



HAL
open science

Biocultural approaches to well-being and sustainability indicators across scales

Eleanor J. Sterling, Christopher Filardi, Anne Toomey, Amanda Sigouin, Erin Betley, Nadav Gazit, Jennifer Newell, Simon Albert, Diana Alvira, Nadia Bergamini, et al.

► **To cite this version:**

Eleanor J. Sterling, Christopher Filardi, Anne Toomey, Amanda Sigouin, Erin Betley, et al.. Biocultural approaches to well-being and sustainability indicators across scales. *Nature Ecology & Evolution*, 2017, 1 (12), pp.1798-1806. <10.1038/s41559-017-0349-6>. <hal-02107213>

HAL Id: hal-02107213

<https://hal.science/hal-02107213v1>

Submitted on 27 Dec 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

1

2 Title: Biocultural approaches to well-being and sustainability indicators across
3 scales

4

5 Author Information

6 Eleanor J. Sterling^{a,*}, Christopher Filardi^a, Anne Toomey^{a,b}, Amanda Sigouin^a, Erin
7 Betley^a, Nadav Gazit^a, Jennifer Newell^c, Simon Albert^d, Diana Alvira^e, Nadia
8 Bergamini^f, Mary Blair^a, David Boseto^g, Kate Burrows^h, Nora Bynum^e, Sophie
9 Caillonⁱ, Jennifer E. Caselle^j, Joachim Claudet^k, Georgina Cullman^a, Rachel Dacks^l,
10 Pablo B. Eyzaguirre^f, Steven Gray^m, James Herreraⁿ, Peter Kenilorea^o,
11 Kealohanuiopuna Kinney^{p,q}, Natalie Kurashima^{r,s}, Suzanne Macey^a, Cynthia Malone^a,
12 Senoveva Mauli^t, Joe McCarter^a, Heather McMillen^u, Pua'ala Pascua^v, Patrick
13 Pikacha^d, Ana L. Porzecanski^a, Pascale de Robert^w, Matthieu Salpeteurⁱ, Myknee
14 Sirikolo^x, Mark H. Stege^y, Kristina Stege^z, Tamara Ticktin^r, Ron Vave^{aa}, Alaka Wali^{ab},
15 Paige West^{ac}, Kawika B. Winter^{x,ad}, and Stacy D. Jupiter^{ae}

16

17 ^aCenter for Biodiversity and Conservation, American Museum of Natural History,
18 New York, NY 10024, USA

19

20 ^bDepartment of Environmental Studies and Science, Pace University, One Pace Plaza,
21 New York, NY 10038, USA

22

23 ^cEast Pacific Collection, Australian Museum, Sydney, NSW 2010, Australia

24

25 ^dSchool of Civil Engineering, The University of Queensland, Queensland, 4072,
26 Australia

27

28 ^eKeller Science Action Center, The Field Museum, Chicago, IL 60605, USA

29

30 ^fBioversity International, 00054 Maccarese, Rome, Italy

31

32 ^gEcological Solutions Solomon Islands, P.O. Box 180, Gizo, Western Province,
33 Solomon Islands

34

35 ^hSchool of Forestry & Environmental Studies, Yale University, New Haven, CT 06511,
36 USA

37

38 ⁱNational Center for Scientific Research, CEFE UMR 5175, 34293, Montpellier,
39 France

40

41 ^jMarine Science Institute, University of California Santa Barbara, Santa Barbara, CA

42 93106, USA
43
44 ^kNational Center for Scientific Research, CRIOBE, USR 3278 CNRS-EPHE-UPVD,
45 66860, Perpignan, France and Laboratoire d'Excellence CORAIL, France
46
47 ^lDepartment of Biology, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA
48
49 ^mDepartment of Community Sustainability, Michigan State University, East Lansing,
50 MI 48823, USA
51
52 ⁿDepartment of Mammalogy, American Museum of Natural History, New York, NY
53 10024, USA
54
55 ^oOffice of the High Representative for the Least Developed Countries, United
56 Nations, New York, NY 10017, USA
57
58 ^pInstitute of Pacific Islands Forestry, Pacific Southwest Research Station, USDA
59 Forest Service, Hilo, Hawai'i 96720, USA
60
61 ^qBrown University, Box G-W, 80 Waterman Street, Providence, RI 02912, USA
62
63 ^rDepartment of Botany, University of Hawai'i at Mānoa, Honolulu, HI 96822, USA
64
65 ^sKamehameha Schools, Natural and Cultural Resources, Kailua-Kona, HI, 96740, USA
66
67 ^tSolomon Islands Community Conservation Partnership, P.O. Box 2378, Honiara,
68 Solomon Islands
69
70 ^uUSDA Forest Service, Northern Research Station, NYC Urban Field Station, Bayside,
71 NY 11359, USA
72
73 ^vDepartment of Natural Resource and Environmental Management, University of
74 Hawai'i at Mānoa, Honolulu, HI 96822, USA
75
76 ^wInstitut de Recherche pour le Développement, UMR PALOC IRD/MNHN, 75231
77 Paris cedex 05, France
78
79 ^xSolomon Islands Ministry of Forests and Research, PO Box G.24, Honiara, Solomon
80 Islands
81
82 ^yMarshall Is. Conservation Society, College of the Marshall Islands, P.O. Box 1258,
83 Majuro, MH, Marshall Islands
84
85 ^zMarTina Corporation, P.O. Box 403, Majuro, Marshall Islands

