Conceptualizing and Operationalizing Human Wellbeing for Ecosystem Assessment and Management

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Abstract

There is growing interest in assessing the effects of changing environmental conditions and management actions on human wellbeing. A challenge is to translate social science expertise regarding these relationships into structured terms usable by environmental scientists, policymakers, and managers. Here, we present a comprehensive, structured, and transparent conceptual framework of human wellbeing designed to guide the development of indicators and a complementary social science research agenda, for ecosystem-based management. Our framework grew out of an effort to develop social indicators for an integrated ecosystem assessment (IEA) of the California Current large marine ecosystem. Drawing from scholarship in international development, anthropology, geography, and political science, we define human wellbeing as *a state of being with others and the environment, which arises when human needs are met, when individuals and communities can act meaningfully to pursue their goals, and when individuals and communities enjoy a satisfactory quality of life.* We propose four major social science-based constituents of wellbeing: connections, capabilities, conditions, and cross-cutting domains. The latter includes the domains of equity and justice, security, resilience, and sustainability, which may be assessed through crosscutting analyses of other constituents. We outline a process for identifying policy-relevant attributes of wellbeing that can guide ecosystem assessments. To operationalize the framework, we provide a detailed table of attributes and a large database of available indicators, which may be used to develop measures suited to a variety of management needs and social goals. Finally, we discuss four guidelines for operationalizing human wellbeing measures in ecosystem assessments, including considerations for context, feasibility, indicators and research, and social difference. Developed for the US west coast, the framework may be adapted for other regions, management needs, and scales with appropriate modifications.

Keywords

Human wellbeing; indicators; ecosystem-based management; integrated ecosystem assessment; social-ecological system; sustainability

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1. Introduction

The concept of *human wellbeing* is attracting increasing attention in environmental science, policy, and management, most recently at the global scale and in marine contexts (Adger et al., 2005; Cope et al., 2013; Díaz et al., 2015; Mace, 2014; McLeod et al., 2005; Millennium Ecosystem Assessment, 2005a). In part, this is due to the inclusion of people and human societies in definitions of "ecosystem" (Mace, 2014; McLeod et al., 2005); the rise of the paradigm of ecosystem services (Díaz et al., 2015; Millennium Ecosystem Assessment, 2005a); and a renewed appreciation for human wellbeing as a better measure of social progress than conventional economic measures such as gross domestic product (GDP) (Cobb and Rixford, 1998; Gough and McGregor, 2007; Stiglitz and Sen, 2009). Social scientists, in fields such as fisheries anthropology, social forestry, health, and international development have produced a rich literature on human wellbeing as it pertains to the environment at individual, community and societal scales, using a range of approaches (Chan et al., 2012; Charnley et al., 2012, 2008; Coulthard, 2012; Donatuto et al., 2014; García-Quijano, 2015; Pollnac et al., 2006; Pollnac and Poggie, 2006; Satterfield et al., 2013; Stephanson and Mascia, 2014). The challenge is to translate these diverse insights from the social sciences into a cohesive framework for assessing human wellbeing that is specifically designed for the current demands of environmental science, policy, and management (Breslow 2015, Castree et al. 2014, Fish 2011, Hicks et al. 2016, Levin et al., 2014; Samhouri et al., 2014, Satterfield et al. 2013).

Ecosystem-based management (EBM) represents a shift from a single-species, extraction-oriented focus in resource management toward a more holistic philosophy that strives to balance the multiple interrelated dimensions of ecological integrity and human wellbeing (McLeod and Leslie, 2012; Millennium Ecosystem Assessment, 2005a). Integrated Ecosystem Assessments (IEAs) were formalized as an approach for implementing EBM in marine ecosystems (Levin et al., 2009), and seek to answer three primary questions: 1) What constitutes a "heathy" ecosystem?; 2) Is the ecosystem being assessed currently healthy?; and, 3) What management strategies can maintain or improve ecosystem health? IEAs use indicators to help answer these questions. Indicators represent features of the social or biophysical system that can be easily measured and tracked over time in order to understand how the system is changing, what interventions may be necessary, and whether these interventions are effective (Mascia et al., 2014). To date, IEAs have largely employed biophysical indicators to assess ecological conditions (Samhouri et al., 2014). However, because IEAs promise to consider the full social-ecological system (Levin et al., under review), they must explicitly include human wellbeing in the assessment, and thus must confront the challenge of operationalizing the concept of human wellbeing.

Human wellbeing evokes, variably, quality of life, happiness, and the social and economic conditions of individuals, communities and societies. Here we define human wellbeing as *"a state of being with others and the environment, which arises when human needs are met, when individuals and communities can act meaningfully to pursue their goals, and when*

individuals and communities enjoy a satisfactory quality of life." We build on the definition developed by the Wellbeing in Developing Countries research group (WeD) (Coulthard et al., 2011; McGregor, 2008), and adapt it for EBM by emphasizing a dynamic set of conditions whereby the major dimensions of wellbeing operate at multiple social scales within a social-ecological context.

Global assessments of human wellbeing use comparable, objective, quantitative indicators to measure tangible qualities of the economy, the environment, human health, and education (United Nations, 2008; United Nations and Department of Economic and Social Affairs, 2007; United Nations Human Development Programme, 2014). These global efforts leave less tangible, yet important dimensions of wellbeing unassessed, such as social relationships, and cultural and spiritual values (Satterfield et al., 2013; Turner et al., 2008). National and regional assessments use more diverse measures than these global assessments, yet human connections to the environment remain underrepresented (e.g. Michalos et al., 2011; OECD, 2013a; Office for National Statistics, 2015) or limited due to lack of indicators and data (Australian Bureau of Statistics, 2013; see also the review by Smith et al., 2013). In cases where measures of wellbeing have been designed specifically for environmental management, they are typically assessed at scales that are too coarse to definitively track the social effects of acute environmental events, such as an oil spill, or specific management actions, such as catch shares and boat buy-back programs (Dillard et al., 2013; Dunn, 2013; Leisher et al., 2013; Summers et al., 2014). Others are very specific, focused, for example, on fishing communities (e.g. Colburn and Jepson, 2012; Pollnac and Poggie, 2006), marine protected areas (Mascia et al., 2010) or forest ecosystems (Edwards, 2011), and therefore may not translate effectively to other social and ecological contexts. Additionally, ecosystem services frameworks (e.g. Millennium Ecosystem Assessment, 2005a) primarily attend to the one-way delivery of benefits from the natural environment to humans, without fully accounting for the interdependencies between social and ecological systems, and how management might directly affect wellbeing (Breslow, 2015; Fish, 2011; Satz et al., 2013).

Here we develop a comprehensive framework of human wellbeing as it relates to environmental conditions and management actions. Our effort was initiated by the U.S. National Oceanic and Atmospheric Administration (NOAA) to inform the IEA of the California Current, the large marine ecosystem that stretches from Vancouver Island, Canada, through the US West Coast, to Baja California, Mexico (http://www.noaa.gov/iea/regions/california-current-region/index.html). We combine an analysis of US marine and environmental management priorities with a synthesis of existing wellbeing concepts to advance a framework of human wellbeing that is expressly designed for EBM. Below, we propose four major constituents of wellbeing, outline a process for identifying policy-relevant attributes of wellbeing, and recommend guidelines for using the framework to select indicators and scope complementary social science research for ecosystem assessments. While our focus is on U.S. marine

management, our approach is designed to be adaptable to other regions, management needs, and scales, with appropriate modifications.

2. A Conceptual Framework of Human Wellbeing

We developed a detailed conceptual framework of human wellbeing to guide the selection and analysis of social indicators for an IEA, and scope complementary social science research. In developing the framework, we strove to serve the needs of resource managers, while improving social science literacy and awareness of the multidimensionality of human wellbeing. Our framework is distinguished from several well-known examples in its very pragmatic emphasis on management needs. While other frameworks begin with theoretical principles (e.g. Meadows 1998), empirical observations (Millennium Ecosystem Assessment 2005b), or a review of existing domains and indicators (Smith et al. 2013), ours is built on an analysis of managers' responsibilities vis a vis human wellbeing as articulated in management and policy documents. These are then augmented and organized according to social science principles. In this way, the framework focuses attention on aspects of human wellbeing for which managers, and decision-makers, may be held accountable (Cobb and Rixford 1998, Sojka 2014). The framework is furthermore designed to serve as a conceptually sound structure through which managers can meet the increasingly common expectation to conduct ecosystem assessments using available indicators and existing data. At the same time, it serves to highlight where original social science research is needed to understand the complex, intangible, subjective, and currently understudied dimensions of human wellbeing. Finally, like many other approaches, we stress that the framework should be adapted to local social goals and values using participatory processes. Yet since public participation is not always democratic or equitable (Cobb and Rixford 1998, Scott 2012), we deliberately build in measures of freedom and voice, and equity and justice. Our framework encourages a pragmatic and conceptually robust approach to assessing human wellbeing, rather than one dictated by available indicators and data.

