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ABSTRACT

Introduction: Interrelated social and ecological challenges demand an understanding of how environmental change and management decisions affect human well-being. This paper outlines a framework for measuring human well-being for ecosystem-based management (EBM). We present a prototype that can be adapted and developed for various scales and contexts. Scientists and managers use indicators to assess status and trends in integrated ecosystem assessments (IEAs). To improve the social science rigor and success of EBM, we developed a systematic and transparent approach for evaluating indicators of human well-being for an IEA.

Methods: Our process is based on a comprehensive conceptualization of human well-being, a scalable analysis of management priorities, and a set of indicator screening criteria tailored to the needs of EBM. We tested our approach by evaluating more than 2000 existing social indicators related to ocean and coastal management of the US West Coast. We focused on two foundational attributes of human well-being: resource access and self-determination.

Outcomes and Discussion: Our results suggest that existing indicators and data are limited in their ability to reflect linkages between environmental change and human well-being, and extremely limited in their ability to assess social equity and justice. We reveal a critical need for new social indicators tailored to answer environmental questions and new data that are disaggregated by social variables to measure equity. In both, we stress the importance of collaborating with the people whose well-being is to be assessed.

Conclusion: Our framework is designed to encourage governments and communities to carefully assess the complex tradeoffs inherent in environmental decision-making.

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Human well-being; indicators; ecosystem-based management; integrated ecosystem assessment; resource access; self-determination

Introduction

Global climate change, widespread habitat conversions, and the continued exploitation of natural resources are dramatically affecting ecosystems and the people who depend on them (Millenium Ecosystem Assessment 2005; IPCC 2014; Díaz et al. 2015). It is critical to understand how such unprecedented environmental change – and related social and management changes – affect human well-being. Here, we develop a framework for measuring human well-being as part of an integrated ecosystem assessment (IEA). IEAs are widely used to assess the status of social–ecological systems and evaluate management and policy strategies to support ecological integrity and human well-being (Levin et al. 2009; Levin and Möllmann 2015). IEAs analyze status and trends in biophysical and human conditions through carefully selected sets of indicators. Indicators are commonly chosen according to predefined criteria for their relevance to management, conceptual validity, sensitivity to environmental change, measurability, and understandability (Keeney and Gregory 2005; Rice and Rochet 2005; Boyd and Charles 2006). Hundreds of indicators have been proposed for use in IEAs, and there are perhaps equally as many frameworks for selecting indicators

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(e.g., Rice and Rochet 2005; Andrew et al. 2012). Yet these efforts have largely focused on biophysical, rather than social, indicators.

In the California Current, the large marine ecosystem running the length of the US West Coast, IEA practitioners have developed a systematic method for selecting indicators of ecological integrity (James et al. 2012; Kershner et al. 2011), but a similar effort has not been completed for human well-being. Elsewhere, indicators of human well-being have been developed to inform sustainable development, conservation (e.g., Mascia, Claus, and Naidoo 2010), ecosystem recovery (e.g., Dillard et al. 2013; Biedenweg et al. 2014), and vulnerability assessments (e.g., Jepson 2007). We draw from these initiatives, and modify the approach developed for biophysical indicators (Kershner et al. 2011; James et al. 2012), to develop a structured and transparent method for identifying indicators of human well-being that is tailored to the needs of an IEA. We present a prototype that can be adapted and developed for a variety of management scales and contexts. Our goal is to improve IEAs so that they capture the social, as well as ecological, dimensions of ecosystem-based management (EBM).

We follow an established protocol for selecting indicators: identifying overall goals for the assessment, operationalizing these goals through a conceptual framework, collecting and developing candidate indicators, defining screening criteria for selecting indicators, evaluating the candidate indicators according to these screening criteria, and selecting a parsimonious suite of complementary indicators that delivers useful information toward achieving the overall goals (Michalos 1997; Sainsbury and Sumaila 2003; Boyd and Charles 2006). We tailor each of these steps according to social science considerations and the specific aim of selecting social indicators for EBM. To ensure its relevance to management needs (Sojka 2014), our process includes a detailed review of human well-being goals and responsibilities found in policy and management documents pertaining to the California Current ecosystem (Appendix 1). Our entire process – including conceptualizing human well-being, developing a method for evaluation, and evaluating indicators – was conducted over a 2-year period, guided by a working group of environmental social scientists with expertise in anthropology, political science, geography, and international development. If others begin with the frameworks we already developed, the process will take less time, and we recommend additional ways to shorten the process in the discussion.

We test our approach for two focal attributes of human well-being related to EBM: *resource access* and *self-determination* (for more in-depth discussion of human well-being attributes related to EBM, see Breslow et al. 2016). We find these two attributes, when fully conceptualized, provide rich insight into multiple areas of human well-being. *Resource access* means "the ability to benefit from nature and natural resources" (Ribot and Peluso 2003) and includes the physical, economic, legal, social, and cognitive capacities to access these benefits. *Self-determination* means the ability for individuals and communities to shape their own lives and adapt to circumstances, here broadly connoting agency, free will, and autonomy, and most specifically for an EBM context, local and indigenous sovereignty and participation in decision-making (Sen 2000; Ryan 2009; Willow 2013). Resource access and self-determination are interrelated attributes and provide a foundation for many other dimensions of human well-being related to EBM. When analyzed across social variables, they are important to understanding inequities in environmental benefits and decision-making. We illustrate a systematic process for selecting indicators of human well-being by screening and evaluating existing indicators of resource access and self-determination.

Conceptualizing human well-being for EBM and indicator selection

A comprehensive conceptual framework of human well-being

EBM strives to achieve the mutual well-being of humans and ecosystems (McLeod et al. 2005), and an IEA strives to assess conditions to inform choices about potential management actions in and across complex systems. To operationalize these aims, we use a framework that facilitates a comprehensive yet flexible understanding of human well-being (Breslow et al. 2016). The framework is designed to address several of the major challenges in assessing human well-being: it captures the variable, interdependent, and subjective qualities of well-being; accommodates multidirectional relationships among ecological, social, and management factors; and encourages broadly comparable categories based on contextually defined factors (Biedenweg et al. 2014; Ostrom 2007; Leslie et al. 2015). Following this framework, we conceptualize human well-being as a set of constituents, domains, and attributes that can be tailored to specific contexts and assessed via indicators (Figure 1) (Breslow et al. 2016).

Defining focal attributes

In this paper, we illustrate the indicator selection process with two focal attributes of human well-being: resource access and self-determination. These attributes are widely recognized in the social science literature as important areas of human well-being