86

87 ^{aa}Fisheries Ecology Research Lab, University of Hawai'i at Mānoa, Honolulu, HI
88 96822, USA

89

90 ^{ab}Science and Education, The Field Museum, Chicago, IL 60605, USA

91

92 ^{ac}Department of Anthropology, Barnard College and Columbia University, New York,
93 NY 10027, USA

94

95 ^{ad}Limahuli Garden and Preserve, National Tropical Botanical Garden, HI 96746, USA

96

97 ^{ae}Wildlife Conservation Society, Melanesia Program, 11 Ma'afu Street, Suva, FIJI

98

99 Corresponding author:

100 Eleanor J. Sterling

101 Center for Biodiversity and Conservation, American Museum of Natural History,
102 New York, NY 10024 USA

103 Telephone: +1-212-769-5266

104 E-mail address: sterling@amnh.org

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^{1,2}. Monitoring and
131 evaluation are central to ensuring these approaches are effective³⁻⁵. 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 scientists².

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 systems⁶⁻⁸. 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^{9,10}. Disconnects can result in
145 miscommunication, policies that fail to inspire appropriate action, and misdirected
146 resources¹¹. 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^{12,13}. 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 sustainably¹⁴⁻¹⁶ (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.^a

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 2000¹⁷) 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^{18–22}. These approaches, in combination with methods for
173 synthesising across evidence from multiple sources^{23,24}, can also help to develop the
174 indicators that are required to meet current complex challenges²⁵. 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^{21,22,26}. 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^{7,8,27,28}.

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 norms²⁹. Yet place-based actors
185 are critical to guide the implementation and monitoring of natural resource
186 management for ethical and practical reasons^{13,30}. Indigenous peoples and other in-
187 situ communities manage lands and seas that hold significant portions of the
188 planet’s biodiversity³¹ and carbon stocks³². In addition, place-based communities
189 have generated creative resilient responses to global pressures, despite
190 experiencing outsized impacts from them^{33,34}.

191 Scholarship and stories stemming from Participatory Action Research³⁵ and
192 ethnobiology (e.g., research into Traditional Ecological Knowledge - TEK) have
193 documented local capacity to respond to stresses³⁶. 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^{11,37,38}. However, it is
198 increasingly recognised that local institutions are nested within complex multi-level
199 governance systems³⁹. 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^{10,40,41}.

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^{42,43}. For instance, the recently developed
209 Sustainable Development Goals, stemming from the Millennium Ecosystem
210 Assessment³, theoretically support planning, tracking, and reporting that integrate

211 across social and ecological systems⁴⁴. 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^{45,46}.

215 One theory that provides guidance in linking between local and global resource
216 management is social-ecological systems theory⁴⁷ (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^{25,48}.
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^{34,48,49}. This can inadvertently erode local
224 perceptions of well-being and direct blame toward place-based communities, thus
225 fostering a framing of helplessness^{50,51}. 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 televisions⁵². 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 relations⁵³.

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^{19,36,54}. 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 key⁷. 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 essential⁵⁵.

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^{56,57}.
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^{18,54}.

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^{58,59}. 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 organs⁶⁰.

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^{57,61,63}. 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 management⁶³.

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 capacity⁶⁴ and yet are often
290 deemed intangible and thus potentially unmeasurable⁶⁵. 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 colleagues⁶⁶ 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 change⁴¹. 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^{41,67-69}.

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 consultation⁶⁵. 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 system⁶⁵. 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 narratives⁷⁰.

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 entities⁷¹. 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 settings⁷². 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^{21,23,73}. The process of co-creation of indicators across groups
332 can help to frame questions and solutions that span scales⁷ and ensure that
333 indicators are relevant to users⁷⁴ (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 outcomes⁷⁵⁻⁷⁸.

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 frameworks⁷⁹.