The resulting "4-C's" framework (Figure 1) draws inspiration from several major, independent conversations regarding human wellbeing and the human dimensions of environmental challenges. It conceptually integrates insights from fields currently underrepresented in environmental science, including anthropology, geography, and political science, with more commonly encountered approaches to wellbeing found in economics and international development (Appendix A).

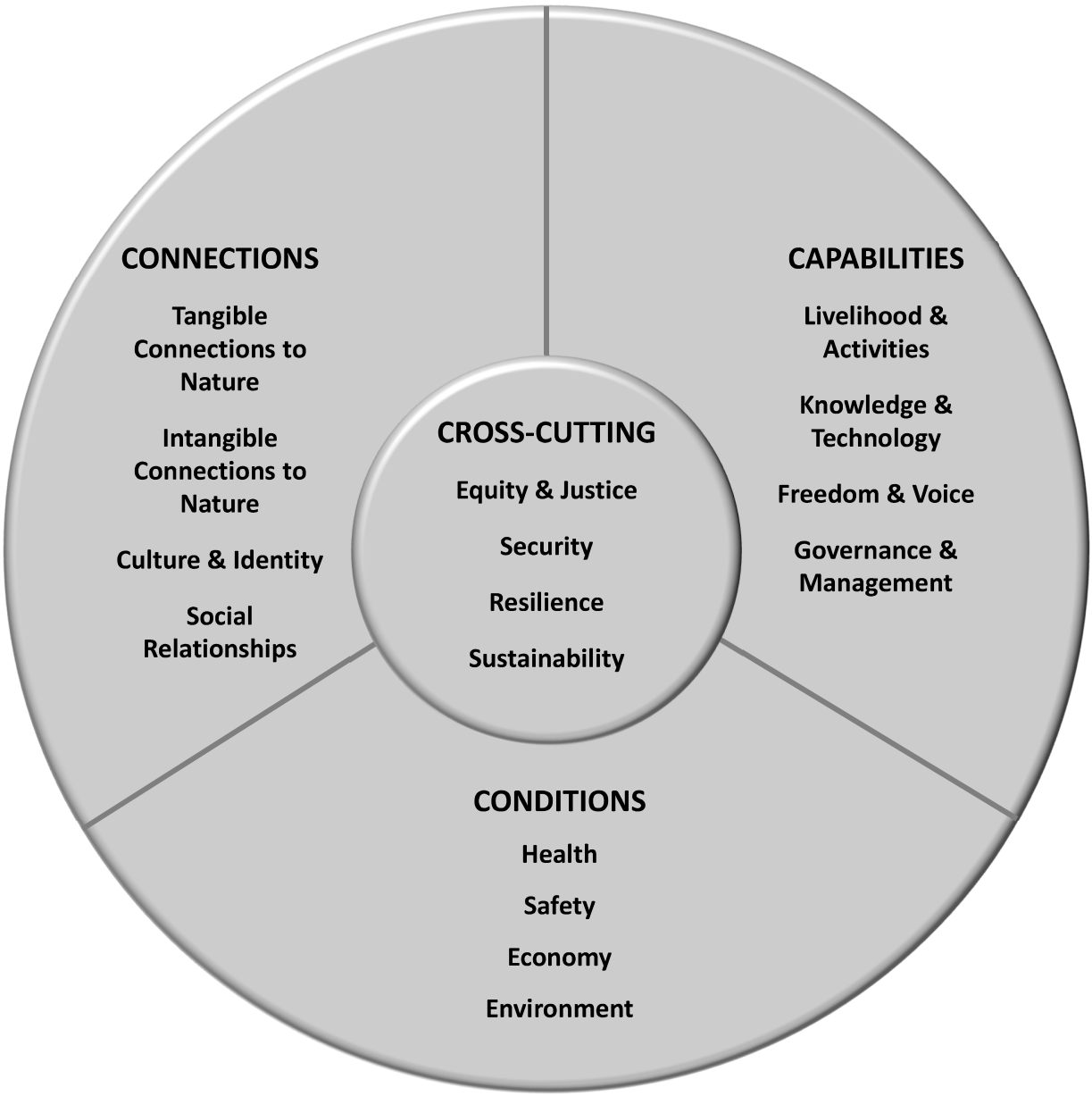


Figure 1. The 4-C's conceptual framework of human wellbeing.
A framework of human wellbeing for ecosystem-based management that calls attention to four major constituents of human wellbeing: *connections, capabilities, conditions,* and *cross-cutting domains.* Each constituent is in turn associated with four major domains.

The framework is structured according to a set of nested categories: constituents, domains, attributes, and indicators (Figure 2).

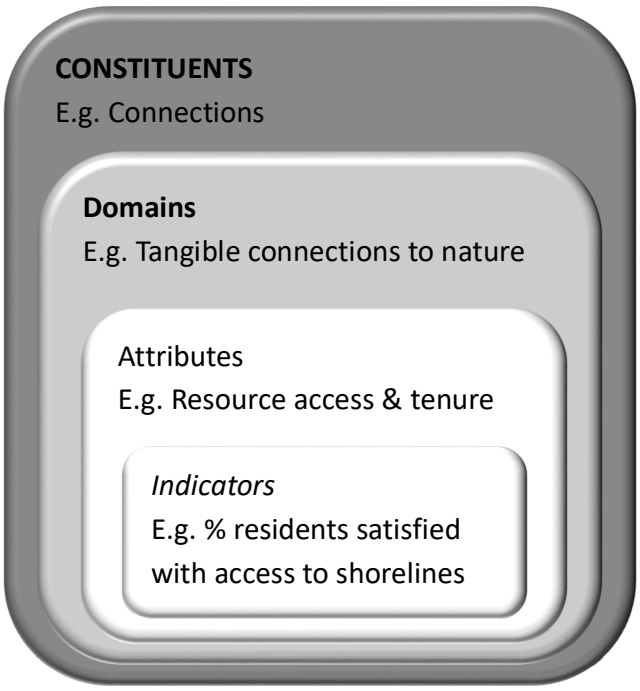


Figure 2. The nested structure of the 4-C's framework of human wellbeing.

We operationalize human wellbeing by decomposing it into four major constituents: *conditions, connections, capabilities*, and *cross-cutting domains* (hence "4-C's"). Each constituent is in turn composed of four recognizable domains with relevance to EBM. Note that each constituent also reflects a clause of our definition. *Conditions* refer to circumstances in which "human needs are met," and include the tangible qualities of environment, economy, safety, and human health, which are commonly measured in general wellbeing assessments. *Connections* refer to "being with others and the environment," and include the tangible and intangible interrelationships we have with other people and with nature, and our cultural values and identities. *Capabilities* are the factors directly enabling individuals and communities to "act meaningfully to pursue their goals," including activities, knowledge systems, political participation, and governance. Finally, the *cross-cutting* domains of equity and justice, security, resilience, and sustainability suggest a state of caring for oneself, other people and living things, and sustaining our collective "satisfactory quality of life," now and into the future. These are inherent domains of wellbeing in that they impinge directly on one's wellbeing, and they are also "cross-cutting" because their status results from variabilities and interactions among all constituents.

The 4-Cs framework calls central attention to the four cross-cutting domains. *Equity and justice* are central concerns in social sciences and studies of human wellbeing, yet their

significance for EBM remains underappreciated (Hicks et al., 2016, Turner et al., 2008). Relative experiences and perceptions of inequity directly influence wellbeing: one's location in a social hierarchy contributes to one's negative or positive quality of life in a self-reinforcing pattern (Luttmer, 2004; Marmot et al., 1991; Morris and Halkitis, 2015; Wilkinson, 2010). Pragmatically, inequities in resource access and decision-making can lead to inter-group conflicts and retaliation that complicate management goals (Breslow, 2014a, 2014b; Goldman et al., 2013), and managers may have a legal responsibility to identify and reduce inequities in exposure to environmental hazards, e.g. as mandated in the US executive order on environmental justice (Executive Order 12898). Similarly, having confidence in the *security* of favorable conditions, such as employment or democratic governance, and in one's *resilience* or adaptability to changing conditions, such as climate change, contributes directly to one's wellbeing (Adger, 2006; Nelson et al., 2007; Smit and Wandel, 2006). More broadly, the wellbeing of human society over the long term depends on its ability to sustain all elements of human wellbeing while maintaining the quality of the environment on which it depends (Stiglitz et al., 2010).