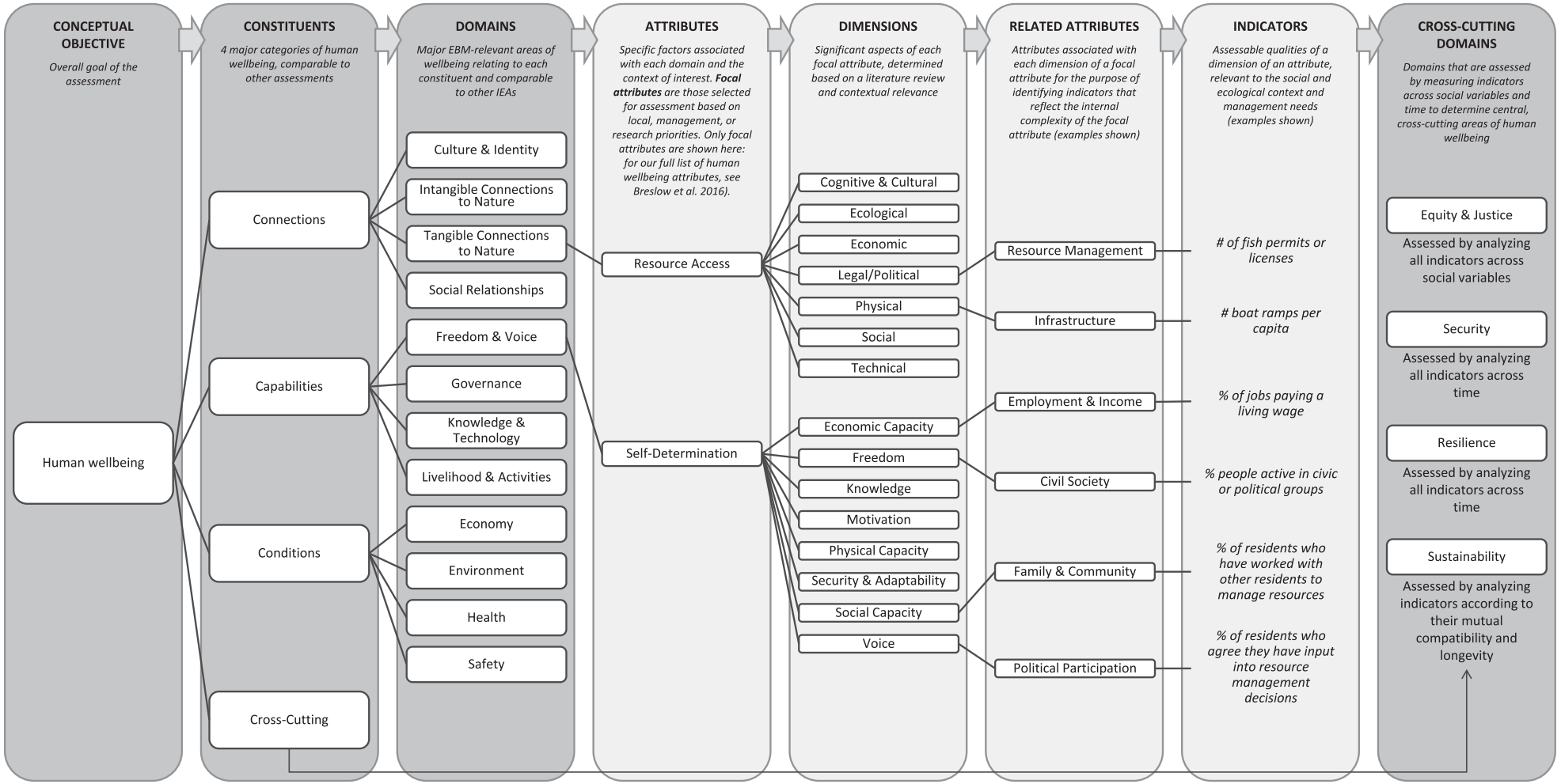

Figure 1. Steps, and definitions of terms, used in identifying indicators of human well-being, illustrated (in light grey columns) for two focal attributes, resource access and self-determination. This is a procedural view of our conceptual framework of human well-being that illustrates how all elements are linked. Starting with a conceptual objective, human well-being is broken down into recognizable categories (constituents, domains); focal areas are identified (attributes) and conceptualized (dimensions and related attributes); indicators are selected (indicators); and the cross-cutting domains of well-being are assessed by analyzing all final indicators across demographic variables and time.

Box 1. Resource access.

Resource access is defined as "the ability to benefit" from nature and natural resources (Ribot and Peluso 2003). Multiple factors influence resource access. Departing slightly from Ribot and Peluso, we distinguish *dimensions* of access from *mechanisms* of access (Charnley, McLain, and Poe in press). "Dimensions" are the structural conditions that influence one's ability to benefit from natural resources, such as physical barriers, economic capacity, legal permission, the ecological condition of resources, and ecological knowledge. "Mechanisms" are the processes and strategies through which people gain, maintain, and control access to resources (Ribot and Peluso 2003). Here we focus on the *dimensions* of access.

Box 2. Self-determination.

Self-determination refers to the willingness, ability, and actions of individuals or groups to actively shape their own lives and adapt to circumstances and is considered a primary constituent of human well-being (Ryan 2009; Durie 1998). Here we use self-determination in a general sense to include the concepts of *agency, free will*, and *autonomy*. These are enabled through social conditions that promote freedom, availability of appropriate choices, and the motivation as well as capability to thrive (Sen 2000; Ryan 2009). Various conditions can hinder self-determination, including: physical, monetary or material constraints; lack of education or information; governmental, social, or cultural restrictions; lack of culturally appropriate opportunities; poor mental health; and lack of positive social relationships. In the context of EBM, self-determination depends on (1) social conditions enabling individuals and groups to exercise free will as it relates to environmental management; (2) individuals' perceptions of relatedness; and (3) stakeholders' willingness and ability to fully participate in environmental decision-making (Beierle 2002; Ryfe 2002; Ryfe 2005; Dietz 2013). Here "stakeholders" can refer to individuals, interest groups, government agencies, or sovereign entities such as indigenous nations. For place-based and indigenous communities, the exercise of rights to land and resources is especially central to self-determination. This includes the ability to use resources for livelihoods, as well as the ability to shape the regulations, institutions, knowledge, discourse (Willow 2013), and priorities that govern resource use, whether independently or through co-management.

related to environmental management. Both are foundational for achieving multiple dimensions of well-being identified in our conceptual framework, and both can also account for idiosyncratic and unarticulated areas of well-being. Access to resources and nature makes it possible for people to enjoy attributes of well-being they personally associate with the ocean and coast, such as economic, social, and spiritual qualities, in addition to unstated or ineffable qualities. Similarly, the capacity to determine one's own choices and future means people are able to actively participate in managing, using, and making decisions about natural resources and natural places in ways they find personally meaningful and beneficial. In addition, self-determination has a known link to psychological health (Ryan 2009) and facilitates individual and collective resilience (Brown and Westaway 2011).

Drawing from the social science literature, we developed definitions for each of these focal attributes (Box 1 and Box 2) and identified their major dimensions (Table 1). We then further conceptualized these dimensions according to their most closely related attributes, drawn from our conceptual framework (see Breslow et al. 2016 for definitions of each attribute). For example, resource access is composed of 8 dimensions, which can be collectively associated with 21 related attributes (see Table 1). We found that this step effectively filters a large number of indicators reflecting multiple attributes of well-being through the lens of one focal attribute. It captures the way in which many attributes of well-being are mutually constituted and interdependent and illustrates how it is possible to select indicators for only a handful of focal attributes while still reflecting the multidimensionality of human well-being.

Methods: a generalizable approach to indicator selection

Collecting and developing candidate indicators

To develop a generalizable approach to indicator selection, we conducted a global search for indicators of human well-being already used or proposed in existing social–ecological indicator projects. Projects were selected according to five predefined criteria: systematic assessment of social conditions; attention to environmental conditions or natural resource management; focus on real-world application; documentation of process and results; and potential to influence other projects, whether due to geographic scope, presence in the literature or media, or level of funding (Sojka 2014). A total of 2310 indicators were ultimately drawn from 34 projects focusing on environmental management, sustainability, indigenous communities, or general well-being at national to global scales. The indicators were then categorized according to one or more of the attributes defined in our conceptual framework of human well-being. (Selected projects are listed in Appendices 2 and 3 under "Existing Projects," and the resulting list of indicators is published in Breslow et al. 2016, Appendix B.)

Defining screening criteria

Following advice in the literature for achieving systematic analysis, consistency, and transparency, we established screening criteria for evaluating and selecting indicators (Keeney and Gregory 2005; Rice and Rochet 2005; Boyd and Charles 2006). We began with criteria established for biophysical indicators (Kershner et al. 2011; James et al. 2012) and modified these according to social science considerations for social indicators. We organized the resulting criteria into five sections (Table 2). *General criteria* (A) pertain to any indicators, regardless of context or data availability. *Context-specific criteria* (B) relate to the

Table 1. Typologies of *resource access* and *self-determination*.