347 Elucidating culturally grounded understandings requires time and skills, to translate
348 between different types of knowledge and scales of governance^{21, 80}. Collaborators
349 need to observe and listen carefully, and be open to the validity and deep complexity
350 of other ways of knowing⁸¹. They must also have skills to identify indicators
351 embedded in multiple cultural forms⁵⁹. Indigenous indicators may be integrated
352 within social contexts that are unfamiliar to ex-situ scientists^{12,82} 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”^{21,75,82,83}. Including information from different
356 knowledge systems can provide a more complete picture for decision-making^{84,85}.
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 effects⁸⁶.

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 incompatible⁸⁷. Overcoming this requires that ex-situ actors take the time to
366 understand the local context for these knowledges and not dismiss them⁸⁸. 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 management¹⁰. 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^{82,87}.

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 system⁸⁹; 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 processes⁹⁰. 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^{21,26}.

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 scientists⁹¹. 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 knowledge²⁴. 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^{13,24,55}. 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^{13,55,92}. 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-making⁹³. When synthesising different
408 knowledges, approaches that are iterative, collaborative, and include methods to
409 evaluate validity and reliability can be helpful²⁴, as are strategies that use validation
410 processes internal to each system to ensure that the highest calibre knowledge is
411 available for consideration^{23,73}.

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 specificity⁸².

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^{43,94}. 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 locally⁹⁵. 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 settings⁹⁶; while the indicators relate to a specific location, the
440 indicator groupings and methods for scoring the results are fixed, facilitating
441 comparability across communities⁵⁴.

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 metrics⁹⁷. Similarly, in Latin
445 America, emerging well-being concepts such as Buen Vivir (“living well”) use
446 culturally grounded quantitative approaches⁹⁸. 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 groups⁹⁹.
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,^{45,46} 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 sectors¹⁰⁰.
464

465 Conclusion

466 Global targets such as sustainability and well-being are best addressed through
467 multi-level governance¹⁰⁰, 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-making⁷⁵. While great strides are being made in
475 better articulating methods for collaboration and not just participation^{13,26,30}, 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.

481

482 References

- 483 1. Sterling, E. J., Gómez, A. & Porzecanski, A. L. A systemic view of biodiversity and its
484 conservation: Processes, interrelationships, and human culture. *Bioessays* 32, 1090–
485 1098 (2010).
- 486 2. Carpenter, S. R. et al. Science for managing ecosystem services: Beyond the Millennium
487 Ecosystem Assessment. *Proceedings of the National Academy of Sciences* 106, 1305–
488 1312 (2009).
- 489 3. Millennium Ecosystem Assessment. *Ecosystems and Human Well-Being: Synthesis*.
490 (Washington, DC: Island Press, 2005).
- 491 4. Mascarenhas, A., Coelho, P., Subtil, E. & Ramos, T. B. The role of common local
492 indicators in regional sustainability assessment. *Ecol. Indic.* 10, 646–656 (2010).
- 493 5. Hinkel, J. 'Indicators of vulnerability and adaptive capacity': Towards a clarification of
494 the science–policy interface. *Glob. Environ. Change* 21, 198–208 (2011).
- 495 6. Cunningham, A. B. *Applied Ethnobotany: People, Wild Plant Use and Conservation*.
496 (London: Earthscan, 2001).
- 497 7. Fraser, E. D. G., Dougill, A. J., Mabee, W. E., Reed, M. & McAlpine, P. Bottom up and top
498 down: Analysis of participatory processes for sustainability indicator identification as a
499 pathway to community empowerment and sustainable environmental management. *J.*
500 *Environ. Manage.* 78, 114–127 (2006).
- 501 8. Winter, K. & McClatchey, W. Quantifying evolution of cultural interactions with plants:
502 Implications for managing diversity for resilience in social-ecological systems. *Func.*
503 *Ecosyst. Commun.* 2, 1–10 (2008).
- 504 9. Tallis, H. et al. A global system for monitoring ecosystem service change. *Bioscience* 62,
505 977–986 (2012).