2.1. Identifying and Organizing Attributes

Identifying relevant attributes for each domain of wellbeing is an instrumental step for developing indicators of status and change. Here, attributes were identified for their social science validity, and their relevance to the social, ecological and management context of the California Current region (Table 1). In addition to providing conceptual structure, Table 1 serves as an index to an underlying database of existing indicators (Appendix B), and helps identify areas where new indicators may need to be developed. The table is designed to facilitate the selection of indicator portfolios for an IEA.

Table 1. Human wellbeing attributes identified for their relevance to ecosystem-based management in the California Current region.
Major attributes of human wellbeing identified for their relevance to ecosystem-based management in the California Current region. The left-hand column lists constituents (dark grey), domains (grey), and attributes (light grey). The right-hand column lists working definitions of attributes (in bold), and examples of indicator topics related to each attribute (in italics). See Appendix B for existing indicators relating to each attribute.

Human Wellbeing Categories	**Attribute Definitions** *Indicator Topics*
CONNECTIONS	
Tangible Connections to Nature	
Resource Access & Tenure	Direct avenues & outcomes of access to natural resources *Evidence of access to natural resources (e.g. water, minerals, wildlife, fish); constraints to access; land and resource ownership; modes of access; natural resource harvests*
Access to Nature	Direct avenues & outcomes of access to nature and natural places *Recreational and tourism access; wildlife viewing areas; proximity to green spaces, water, and open space; recreation and tourism experiences*

Stewardship	Active conservation & sustainability practices *Protected areas; restoration; recycling; environmental education; organic farming; ecosystem health; green building*
Intangible Connections to Nature	
Beauty & Inspiration	Aesthetic value and creativity inspired by nature *Viewshed, aesthetic value, inspiration, waterfront*
Sense of Place	Meaning & identity connected to a place *Activities on the landscape, heritage, social and emotional connections to places*
Spirituality	Sense of spirituality or connectedness with environment
Culture & Identity	
Identity	Sense of self or community *Individual, household, and community symbolic sense of relationships; self-definition (individually and in relation to community); sense of connection to labor and environment*
Cultural Values & Practices	Culture, language, & the arts *Languages spoken; cultural sites; cultural practices; arts; traditional ecological knowledge; environmental ethos; community events*
Heritage	Generational connections to place & culture *Multi-generational interaction with natural resources; archeological and historic sites; cultural resources; acceptable historical change*
Social Relationships	
Family & Community	Personal relationships & community support *Family, joint family endeavors; sense of community, trust in neighbors, marriage & divorce, childcare, community spaces (e.g. play grounds and community halls)*
Civil Society	Non-governmental society *Private and non-profit organizations (e.g. religious, environmental, and social service groups); volunteering*
Social Diversity & Integrity	Social fabric & inter-community relations *Demographic characteristics (population, density, race/ethnicity, immigration and emigration, age and gender distributions); trust in people; inter-group relations; refugees; urbanization*
CAPABILITIES	
Livelihood & Activities	
Subsistence	Harvesting food & materials for self, family, or community *Subsistence harvests, access to resources and knowledge, ability to meet costs and obtain permits*
Job Quality	Job quality *Job duration, employment options, living wage, benefits & flexibility, job satisfaction*
Recreation & Tourism	Recreation and tourism assets, opportunities, & attendance
Time for Fulfilling Activities	Amount of leisure time *Time spent working, commuting, volunteering, voting, recreating; work-life balance*
Knowledge & Technology	
Education & Information	Possession & transmission of knowledge, information & skills *Literacy rates; educational access, attendance and achievement; training; qualifications; access to information; advisories; outreach; specialized knowledge & skills*
Research & Technology	Production of new knowledge & tools *Support for and level of research and technology; patents; access to technology*

	and data; ability to produce/contribute new knowledge
Freedom & Voice	
Self-Determination	Independence, agency, freedom from social or governmental constraints *Autonomy and ability to control one's own life; financial independence and debt; access to credit*
Political Participation	Having a voice in decision-making *Voting; participation in decision-making processes and leadership; stakeholder processes; exercising rights; interest in politics*
Sovereignty	Self-governance & tribal sovereignty *Local, regional or tribal control; treaty rights*
Governance & Management	
Resource Management	Governmental management of natural resources *Effectiveness of management; perceptions of management; permits & regulations; adequate funding and staff capacity for achieving management objectives; partners and collaboration; voice and participation in management*
Public Services	Governmental social services *Health & human services; public utilities & transit; public expenditures*
General Governance	Principles and practices of effective governance *Public debt, taxes, governmental expenditures; inter-agency coordination; transparency*
CONDITIONS	
Health	
Food	Food & water access, quality, & security *Agricultural and fisheries harvests; food & drinking water access, abundance, quality, security & sovereignty; nutrition; fertilizers & pesticides*
Physical Health	Health conditions, access to health care & healthy choices *Disease, injuries, life expectancy, birth and death rates, mortality; access to health care, healthy food & lifestyle; health advisories; perceptions of health*
Emotional & Mental Health	Mental health, emotional wellbeing, & perceived quality of life *Happiness, attitude, trust, subjective wellbeing, stress, depression, suicide rates*
Safety	
Disaster Preparedness	Preparedness for large-scale environmental disasters *Preparedness for oil spills, tsunamis, climate change, severe weather; density in hazard zones; communications infrastructure; number of events; life and value lost*
Physical Safety	Safety at work and at home *Occupational risks and emergency services, building codes, injuries*
Peace & Security	Presence, absence and prevention of violence and war *Crime, non-compliance, emergency services, sense of personal safety, acts of violence, refugees*
Economy	
Local & Informal Economies	Exchange of goods and services locally and/or outside of money economy *Farmers' markets; local producers & consumers; gifting, bartering, trading; value, volumes and percentages of reciprocal and in-kind "transactions"*
Material Wealth & Security	Material assets & consumption *Resources consumed, possessions, costs & affordability, basic needs, poverty, debt, access to credit, material security*
Employment & Income	Employment and income levels *Jobs, wages, and income overall & by sector and social variables; sector diversity within a population; poverty (see "job quality" for other employment characteristics)*

Industry & Commerce	Commercial & industrial production, trade & revenue *GDP, investment, general economic activity, business & industry sector characteristics, commercial resource harvests and extraction*
Environment	
Infrastructure	The human built environment *Roads, ports, housing & transit; development configurations; recreational assets; impervious surface*
Pollution & Waste	Anthropogenic pollution & biotoxins *Municipal & hazardous waste, sanitation, recycling, air & water quality, carbon emissions, shellfish & beach closures, fish consumption advisories, surface filtration & run-off*
Environmental Quality	Quality or condition of natural environment & natural resources *Ecosystem health, integrity, productivity; land use intensity; soil & water quality; invasive species, habitat fragmentation & degradation; restored habitats*
Resource Abundance & Distribution	Quantity and coverage of natural resources and ecosystem types *Land cover, use & designations; species assemblages & abundances; protected areas, parks, & gardens*
CROSS-CUTTING	
Equity & Justice	*Comparisons for all attributes among gender, age, ethnicity, income & other variables; evidence of racism & discrimination; rights; human rights violations*
Security	*Evidence of stability of favorable conditions among all other attributes, and ability to plan future in the short-term*
Resilience	*Evidence of social-ecological adaptability to changing conditions among all other attributes*
Sustainability	*Sustainability in the long-term for all other attributes and activities: long-term, multi-generational practices; fossil fuel production and consumption; depletion of non-renewable resources; species extinctions*

We used a systematic process to develop the 4-Cs framework, aiming for both management relevance and conceptual validity. We first identified human wellbeing priorities articulated in U.S. governmental documents. We reviewed twelve major U.S. federal legislative, policy, science, and management documents guiding management of the U.S. west coast marine and coastal region (Table 2). We used qualitative analysis techniques and employed AtlasTi software to select and code keywords, phrases and paragraphs that described how the marine environment and marine management are thought to benefit people directly, or that reflected social goals for marine policy and management.