Focal attribute	Dimensions of focal attribute	Brief explanation	Most closely related attributes
Resource access	Cognitive and cultural	Knowledge required to identify, locate, harvest and process resource; values and ethics about which resources to harvest and quantities to harvest	Cultural values, education and information
	Ecological	Attributes of a resource that make it available and desirable to potential users, such as resource characteristics (size, sex, maturity, abundance, condition), and geographic distribution; environmental conditions that foster resource availability (e.g., water quality)	Environmental quality, pollution and waste, resource abundance and distribution
	Economic	Capital needed to invest in gear, permits, etc. required for obtaining resource; labor and time needed to harvest resource; market value of resource	Activities and time allocation, employment and income, industry and commerce, material wealth, subsistence
	Legal/political	Laws, policies, rules (customary or *de jure*), permits, quotas, etc. that govern access to resources	Resource management
	Physical	The physical infrastructure that affects resource access (e.g., roads, barriers, dams); physical condition of resource user	Infrastructure, physical health
	Resource access (overall)	Access to resource harvests, access to open space for recreation, etc.	Access to nature, recreation and tourism, resource access and tenure, subsistence
	Social	The social context, identity, and networks of the resource user that confer or deny rights of access, e.g., ethnicity, kinship, group membership	Civil society, family and community
	Technical	The technical skills, equipment, etc. required to harvest resources, such as fishing gear, locational devices, boats	Research and technology
Self-determination	Economic capacity	Material, financial, and time constraints and capacity	Available time for fulfilling activities, employment and income, industry and commerce, material wealth
	Freedom	Social and/or governmental freedoms and restrictions	Civil society, governance, independence, public services, resource management, sovereignty
	Knowledge	Understanding of current and future opportunities, the consequences of current and future actions, and alternatives.	Education and information, research and technology
	Motivation	Motivation to do well, to improve, and to thrive	Cultural values and practices, emotional and mental health, senses of place
	Physical capacity	Physical constraints and capacity (e.g., security, safety and health) to achieve self-determination	Disaster preparedness, peace and security, physical health, physical safety, resource access and tenure
	Social capacity	Social relationships and social capital needed for self-determination; capacity for collective action	Equity and justice, family and community, social diversity and integrity
	Stability and adaptability	Conditions necessary for long-term decision-making; resilience; flexibility	Security and resilience
	Voice	Conceptual and practical possibilities for participation in decision-making; having meaningful input in decision-making; representation in government	Political participation

geographic, social, and management contexts in which the indicators will be used. *Data considerations* (C) are important for prioritizing and selecting indicators with available data. *Suite considerations* (D) are used to select a well-rounded set of indicators. Finally, *project considerations* (E) are important questions that need to be addressed at a project level. Here, we used the criteria in groups A–D to test a general method for evaluating indicators, since *project considerations* (E) are more specific and project dependent.

Evaluating indicators using the screening criteria

From the master list of compiled human well-being indicators (Breslow et al. 2016), we selected all indicators associated with each focal attribute (resource access and self-determination) and their related attributes (Appendices 2 and 3). Since many indicators are associated with multiple attributes of human well-being, resulting lists consisted of more than 2000 candidate indicator-attribute pairs for each focal attribute. To narrow these long lists to a useable number, we used a stepwise process, detailed below and illustrated in Figure 2.

1. First cut

Indicators were first evaluated by one working group member, based on expert opinion, with respect to how well they conceptually reflected the focal attribute and its dimensions within a marine/coastal environment and management context (a combination of criteria A1 and A2; see Table 2), with a score of 2 = potential direct relevance; 1 = likely indirect relevance; 0 = very general, very indirect, or no relevance. If not stated, a marine or coastal linkage was assumed. Those indicators scoring an average of 1.5 or above were selected for the next round. This resulted in intermediate lists of approximately 650 indicator-attribute pairs for each focal attribute.

2. Quick screen

The next round of indicators were evaluated by two working group members, using a similar 0–2 ranking,

Table 2. Screening criteria used to evaluate indicators.

A. GENERAL CRITERIA

A1. Conceptually valid
Is this indicator unambiguously related to the attribute it is intended to measure? Is there peer-reviewed evidence for its theoretical validity?

A2. Environmental linkage
Is this indicator linkable theoretically and/or via empirical evidence to environmental conditions, the human-environment connection, and/or environmental management? This linkage can be direct and material, and/or intangible. The type of ecosystem can be specified if desired (e.g., marine/coastal).

A3. Social indicator
Is this indicator clearly related to social phenomena, and not strictly a measurement of the biophysical environment? (Note that biophysical conditions may be used as proxies for human wellbeing when no suitable social indicators are available.)

A4. Understandable
Is this indicator understandable or identifiable by decision-makers and by the people being measured? Can it be explained in one paragraph or less? Is it easy to understand the consequences and trade-offs revealed by this indicator?

A5. Concrete and measurable
Assuming scope is specified, does this indicator represent a specific aspect of the world that can be measured directly? (Note that many subjective and seemingly qualitative indicators, such as "% of residents who are satisfied with their access to public shorelines," are measurable via a Likert scale using a survey.)

A6. Conforms to rules for good scales (Keeney and Gregory 2005)
Type of scale: Is this indicator natural, constructed or proxy? Range: Does this indicator capture a reasonably full range of possibilities? Directionality/reference points: Is it possible to specify which direction in trends is positive or negative, and to identify reference points? Unit ratios: Do points on the scale have a clear ratio of differentiation? Sensitivity to change: See B4 and B5. (Scored 0 if meeting 0–1 rules; 1 if meeting 2–3 rules; and 2 if meeting all 4 rules).

B. CONTEXT-SPECIFIC CRITERIA

B1. Geographically relevant and comprehensive
Is this indicator relevant to the geographic context and scale of interest? Does it reflect the diversity of ecosystem types of interest? Does the indicator apply widely to a diversity of resource types?

B2. Socially relevant and comprehensive
Is this indicator relevant to the social and cultural context and scale of interest? Does it refer to the social diversity of interest? Does the indicator apply widely to a diversity of people? Does this indicator reflect the social goals, priorities, and/or thresholds of wellbeing as defined by the people whose wellbeing will be measured?

B3. Relevant for decision-making context
Is this indicator relevant to the local decision-making context(s) and scale of interest (e.g., federal, state, municipal, tribal, etc.)?

B4. Sensitive and responsive to specific, context-relevant environmental changes
Is this indicator something environmental conditions in the geographic area of interest can affect? Does the indicator respond quickly and noticeably to real changes? Is it possible to distinguish how other factors influence the response?

B5. Sensitive and responsive to specific, context-relevant management changes
Does this indicator reflect something managers can influence? Does the indicator respond quickly and noticeably to real changes? Is it possible to distinguish how other factors influence the response?

C. DATA CONSIDERATIONS

C1. Data availability
Are there data available appropriate to the target region, social groups, and/or questions?

C2. Variables measured
Which variables are measured in the available data set? Are these relevant to the overall assessment?

C3. Spatial scope & resolution
At what geographic scope and resolution is data available? Is this scope and resolution useful to the overall assessment?

C4. Temporal scope & resolution
How far back is data available, and at what frequency? Is this scope and resolution useful to the overall assessment?

C5. Level of data disaggregation
Are data broken down by different social characteristics of interest? If so, which ones? Are these adequate for assessing cross-cutting domains?