506 551
507 552
508 553
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550

10. Mistry, J. & Berardi, A. Bridging indigenous and scientific knowledge. *Science* 352, 1-74-81 (2015).
11. Cullman, G. Community forests management as virtualism in northeastern Madagascar. *Hum. Ecol.* 43, 29–41 (2015).
12. West, P. *Conservation is Our Government Now: The Politics of Ecology in Papua New Guinea*. (Durham: Duke University Press, 2006).
13. Sterling, E. J. et al. Assessing the evidence for stakeholder engagement in biodiversity conservation. *Biol. Conserv.* 209, 159–171 (2017).
14. Smith, L. T. *Decolonizing Methodologies: Research and Indigenous Peoples*. (London: Zed books, 1999).
15. Chan, K. M. A. et al. Why protect nature? Rethinking values and the environment. *Proc. Natl Acad. Sci.* 113, 1462–1465 (2016).
16. Daniel, T. C. et al. Contributions of cultural services to the ecosystem services agenda. *Proc. Natl Acad. Sci.* 109, 8812–8819 (2012).
17. Thaman, K. H. in *Local Knowledge and Wisdom in Higher Education* (eds. Teasdale, B. & Ma Rhea, Z.) pp 43–50 (Oxford: Elsevier Science Ltd, 2000).
18. Reimaan National Planning Team. *Reimaanlok: Looking to the Future: National Conservation Area Plan for the Marshall Islands*. (Melbourne: N. Baker, 2008).
19. Gavin, M. C. et al. Defining biocultural approaches to conservation. *Trends Ecol. Evol.* 30, 140–145 (2015).
20. van Oudenhoven, F. J. W., Mijatović, D. & Eyzaguirre, P. B. Social-ecological indicators of resilience in agrarian and natural landscapes. *Manage. of Environ. Quality* 22, 154–173 (2011).
21. Ens, E. J. in *People on Country: Vital Landscapes, Indigenous Futures*. (Eds J. Altman and S. Kerins.) pp 45–64 (Leichhardt: The Federation Press, 2012).
22. Preuss, K. & Dixon, M. 'Looking after country two-ways': Insights into Indigenous community-based conservation from the Southern Tanami. *Ecol. Manage. Restor.* 13, 2–15 (2012).
23. Tengö, M., Brondizio, E. S., Elmqvist, T., Malmer, P. & Spierenburg, M. Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio* 43, 579–591 (2014).
24. Raymond, C. M. et al. Integrating local and scientific knowledge for environmental management. *J. Environ. Manage.* 91, 1766–1777 (2010).
25. Leenhardt, P. et al. Challenges, insights and perspectives associated with using social-ecological science for marine conservation. *Ocean & Coastal Manage.* 115, 49–60 (2015).
26. Ens, E. J., Daniels, C., Nelson, E., Roy, J. & Dixon, P. Creating multi-functional landscapes: Using exclusion fences to frame feral ungulate management preferences in remote Aboriginal-owned northern Australia. *Biol. Conserv.* 197, 235–246 (2016).
27. Jupiter, S. Culture, kastom and conservation in Melanesia: What happens when worldviews collide? *Pac. Conserv. Biol.* (2017).
28. Pascua, P., McMillen, H., Ticktin, T., Vaughan, M. & Winter, K. B. Beyond services: A process and framework to incorporate cultural, genealogical, place-based, and indigenous relationships in ecosystem service assessments. *Ecosyst. Serv.* (2017).
29. Harding, S. *Science and Social Inequality: Feminist and Postcolonial Issues*. (Champaign: University of Illinois Press, 2006).
30. Reed, M. S. et al. A theory of participation: What makes stakeholder and public Ecosyst. Commun. 2, 1–10 (2008).
9. Tallis, H. et al. A global system for monitoring ecosystem service change. *Bioscience* 62, 977–986 (2012).

e
n
g
a
g
e
m
e
n
t
i
n

or. Ecol. (In press). DOI

e
n
v
i
r
o
n
m
e
n
t
a
l
m
a
n
a
g
e
m
e
n
t
w
o
r
k
?