Table 2. U.S. legislative, policy, science and management documents pertaining to marine and coastal management of the California Current region initially analyzed for attributes of wellbeing.

Legislative documents
Magnuson Stevens Act Amended (2007)
National Marine Fisheries Service National Standards Guidelines (2009)

Policy documents
Executive Order: Stewardship of the Ocean, Our Coasts, and the Great Lakes (2010)
Ocean Policy Task Force Final Recommendations (2010)

Ocean Research Priorities Plan Update (2013)
National Ocean Policy Implementation Plan (2013)

Science and management documents
California Current Integrated Ecosystem Assessment Report Summary (2012)
California Current Integrated Ecosystem Assessment Human Dimensions Chapter (2013)
California Current Integrated Ecosystem Assessment Engagement Chapter (2013)
Pacific Fisheries Management Council Draft Indicators (2013)
Pacific Fisheries Management Council Pacific Coast Ecosystem Fishery Plan (2013)
Pacific Fisheries Management Council Pacific Coast Fishery Ecosystem Plan Ecosystem Initiatives Appendix (2013)

Using the same technique, we next identified attributes of wellbeing articulated in reports of the Commission on the Measurement of Economic Performance and Social Progress (also known as the Sarkozy Commission), a high profile initiative led by internationally-recognized social scientists to identify alternatives to gross domestic product (GDP) as a metric of human progress (Alkire, 2008; Stiglitz et al., 2010; Stiglitz and Sen, 2009).

We then compared the two lists of attributes. Many of the major areas of wellbeing expressed in these two sets of documents overlap, while others are unique to each source (Table 3). Those unique to the legislative and policy documents suggest areas of wellbeing that may be of specific interest to U.S. environmental decision-makers and managers. Areas unique to the Sarkozy Commission reports may suggest concepts of wellbeing developed in the social sciences that have not yet captured the attention of U.S. environmental managers. Together, they begin to construct a comprehensive typology of human wellbeing applicable to EBM in the California Current region.

Table 3. Preliminary attributes of wellbeing resulting from an analysis of US governmental documents (Table 2) and the Sarkozy Commission reports (Alkire, 2008; Stiglitz et al., 2010; Stiglitz and Sen, 2009). # = domains unique to the US governmental documents; * = domains unique to the Sarkozy Commission reports.

	Agency/Self-Governance/Sovereignty
#	Archaeological/Historic Heritage
	Beauty/Aesthetics/Amenities
	Certainty/Predictability/Ability to Plan Future
*	Civil Society
	Commerce/Trade/Revenue
#	Community Vibrancy/Integrity/Stability/Adaptability
	Conflict Reduction/Resolution
	Cultural Values/Traditions/Valued Practices
	Demographics – Diversity/Density
#	Diversity/Multiple Resource Users
	Education/Outreach/Awareness
*	Emotion/Attitude
	Environmental Quality
#	Environmentalism/Stewardship/Conservation
#	Food/Nutrition/Food Security
	Governance/Management/Public Services
	Health (Physical and Mental)
	Infrastructure/Built Environment/Housing
	Jobs/Livelihood/Employment
	Local Economies/Corporate Consolidation
	Material Wellbeing/Wealth/Prosperity/Economic Security
*	Personal Activities/Time Allocation
	Place Attachment/Sense of Place/Place-Based
	Public/Political/Democratic Participation
	Recreation and Tourism
	Resilience/Hazards Preparedness
#	Resource Access, Availability, Utility
	Science/Research/Knowledge
	Security/Peace/Safety
	Social Capital
	Social Justice/Equity
*	Social Relationships
#	Subsistence
	Sustainability/Future Generations' Wellbeing
#	Wonder/Spirituality/Existence Value

* Identity

We tested the operational utility of this preliminary list of attributes by using it to organize and code 2300 existing indicators (Appendix B). While the preliminary list proved to be relatively stable, this step led us to add or modify several attributes in order to accommodate the wide range of existing indicator topics. We further tested the ability of the list to capture human wellbeing priorities identified in several additional governmental documents (Appendix D), including general US and Canadian federal environmental legislation and the UN Declaration on the Rights of Indigenous People. In these ways, the list of attributes was tested and modified for applicability to regions beyond the U.S. west coast.

Finally, we organized these preliminary attributes into thematic clusters that became the domains of our conceptual framework. We then worked in an iterative fashion to modify the categories and wording of the domains and attributes to achieve a final list that reflected our shared expertise regarding human wellbeing, resonated with key subjects in the social science and management literatures, and could serve as an index to existing indicators (Table 1).

3. Guidelines for Operationalizing the Framework

The 4-C's framework is designed to assist in selecting a conceptually valid and pragmatic set of social indicators for EBM, and in outlining where additional social science research is needed. To operationalize the 4-Cs framework, and by way of discussion, we provide the following guidelines. (For detailed examples of guidelines 2 and 3, see Breslow et al., n.d. For best practices in social science research methods and data, see Charnley et al., in review).

1. Tailor the framework to the context of interest. Although designed for generalizability, the 4-Cs framework was initiated for the U.S. west coast region, and will need to be modified for other contexts. To achieve local validity while maintaining conceptual validity, the goal is to revise domains, attributes, and indicators so they are meaningful to the intended audience, while still reflecting the major constituents of wellbeing. Large-scale and comparative assessments must take special care to ground-truth local validity before generalizing results across diverse social groups and geographies. Contextual relevance can be achieved through analysis of stated management goals and responsibilities for the region of interest, as illustrated above (see also Sojka, 2014), contextual research such as historical and ethnographic studies, and participatory processes that identify local social goals and concepts of wellbeing (e.g. see Biedenweg et al., 2014; Britton and Coulthard, 2013; Donatuto et al., 2014, 2011). The latter may entail public meetings with representative decision-makers and stakeholders, community meetings, focus groups, and in-depth interviews. Note that this is a major step still required for the California Current indicators. In addition to improving the final set of indicators, participatory processes can themselves improve human wellbeing by fostering social relationships and trust (Eldridge, 2013; Fraser et al., 2006; Levine and Feinholz, 2015; Scott, 2012).

2. Identify and conceptualize focal attributes. Indicators serve multiple purposes, from technical analyses to symbolic communication, and they require resources to develop and use. It

may not be desirable, nor feasible, to develop indicators for all attributes in Table 1. This raises the question of how to select a small set of indicators that collectively reflect the complexity of human wellbeing. One solution is to work with managers and stakeholders to identify a subset of priority areas of wellbeing, here called *focal attributes*, with at least one drawn from each of the outer constituents of the framework (conditions, connections, and capabilities). If fully conceptualized, focal attributes can reflect the breadth of wellbeing while focusing indicators on priority areas. This is because, despite the analytic need for distinct categories, attributes of human wellbeing are not inherently mutually exclusive entities (Alkire, 2008). An in-depth conceptualization of each *focal attribute* will reveal that it overlaps with many of the other attributes in the conceptual model. For example, "resource access" depends on many factors, such as environmental and economic conditions, physical health, social relationships, and participation in resource management decisions (Breslow et al., n.d.). Thus, as a focal attribute, "resource access" can provide insight into each of these related attributes of wellbeing, with an emphasis on their significance with respect to accessing natural resources. In this way, carefully selecting a set of *focal attributes* can create a more manageable, yet still balanced framework through which to select indicators.

3. Develop a set of indicators for each focal attribute, and identify where complementary research is needed. Choosing indicators for a specific attribute typically involves compiling available candidate indicators, screening them according to predefined criteria, and selecting parsimonious sets that serve the purpose at hand (James et al., 2012; Kershner et al., 2011; Levin et al., 2009). To facilitate the selection process, we developed a database of nearly 2300 existing social indicators (Appendix B) compiled from 34 projects around the world (Appendix C) and coded each indicator with relevant attributes from Table 1. With this database, one can quickly identify a list of indicators pertaining to one or more attributes. If needed, additional indicators can be added to the database, and the coding scheme can be modified. Standard guidelines outline criteria for selecting valid and measurable indicators; specific criteria for IEA indicators are sensitivity and responsiveness to environmental or management change (Gregory, 2012; Keeney and Gregory, 2005). With these criteria, new indicators may need to be developed to fully assess human wellbeing in an EBM context (Breslow et al., n.d.).