D. SUITE CONSIDERATIONS

D1. Objective or subjective
Is this an indicator of objective or subjective wellbeing? Does the indicator reflect a measureable state of things outside people's thinking (objective)? Or does the indicator reflect people's intuitive assessment or perception of something, such as their own happiness; or the belief that water is safe to drink, independent of water quality measures (subjective)?

D2. Units of social organization
What scale of social organization does the indicator reflect (e.g., individual, household, community, society)?

D3. Leading or Lagging
Does this indicator anticipate change (leading) or report on change that has already happened (lagging)?

D4. Broad or specific reflection of human wellbeing
Does this indicator reflect multiple domains of wellbeing (holding "big picture" value) or is it specific to one domain or attribute?

E. PROJECT CONSIDERATIONS

E1. Can this indicator be measured, reported, and integrated into an IEA?
What methods are best used to measure this indicator, and how are results best communicated? E.g., existing data, interviews, surveys; charts, images, narratives, maps, etc.

E2. Estimated cost
What is the estimated cost to measure this indicator? Is it affordable?

E3. Potential harm
Are there any potential concerns about how this indicator may harm the people it measures – e.g., by revealing private information; specifying too concretely what counts as wellbeing to the neglect of other hidden or poorly-understood dimensions; putting a limit on when wellbeing is reached; etc.? Note if and how harm may vary with measurement method, level of detail, and how results are presented. Provide guidance on whether and how the indicator should be used.

E4. Collaboration with populations whose wellbeing is being measured
Was this suite of indicators developed in collaboration with the people it measures? Were the indicators proposed and/or vetted through interviews, focus groups, workshops, or other direct dialogue with the people they measure?

Criteria were developed by comparing, modifying and adding to criteria used in related studies (Keeney and Gregory 2005; Rice and Rochet 2005; Boyd and Charles 2006; Kershner et al. 2011). This table has been color-coded for easy reference. If printing in grayscale, please refer to the main text for full interpretation.

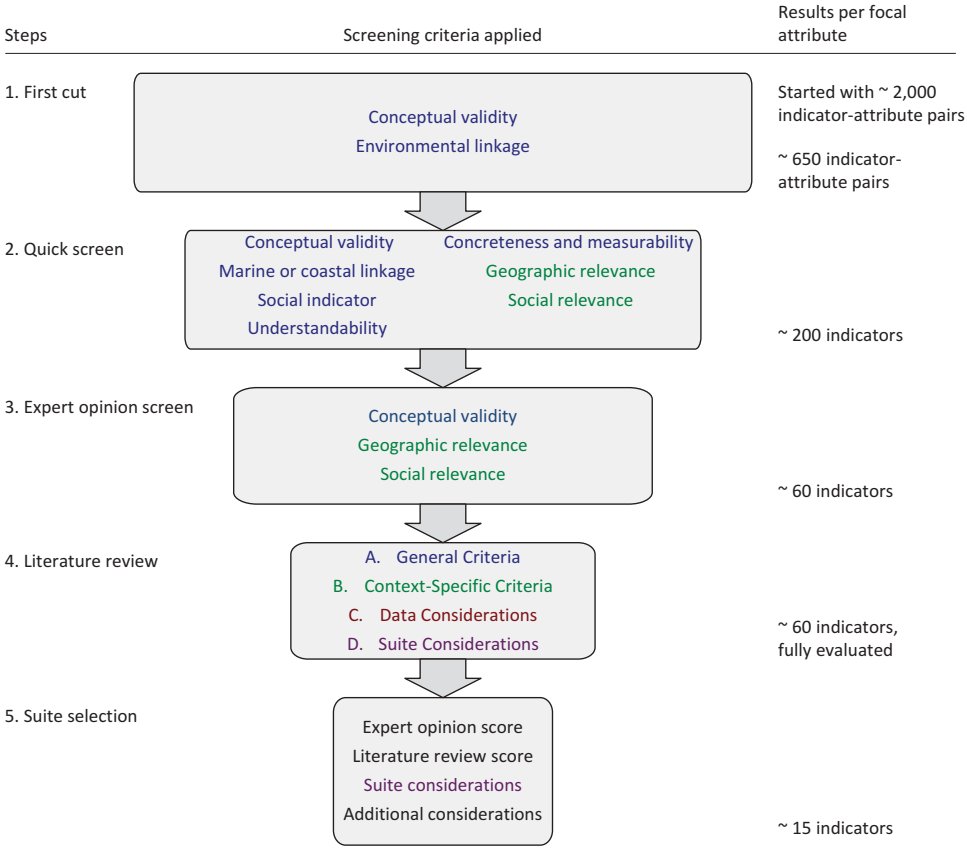

Figure 2. Steps in the indicator evaluation process. Starting with more than 2000 indicator-attribute pairs for each focal attribute, we used a series of steps to filter and narrow these to a manageable number for a literature review and selection of a suite. Colors match those used in Table 2. Each step of the evaluation was conducted by up to three experts from our team of environmental social scientists, except for Step 3, which was conducted by groups of 10–12 experts. (Note: This figure has been color-coded for easy reference. If printing in grayscale, please refer to the main text for full interpretation.)

according to seven criteria: marine/coastal linkage, social or biophysical indicator, conceptual validity, understandability, geographic relevance, social relevance, and concreteness and measurability. For each related attribute, all indicators scoring an average score of 1.9 or above were selected for the next round. If none scored this highly, then the two most top-scoring indicators for each related attribute were selected so that each had at least two candidate indicators. Recurring indicators that had been coded with more than one attribute were assigned to their most relevant attribute, with other related attributes noted. During this step, a number of indicators were re-categorized according to expert opinion. This step resulted in a list of approximately 200 distinct candidate indicators for each focal attribute.

3. Expert opinion screen

Multiple working group members then screened each of these indicators based on their opinion of how well it reflected its respective dimension of the focal attribute within a US West Coast context, with 0 = poor; 1 = mediocre; 2 = best. Twelve group members evaluated the resource access indicators, and 10 evaluated the self-determination indicators. All indicators scoring an average of 1.33 (for resource access) or 1.5 (for self-determination) or above, plus all those with at least 6 (resource access) or 5 (self-determination) scores of 2 were selected for the final round. If there were no top-scoring indicators for a dimension, then the top two highest-scoring indicators in that dimensions were selected. As a final step, indicators with similar meanings were merged.

We chose our cut-off points to achieve a manageable and roughly similar number of candidate indicators for each focal attribute for further evaluation via a literature review. Note that one could introduce sensitivity analyses to investigate the robustness of scores at this and other stages of evaluation: using robustness as a decision cut-off may result in widely varying numbers of candidate indicators for different focal attributes and leave some dimensions without candidate indicators. We chose to prioritize content and complementarity over strictly robustness since a degree of subjectivity in the evaluation process is unavoidable anyway.

4. Literature review

Research assistants then evaluated the resulting lists of candidate indicators according to all criteria and considerations in sections A–D of Table 2. Evaluations of conceptual validity (A1) and

sensitivity and responsiveness to environmental and management changes (B4, B5) were based on peer-reviewed literature and expert opinion. Evaluations of understandability (A4) and social and geographic relevance (B1, B2) relied additionally on popular media sources relating to the California Current region. Conformity to rules for good scales (A6) (Keeney and Gregory 2005) was evaluated using logical deduction. Relevance to decision-making context (B3) was evaluated through an analysis of human well-being responsibilities and priorities articulated in the major US federal and state environmental laws, policies, and management guidelines pertaining to marine and coastal management of the US West coast (for methods and results, see Appendix 1).