R
e
s
t

- 554 10.1111/rec.12541
- 555 31. Kainer, K. A. et al. Partnering for greater success: Local stakeholders and research in
556 tropical biology and conservation. *Biotropica* 41, 555–562 (2009).
- 557 32. Walker, W. et al. Forest carbon in Amazonia: The unrecognized contribution of
558 indigenous territories and protected natural areas. *Carbon Manage.* 5, 479–485 (2014).
- 559 33. McMillen, H. L. et al. Small islands, valuable insights: Systems of customary resource
560 use and resilience to climate change in the Pacific. *Ecol. Soc.* 19, (2014).
- 561 34. Campbell, J. Islandness: Vulnerability and resilience in Oceania. *Shima: The Int. Journal*
562 *of Research into Island Cultures* 3, 85–97 (2009).
- 563 35. Chambers, R. Participatory rural appraisal (PRA): Challenges, potentials and paradigm.
564 *World Dev.* 22, 1437–1454 (1994).
- 565 36. Berkes, F. *Sacred Ecology: Traditional Ecological Knowledge and Resource Management.*
566 Third edition. (New York: Routledge, 2012).
- 567 37. Berkes, F., Colding, J. & Folke, C. Rediscovery of traditional ecological knowledge as
568 adaptive management. *Ecol. Appl.* 10, 1251–1262 (2000).
- 569 38. Lawrence, A., Paudel, K., Barnes, R. & Malla, Y. Adaptive value of participatory
570 biodiversity monitoring in community forestry. *Environ. Conserv.* 33, 325–334 (2006).
- 571 39. Berkes, F. Rethinking community-based conservation. *Conserv. Biol.* 18, 621–630
572 (2004).
- 573 40. Turner, N. J., Gregory, R., Brooks, C., Failing, L. & Satterfield, T. From invisibility to
574 transparency: Identifying the implications. *Ecol. Soc.* 13, 7 (2008).
- 575 41. Leonard, S., Parsons, M., Olawsky, K. & Kofod, F. The role of culture and traditional
576 knowledge in climate change adaptation: Insights from East Kimberley, Australia. *Glob.*
577 *Environ. Chang.* 23, 623–632 (2013).
- 578 42. Steffen, W. et al. Planetary boundaries: Guiding human development on a changing
579 planet. *Science* 347, 1259855 (2015).
- 580 43. Hicks, C. C. et al. Engage key social concepts for sustainability. *Science* 352, 38–40
581 (2016).
- 582 44. Selomane, O., Reyers, B., Biggs, R., Tallis, H. & Polasky, S. Towards integrated social-
583 ecological sustainability indicators: Exploring the contribution and gaps in existing
584 global data. *Ecol. Econ.* 118, 140–146 (2015).
- 585 45. Díaz, S., Demissew, S., Carabias, J. & Joly, C. The IPBES Conceptual Framework—
586 connecting nature and people. *Curr. Opin. Environ. Sustain.* 14, 1–16 (2015).
- 587 46. Pascual, U. et al. Valuing nature’s contributions to people: The IPBES approach. *Curr.*
588 *Opin. Environ. Sustain.* 26, 7–16 (2017).
- 589 47. Ostrom, E. A general framework for analyzing sustainability of social-ecological
590 systems. *Science* 325, 419–422 (2009).
- 591 48. Cinner, J. E. et al. Evaluating social and ecological vulnerability of coral reef fisheries to
592 climate change. *PLoS One* 8, e74321 (2013).
- 593 49. Barnett, J., Lambert, S. & Fry, I. The hazards of indicators: Insights from the
594 Environmental Vulnerability Index. *Ann. Assoc. Am. Geogr.* 98, 102–119 (2008).
- 595 50. Haalboom, B. & Natcher, D. C. The power and peril of ‘vulnerability’: approaching
596 community labels with caution in climate change research. *Arctic* 65, 319–327 (2012).
- 597 51. West, P. *Dispossession and the Environment: Rhetoric and Inequality in Papua New*
598 *Guinea.* (New York: Columbia University Press, 2016).
- 599 52. Le Tourneau, F.-M. et al. Assessing the impacts of sustainable development projects in
600 the Amazon: the DURAMAZ experiment. *Sustain. Sci.* 8, 199–212 (2013).
- 601 53. de Robert, P., Lopez Garcés, C., Laques, A.-E. & Coelho-Ferreira, M. A beleza das roças:

602 647
603 648
604 649
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646

a
g
r
o
b
i
o
d
i
v
e
r
s
i
d
a
d
e
M
e
b
ê
n
g
ô
k
r
e
-
K
a
y
a
p
ó
e
m
t
e
m
p
o
599
600
601

s de globalização. *Boletim do Museu Paraense Emílio Gódi. Ciências Humanas* 7, 339–369 (2012).

54. Sterling, E. J. et al. How do we build culturally-grounded indicators of resilience and adaptation, and address the disconnect between local and global indicators? *Environ. Soc.* (In Press). DOI [10.3167/ares.2016.080104](https://doi.org/10.3167/ares.2016.080104).

55. Estrella, M. & Gaventa, J. Who counts reality?: Participatory monitoring and evaluation: A literature review. 70 (Institute of Development Studies, 1998).

56. Cullen-Unsworth, L. C., Hill, R., Butler, J. R. A. & Wallace, M. Development of linked cultural and biophysical indicators for the Wet Tropics World Heritage Area. *Int. Sci. Soc.* 2, (2011).

57. Escobar, C. in *Community Well-being in Biocultural Landscapes* pp 42–57 (Warwickshire: Practical Action Publishing, 2014).

58. Oba, G. & Kotile, D. G. Assessments of landscape level degradation in southern Ethiopia: Pastoralists versus ecologists. *Land Degrad. Dev.* 12, 461–475 (2001).

59. Aó utsýl K'e Dene Elders and land-users et al. *Traditional Knowledge in the Kache Tué Study Region: Phase Three - Towards a Comprehensive Environmental Monitoring Program in the Kakinýne Region.* (Yellowknife: West Kitikmeot Slave Study Society, 2002).