After the screening process has identified a short list of candidate indicators, it is important to evaluate them for their coverage of desired qualities. For example, it may be desirable to measure indicators that provide insight into wellbeing at various levels of social organization (individual, community, societal); that track leading causes as well as lagging consequences of change; and that can provide general as well as specific insights into wellbeing. In particular, social indicators, unlike biophysical indicators, can be both *objective* and *subjective*, meaning they can measure both externally observable features of wellbeing, as well as how people perceive their own wellbeing -- which is in itself an important dimension of wellbeing. For example, an objective measure of "resource access" might be miles of publicly accessible shoreline, while a subjective measure might be whether a respondent feels they have

sufficient access to the shoreline. We suggest it is important to develop a mix of objective and subjective indicators for each focal attribute, to enable comparisons among objective circumstances, test how they relate to subjective experiences, and assess if and how both differ across social variables.

At this stage it is important to evaluate whether existing indicators and data can adequately assess focal attributes and overall human wellbeing in the region or community. A gap analysis can help identify where complementary qualitative or quantitative social science research may be needed, such as to assess the less tangible and subjective dimensions of wellbeing and the interrelationships among multiple dimensions of wellbeing.

4. Measure indicators, and conduct cross-cutting analyses, and contextual research. Both quantitative and qualitative data are valuable for measuring and assessing social indicators. Quantitative data presented in tables, charts, and maps can quickly communicate status and trends in human wellbeing. Qualitative information can provide essential detail regarding the contexts and causal relationships that explain if and how those trends are related to environmental and management changes. Qualitative data often provide more robust insight into certain domains of human wellbeing, such as culture and identity, and intangible connections to nature. However, sufficient data of either type may not be readily available, and new data collection will likely be necessary. Specifically, measuring subjective indicators will likely require surveys and interviews.

A crucial step is to analyze indicators across social variables and time in order to assess cross-cutting domains. While aggregated indices or average indicator values can be useful, measuring and comparing the wellbeing of different social groups is necessary in order to reveal inequities (Daw et al., 2011). Furthermore, measuring attributes over time – whether using historical data or periodic monitoring – enables assessment of the degree of security, change, and resilience to disruptive change that individuals and communities experience in multiple aspects of their lives. At the broadest scale, an assessment of social-ecological sustainability entails evaluating key variables, such as energy production and consumption, resource use and condition, and social equity, as to whether they can collectively persist in desired conditions over multiple generations (Stiglitz and Sen, 2009).

Finally, research into the historical and social context of the region and community is essential for accurately interpreting the significance of indicator results (Breslow 2014b, Charnley et al. in review).

4. Conclusion

With increasing attention to the human dimensions of environmental problems, efforts are underway to assess the effects of changing environmental conditions on human wellbeing. Here, we present and operationalize a comprehensive framework to guide the selection of indicators and scope a complementary research agenda. The framework is designed to promote structured, transparent, and comprehensive indicator sets and research that can capture how the

major constituents of wellbeing are affected by both environmental changes and management strategies. We offer this framework in the spirit of encouraging richer engagement with the social sciences in EBM, a deeper understanding of the human-environment relationship, and, ultimately, the meaningful improvement of human wellbeing as an integral part of planetary sustainability.

REFERENCES

Adger, W.N., 2006. Vulnerability. Glob. Environ. Change 16, 268–281. doi:10.1016/j.gloenvcha.2006.02.006

Adger, W.N., 2000. Social and ecological resilience: are they related? Prog. Hum. Geogr. 24, 347–364. doi:10.1191/030913200701540465

Adger, W.N., Hughes, T.P., Folke, C., Carpenter, S.R., Rockström, J., 2005. Social-ecological resilience to coastal disasters. Science 309, 1036–1039. doi:10.1126/science.1112122

Agrawal, A., Lemos, M.C., 2007. A greener revolution in the making? Environmental governance in the 21st century. Environ. Sci. Policy Sustain. Dev. 49, 36–45. doi:10.3200/ENVT.49.5.36-45

Alkire, S., 2008. The capability approach to the quality of life. Backgr. Rep. Prep. Comm. Meas. Econ. Perform. Soc. Prog. Paris.

Australian Bureau of Statistics, 2013. Measures of Australia's progress.

Berkes, F., Ross, H., 2013. Community resilience: toward an integrated approach. Soc. Nat. Resour. 26, 5–20. doi:10.1080/08941920.2012.736605

Biedenweg, K., Hanein, A., Nelson, K., Stiles, K., Wellman, K., Horowitz, J., Vynne, S., 2014. Developing human wellbeing indicators in the Puget Sound: focusing on the watershed scale. Coast. Manag. 42, 374–390. doi:10.1080/08920753.2014.923136

Brechin, S.R., Wilshusen, P.R., Fortwangler, C.L., West, P.C., 2002. Beyond the square wheel: toward a more comprehensive understanding of biodiversity conservation as social and political process. Soc. Nat. Resour. 15, 41–64. doi:10.1080/089419202317174011

Breslow, S.J., 2015. Accounting for neoliberalism: "social drivers" in environmental management. Mar. Policy. doi:10.1016/j.marpol.2014.11.018

Breslow, S.J., 2014a. Tribal science and farmers' resistance: a political ecology of salmon habitat restoration in the American Northwest. Anthropol. Q. 87, 727–758.

Breslow, S.J., 2014b. A complex tool for a complex problem: political ecology in the service of ecosystem recovery. Coast. Manag. 42, 308–331. doi:10.1080/08920753.2014.923130

Breslow, S.J., Allen, M., Danielle Holstein, Sojka, B., Barnea, R., Agrawal, A., Basurto, X., Carothers, C., Charnley, S., Dolsak, N., Donatuto, J., Garcia-Quijano, C., Hicks, C., Levine, A., Mascia, M., Norman, K., Poe, M., Satterfield, T., Martin, K.S., Levin, P.S., unpublished manuscript. Selecting indicators of human wellbeing for ecosystem-based management.

Britton, E., Coulthard, S., 2013. Assessing the social wellbeing of Northern Ireland's fishing society using a three-dimensional approach. Mar. Policy 37, 28–36. doi:10.1016/j.marpol.2012.04.011

Castree N., Adams, W.M., Barry, J., Brockington, D., Büscher, B., Corbera, E., et al. 2014. Changing the intellectual climate. Nat. Clim. Change. 4, 763–768.

Chan, K.M.A., Satterfield, T., Goldstein, J., 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecol. Econ. 74, 8–18. doi:10.1016/j.ecolecon.2011.11.011

Charnley, S., Carothers, C., Satterfield, T., Levine, A., Poe, M., Norman, K., Donatuto, J., Mascia, M., Breslow, S., Levin, P., Basurto, X., Hicks, C., Garcia-Quijano, C., St. Martin, K., Agrawal, A., Dolsak, N., in review. Best available social science for natural resource management decision-making. Environmental Science and Policy.

Charnley, S., Donoghue, E.M., Moseley, C., 2008. Forest management policy and community well-being in the Pacific Northwest. J. For. 106, 440–447.

Charnley, S., Jakes, P.J., Schelhas, J., 2012. Socioeconomic assessment of Forest Service American Recovery and Reinvestment Act projects: key findings and lessons learned. General Technical Report PNW-GTR-832. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Cobb, C.W., Rixford, C., 1998. Lessons learned from the history of social indicators. Redefining Progress, San Francisco, California.

Colburn, L.L., Jepson, M., 2012. Social indicators of gentrification pressure in fishing communities: a context for social impact assessment. Coast. Manag. 40, 289–300. doi:10.1080/08920753.2012.677635

Cope, M.R., Slack, T., Blanchard, T.C., Lee, M.R., 2013. Does time heal all wounds? Community attachment, natural resource employment, and health impacts in the wake of the BP Deepwater Horizon disaster. Soc. Sci. Res. 42, 872–881. doi:10.1016/j.ssresearch.2012.12.011

Coulthard, S., 2012. What does the debate around social wellbeing have to offer sustainable fisheries? Curr. Opin. Environ. Sustain. 4, 358–363. doi:10.1016/j.cosust.2012.06.001

Coulthard, S., Johnson, D., McGregor, J.A., 2011. Poverty, sustainability and human wellbeing: A social wellbeing approach to the global fisheries crisis. Glob. Environ. Change 21, 453–463. doi:10.1016/j.gloenvcha.2011.01.003

Cronon, W., 1996. Uncommon Ground: Rethinking the Human Place in Nature. W.W. Norton, New York.

