 holistic well-being, Bhutan’s Gross National Happiness Index, focuses on non-  
448 economic development measures and has received much global attention, though  
449 these efforts have also been critiqued in relation to exclusion of minority groups<sup>99</sup>.  
450 National-level understanding of local systems and patterns can lead to better  
451 tracking of whether or not global targets are being met and enable policy  
452 development and action on the ground to meaningfully address local issues.  
453 Initiatives that work with national governments to develop indicator strategies for  
454 international conventions, such as the Convention on Biological Diversity’s (CBD)  
455 National Biodiversity Strategic Action Plan process and the Biodiversity Indicator  
456 Partnership, or to assess the current status of biodiversity, such as IPBES,<sup>45,46</sup> could  
457 help ensure that culturally grounded indicators are developed and used.

458 Joint efforts in implementation of existing international conventions, such as  
459 between the CBD and UNESCO’s Convention for the Safeguarding of the Intangible  
460 Cultural Heritage, could lead to shared indicators of progress that would better  
461 address combined cultural and biological elements at the local scale. These efforts

462 could also promote information sharing, bridge organisational concerns, and  
463 integrate specialised knowledge and actions across multiple scales and sectors<sup>100</sup>.  
464

## 465 Conclusion

466 Global targets such as sustainability and well-being are best addressed through  
467 multi-level governance<sup>100</sup>, and we argue that biocultural approaches can create  
468 space for meaningful local metrics while supporting cross-scale application. Future  
469 work could find ways to compare results from biocultural approaches to indicator  
470 development with those that did not include cultural aspects or feedbacks between  
471 humans and their environments to see if outcomes differ. In addition, more work  
472 needs to be done regarding methods for synthesising across multiple knowledge  
473 systems and identifying ways to maintain the richness of local narratives to counter  
474 reductionist approaches in decision-making<sup>75</sup>. While great strides are being made in  
475 better articulating methods for collaboration and not just participation<sup>13,26,30</sup>, this  
476 remains an ongoing challenge. We believe that by integrating local perspectives and  
477 values into global scale indicator development efforts, biocultural approaches can  
478 both facilitate development of metrics more appropriate for in-situ communities and  
479 support the innovative approaches to research-based policy and action necessary to  
480 confront complex environmental challenges.

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744 End notes

745 <sup>a</sup>We recognise that “local” people interact with others across multiple scales;  
746 individuals can be “local” in some contexts and “external” in others. Additionally,  
747 “culture” is neither monolithic nor static<sup>66,76,109</sup> and there is no single “community”  
748 in a particular location as people self-define with different groups at different times.  
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761 EJS, CF, JN, SDJ, AT, and JM conceptually framed the manuscript. EJS and CF led the  
762 development of the manuscript and integration of content. AS, EB, GC, AT, and NG  
763 synthesised literature. All remaining authors contributed equally to generating  
764 ideas and drafting and revising the manuscript.

765 Competing interests

766 The authors declare no competing financial interests.

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769 Figure 1: Ex-situ and in-situ knowledge production and synthesis. a, Ex-situ and culturally grounded  
770 in-situ perspectives generate different but complementary knowledge systems that can guide  
771 sustainable resource management (image on the right courtesy of Nicolas Pascal). b, Policy and  
772 management driven by ex-situ perspectives: Approaches that are primarily driven by ex-situ  
773 perspectives often deliver knowledge in ways that disrupt or conflict with in-situ worldviews and  
774 well-being, thereby limiting potential for positive interplay between ex-situ and in-situ knowledge  
775 systems. c, Policy and management recognising local perspectives: Approaches recognising and  
776 respecting in-situ as well as ex-situ knowledge systems can lead to more effective syntheses and  
777 enduring on-the-ground impact.

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799 Table 1: Examples of UN Sustainable Development Goal (SDG) indicators and additional or  
800 alternative indicators stemming from biocultural approaches.