Literature review results for criteria A1-C1 were quantified such that indicators with evidence suggesting they fully met a given criteria were scored 2, indicators with evidence suggesting they met criteria only partially or in selective circumstances were scored 1, and indicators with negative evidence or no discovered literature were scored 0. Scores, weighted equally, were averaged to arrive at a "literature review" score for each indicator. Note that criteria can be weighted according to project priorities (Kershner et al. 2011; James et al. 2012). Note also that a literature review of this sort involves considerable interpretation: reliance on different literature sources or avenues of logic could result in substantially different results.

5. Evaluation of top-scoring indicators

Our final step was to select the top-scoring indicators of each related attribute within each dimension of our focal attributes. We opted to select indicators that scored 1.5 or above according to the literature review *and* expert opinion screening steps toward ensuring consistency of quality in the final suite. Using both the literature review and expert opinion scores represents a form of triangulation, since each resulted from a different set of reviewers. This approach effectively weighted conceptual validity, geographic relevance, and social relevance, since these criteria were used in both evaluations. Once the top-scoring indicators were identified, we evaluated them according to their data availability, suite-level considerations, and additional considerations.

Suite considerations (Table 2, section D) are useful for selecting a final set of indicators with a mix of complementary qualities (Levin et al. 2009; Kershner et al. 2011). In crafting suite considerations for social indicators, we strove for a number of qualities: a combination of objective measures, which reflect conditions observable regardless of an individual's personal experience, and subjective measures, which reflect an individual's perceptions or feelings about a matter (D1); indicators that collectively represent well-being at different levels of social organization, from individual well-being to community and societal well-being (D2); both "leading" indicators that anticipate changes in well-being, and "lagging" indicators that report on changes that have already happened (D3); and indicators that are both "broad," reflecting multiple attributes or domains of well-being, and "specific," primarily reflecting one attribute (D4).

Results

Candidate indicators

From the 2000 indicator-attribute pairs initially identified, we used steps 1–3 outlined above to select 53 candidate indicators of resource access and 67 candidate indicators of self-determination for detailed evaluation via literature review (Step 4; full results in Appendices 2 and 3). Through this structured process we identified several high-scoring, currently measurable indicators of each focal attribute. We also identified gaps where further indicator development and data collection are needed.

Results (Appendices 2 and 3) reveal that the number of candidate indicators and data availability varied widely among the dimensions and related attributes of the focal attributes. This variability is summarized in Figures 3 and 4. In general, more candidate indicators and data were available for the ecological, economic, and resource access dimensions of resource access, while fewer were available for the cognitive, legal/political, social, and technical dimensions. More candidate indicators and data were available for the economic capacity, physical capacity, and social capacity dimensions of self-determination, and fewer for its knowledge, stability and adaptability, and voice dimensions. A high number of subjective indicators in the freedom and motivation dimensions explains the low data availability for these dimensions, since subjective indicators can only be measured directly via surveys or interviews, while objective indicators are often measured indirectly via available data, such as economic, spatial, and legal data that has been collected for other purposes (e.g., property values, length of trails, number of permits). The patterns we observed in indicators and data availability corroborate the growing acknowledgement that tangible dimensions of human well-being are frequently assessed, using readily available economic and demographic data, while intangible, cultural, and largely subjective dimensions remain understudied (Turner et al. 2008; Chan et al. 2012; Satterfield et al. 2013).

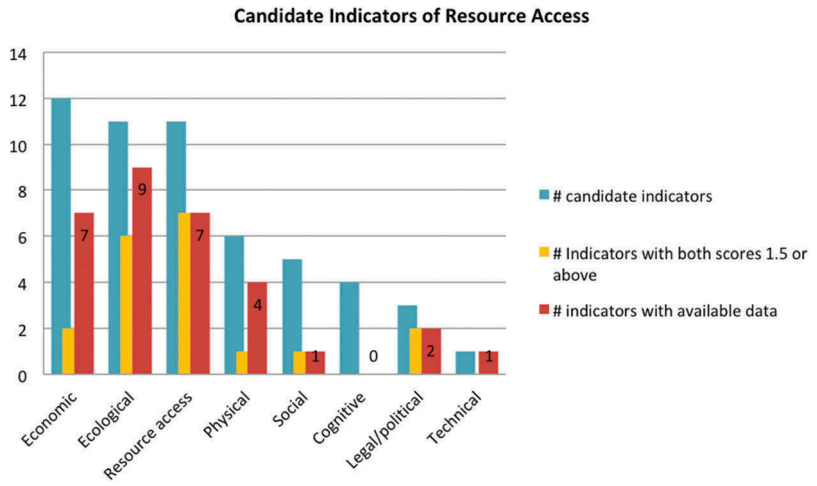

Figure 3. Resource access candidate indicators: summary of evaluation results.

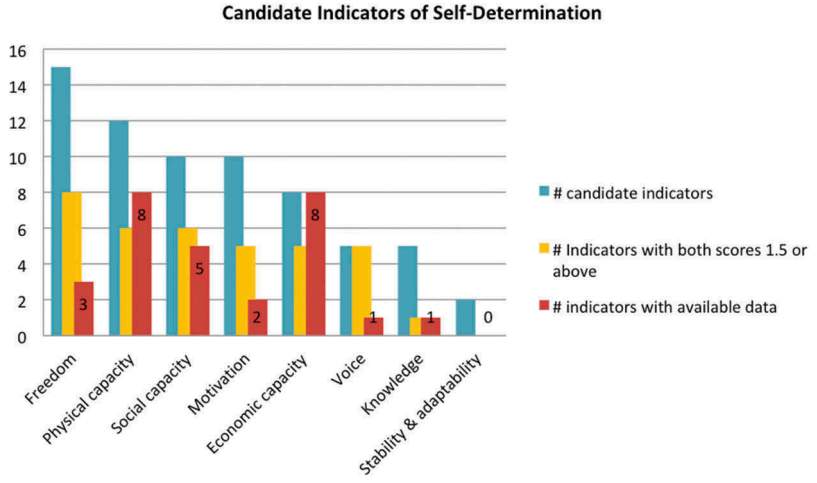

Figure 4. Self-determination candidate indicators: summary of evaluation results.

Top-scoring indicators

Resource access indicators

A total of 19 candidate indicators of resource access scored 1.50 or above out of 2.00 in both the expert opinion screen and literature review evaluation (Appendix 2, "Candidate Indicators"). These were distributed among 6 of the 8 dimensions, and 12 of the 20 related attributes, leaving 2 dimensions and 8 related attributes without high-scoring indicators. Of the 13 top-most scoring indicators for each related attribute (2 tied as top scorers in the resource abundance and distribution attribute), 6 had data available for the topic and region of interest; 3 had partial data available for the topic or region; and 4 had no data available, or the indicator was too vague to determine if data were available (Table 3). One was a subjective measure of well-being (% of residents who are satisfied with their access to public shorelines), and all others were objective measures. In other ways, they represented a mix of suite-level qualities.

Self-determination indicators

A total of 36 candidate indicators of self-determination scored 1.50 or above out of 2.00 in both the expert opinion screen and literature review evaluation (Appendix 3, "Candidate Indicators"). These were distributed among 7 of the 8 dimensions, and 18 of the 25 related attributes, leaving 1 dimension and 7 related attributes without high-scoring indicators. Of the 18 top-most scoring indicators for each related attribute (Table 4), 6 had data available for the topic and region of interest; one had partial data available for the topic or region; and 11 had no data available. These top-scoring indicators represented a mix of suite-level qualities.

Indicator suite selection

Selecting a final suite of indicators to include in an integrated assessment is an art as much as a science, ideally involving deliberation by managers and stakeholders (Levin, Damon, and Samhouri 2010). We

Table 3. Top-scoring resource access indicators, with suite characteristics, recommended data collection method, and data availability for each.

