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# Human dimensions indicators of coastal ecosystem services: A hierarchical perspective

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ABSTRACT

Coastal resource management revolves around defining the dynamic between people and the marine and coastal resources they use and depend upon for a large range of goods and services. The process of defining that dynamic is iterative and must account not only for changing natural resource conditions but also for changing social conditions. Decision-making therefore happens within a context of a social system that includes differing levels of capacity, commitment, economics, political mandates and pressures, and cultural and traditional frameworks. The aim of this paper is to introduce a hierarchical approach in which the large number of variables needed to measure the complex, numerous and abstract social concepts used to evaluate the delivery of ecosystem services can be aggregated into smaller sets of indicators, which can ultimately be aggregated into a single report card. These variables and indicators can identify and describe non-economic human dimensions societal benefits derived as ecosystem services that are readily collected, that can identify changes over time, and are appropriate to specific coastal regions. The identified indicators would capture changes in the delivery of overall ecosystem services impacted by, or that will impact, changes in particular sets of environmental characteristics that are valued by society at large.



## 1. Introduction

Coastal management is driven by the values and priorities of society as expressed by our social, political, and economic systems (Kennedy and Thomas, 1995). Because of this, humans are implicit in the discussion of ecosystem services. Most benefits are readily apparent, such as those from recreation opportunities, seafood, jobs, and scenic views. People place importance on a wide variety of national, regional and local services provided by marine and coastal ecosystems, including tourism, recreation, fisheries, trade, and esthetic and cultural values. Other benefits, however, such as protection from disease, waste remediation and oxygen provision are not as readily noticed by people on a day-to-day basis. In total, all contribute to well-being and a higher quality life. Therefore, the way in which different shorelines and marine environments are managed, and what they are managed for, should be a reflection of what society wants from those environments.

Although it is the stated aim of most agencies and groups to provide such ecosystem services, management has largely been driven by an incomplete information picture with regard to the non-economic human dimensions of ecosystem services. While a range of scientific data have been sought out for decision-making, existing information often lacks many of the different types of social sciences data necessary to help guide this socially driven, value-based process (Loomis and Paterson, 2014). Large-scale management must make informed decisions of what to regulate, what enterprises and initiatives to promote, how society wants the system to function as a whole, and which ecosystem goods and services are most important to citizens and businesses (Erneston et al., 2008; Turner et al., 2003). Decision-making happens within a context of a social system that includes differing levels of capacity, commitment, economics, political mandates and pressures, and cultural and traditional frameworks (Bellamy et al., 1999; Klug, 2002; Lockwood et al., 2010; Paterson, 2013).

While sophisticated indicators, and the metrics or variables needed to measure these indicators, may have been developed and utilized to track how some of these ecosystem services benefit society (Ranganathan et al., 2008; Vaze et al., 2006), the picture is incomplete. The aim of this paper to introduce a hierarchical approach in which the large number of variables needed to measure the complex, numerous and abstract social concepts used to evaluate the delivery of ecosystem services can be aggregated into smaller sets of indicators. These indicators can then, in turn, be aggregated into a single report card. The variables and indicators identified in this paper describe non-economic human dimensions societal benefits derived as ecosystem services that are readily

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collected, that can identify changes over time, and are appropriate to specific coastal regions. The identified indicators would capture changes in the delivery of overall ecosystem services impacted by, or that will impact, changes in particular sets of environmental characteristics that are valued by society at large.

This will enable these indicators to be used, in conjunction with a parallel set of biophysical and economic indicators, to adaptively manage regional resources in a holistic fashion. As with biophysical parameters, changes in non-economic ecosystem services and the values associated with those services can and should be measured and monitored over time. Again, as with any biophysical monitoring, standard social science procedures and methods should be adhered to in order to properly develop and monitor appropriate indicators for non-economic ecosystem services. The value of this paper is in its applicability to produce indicators that inform a Drivers-Pressures-Ecosystem Services-Response (DPSER) model (Kelble et al., 2013) for ecosystem-based management.