Issue	Relevant Sustainable Development Goal	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?” <sup>101</sup>	Some Pacific Island countries have strong cultural obligations to provide family/guests with food <sup>102</sup> . Standardised vulnerability-framed questions about food security may not generate accurate data due to cultural reluctance to admit to food shortages. Biocultural framing would emphasise local knowledge and definitions of resource systems, and innovation for resilience.	(i) 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.  (ii) Average length of time for which households in the community have a stable, culturally valued food supply after a disaster.
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 <sup>17,103</sup> .	Vitality (i.e., 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 <sup>95</sup> .
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 <sup>83</sup> .	The Maori-based Cultural Health Index for Streams includes: (i) site status (e.g., traditional significance); (ii) the intangible and tangible value of a site; and (iii) stream health measures that were developed through participatory processes <sup>83</sup> .

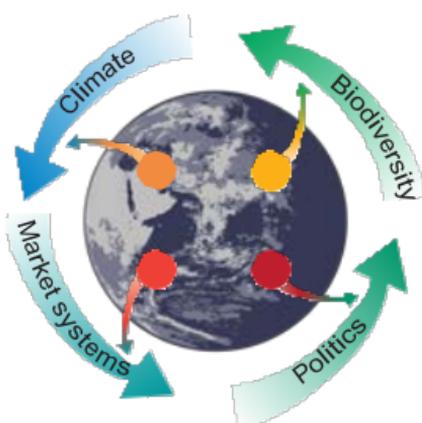
Issue	SDG goal	<i>Ex-situ</i> metric(s)	Discussion	Revised indicator
Sustainable tourism	Goal 8: “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”	Indicator 8.9.1: “Tourism direct GDP as a proportion of total GDP and in growth rate”	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 <sup>104</sup> .	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 (e.g., 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 MPA coverage does not account for effectiveness of MPA location, design, or management <sup>105</sup> . 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 <sup>106</sup> . 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 <sup>33,107</sup> .	(i) Are common marine resources managed sustainably, through locally supported customary management systems?  (ii) 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, though it can also be scalable to national and regional levels <sup>108</sup> .
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	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?

			reflect both the status of local forest resources as well as interest in maintaining cultural practices.	
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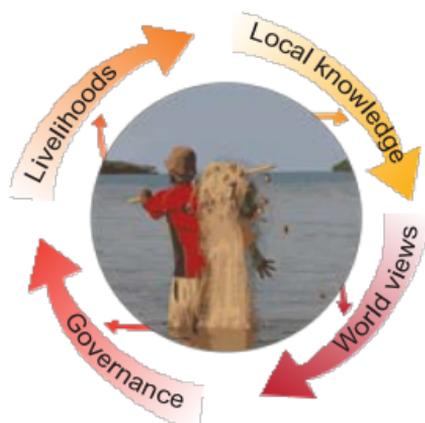
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a Generalized ex-situ knowledge production

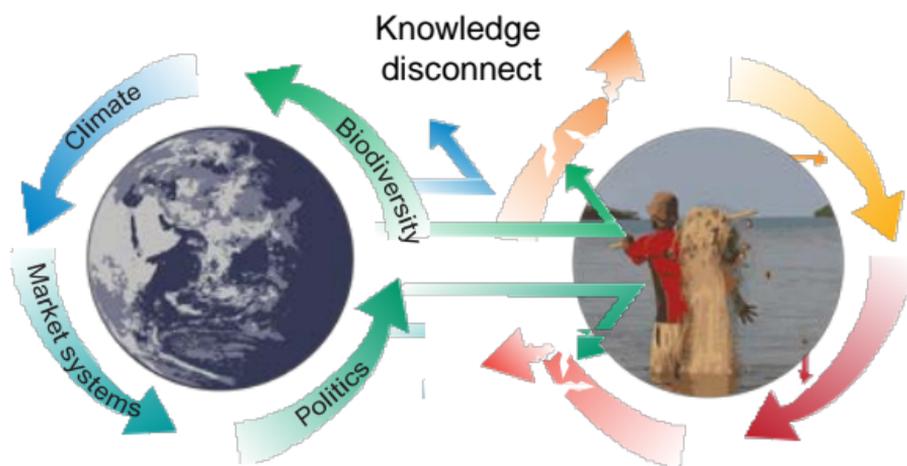


Culturally-grounded in-situ knowledge production



Diverse in-situ knowledge sources

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