Dimension	Indicator	O	S	Social scale	→	←	B	s	Method	Data available	Variables measured	Spatial scope and resolution	Temporal scope and resolution	Disagg. by social variables
Cognitive	*No top-scoring indicator available*	–	–	–	–	–	–	–	–	–	–	–	–	–
Ecological	Access to clean water	x		Individual		x	x		Multiple	No: Too vague	–	–	–	–
	Days x miles of shoreline closed due to sewage, biotoxins or pollution	x		NA		x	x		Existing data	Yes: WA Department of Health, OR Health Authority, CA State Water Resources Control Board	Days and miles of shorelines closed due to sewage and pollution.	By state (OR, WA); by county (CA)	Weekly (during summer only in OR & WA)	None
	Abundance of selected key species	x		Society	x		x		Existing data	Some: Some data is available for certain species	–	–	–	–
	Marine habitat health (% cover key ecosystems/ species)	x		Society	x		x		Existing data	Yes: Ocean Health Index	Index score calculated via Ocean Health Index	US West Coast	Annually	
Economic	Coastal Livelihoods and Economies: current adjusted values by sector for jobs, wages, and revenue (value)	x		Society		x	x		Existing data	Yes: Ocean Health Index	Job & wage data for 20 marine-related sectors	By state	Differs for each variable	By job sector and livelihood
	No. [of type] of vendors of locally caught and raised seafood	x		Community	x	x		x	Survey	No: may be available for specific location	–	–	–	–
Legal and political	No. of fish permits/licenses (by community and fishery; total per capita; held locally and non-locally, indigenous, % of productive activity by plan area companies and indigenous)	x		Community-Society	x			x	Survey	Yes: PacFIN, Karma Norman at NWFSC (not all variables)	# of permits/licenses	WA, OR, CA, by community/port group	Weekly and annually since 1981 (varies)	By fishery and community
Physical	Boat ramps (No.; per capita; per 1000 people; use)	x		NA	x			x	Existing data	Yes: OR State Marine Board (data.gov), WA Recreation and Conservation office, CA State Parks, Division of Boating and Waterways	Y: No. of boat ramps	By state (WA only)	Once in 1997 (WA only)	None
Resource access	% of residents who are satisfied with their access to public shorelines		x	Individual		x	x		Survey	No: can be collected via survey	–	–	–	–
	% of shoreline that is publicly accessible or owned	x		Society	x		x		Existing data	Yes: CA Coastal Access Guide, OR: All shoreline is public, WA Department of Ecology Marine Shoreline Access Project	Miles of accessible shoreline	By local jurisdiction (CA); by county (WA); all public (OR)	2008–2010 (WA), 1999–2010 (CA); updated irregularly	None
	Recreational fishing licenses/ permits (sold annually/used on recreational lands)	x		Individual		x				Some: WA Dept of Fish and Wildlife, OR Dept of Agriculture; Recfin; Karma Norman at NWFSC	Number of recreational fishing licenses/permits (no fresh/ saltwater distinction)	WA, OR by community, CA by marine area	Annually since 1980 (dependent on state and permit type)	Broken down by target species and community
	Subsistence harvest (No. and type of species consumed)	x		Individual		x				Some: Listed in Puget Sound, WA-Human Wellbeing Indicators in Hood Canal		Per regulatory area	Annual catch data, survey data	Puget Sound: by gender, age, and sub-region

(*Continued*)

Table 3. (Continued).

Dimension	Indicator	O	S	Social scale	→	←	B	s	Method	Data available	Variables measured	Spatial scope and resolution	Temporal scope and resolution	Disagg. by social variables
Social	% of residents who have worked with other residents to share harvested goods in the past year	x		Community	x		x		Survey	No: Would likely have to be obtained via a survey.	–	–	–	–
Technology	*No top-scoring indicator available*	–	–	–	–	–	–	–	–	–	–	–	–	–

O = objective; S = subjective; →=leading; ←=lagging; B = broad; s = specific.

recommend an approach that provides transparency and flexibility in selecting indicators that best meet the situation at hand.

A list of candidate indicators evaluated according to desirable qualities, as illustrated in Tables 3 and 4, can help structure decisions. There are multiple potential pathways to a final suite. Initial lists of indicators and screening criteria may vary; evaluation results may differ; criteria may be weighted according to unique priorities and circumstances; and evaluators as well as decision-makers may use different lines of reasoning. Under each of these scenarios, top-scoring indicators will differ. For example, under the current evaluation, the top-most scoring indicator for resource access is "% of shoreline that is publicly accessible or owned" and for self-determination it is "% of (rural) residents who agree that they have input into decision services in area." If data availability is imposed as a requirement, the top-most scoring indicator for resource access does not change, but for self-determination it becomes "% of jobs paying a living wage, by household type," tied with "% employed people living in poverty."

Suite-level considerations

Once a list of high-scoring indicators has been identified, one can review dimensions and related attributes with multiple high-scoring indicators and select among them to achieve a balanced mix of suite-level qualities. For example, to help balance subjective and objective indicators in the resource access suite, one could substitute "% of (rural) residents who agree that they have input into decisions (services) in area" as a possible high-scoring subjective indicator of the "legal and political" dimension.

Additional considerations

A number of additional considerations are useful in selecting a final suite. First, one can review the interim list for internal redundancies. For example, "% of jobs paying a living wage, by household type" and "% employed people living in poverty" suggest very similar aspects of well-being, so only one of them needs to be included in a parsimonious assessment of self-determination. Furthermore, "% of residents who are satisfied with their access to public shorelines" ranked among the top-most indicators for both focal attributes, so should be assigned to only one. One can also review the list for redundancies within the IEA as a whole. For example, "abundance of selected key species" and "marine habitat health (% cover key ecosystems/species)" will likely be included in a suite of ecological indicators so need not be selected here.

Second, one could modify or clarify promising indicators to improve their quality and usability. For example, "access to clean water" scored highly for

Table 4. Top-scoring "self-determination" indicators, with suite characteristics, recommended data collection method, and data availability for each.

Dimension	Indicator	O	S	Social scale	→	←	B	s	Method	Data available	Variables measured	Spatial scope and resolution	Temporal scope and resolution	Disagg. by social variables
Economic capacity	% of jobs paying a living wage, by household type	x		Household	x		x		Existing data	Yes: Living wage is defined by $15/hour (The Job Gap 2015).	% job openings paying <$15/hr	By state	Once in 2013	By single adult and single adult w/2 children
	% employed people living in poverty	x		Individual		x	x		Existing Data	Yes: WPFP (2014)	Low Income Working Families	By state	Annually	Minority working families, with no HS Degree/GED, with no postsecondary experience, paying 1/3 or more for housing, parent without health insurance, children, adults 18–64 with no HS Degree/GED, occupations paying below poverty
	Somewhat, mostly or completely satisfied with their amount of leisure time		x	Individual		x		x	Existing Data	Yes: By state (GFK 2015).	Satisfaction w/ amt of leisure time	US, by state	Once in 2014; research ongoing	By gender
Freedom	Proportion of persons active in civic or political groups	x		Society		x		x	Survey	No	–	–	–	–
	No. of residents who report trust in experts and local and state government and collaborative government efforts		x	Society	x			x	Survey	No	–	–	–	–
	Public satisfaction with social services/Satisfaction with access to services		x	Society		x		x	Survey	No	–	–	–	–
	Lands and waters co-management by indigenous and local communities	x		Community		x		x	All	Some: NOAA Fisheries 2015	Descriptive: guidance, members	WA, OR, CA	NA	NA
Knowledge	No. persons participating in natural resource education activities	x		Individual		x		x	Survey	No	–	–	–	–
Motivation	Proportion of adults encountering barriers which prevent them from experiencing particular cultural activities	x	x	Community		x	x		Interview	No	–	–	–	–
	% reporting very or somewhat strong sense of belonging to community		x	Community	x		x		Survey	No	–	–	–	–
	% of residents who express high life satisfaction or happiness and % who express living in the region as a contributor to this		x	Individual		x	x		Survey	No	–	–	–	–

(*Continued*)

Table 4. (Continued).