There is a danger that, due to the sheer number of ecosystem services provided to us by coastal environments, the quantity of possible non-economic indicators and the variables used to measure those indicators may be virtually limitless. In order to ensure the utility of this effort to managers and decision makers, it is important to be able to consolidate or aggregate first the variables and then the associated indicators into a smaller number of status checkpoints that are managerially relevant and easily communicated. These indicators can be further aggregated to an easily evaluated "report card". This implies the importance of a hierarchical approach where individual variables combined into indicators specific to one component of a particular ecosystem service can be aggregated with other indicators that represent different components of the same service to provide information at the report card level that is functional, practical, and valid. The ultimate purpose of this paper is to identify and describe a hierarchical process (variables, to indicators of an ecosystem service, to an index) focusing upon variables and indicators that could potentially fulfil the role of measuring coastal ecosystem services benefits from a non-economic, human dimensions perspective.

## 2. Ecosystem services

Ecosystem services can be defined as the services, both tangible and intangible, created by ecological characteristics that are explicitly tied to social value (Ranganathan et al., 2008). In other words, ecosystem services are the outcomes of ecosystem functions that yield value to people socially, economically or culturally (Wallace, 2007). From a human dimensions perspective they represent the things provided by the marine and coastal environment that people care about. Negative changes to those services that result in a reduction of benefits to the people that utilize them can have large impacts upon social structure and function.

An ecosystem services approach to resource management moves beyond how people affect ecosystems to instead include how people depend on and benefit from ecosystems (Reyers et al., 2009). Explicitly accounting for these benefits, using a range of economic and non-economic metrics, can reveal hidden benefits and costs to many current practices not typically measured by market forces or considered in management deliberations. Understanding these benefits and costs will result in improved decisions that most readily reflect the true value of the natural environment to society (Clua et al., 2005). Since many of the benefits derived from ecosystem services, and the trade-off costs of acceptable environmental impacts, are often not part of the traditional economy or directly traded in markets, many important and highly relevant ecosystem services are often neglected when decisions are made (Turner et al., 2003). These valuations are off the ledgers of the public and policymakers, and thus taken for granted, yet are nonetheless integral to human well-being (Costanza, 2000; Costanza et al., 1999). Not properly incorporating these services into management scenarios, along with economic and non-economic valuations of them, contributes to the gradual erosion of essential, communal life support services such as climate regulation, carbon storage, cultural heritage, esthetics, erosion protection, and waste disposal. Balancing the demands between public goods, private enterprise, development, and resource protection has become the major natural resource management challenge. Instead of simply "protecting" ecosystems from development or any potential adverse environmental impacts, an ecosystem approach also considers how to best invest in managing ecosystems for sustainable development and use. Our daily lives depend on a range of services the natural environment provides including energy security, biodiversity, food production, fresh water provisions, health, natural hazard protection, infrastructure and housing (Rechkemmer and von Falkenhayn, 2009).

## 3. The measurement of ecosystem services

Indicators can show the current status of an ecosystem service or its value, or can reveal if something is changing and in what direction that change is occurring, in this case the biological, physical, economic or social aspects of marine and coastal ecosystem services. Indicators are often direct measures, such as the number of people that live in a discrete area, the average income of a population, or the number of boats in a commercial fishing fleet. However, they may also be proxies or indirect measures based upon a relationship between what can be measured and an actual focus of interest that might be harder, more expensive or impossible to measure. For example, measuring the number of recreational tour guides can be used to provide information about any change in the quality of a recreation resource or experience. It might be that an increase in the number of tour guides is an indicator of an improved resource condition which has led to an increase in demand for recreational opportunities and thus ecosystem service value. In contrast, however, an increase in the number of tour guides may be a signal that a resource is potentially being overused and/or degraded, and ecosystem service value will begin to decline. Knowing that a change is taking place, the direction of the change, and perhaps the degree of change allows potential negative trends to be mitigated through policy or technology changes, or allows the development of policy to take advantage of beneficial opportunities. Social indicators are used on many scales from local to global and can be used to assess changes in societal benefits from changes in ecosystem services.