60. Cobb, D., Berkes, M. K. & Berkes, F. in *Breaking Ice: Renewable Resource and Ocean Management in the Canadian North* (ed. Berkes, F. Huebert, R. Fast, H. Mansequ, M. Diduck, A.) pp 71–93 (Calgary: University of Calgary Press, 2005).

61. Townsend, C. R., Tipa, G., Teirney, L. D. & Niyogi, D. K. Development of a tool to facilitate participation of Maori in the management of stream and river health. *Ecohealth* 1, 184–195 (2004).

62. Jackson, M. V. et al. Developing collaborative marine turtle monitoring in the Kimberley region of northern Australia. *Ecol. Manage. Restor.* 16, 163–176 (2015).

63. Bergamini, N. et al. Indicators of resilience in socio-ecological production landscapes (SEPLs), UNU-IAS policy report. United Nations University Institute of Advanced Studies, Yokohama (2013).

64. Kati, V. & Jari, N. Bottom-up thinking—identifying socio-cultural values of ecosystem services in local blue–green infrastructure planning in Helsinki, Finland. *Land use policy* 50, 537–547 (2016).

65. Satterfield, T., Gregory, R., Klain, S., Roberts, M. & Chan, K. M. Culture, intangibles and metrics in environmental management. *J. Environ. Manage.* 117, 103–114 (2013).

66. Biggs, D. et al. The implementation crisis in conservation planning: Could ‘mental models’ help? *Conser. Lett.* 4, 169–183 (2011).

67. Schwarz, A. M. et al. Vulnerability and resilience of remote rural communities to shocks and global changes: Empirical analysis from Solomon Islands. *Glob. Environ. Chang.* 21, 1128–1140 (2011).

68. Pyhälä, A. et al. Global environmental change: Local perceptions, understandings, and explanations. *Ecol. Soc.* 21, (2016).

69. Bennett, N. J. Using perceptions as evidence to improve conservation and environmental management. *Conserv. Biol.* 30, 582–592 (2016).

70. Nic Eoin, L., Owens, E. & King, R. *Memories of Metolong: The challenges of archiving intangible heritage in development contexts in 2013* Digital Heritage International.

52. Le Tourneau, F.-M. et al. Assessing the impacts of sustainable development projects in the Amazon: the DURAMAZ experiment. *Sustain. Sci.* 8, 199–212 (2013).

53. de Robert, P., Lopez Garcés, C., Laques, A.-E. & Coelho-Ferreira, M. A beleza das roças:

LifeMosaic. Territories of Life: A video toolkit for indigenous peoples about land and rights. Life Plan - Territories of Life (2015). Available at:

C
o
n
g
r
e
s
s

(
D
i
g
i
t
a
l
H
e
r
i
t
a
g
e
)

2
,
3
7
-
4
4

(
2
0
1
3
)

7

.
1
.

