

Selecting Human Dimensions Indicators for South Florida's Coastal Marine Ecosystem – Noneconomic Indicators

Draft; 8 March 2013

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Summary

The Marine and Estuarine Goal Setting for South Florida (MARES) project is developing a suite of indicators and indices that provides an integrated assessment of the South Florida coastal marine ecosystem (SFCME). Two types of ecosystem indicators and indices are being developed: 1) State indicators of the ecosystem, and 2) human dimensions science indicators. The development of human dimensions science indicators was completed in two phases. One phase centers on economic indicators (see MARES White Paper No. 9) and the second, focuses on all other aspects of human dimensions science including cultural, regulating and provision services generated by the SFCME. This distinction was made due to differences in human dimensions science methodologies and the expertise of the researchers involved in the MARES project. Together, these indicators and indices provide a complete picture of the human dimensions.

Humans are implicit in the discussion of ecosystem services. Benefits from recreation opportunities, seafood, jobs, and beautiful views are readily apparent. Other benefits such as protection from disease, waste remediation and oxygen provision are not as readily noticed by people day-to-day. All contribute to well-being and a quality life. While sophisticated indicators for tracking how many of these services benefit society may be achieved, it is the aim of this paper to describe indicators of societal impacts that are easily collected, change over time and are appropriate to the region so that they can be used, together with the biophysical indicators to adaptively manage regional resources in a holistic fashion.

A small group of social scientists met to describe the interactions between coastal communities, other ecosystem service beneficiaries, such as tourists, and the SFCME. The goal was to identify indicators and measures that would capture changes in these populations that will impact or be impacted by changes in ecosystem services. The process began with information being assembled into the integrated conceptual ecosystem models of the coastal marine ecosystem, with special attention paid to the ecosystem services identified in these models, Figure 1. A number of possible indicators are explored based on the ecosystem and the societal needs and activities in the SFCME. These are then evaluated by criteria that include assurance of consistency, system-wide applicability, and common understanding. The resulting indicators were organized into a framework for analysis that includes measures that are easily captured repeatedly over time and other measures that will help managers understand the data that they are using, Table 1. For this report the strategy is laid out. Data representing the measures for one indicator, public safety, is collected and presented at two time points to provide an example of what an operationalized system might look like.

Figure 1: Matrix of services, indicators and measures developed by the MARES social Human Dimensions workshop

HUMAN DIMENSIONS INDICATORS

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
<i>RECREATION/TOURISM RELATED</i>					
User satisfaction rating					
Facilities and Accessibility					
Annual recreation visitor days					
Recreational fishing catch indicators					
<i>HUMAN HEALTH RELATED</i>					
Health advisories					
Level of compliance with water quality standards					
Area of lifeguard protected beaches					
Shoreline protection					
<i>SOCIAL VALUES</i>					
Viewscape quality					
Acres of open space					
Acres of preserved land					
Degree of unobstructed view					
Opportunities for ocean viewing					
Level of existence value					
Level of bequest value					
Level of option value					
Cultural/historical events					
Spiritual services					
Spiritual sites					
Perceptions of marine associated spirituality					
Historically designated sites					
Tribally designated sites					
Preserved natural/historical/cultural values					
<i>BIODIVERSITY RELATED</i>					
Species richness					
Existence of megafauna					
Opportunities to see megafauna					
Perceptions of ecosystem health					
Acceptability of coral reef health parameters					
Wildlife interactions					
Rare species interactions					
Wildlife/marine debris interactions					
<i>EDUCATION RELATED</i>					
Programs oriented for K-12					
Interpretive centers					
Family programs					
Field trips					
Research activities (university level)					
Museums/marine parks					
Informal education					
Self guided tours (miles)					
Citizen involvement					
NGOs					
Offender education					

Table 1: Human dimensions indicators identified for the South Florida coastal marine ecosystem

Proposed Indicator	Indicator Description	Description of Ecosystem Services Measured By Indicator
Public Safety	Protection from coastal hazards and recovery following events	<i>Property Protection</i> -Protection from coastal hazards and recovery following events, chronic impacts such as due to sea level rise; <i>Seafood Safety</i> ; <i>Pollution Treatment</i> (beach closures)
Recreation	Opportunity to access marine and coastal areas	<i>Recreational Opportunities</i> e.g., beach activities, wildlife viewing, fishing, diving, snorkeling, boating
Culture	Opportunity to attend events held in coastal zone and protection of historic or tribal sites	<i>Cultural identity</i> —participation in way of life and opportunity to attend events focused on coastal benefits such as seafood and waterway as well as protection of historic or tribal sites
Education (Informal)	Opportunity to explore and tour marine and coastal areas	<i>Education/Living laboratory</i> -Opportunity to explore and tour marine and coastal areas while learning about nature and including ecosystem services
Occupation Structure	Job dependence on presence and health of marine resources	<i>Food supply chain</i> (several ES wrapped up into this term-Opportunity to harvest and consume commercial fishery species; Opportunity to catch and consume recreational fishery species; Opportunity for subsistence fishing; Natural materials for research and development, Business opportunities to provide nature tours, services for recreation, accommodations for visitors
Aesthetics	Opportunity for wildlife viewing and recreation and the existence of the coastal marine ecosystem	<i>Aesthetic</i> quality of aquatic and terrestrial environments and open space – visual, olfactory, auditory; <i>Wildlife abundance</i> , diversity and habitat

Additionally, the social scientists recognized the importance of institutions in accomplishing management tasks. To that end, they generated additional indicators that represent the *plausibility of success* that suggests policy changes might occur. It is intended that when needed management changes are identified that the plausibility of success will be considered so that resource and public managers might tackle the easy to accomplish challenges while initiating additional work. As such, further research or communications projects will allow them to be successful in other measures that result in protecting valuable ecosystem services.