As stated previously, ecosystem services are the outcomes of ecosystem functions that yield value to people socially or economically. Unfortunately, it is virtually impossible to define a small number of direct human dimensions indicators that will address the full range of potential coastal ecosystem services. Human dimensions science encompasses a large and diverse range of disciplines, including but not limited to sociology, geography, psychology, economics, anthropology, outdoor recreation, political science, health and public administration. Not only would the task of developing a completely comprehensive list of indicators for all ecosystem services specific to every disciplinary perspective relevant to human dimensions be daunting, but the product would be virtually unusable. The indicators presented in this paper are a subset derived from an undefined larger, effectively limitless, pool of indicators. They also provide the option of being able to be aggregated into a hierarchy as initially described in Section 1.

## 4. Constructing a hierarchical index

In order to fully understand the notion of the proposed hierarchical index it is important to examine each step of the process. A hierarchical index is formed when individual indicators are compiled into a single metric on the basis of an underlying model (Saltelli, 2007). Once developed, a hierarchical index should ideally represent fundamental multidimensional concepts that cannot be captured by a single indicator, e.g. competitiveness, industrialization, sustainability, power, social resilience and social vulnerability (Barnett et al., 2008; Cutter et al., 2003; Yohe and Tol, 2002). Hierarchical indices that compare performance across multidimensional issues have been increasingly recognized as useful tools in policy analysis and public communication. This usefulness has especially been demonstrated on a global scale when comparing country performance on a range of large-scale economic, social, political or environmental measures (Bandura, 2008).

Aggregated indices have become more widely used, although not without controversy. Some authors state that indices are useful in terms of simplifying and quantifying highly complex concepts or phenomenon in ways that are scientifically rigorous, easily interpreted and useful to decision makers (Barnett et al., 2008). However, on the opposite end of the spectrum, some believe that the majority of indices recently created have been developed in such a way that they oversimplify complex problems into single metrics and are too generic to be truly useful (Boruff et al., 2005). A strong argument for the development of indices is that it is simpler for the general public to interpret composite indicators than attempt to identify common trends across many separate indicators (Hoskins and Mascherini, 2009). They also allow for benchmark setting across the global community, a key component of the ever-shrinking political landscape.

Hierarchical indices can send misleading policy messages if they are poorly constructed or misinterpreted, and the nature of the simplified results may invite users to draw simplistic analytical or policy conclusions. It is, therefore, vital that these measures be seen as a means of initiating discussion and stimulating public interest rather than as the sole guide to policy development (Reisig et al., 2007; Saltelli, 2007; Waner, 2010). In addition capturing the status of any complex system in a single metric, such as a hierarchical index, unavoidably raises issues such as data quality, indicator selection, indicator importance and weighting (Eakin and Luers, 2006). There are several additional technical issues that must be considered when developing a hierarchical index. These typically fall under four themes and include (a) inconsistent use of subscales and indicators to reflect the construct under investigation, (b) inattention to the construct validity of key concepts, (c) failure to utilize statistical methods that are appropriate for the type of indicator data being collected, and (d) the inclusion of similar indicators on both sides of regression analysis equations contributing to inaccurate and confounded correlation statistics (Henderson et al., 2010; Reisig et al., 2007).

Construct validity is based on the extent to which a measurement (i.e., variable, indicator, ecosystem service or report card level in our case) reflects the specific intended domain of content. In other words, how well does the variable measure the indicator it is designed to measure, and in turn how well does the indicator measure ecosystem service, the next hierarchical step of the index. Utilizing statistical methods such as bivariate comparisons, Cronbach's coefficient alpha, and inter-item predictability are key steps to determining the internal validity of any index. It is also important to keep in mind that while some single variables, on their own, may not serve as very good indicators, when used in combination with other variables they may be very useful in measuring the indicator. Measuring multiple, often related, variables for a particular indicator can help validate the measurement and strengthen any conclusions regarding that indicator.