Dimension	Indicator	O	S	Social scale	→	←	B	s	Method	Data available	Variables measured	Spatial scope and resolution	Temporal scope and resolution	Disagg. by social variables
Physical Capacity	Capacity to anticipate change and to develop strategies to respond (measured by content organizing responses to open ended questions relating to a hypothetical 50% decline in fish catch)	x	x	Individual-Society		x	x		Interview	No	–	–	–	–
	% of people who feel safe in their communities		x	Community	x			x	Existing Data	Yes: Only per state and the cities with the highest populations along the coast (San Jose, San Francisco, San Diego, and LA) (Gallup 2015).	Communities where people feel unsafe	CA cities	Annually, 2013–2014	None
	% of Adults ages 18+ with limited activity due to poor physical or mental health	x	x	Individual	x	x		x	Existing Data	Yes: WA Department of Health, OR Health Authority, CA Department of Health	Same as indicator	By state	Annually	By age and risk factor (WA) and gender (OR); prevalence and disease (CA)
	% of residents who are satisfied with their access to public shorelines		x	Individual		x	x		Survey	No				
Social Capacity	Reports of recent treatment that is perceived as unfair based on gender, age, race or color, ethnic background, language, socioeconomic position, social class, sexual orientation, religion or disability		x	Society		x		x	Existing Data	Yes: By state, not broken down to coastal areas (EEOC 2015).	No. of filings (EEOC Charge Receipts)	By state	Annually, 2009–2014	By race, sex, national origin, religion, gender, age, disability, pay, etc.
	% of residents who have worked with other residents to manage resources	x		Individual–Community		x		x	Survey	No	–	–	–	–
Stability & Resilience	*No top-scoring indicator available*	–	–	–	–	–	–	–	–	–	–	–	–	–
Voice	% of (rural) residents who agree that they have input into decision services in area		x	Individual		x		x	Survey	No	–	–	–	–

O = objective; S = subjective; →=leading; ←=lagging; B = broad; s = specific.

resource access, but is too vague to measure: does it mean access to clean drinking water, access to clean bodies of water, or something else? More specific language would improve its eligibility for the final suite. Improving candidate indicators could furthermore help fill gaps in dimensions and related attributes lacking top-scoring indicators. For example, the related attribute of self-determination, "independence," currently lacks a high-scoring indicator. The candidate indicator "decision latitude at work" scored 1.50 in expert opinion and 1.36 in the literature review, putting it just below our selection threshold. The literature review (Appendix 3) reveals its low score is due to it being marked "unclear" for understandability, and in need of a measurable scale. Using more common language and developing a consistent scale could improve this indicator sufficiently to serve as an indicator of "independence."

Third, and finally, it is important to identify gaps where additional indicators and primary data collection are needed to achieve a robust assessment of focal attributes. Gaps may be filled by clarifying or modifying existing indicators, or by developing new indicators. Or, gaps may suggest a dimension of well-being that is difficult to assess using a quantitative measure. For example, cultural values related to resource access are likely best understood through qualitative research presented as narrative explanation alongside the quantitative results of the IEA. Filling gaps inevitably entails the costs of developing new indicators and collecting new data.

Discussion: cautions and recommendations

The limitations of existing indicators and data

From a starting list of more than 2000 globally sourced indicators, our screening process identified short lists of potential indicators of resource access and self-determination for the California Current IEA (Tables 3 and 4). What these indicators can actually tell us about human well-being related to specific environmental conditions and management strategies requires a closer look at the resolution and disaggregation of available data. While the indicators are able to offer general insight into our focal attributes, they are limited in their ability to answer specific management questions.

Currently measurable indicators could broadly assess several ecological, economic, physical, and legal dimensions of resource access as an attribute of well-being: namely, how pollution and waste result in shoreline closures; general marine ecosystem health; the economic conditions of ocean-dependent livelihoods; boat ramps per capita; number of acquired fishing permits; and the ownership patterns of shorelines. Similarly, currently measurable indicators of self-determination could broadly assess its economic and physical dimensions by tracking wages, poverty levels, and satisfaction with leisure time, perceptions of safety, and physical and mental health. In addition, equity and justice as an attribute of social capacity can be assessed through measuring reports of discrimination.

However, of the resource access indicators, only three currently have data available for the whole California Current region that are collected at spatial and temporal resolutions relevant to environmental or management changes: days x miles of shoreline closed due to sewage, biotoxins or pollution; general marine ecosystem health; and certain sectors measured in the coastal livelihoods and economies index (i.e., mariculture, whale-watching, ports and harbors, and shipping and boat-building). None of the top-scoring self-determination indicators have data available at a resolution that can capture responses to specific environmental or management changes.

The only indicator sufficiently disaggregated by social variables to assess the cross-cutting domain of equity and justice is the one self-determination indicator of equity and justice: "reports of recent treatment that is perceived as unfair based on gender, age, race or color, ethnic background, language, socioeconomic position, social class, sexual orientation, religion or disability." In addition, several of the listed datasets could be potentially paired with other existing data, such as census data, to gain insight into social variability. For example, one could overlay the location of shoreline closures with spatialized demographic data of coastal residents to understand how closures affect them differently. Note that this would not account for differential effects on long-distance visitors.

Gaps, and the need for new social indicators and original research

For resource access, no top-scoring indicators with adequate existing data were found for its cognitive and cultural, social, and technological dimensions. For self-determination, no top-scoring indicators with adequate existing data were found for the dimensions of freedom, knowledge, motivation, stability and resilience, and voice.

In addition, 12 of the 16 top-scoring indicators with any measurable data lacked data with the spatial and temporal resolution necessary to assess how human well-being is affected by specific environmental changes or management strategies: that is, they are collected for only part of the region, at a spatial resolution that is too large (i.e., by county or state), and/or too irregularly in time. In addition, all but one of the currently measurable indicators lacked the disaggregation by social variables, such as race,

class, and gender that is necessary to assess equity, a major cross-cutting constituent of well-being.

Many of the indicators for which data were unavailable measure the subjective perceptions or experiences of resource users and area residents. Obtaining data for these indicators would require conducting surveys and interviews. These research methods could also enhance the assessment of objective social indicators. For example, a survey question regarding how health conditions facilitate or limit resource access would increase the resolution of the physical health indicator and its sensitivity to environmental and management changes. Likewise, additional subjective social indicators can helpfully complement objective indicators. For example, a question about individuals' perceptions of how economic conditions affect resource access would greatly assist in interpreting the coastal livelihoods index. In general, surveys and interviews can significantly increase the amount, resolution, local validity, and explanatory power of information collected for any social indicator.

These results corroborate two common observations among environmental social scientists. One, the preponderance of EBM indicators have focused on the ecological, economic, and physical "conditions" of human well-being, with considerably less attention directed to those constituents of well-being we identify as "connections" and "capabilities," and the cross-cutting domain of "equity and justice." This discrepancy is likely due to narrow conceptualizations of human well-being and limited data availability (Satz et al. 2013; Breslow et al. 2016). Two, existing social indicators and data are typically too broad in scope and resolution to meet the needs of an IEA and EBM. We need new social indicators that are tailored and measured specifically for environmental questions.