- 650 <http://www.lifemosaic.net/eng/tol/life-plan/>. (Accessed: 2017)
- 651 72. Kazakova, Y. & Stefanova, V. High Nature Value Farming in the Western Balkans: Current
652 Status and Key Challenges—a Scoping Document. (European Forum on Nature
653 Conservation and Pastoralism, 2010).
- 654 73. Fazey, I. et al. Knowledge exchange: A review and research agenda for environmental
655 management. *Environ. Conserv.* 40, 19–36 (2013).
- 656 74. Izurieta, A. et al. Developing indicators for monitoring and evaluating joint
657 management effectiveness in protected areas in the Northern Territory, Australia. *Ecol.*
658 *Soc.* 16, (2011).
- 659 75. Peterson, R. B., Russell, D., West, P. & Brosius, J. P. Seeing (and doing) conservation
660 through cultural lenses. *Environ. Manage.* 45, 5–18 (2010).
- 661 76. Ens, E. J., Scott, M. L., Rangers, Y. M., Moritz, C. & Pirzl, R. Putting indigenous
662 conservation policy into practice delivers biodiversity and cultural benefits. *Biodivers.*
663 *Conserv.* 25, 2889–2906 (2016).
- 664 77. Armitage, D., Berkes, F., Dale, A., Kocho-Schellenberg, E. & Patton, E. Co-management
665 and the co-production of knowledge: Learning to adapt in Canada’s Arctic. *Glob.*
666 *Environ. Chang.* 21, 995–1004 (2011).
- 667 78. Finn, M. & Jackson, S. Protecting indigenous values in water management: A challenge
668 to conventional environmental flow assessments. *Ecosystems* 14, 1232–1248 (2011).
- 669 79. Housty, W. G. et al. Grizzly bear monitoring by the Heiltsuk people as a crucible for First
670 Nation conservation practice. *Ecol. Soc.* 19, 70 (2014).
- 671 80. Ens, E., Burns, E., Russes-Smith, J., Sparrow, B. & Wardle, G. in *Biodiversity and*
672 *Environmental change: Monitoring, Challenges and Direction* pp 83–107 (2014).
- 673 81. Sable, T., Howell, G., Wilson, D. & Penashue, P. in *Local Science vs Global Science:*
674 *Approaches to Indigenous Knowledge in International Development* (ed. Sillitoe, P.)
675 (Oxford: Berghahn Books, 2009).
- 676 82. West, P. Translation, value, and space: Theorizing an ethnographic and engaged
677 environmental anthropology. *Am. Anthropol.* 107, 632–642 (2005).
- 678 83. Tipa, G. & Teirney, L. D. A Cultural Health Index for Streams and Waterways: Indicators
679 for Recognising and Expressing Māori Values. 58 (Ministry for the Environment, 2003).
- 680 84. Robertson, H. A. & McGee, T. K. Applying local knowledge: The contribution of oral
681 history to wetland rehabilitation at Kanyapella Basin, Australia. *J. Environ. Manage.* 69,
682 275–287 (2003).
- 683 85. Woodward, E., Jackson, S., Finn, M. & McTaggart, P. M. Utilising Indigenous seasonal
684 knowledge to understand aquatic resource use and inform water resource
685 management in northern Australia. *Ecol. Manage. Restor.* 13, 58–64 (2012).
- 686 86. Ka’ūpūlehu community, McMillen, H, Ticktin, T, and N Kurashima. Natural-cultural
687 resources and climate change. Ka’ūpūlehu Local Ecological Knowledge and Climate
688 Change Portal (2014). Available at:
689 <http://hbmpweb.pbrc.hawaii.edu/kaupulehu/cultural-resources>. (Accessed: 2017)
- 690 87. Povinelli, E. A. Do rocks listen? The cultural politics of apprehending Australian
691 aboriginal labor. *Am. Anthropol.* 97, 505–518 (1995).
- 692 88. Lauer, M. & Aswani, S. Indigenous ecological knowledge as situated practices:
693 Understanding fishers’ knowledge in the western Solomon Islands. *Am. Anthropol.* 111,
694 317–329 (2009).
- 695 89. Aini, J. & West, P. in *Resilience Sourcebook: Case Studies of Social-Ecological Resilience in*
696 *Island Systems* (ed. Cullman, G.) (Center for Biodiversity and Conservation, American
697 Museum of Natural History, New York 2014).

- 698 90. Gegeo, D. W. & Watson-Gegeo, K. A. 'How we know': Kwara'ae rural villagers doing
699 indigenous epistemology. *Contemp. Pac.* 13, 55–88 (2001).
- 700 91. Gray, S., Chan, A., Clark, D. & Jordan, R. Modeling the integration of stakeholder
701 knowledge in social–ecological decision-making: Benefits and limitations to knowledge
702 diversity. *Ecol. Model.* 229, 88–96 (2012).
- 703 92. Carter, J. L. Thinking outside the framework: Equitable research partnerships for
704 environmental research in Australia. *Geogr. J.* 174, 63–75 (2008).
- 705 93. Clark, W. C., van Kerkhoff, L., Lebel, L. & Gallopin, G. C. Crafting usable knowledge for
706 sustainable development. *Proc. Natl. Acad. Sci.* 113, 4570–4578 (2016).
- 707 94. UNU-IAS, Bioersivity International, IGES & UNDP. Toolkit for the Indicators of Resilience
708 in Socio-ecological Production Landscapes and Seascapes (SEPLS). (2014).
- 709 95. Zent, S. & Maffi, L. Final Report on Indicator No. 2: Methodology for Developing a Vitality
710 Index of Traditional Environmental Knowledge (VITEK) for the Project 'Global Indicators
711 of the Status and Trends of Linguistic Diversity and Traditional Knowledge'. (Terralingua,
712 2009).
- 713 96. Morgan, T. Decision-support tools and the indigenous paradigm. *Eng. Sustain.* 159,
714 169–177 (2006).
- 715 97. Malvatumauri National Council of Chiefs. Alternative Indicators of Well-Being for
716 Melanesia: Vanuatu Pilot Study Report. (Malvatumauri National Council of Chiefs, 2012).
- 717 98. Guardiola, J. & García-Quero, F. Buen Vivir (living well) in Ecuador: Community and
718 environmental satisfaction without household material prosperity? *Ecol. Econ.* 107,
719 177–184 (2014).
- 720 99. Mason Meier, B. & Chakrabarti, A. The paradox of happiness: Health and human rights
721 in the kingdom of Bhutan. *Health Hum. Rights* 18, 193–208 (2016).
- 722 100. Berkes, F. Community-based conservation in a globalized world. *Proc. Natl. Acad. Sci.*
723 104, 15188–15193 (2007).
- 724 101. Ballard, T. J., Kepple, A. W. & Cafiero, C. The Food Insecurity Experience Scale: Developing
725 a Global Standard for Monitoring Hunger Worldwide. (FAO, 2013).
- 726 102. Ravuvu, A. Vaka i Taukei: The Fijian Way of Life. (Institute of Pacific Studies of the
727 University of the South Pacific, 1983).
- 728 103. Brayboy, B. M. J. & Castagno, A. E. Self-determination through self-education: Culturally
729 responsive schooling for Indigenous students in the USA. *Teaching Education* 20, 31–
730 53 (2009).
- 731 104. Tilley, C. Performing culture in the global village. *Crit. Anthropol.* 17, 67–89 (1997).
- 732 105. Wood, L. J., Fish, L., Laughren, J. & Pauly, D. Assessing progress towards global marine
733 protection targets: Shortfalls in information and action. *Oryx* 42, 340–351 (2008).
- 734 106. Jupiter, S. D., Cohen, P. J., Weeks, R., Tawake, A. & Govan, H. Locally-managed marine
735 areas: Multiple objectives and diverse strategies. *Pac. Conserv. Biol.* 20, 165–179
736 (2014).
- 737 107. Friedlander, A. M., Stamoulis, K. A., Kittinger, J. N., Drazen, J. C. & Tissot, B. N. in
738 *Advances in Marine Biology* (eds. Johnson, M. L. & Sandell, J.) pp 153–203 (Oxford:
739 Academic Press, 2014).
- 740 108. Isechal, A. L., Victor, S. & (eds.). Micronesia protected area management effectiveness: A
741 guide to administering the MPAME tool. (Micronesia Conservation Trust, 2013).
- 742 109. West, P. An anthropology for 'the assemblage of the now'. *Anthropological Forum* 26,
743 438–445 (2016).