## 5. Indicator workshop

A small group of social scientists met January 25–27, 2012 to develop a set of non-economic human dimensions indicators that could be used to measure and monitor ecosystem services for the south Florida coastal marine ecosystem (SFCME). This workshop was part of the larger MARES project.

With this background, five guiding criteria for identifying ecosystem service indicators were developed:

1. Employ a total system approach that was not constrained by political or social boundaries.
2. Ensure that the indicators selected are pragmatic, useful and practical for managers and decision makers.
3. Ensure that the selection of indicators should not be constrained to use only existing data. Both primary and secondary collections should be considered in order to adequately monitor changes in societal conditions.
4. Limit the focus of this effort to non-economic indicators and indices. Our focus is therefore on those services not properly or easily measured using economic indicators. Attempts were also made to develop non-economic indicators for services that may be traditionally considered economic in nature but can be measured using both economic and non-economic indicators.
5. Include the multi-dimensional, overarching constructs of resilience, sustainability, and vulnerability as important considerations when selecting and developing final indicators.

### 5.1. Indicator framework

The goal of the workshop was to identify indicators that would capture changes in the delivery of overall ecosystem services impacted by, or that will impact, changes in particular sets of environmental characteristics. This was achieved by developing a matrix framework that allowed a visual representation of indicators, which can then be aggregated into higher level ecosystem services, which could then be aggregated into the highest report card level. The framework was created by modifying an existing matrix developed at an expert workshop conducted in 2004, which focused on monitoring the human dimensions of coastal restoration (Salz and Loomis, 2005).

### 5.2. Hierarchy

We began by first recognizing that it is possible to identify, organize, and aggregate ecosystem services into a small number of reasonable and useful categorization schemes, or hierarchies, accepting the recursive relationship scheme among indices and indicators that is the foundation of the MARES approach (Ortner et al., 2014). Under different circumstances one categorization scheme might be preferable to another. For this particular effort, the initial focus was on the highest level of aggregation possible, to what could be described as a "report card level" with respect to ecosystem services (Fig. 1). Report card level is conceptually similar to the US Ocean Policy Report Card designed by the Joint Ocean Commission Initiative (2012), the Florida Coastal and Ocean Policy Report Card (2009) and the biannual South Florida Ecosystem Restoration Task Force Report (2012). As with school report cards we are all familiar with, an ecosystem service positively contributing social or cultural value to people would receive a grade of "A" or "B". A grade of "C" would be assigned to a service that is beginning to be compromised in terms of quality, or perhaps beginning an