Daw, T., Brown, K., Rosendo, S., Pomeroy, R., 2011. Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. Environ. Conserv. 38, 370–379. doi:10.1017/S0376892911000506

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Baldi, A., others, 2015. The IPBES Conceptual Framework—connecting nature and people. Curr. Opin. Environ. Sustain. 14, 1–16.

Dillard, M.K., Goedeke, T.L., Lovelace, S., Orthmeyer, A., 2013. Monitoring well-being and changing environmental conditions in coastal communities: development of an assessment method (No. NOAA Technical Memorandum NOS NCCOS 174). NOAA National Centers for Coastal Ocean Science, Silver Spring, Maryland.

Donatuto, J., Grossman, E.E., Konovsky, J., Grossman, S., Campbell, L.W., 2014. Indigenous community health and climate change: integrating biophysical and social science indicators. Coast. Manag. 42, 355–373. doi:10.1080/08920753.2014.923140

Donatuto, J.L., Satterfield, T.A., Gregory, R., 2011. Poisoning the body to nourish the soul: prioritising health risks and impacts in a Native American community. Health Risk Soc. 13, 103–127. doi:10.1080/13698575.2011.556186

Donoghue, E., Sturtevant, V., 2007. Social science constructs in ecosystem assessments: revisiting community capacity and community resiliency. Soc. Nat. Resour. 20, 899–912. doi:10.1080/08941920701561114
Dunn, M., 2013. Indicators of Human Well-being in Coastal Communities (MA Thesis). University of Washington, Bothell.
Edwards, D., 2011. Social and cultural values associated with European forests in relation to key indicators of sustainability. EFORWOOD Tools Sustain. Impact Assess. Rep. D2 3.
Eldridge, C., 2013. Participatory methods, behaviour-influence and development. Discussion paper. http://pubs.iied.org/pdfs/G03636.pdf. Accessed July 29, 2016.
Fairhead, J., Leach, M., 1996. Misreading the African Landscape: Society and Ecology in a Forest-Savanna Mosaic. Cambridge University Press, Cambridge.
Fish, R.D., 2011. Environmental decision making and an ecosystems approach: some challenges from the perspective of social science. Prog. Phys. Geogr. 35, 671–680. doi:10.1177/0309133311420941
Folke, C., 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. Glob. Environ. Change 16, 253–267. doi:10.1016/j.gloenvcha.2006.04.002
Folke, C., Carpenter, S., Walker, B.H., Scheffer, M., Chapin, T., Rockström, J., 2010. Resilience thinking: integrating resilience, adaptability and transformability. Ecol. Soc. 15.
Fraser, E.D.G., Dougill, A.J., Mabee, W.E., Reed, M., McAlpine, P., 2006. Bottom up and top down: analysis of participatory processes for sustainability indicator identification as a pathway to community empowerment and sustainable environmental management. J. Environ. Manage. 78, 114–127. doi:10.1016/j.jenvman.2005.04.009
García-Quijano, C.G., 2015. Coastal resource foraging, life satisfaction, and well-being in southeastern Puerto Rico. J. Anthropol. Res. 71, 145. doi:10.3998/jar.0521004.0071.201
Ghimire, K., Pimbert, M.P., 1997. Social Change and Conservation: Environmental Politics and Impacts of National Parks and Protected Areas. Earthscan, London.
Goldman, M.J., de Pinho, J.R., Perry, J., 2013. Beyond ritual and economics: Maasai lion hunting and conservation politics. Oryx 47, 490–500. doi:10.1017/S0030605312000907
Gough, I., McGregor, J.A., 2007. Wellbeing in Developing Countries: From Theory to Research. Cambridge University Press, Cambridge.
Gregory, R., 2012. Structured Decision Making: A Practical Guide to Environmental Management Choices. Wiley, Hoboken.
Hicks, C.C., Levine, A., Agrawal, A., Basurto, X., Breslow, S., Carothers, C., Charnley, S., Coulthard, S., Dolsak, N., Donatuto, J., Garcia-Quijano, C., Mascia, M.B., Norman, K., Poe, M., Satterfield, T., Martin, K.S., Levin, P.S., 2016. Engage key social concepts for sustainability. Science 352:6281, 38-40.
James, C.A., Kershner, J., Samhouri, J., O'Neill, S., Levin, P.S., 2012. A methodology for evaluating and ranking water quantity indicators in support of ecosystem-based management. Environ. Manage. 49, 703–719. doi:10.1007/s00267-012-9808-7
Jepson, M., Colburn, L.L., 2013. Development of Social Indicators of Fishing Community Vulnerability and Resilience in the US Southeast and Northeast Regions. Woods Hole MA US Dep. Commer.
Keeney, R.L., Gregory, R.S., 2005. Selecting attributes to measure the achievement of objectives. Oper. Res. 53, 1–11. doi:10.1287/opre.1040.0158

Kershner, J., Samhouri, J.F., James, C.A., Levin, P.S., 2011. Selecting indicator portfolios for marine species and food webs: a Puget Sound case study. PLoS ONE 6, 1–12. doi:10.1371/journal.pone.0025248

Kusel, J., 2001. Assessing well-being in forest dependent communities. J. Sustain. For. 13, 359–384. doi:10.1300/J091v13n01_10

Leisher, C., Samberg, L., van Buekering, P., Sanjayan, M., 2013. Focal areas for measuring the human well-being impacts of a conservation initiative. Sustainability 5, 997–1010. doi:10.3390/su5030997

Levine, A.S., Feinholz, C.L., 2015. Participatory GIS to inform coral reef ecosystem management: mapping human coastal and ocean uses in Hawaii. Appl. Geogr. 59, 60–69. doi:10.1016/j.apgeog.2014.12.004

Levin, P., Breslow, S.J., Harvey, C., Norman, K.C., Poe, M.R., Williams, G., Plummer, M., in press. Conceptualization of social-ecological systems of the California Current: an examination of interdisciplinary science supporting ecosystem-based management. Coast. Manag.

Levin, P.S., Fogarty, M.J., Murawski, S.A., Fluharty, D., 2009. Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. PLoS Biol. 7, e14. doi:10.1371/journal.pbio.1000014

Levin, P.S., Kelble, C.R., Shuford, R.L., Ainsworth, C., deReynier, Y., Dunsmore, R., Fogarty, M.J., Holsman, K., Howell, E.A., Monaco, M.E., Oakes, S.A., Werner, F., 2014. Guidance for implementation of integrated ecosystem assessments: a US perspective. ICES J. Mar. Sci. 71, 1198–1204. doi:10.1093/icesjms/fst112

Luttmer, E.F.P., 2004. Neighbors as negatives: relative earnings and well-being (Working Paper No. 10667). National Bureau of Economic Research.

Mace, G.M., 2014. Whose conservation? Science 345, 1558–1560. doi:10.1126/science.1254704

Marmot, M.G., Stansfeld, S., Patel, C., North, F., Head, J., White, I., Brunner, E., Feeney, A., Smith, G.D., 1991. Health inequalities among British civil servants: the Whitehall II study. The Lancet, Originally published as Volume 1, Issue 8754 337, 1387–1393. doi:10.1016/0140-6736(91)93068-K

Mascia, M.B., Claus, C.A., Naidoo, R., 2010. Impacts of marine protected areas on fishing communities: MPA social impacts. Conserv. Biol. 24, 1424–1429. doi:10.1111/j.1523-1739.2010.01523.x

Mascia, M.B., Pailler, S., Thieme, M.L., Rowe, A., Bottrill, M.C., Danielsen, F., Geldmann, J., Naidoo, R., Pullin, A.S., Burgess, N.D., 2014. Commonalities and complementarities among approaches to conservation monitoring and evaluation. Biol. Conserv. 169, 258–267. doi:10.1016/j.biocon.2013.11.017

McGregor, J.A., 2008. Wellbeing, Poverty and Conflict, WeD Policy Briefing.

McLeod, K., Leslie, H., 2012. Ecosystem-Based Management for the Oceans. Island Press, Washington, DC.

McLeod, K.L., Lubchenco, J., Palumbi, S.R., Rosenberg, A.A., 2005. Scientific consensus statement on marine ecosystem-based management. Signed by 221 academic scientists and policy experts with relevant expertise and published by the Communication Partnership for Science and the Sea at http://www.compassonline.org/sites/all/files/document_files/EBM_Consensus_Statement_v12.pdf.