744 End notes

745 ^aWe 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^{66,76,109} and there is no single “community”
748 in a particular location as people self-define with different groups at different times.
749

750 Acknowledgements

751 We thank Felicity Arengo, Tamara Milton, Katherine Careaga, Maximilien Gueze, Lea
752 Sebastien, and Marie Roué for contributions. The material is based upon work
753 supported by the National Science Foundation under Grants No. EF-1427091 and
754 1444184. Any opinions, findings, and conclusions or recommendations expressed in
755 this material are those of the authors and do not necessarily reflect the views of the
756 National Science Foundation. Support for this project also comes from the Gordon
757 and Betty Moore Foundation, Lynette and Richard Jaffe, and the Jaffe Family
758 Foundation.

759

760 Contributions

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.

767

768

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.

778

779

780

781

782

783

784

785

786

787

788

789

790

791

792

793

794

795

796

797

798

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?” ¹⁰¹	Some Pacific Island countries have strong cultural obligations to provide family/guests with food ¹⁰² . 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 ^{17,103} .	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 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: (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 ⁸³ .

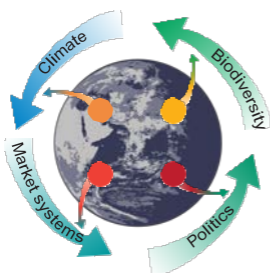
Issue	SDG goal	<i>Ex-situ</i> metric(s)	Discussion	Revised indicator
Sustainable tourism	Goal 8: “Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all”	Indicator 8.9.1: “Tourism direct GDP as a proportion of total GDP and in growth rate”	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 ¹⁰⁴ .	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 ¹⁰⁵ . 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 ¹⁰⁶ . 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 ^{33,107} .	(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 ¹⁰⁸ .
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.	
--	--	--	--	--

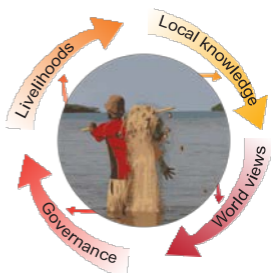
801

802

a Generalized ex-situ knowledge production

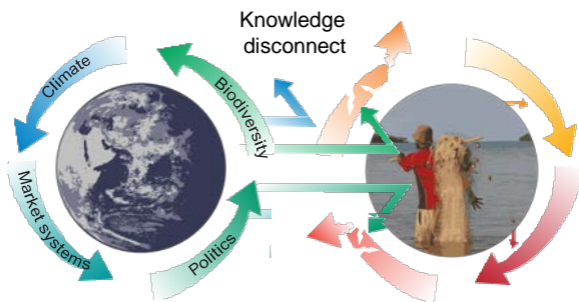


Culturally-grounded in-situ knowledge production



Diverse in-situ knowledge sources

b



c