| **REPORT CARD PARAMETERS** | RECREATION | | | | CULTURAL/ HISTORICAL/ SPIRITUAL | | | PUBLIC HEALTH AND SAFETY | | | AESTHETICS | | | EDUCATION | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ECOSYSTEM SERVICES** | Number of recreational opportunities | Level of recreational activity | Quality of recreational opportunities | Access to coastal resources | Cultural | Historical | Spiritual | Seafood | Beaches | Personal and property damage protection | Viewscape | Watchable wildlife | Species richness | Formal opportunities | Informal opportunities |
| RECREATION/TOURISM RELATED | | | | | | | | | | | | | | | |
| User satisfaction rating | x | x | x | x | x | x | x | | | | x | x | x | x | x |
| Facilities and Accessibility | x | x | x | x | | | | | | | | | | | |
| Annual recreation visitor days | x | x | x | x | | | | | | | | | | | |
| Recreational fishing catch indicators | x | x | x | x | | | | | | | | | x | | |
| HUMAN HEALTH RELATED | | | | | | | | | | | | | | | |
| Health advisories | | | | | | | | x | x | x | | | | | |
| Level of compliance with water quality standards | | | | | | | | x | x | x | | | | | |
| Area of lifeguard protected beaches | | | | | | | | x | x | x | | | | | |
| Shoreline protection | | | | x | | | | | x | x | x | | | | |
| SOCIAL VALUES | | | | | | | | | | | | | | | |
| Viewscape quality | | | x | | | | | | | | x | | | | |
| Degree of unobstructed view | | | x | | | | | | | | x | | | | |
| Opportunities for ocean viewing | | | x | | | | | | | | x | | | | |
| Acres of open space | | | x | | | | | | | | x | | | | |
| Acres of preserved land | | | x | | x | x | x | | | | x | | | | |
| Spiritual sites | | | | | | | x | | | | | | | | |
| Historically designated sites | | | | | | x | | | | | | | | | |
| Tribally designated sites | | | | | x | | | | | | | | | | |
| Preserved natural/historical/cultural values | | | | | x | x | x | | | | | | | | |
| Cultural/historical events | | | | | x | x | | | | | | | | | |
| Spiritual services | | | | | | | x | | | | | | | | |
| Perceptions of marine associated spirituality | | | | | | | x | | | | | | | | |
| Level of existance value | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Level of bequest value | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| Level of option value | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| BIODIVERSITY RELATED | | | | | | | | | | | | | | | |
| Species richness | | | | | x | x | x | | | | | x | x | x | x |
| Existence of megafauna | | | | | x | x | x | | | | | x | x | x | x |
| Opportunities to see megafauna | x | x | x | | x | x | x | | | | | x | x | x | x |
| Perceptions of ecosystem health | | | x | | x | | | | | | | x | x | x | x |
| Acceptability of coral reef health parameters | x | x | x | | | | | | | | | | | | |
| Wildlife interactions | x | x | x | | x | x | x | | | | | x | x | x | x |
| Rare species interactions | x | x | x | | x | x | x | | | | | x | x | x | x |
| Wildlife/marine debris interactions | x | x | x | x | | | | x | x | x | x | | | | |
| EDUCATION RELATED | | | | | | | | | | | | | | | |
| Programs oriented for K-12 | | | | | | | | | | | | | | x | x |
| Interpretive centers | | | | | | | | | | | | | | x | x |
| Family Programs | | | | | | | | | | | | | | | x |
| Field trips | | | | | | | | | | | | | | x | x |
| Research activities (university level) | | | | | | | | | | | | | | x | |
| Musuems/marine parks | | | | | x | x | x | | | | | | | x | x |
| Informal education | | | | | | | | | | | | | | | x |
| Self guided tours (miles) | | | | | | | | | | | | | | | x |
| Citizen involvement | | | | | x | x | x | | | | | | | | x |
| NGOs | | | | | x | x | | | | | | | | x | |
| Offender education | | | | | | | | | | | | | | x | |

**Fig. 1.** A matrix framework of non-economic human dimensions ecosystem services.

**Table 1**
Human dimensions ecosystem services identified for coastal and marine environments.

| Report card services | Service description |
|---|---|
| *Recreation* | Amount, quality, intensity, and distribution of recreational opportunities including to access marine and coastal areas for recreational purposes |
| *Cultural/historical/spiritual* | Amount, quality, intensity, and distribution of cultural/historical/spiritual opportunities |
| *Public health and safety* | Protection from coastal hazards ranging from seafood contamination and pollution to property protection from chronic impacts of erosion and sea level rise. Includes recovery capacity following events. |
| *Esthetics* | Esthetic quality of physical and biological components of coastal and marine systems—visual, olfactory, and auditory |
| *Education* | Formal and informal educational opportunities created by access and proximately to coastal and marine ecosystems |

initial recovery from degradation. Finally a grade of "D" or "F" would be assigned to an ecosystem service that has been compromised to a point where the level of social expectations for that service is no longer being met. Although the cause of any degradation or the reason why the expected level of quality of the service is not explained by the accompanying grade, the report card can provide decision-makers with a broad constructive perspective for directing initial management focus and inquiry. For the purposes of this project, five report card level categories were selected to encompass the broad range of ecosystem services provided by the marine and coastal environment: (1) recreation, (2) cultural, historical, spiritual, (3) public health and safety, (4) esthetics, and (5) education (Table 1). Of interest is the fact that although these are all ecosystem services, two or more of these services can potentially be in conflict with each other given particular sets of circumstances. For example, an increase in the delivery of recreational opportunities might come at the expense of public safety, or esthetics. It is also possible that an increase in one form of recreation (mechanized boating) could impair the quality of other types of recreation (sailing, or fishing).