Generalizability, scalability, and the need for tiered indicator systems

Our overall approach to selecting indicators was designed to be generalizable, with appropriate modifications, to multiple contexts and scales. Specifically, our conceptual framework of human well-being (Figure 1), screening criteria (Table 2), method for analyzing management relevance (Appendix 1), and process for selecting indicators (Figure 2) may be applied to IEAs and EBM, in general, if adapted for individual circumstances. In addition, our database of available indicators (Breslow et al. 2016) was generated from worldwide sources and may be used, and added to, as a reference. However, our resulting analyses and indicators are specific to marine and coastal management of the western United States (the California Current) and should not be generalized to other regions – with several exceptions. Our analysis of management relevance (Appendix 1) may be extended to other US environmental management contexts. In addition, it may be desirable to develop indicators that are comparable to those presented here. For example, the National Oceanic and Atmospheric Administration (NOAA) may wish to compare the status of the same indicators across multiple IEAs under its jurisdiction. In this case, it will be necessary to screen these indicators for geographic, social, and management relevance in all areas where they will be applied.

These questions of generalizability lead to the more complicated dilemma of scalability. In screening indicators for the California Current ecosystem, it was difficult to find indicators reflecting its full geographic and social diversity. We were forced to exclude a number of indicators that were crucial to distinct places and communities within the region (such as shellfish closures, subsistence harvesting expenses, and outdoor recreational amenities), but were not sufficiently applicable to the region's population as a whole to warrant inclusion in the final suite. In this way, the expectation to compare generalizable indicators of human well-being risks overlooking areas of well-being that are extremely important to certain people, and especially to marginalized communities, such as non-English speakers, who are unable to advocate for their interests in a management context. In contrast, indicators of well-being pertaining to high-profile or economically valuable resources, such as commercial fisheries, will likely be prioritized by managers. In effect, a standardized set of indicators informing policy at a large scale can undermine the well-being of sub-populations by excluding their concerns, including their very disenfranchisement, from view.

This dilemma illustrates that not only are the suites of indicators presented here for the California Current not scalable; they are also not sufficient. Instead, the implicit function of indicators of human well-being – to be comparable, and to actively promote the well-being of a diverse society – suggests the need for tiered sets of indicators, that is, one set that is broadly comparable, and one or more sets that are tailored to smaller scales. The broader set can consist of objective indicators measured with available data, as well as subjective indicators assessed through standard survey questions. The localized sets can be developed such that different indicators appropriate to local scales are developed for the same attribute, which is then qualitatively compared across people and regions. For local validity, as well as to promote self-determination as an attribute of well-being, locally specific indicators should be developed by the people whose well-being is to be assessed (e.g., see Mascia, Claus, and Naidoo 2010; Biedenweg et al. 2014; García-Quijano 2015; Donatuto, Campbell, and Gregory 2016).

Addressing the social consequences of indicators

In selecting indicators of well-being, it is important to keep in mind that indicators are themselves products of a social system, and can have unintended social consequences. For example, indicators can simplify reality in ways that can undermine human well-being; they can shift attention toward easily quantifiable conditions, and away from other critical aspects of well-being; they are often presented as objective measures without acknowledgment of their political origins and underlying assumptions about social change; they can present social–ecological challenges as technical rather than moral and political problems; and they shift resources, power and attention away from stakeholders and democratic processes to professional experts and indicator development and measurement processes (Mccool and Stankey 2004; Merry 2011; Breslow 2015; Hicks et al. 2016).

Indicators, and indicator selection and measurement processes, must be deliberate in addressing these, and other, cautions. Cobb and Rixford note that the "symbolic value of an indicator may outweigh its literal value" (1998, 1, 19) in its political utility and ultimate capacity to effect real change. They observe that indicators will more likely lead to meaningful change if they focus on the causes rather than symptoms of underlying problems, and if they are tailored to the needs of agents with the power and authority to effect change. Furthermore, they explain that a democratic indicators program requires more than a good public participation process: social indicators must inherently serve to enhance principles of justice and equity in the way they are defined, analyzed, and reported.

Key takeaways for practitioners

By testing a comprehensive approach to evaluating social indicators, we show environmental practitioners that it is possible to think systematically, and deeply, about human well-being. We illustrate why it is important to consider a rich set of indicators that reflects the multiple dimensions, and all four "Cs," of well-being (Table 1). We recommend using a fully participatory process to ensure indicators are valid and useful for local people. And we identify an important need to invest in collecting social data in more subject areas and at finer scales if human well-being is to be taken seriously as part of IEAs.

Practitioners need not repeat all of our steps. We designed adaptable frameworks, compiled and categorized worldwide indicators (Breslow et al. 2016), developed a full set of screening criteria, and scoped indicators for two central areas of well-being (resource access and self-determination) as a foundation for others to build from. Concretely, an immediate next step for users of our approach is to evaluate indicators for an additional focal attribute drawn from each "C," and continue this process in an iterative way until overlap in selected indicators reaches a saturation effect (Strauss and Corbin 1990). To save time, users may choose to forego the conceptualization of focal attributes into dimensions and related attributes, reduce or group the screening criteria, and use an expert team to evaluate indicators rather than a full literature review. Priorities are to adapt the frameworks to the local context, ensure local validity of indicators through a participatory process, and develop indicators that truly address the environmental – and social – questions at hand.

The subsequent steps are to scope the data needed to measure the resulting indicators; and, assuming resources are limited, prioritize the most important indicators to invest in with actual assessment, namely by measuring existing data or collecting new data. (Keep in mind that new data collection is not necessarily more resource-intensive than compiling and assessing sources of existing data.) An important caveat to remember is that indicators will never be fully comprehensive, but are meant to provide succinct insights into a complex system to aid in decision-making (Gregory 2012).

The method we propose is admittedly meticulous. Its strength lies in its transparency: in the face of competing indicators, too many indicators, or a highly political atmosphere, this comprehensive and systematic approach demonstrates why certain indicators are chosen over others (Kershner et al. 2011; James et al. 2012). It also reveals important areas of human well-being that have not figured into IEAs and policy and management decisions, in part because we have not yet invested in the necessary human dimensions data collection.

In this paper, we model a way to respond to these cautions and recommendations. A comprehensive conceptualization of human well-being can raise awareness about the multilayered social dynamics of resource management, help identify priorities, and call attention to matters that need further attention. A detailed analysis of management and policy documents ensures indicators are tied directly to the power and stated responsibilities of decision-makers. To mitigate for potential shifts in power and agency away from stakeholders, as well as to improve the local validity of indicators, we emphasize the importance of understandability and transparency, context-specific research, and participatory processes in all stages of indicator development and implementation. Finally, we illustrate how to build equity and justice directly into an indicator system by emphasizing the importance of measuring indicators of resource access and self-determination across social variables, and thereby

assessing inequities and injustices in who benefits from the environment, and in who has a say in environmental decision-making.

Conclusion

An IEA strives to assess the social and ecological conditions of an ecosystem over time in order to track and predict how different management strategies may be affecting ecological integrity and human well-being (Levin et al. 2009). Like the biophysical system, human well-being varies across contexts, and it is difficult to disentangle the influence of environmental and management changes from other social, political, and psychological factors. Furthermore, human well-being depends on both the use and the protection of the environment, and where the balance lies varies for different people. Fairly evaluating human well-being with respect to EBM requires evaluating trade-offs, not only between ecological integrity and human well-being, but also between the well-being of different groups of people. Yet for the most conceptually valid indicators, we found that data are either unavailable, too coarse, or too general to evaluate these trade-offs. These gaps speak to the need to significantly expand our capacity to understand the human well-being of a diverse society, and how it is affected by environmental change and decision-making.

The framework presented here is a prototype: it needs further testing and developing and will need considerable modification to suit diverse contexts. Any further steps should involve the people whose well-being is to be assessed. The framework is designed to encourage governments and communities to support a more just and livable world by rigorously conceptualizing human well-being and deliberately assessing the complex tradeoffs inherent in environmental decision-making.

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