Meadows, D. 1998. Indicators and Information Systems for Sustainable Development: A Report to the Balaton Group. The Sustainability Institute, Hartland Four Corners, Vermont.
Michalos, A.C., Smale, B., Labonté, R., Muharjarine, N., Scott, K., Moore, K., Swystun, L., Holden, B., Bernardin, H., Dunning, B., others, 2011. The Canadian Index of Wellbeing. Canadian Index of Wellbeing and University of Waterloo., Waterloo, Ontario.
Millennium Ecosystem Assessment, 2005a. Ecosystems and human well-being: synthesis. Island Press, Washington, DC. http://www.unep.org/maweb/documents/document.356.aspx.pdf. Accessed July 29, 2016.
Millennium Ecosystem Assessment, 2005b. Ecosystems and human well-being: a framework for assessment. Island Press, Washington DC. http://www.unep.org/maweb/en/Framework.aspx. Accessed July 29, 2016.
Morris, P., Halkitis, P.N., 2015. The influence of context on health. Behav. Med. 41, 77–79. doi:10.1080/08964289.2015.1063869
Nelson, D., Adger, W., Brown, K., 2007. Adaptation to environmental change: contributions of a resilience framework. Annual Review of Environment and Resources. 32(1), 395-419.
OECD, 2013a. OECD Factbook 2013. Organisation for Economic Co-operation and Development, Paris.
OECD, 2013b. OECD Guidelines on Measuring Subjective Well-being. OECD Publishing, Paris.
Office for National Statistics, 2015. Measuring national well-being.
Pacific Fishery Management Council, 2013. Pacific Coast Fishery Ecosystem Plan for the U.S. portion of the California Current Large Marine Ecosystem. Pacific Fishery Management Council, Portland, OR.
Pollnac, R.B., Poggie, J.J., 2006. Job satisfaction in the fishery in two southeast Alaskan towns. Hum. Organ. 65, 329–339.
Pollnac, R., Pollnac, R., Abbott-Jamieson, S., Smith, C., Miller, M., Clay, P., Oles, B., 2006. Toward a model for fisheries social impact assessment. Mar. Fish. Rev. 68, 1–18.
Ribot, J.C., Peluso, N.L., 2003. A theory of access. Rural Sociol. 68, 153–181. doi:10.1111/j.1549-0831.2003.tb00133.x
Samhouri, J.F., Haupt, A.J., Levin, P.S., Link, J.S., Shuford, R., 2014. Lessons learned from developing integrated ecosystem assessments to inform marine ecosystem-based management in the USA. ICES J. Mar. Sci. 71, 1205–1215. doi:10.1093/icesjms/fst141
Satterfield, T., Gregory, R., Klain, S., Roberts, M., Chan, K.M., 2013. Culture, intangibles and metrics in environmental management. J. Environ. Manage. 117, 103–114. doi:10.1016/j.jenvman.2012.11.033
Satz, D., Gould, R.K., Chan, K.M.A., Guerry, A., Norton, B., Satterfield, T., Halpern, B.S., Levine, J., Woodside, U., Hannahs, N., Basurto, X., Klain, S., 2013. The challenges of incorporating cultural ecosystem services into environmental assessment. Ambio 42, 675.
Scott, K., 2012. Measuring Wellbeing: Towards Sustainability? Routledge, New York.
Sen, A., 1997. Editorial: Human capital and human capability. World Dev. 25, 1959–1961.
Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Glob. Environ. Change 16, 282–292. doi:10.1016/j.gloenvcha.2006.03.008
Smith, L.M., Case, J.L., Smith, H.M., Harwell, L.C., Summers, J.K., 2013. Relating ecosystem services to domains of human well-being: foundation for a U.S. index. Ecol. Indic. 28, 79–90. doi:10.1016/j.ecolind.2012.02.032

Sojka, B., 2014. Integrating Human Wellbeing Assessment Into Marine Resource Management (MA Thesis). University of Washington, Seattle, WA.
Stephanson, S.L., Mascia, M.B., 2014. Putting people on the map through an approach that integrates social data in conservation planning: social data in conservation planning. Conserv. Biol. 28, 1236–1248. doi:10.1111/cobi.12357
Stiglitz, J.E., Sen, A., Fitoussi, J.-P., others, 2010. Report by the commission on the measurement of economic performance and social progress. Paris Comm. Meas. Econ. Perform. Soc. Prog.
Stiglitz, J., Sen, A., 2009. The measurement of economic performance and social progress revisited. IDEAS Work. Pap. Ser. RePEc.
Summers, J., Smith, L., Harwell, L., Case, J., Wade, C., Straub, K., Smith, H., 2014. An index of human well-being for the U.S: a TRIO approach. Sustainability 6, 3915–3935. doi:10.3390/su6063915
Turner, N.J., Gregory, R., Brooks, C., Failing, L., Satterfield, T., 2008. From invisibility to transparency: identifying the implications. Ecol. Soc. 13, 7.
United Nations, 2008. Millennium development goals indicators.
United Nations, Department of Economic and Social Affairs, 2007. Indicators of sustainable development: guidelines and methodologies. United Nations, New York.
United Nations Human Development Programme, 2014. Human Development Index.
Wilkinson, R.G., 2010. The Spirit Level: Why Greater Equality Makes Societies Stronger. Bloomsbury Press, New York.

SUPPLEMENTARY MATERIAL

Appendix A. Major fields of literature informing the 4-C's framework.

- The human wellbeing, social wellbeing, community well-being, quality of life, happiness, and international development literatures, which emphasize consideration of capabilities and capacity (e.g. Alkire, 2008; Donoghue and Sturtevant, 2007; Kusel, 2001; Sen, 1997), the social goal of poverty alleviation (e.g. Coulthard et al., 2011; Gough and McGregor, 2007), subjective wellbeing (e.g. OECD, 2013b), and the importance of analyzing cross-cutting themes of equity and sustainability separately from other components (e.g. Daw et al., 2011; Stiglitz and Sen, 2009);
- literature in anthropology, geography and political science that emphasizes how nature and culture are co-constituted (e.g. Cronon, 1996; Fairhead and Leach, 1996), and the implications of environmental governance for questions of self-determination, equity, social justice, and social change (e.g. Agrawal and Lemos, 2007; Brechin et al., 2002; Ghimire and Pimbert, 1997; Ribot and Peluso, 2003);
- the ecosystem services literature, including the Millennium Ecosystem Assessment and IPBES frameworks, which draw special attention to the tangible and intangible benefits and values of ecosystems to people (Díaz et al., 2015; Millennium Ecosystem Assessment, 2005);
- the social-ecological systems and resilience literatures, which emphasize the ability of systems to withstand and adapt to changes over time (e.g. Adger, 2000; Berkes and Ross, 2013; Folke, 2006; Folke et al., 2010);
- the social impact assessment literature, particularly with respect to community vulnerability, livelihoods and job quality (e.g. Charnley et al., 2012; Jepson and Colburn, 2013; Pollnac et al., 2006; Pollnac and Poggie, 2006);
- existing US ecosystem assessments and resource agency reports, which emphasize the condition of the natural environment, commercial benefits of natural resources, anthropogenic impacts on the natural

environment such as pollution and habitat fragmentation, occupational safety such as safety at sea, and human health related to environmental conditions, such as biotoxins (e.g. Pacific Fishery Management Council, 2013)

Appendix B. Master List of Social Indicators. Database of existing indicators, coded with attributes of human wellbeing (see Excel file).

Appendix C. Social-ecological assessment projects from which existing indicators of human wellbeing were compiled and coded (n=34). From a list of 175 candidate projects collected through a literature review and expert consultation, 34 projects were selected for review based on 4 major criteria: 1) inclusion of social and ecological indicators, 2) real-world application, 3) thorough documentation and evaluation, and 4) influential status due to funding level, geographic scope, or presence in the media or literature. (For a detailed comparative analysis of these and other projects, see Sojka 2014.)