The second step in the process involved the identification of specific ecosystem services within each report card category. A key part of the workshop involved interpreting and putting into the non-economic Human Dimensions context the information that had been developed through the creation of the integrated conceptual ecosystem DPSER models. Special attention was paid to the ecosystem services identified in these models. That is, the ecosystem services included in our matrix were derived from the three sub-regional SFCME integrated conceptual ecosystem DPSER models developed as part of the larger MARES project. A total of 15 ecosystem services were selected (Fig. 1). These were then evaluated by criteria that include assurance of consistency, system-wide applicability, and common understanding. The resulting ecosystem services were organized into the matrix framework as subheadings under the Report Card level. These 15 ecosystem services are aggregated into the five higher level Report Card levels.

The third step in the process of developing the framework was to identify the indicators, which could then be aggregated into indices that provide information about each of the 15 ecosystem services (Fig. 1). As noted earlier, many of the identified indicators are directly measurable. Even so, they represent the somewhat abstract representations of ecosystem services that people actually care about.

## 6. Utility of the matrix framework

Another reason to use a matrix framework is to provide management practitioners and decision-makers with a visual tool to understand how specific areas of human dimensions research contribute to an understanding of how society views and values marine and coastal ecosystem services. The crosses that have been placed throughout the matrix (Fig. 1) indicate the potential for multiple indicators to be useful in measuring different aspects of several ecosystem services. The matrix also provides an opportunity to identify both primary and secondary data sources relevant to the attainment of management goals. It is recognized that the variables and indicators that have been used in this matrix are not exhaustive and additional factors may be necessary for a specific research endeavor. Moreover not every indicator would be relevant to each individual management application and the most appropriate indicators could be selected based on management needs, geographical region, time constraints, and budget.

The matrix can be used in another important way. In some cases certain measurable variables may already be being routinely collected by management authorities, but in other cases the matrix may identify additional variables that might increase the utility of the data already being collected. It can thereby drive an agenda and set funding priorities for research funding agencies.

In the end, the ultimate utility of the matrix depends upon the identification of potentially measurable variables corresponding to each indicator of ecosystem services. Typically, the identification of measurable variables would be based on a social science theory, such as user satisfaction rating. Each of these theories encompasses a range of concepts that can, and must, be incorporated in order to provide context and validity. Using the example of satisfaction, this theory encompasses the social concepts of crowding, conflict, expectation/discrepancy theory, normative theory, acceptability, rationalization, baseline and displacement. Therefore, each indicator listed in the matrix relevant to recreation may have more than one variable associated with it. Because these are complex concepts, there will actually be a relatively large number of variables for each indicator of recreation. Determining a complete set of variables for the indicators identified in this paper was beyond the scope of the January workshop, however it remains the logical next step for this research endeavor.

## 7. Conclusions

The utility of an ecosystem approach becomes more tangible, both to the general public and to managers, when the benefits of those services can be identified and measured. By identifying five report card level ecosystem services, and their corresponding indicators, this paper demonstrates how ecosystem services are incorporated into society; they track the link between human well-being and ecosystem health, success of management goals, and overall benefits that society receives from our natural resources. These indicators provide information and context to adapt and improve, add, replace or remove projects as new scientific information becomes available. The approach described in this paper further supports the fact that it is not only important to identify human dimensions indicators of coastal ecosystems, but to also ensure the non-economic human dimensions, economic, and biophysical indicators are fully integrated in order to provide a complete picture of desired ecosystem service status. The use of the matrix framework that can be modified by discipline or aggregated across disciplines allows researchers and policy makers to explicitly understand the trade-off decisions that must be necessarily made in this ever-changing world.

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