NOAA Projects
Accounting for Economic Activities in Large Marine Ecosystems and Regional Seas (UNEP/RSP 2006)
Job Satisfaction, Well-Being and Change in Southern New England Fishing Communities (Pollnac et al. 2011)
Measuring the Social and Economic Performance of Catch Share Programs (Clay et al. 2014)
Monitoring Well-being and Changing Environmental Conditions in Coastal Communities (Dillard et al. 2013)
Selecting Human Dimensions Indicators for South Florida's Coastal Marine Ecosystem (Lovelace et al. 2013)
Social Indicators of Fishing Community Vulnerability and Resilience (Jepson & Colburn 2013)
Toward a Model for Fisheries Social Impact Assessment (Pollnac et al. 2008)

Ecosystem Management Projects (not NOAA)
Constructing a U.S. Human Well-being Index for Ecosystem Services Research (US EPA 2012)
Developing Human Wellbeing Indicators for Hood Canal Watershed (Biedenweg & Hanein 2013)
Evaluating Social and Ecological Vulnerability of Coral Reef Fisheries to Climate Change (Kenya)(Cinner et al. 2013)
Human Well-being Indicators for the Puget Sound Partnership (Schneidler & Plummer 2009)
Integrating Watershed and Coastal Areas Management in Caribbean and Small Island Developing Nations (GEF-IWCAM 2008)
Methodology for the Assessment of Large Marine Ecosystems (IOC-UNESCO 2011)
Ocean Health Index (Halpern et al. 2012)
State of the Marine Environment Report for the East Asian Seas (UNEP/COBSEA 2010)

Indigenous Projects
Social Indicators in Native Village Alaska (Jorgensen et al. 1985)
Voices from the Bay (Manitoba, Canada) (McDonald et al. 1997)

Sustainable Development Projects
CSD (Commission on Sustainable Development) Sustainable Development Indicators (UN 2007)
Identifying Indicators of Community Sustainability in the Robson Valley, British Columbia (Parkins et al. 2004)
Johannesburg Plan of Implementation (UN World Summit 2002) (Source: UNEP 2008)
Millennium Development Goals Indicators (UN IEAG 2014)
SCP (Sustainable Consumption and Production) Indicators for Developing Countries (UNEP 2008)

National/Regional Projects
Canadian Index of Wellbeing (Michalos et al. 2011)
Measures of Australia's Progress (ABS 2013)
Measuring National Wellbeing (United Kingdom) (ONS-UK 2013)

OECD Factbook 2013: Economic, Environmental and Social Statistics (OECD 2013)
State of the USA Health Indicators (IOM 2009)
The Personal Security Index (Canada) (Jackson et al. 2002)

Compilations
Community and Citizen-Driven Societal Indicator Projects (CPRN 2000)
OECD Alternative Measures of Well-Being (OECD 2006)
Social Indicators for Land Use Planning in British Columbia (Morford 2007)
The State of Society: Measuring Economic Success and Wellbeing (Leon & Boris 2010)
Well-being Indicators in the Puget Sound Basin (Hanein & Biedenweg 2012)
West Coast Aquatic Social Ecological Assessment (Vancouver Island) (Loucks 2011)

Appendix D. Governmental documents reviewed for attributes of human wellbeing

Documents marked with an asterisk were coded to produce the preliminary list of attributes shown in Table 3. Codes were then tested for their ability to capture wellbeing priorities in the other documents.

US Federal Legislation
Magnuson Stevens Act Amended (2007)*
National Marine Fisheries Service National Standards Guidelines (2009)*
Clean Air Act
Federal Water Pollution Control Act (Clean Water Act)
National Environmental Policy Act (NEPA)
Marine Mammal Protection Act
Endangered Species Act
Coastal Zone Management Act

US Federal Policy
Executive Order: Stewardship of the Ocean, Our Coasts, and the Great Lakes (2010)*
Ocean Policy Task Force Final Recommendations (2010)*
Ocean Research Priorities Plan Update (2013)*
National Ocean Policy Implementation Plan (2013)*
Executive Order on Government to Government Relations
Executive Order on Environmental Justice

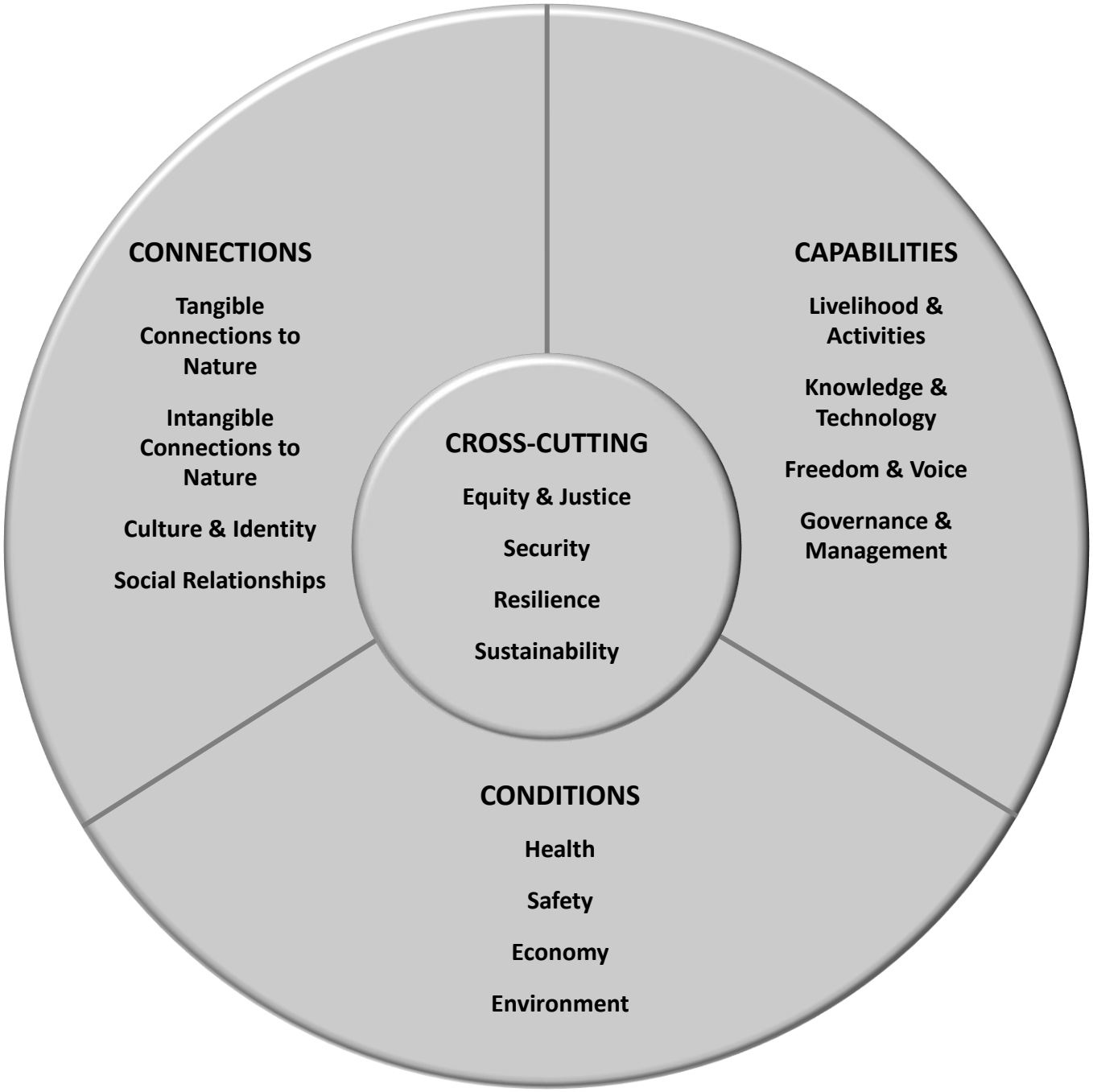
US State Legislation and Policy
California Ocean Protection Act
California Coastal Act
Washington Shoreline Management Act
Oregon Coastal Management Program

US West Coast Science and Management
California Current Integrated Ecosystem Assessment Report Summary (2012)*
California Current Integrated Ecosystem Assessment Human Dimensions Chapter (2013)*
California Current Integrated Ecosystem Assessment Engagement Chapter (2013)*
Pacific Fisheries Management Council Draft Indicators (2013)
Pacific Fisheries Management Council Pacific Coast Ecosystem Fishery Plan (2013)*
Pacific Fisheries Management Council Pacific Coast Fishery Ecosystem Plan Ecosystem Initiatives Appendix (2013)*

Canadian Federal Legislation
Fisheries Act
Coastal Fisheries Protection Act
Canadian Environmental Protection Act

Oceans Act

International Indigenous Rights
United Nations Declaration on the Rights of Indigenous People


CONNECTIONS
Tangible Connections to Nature
Intangible Connections to Nature
Culture & Identity
Social Relationships
CAPABILITIES
Livelihood & Activities
Knowledge & Technology
Freedom & Voice
Governance & Management
CROSS-CUTTING
Equity & Justice
Security
Resilience
Sustainability
CONDITIONS
Health
Safety
Economy
Environment