Human dimensions (HD) indicators reflect 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 South Florida's natural resources. They provide information and context to adapt and improve, add, replace or remove projects as new scientific information becomes available.

Background

Human Dimensions Research for MARES

Human Dimensions are commonly thought of as the social, economic, and political attitudes, processes, and behaviors related to natural resources. These relationships were highlighted and promoted by the Millennium Ecosystem Assessment (2005) in which the values human have for these resources were described as ecosystem services. One goal of the MARES project is to develop indicators that can be used to define and measure these relationships in ways that are beneficial to resource managers.

Human dimensions science studies have been conducted within the MARES project area (Kildow 2006; Leeworthy and Bowker, 1997; Leeworthy and Hospital 2004; Leeworthy and Wiley 1997; Loomis et al 2008a, 2008b, 2008c; Shivlani 2000, 2006; Shivlani et al 2003;). The results provide a broad view of the coupled socio-ecological system and present baseline information of the values of South Florida's natural resources. While some studies focus on economic values (see MARES White Paper No. 9), others reveal more about the non-market values placed on coastal environments.

Economic values of coastal resources are captured in several studies examining the entire state of Florida and the Florida Keys, with some studies linking the economy and the environment. Leeworthy and Wiley (1997) gathered information about market and non-market values of Florida Keys residents that reflect the importance of the quality of the environment to aspects of natural resources, e.g., the amount living coral reef, water quality (visibility), and clean beaches. Leeworthy and Hospital's (2004) research centered on the importance and satisfaction ratings of visitors and residents participating in boating activities, their views on protected areas, and socioeconomic and ecological monitoring and changes over time. Using Leeworthy and Bowker's (1997) conceptual model linking the economy and environment, the research shows a "direct connection between actual and perceptions of conditions and market and nonmarket economic values". In addition, the National Ocean Economics Program performed an evaluation of all coastal and Great Lakes states. The series of reports produced by the program present key findings emphasizing the importance of the ecosystem and the tourism-based economy of coastal states. For example, retirees may have second-homes in South Florida due to the recreational activities provided by the marine and coastal ecosystem. More specifically, in Florida, Kildow

(2006) found that 77% of the coastal economy is tied to its shoreline”, and also noted that “Americans rank Florida first in the nation as a destination for coastal recreation.” The studies show there is a dollar value associated with ecosystem services, the quality of the ecosystem is important to residents and visitors, and ecosystem quality has the potential to impact drivers/pressures of the local and regional coastal-based economy.

Resident and visitor non-economic values for South Florida’s natural resources have been assessed through a series of studies in the Florida Keys. Some of the research examines in-water activities (e.g., SCUBA diving, snorkeling, fishing) while others assess preferences and views of beaches and tourism. Loomis et al. (2008a, 2008b, 2008c) conducted a series of surveys for The Nature Conservancy’s Florida Reef Resilience Program to answer “What do people want and need from coral reefs?” The target audiences for the series were SCUBA divers, snorkelers, and recreational anglers. The research team sought to improve their understanding of the non-economic interactions coral reef users have with these environments. A portion of each survey includes “Coral Reef Characteristics and User Impacts” (e.g., coral bleaching, algal cover, visibility, and fish cohorts) and the responses helped determine the acceptability of reef condition by resource users. All three survey projects suggest both residents and non-residents rate the “current ecological health of coral reefs in the Florida Keys as ‘fair’ to ‘good’ but that the state of the reef is ‘declining somewhat’” (Loomis et al. 2008a, 2008b, 2008c). While a more in depth review of the results reflects variations in the level of experience, or frequency of resource use, it is important to note that a significant number of all users agree on the current condition of reef health.

Shivlani (2000, 2006; Shivlani et al. 2003) led a series of human dimensions science studies in Monroe County, the southeast coast (Martin, Palm Beach, Broward and Miami-Dade counties), and three beaches in Miami-Dade County. While the focus of these projects varied (e.g., beach nourishment, tourism, needs assessment), each captured a glimpse into user views of the environment. All of the studies show some level of concern, or willingness-to-pay for resource management. Shivlani (2000) surveyed over 11,000 registered voters in the Florida Keys to assess their views on tourism. Results illustrate the top 3 benefits of tourism in Monroe County are jobs, lower taxes, and a strong economy, and the top 3 disadvantages are traffic, environmental degradation, and overcrowding (Shivlani, 2000). Shivlani (2006) conducted a needs assessment of coral reefs from Miami-Dade County north to Martin County. The project included interviewing residents and visitors on beaches and surveying boaters to document knowledge of coral reefs, beliefs about coral reefs, fisheries impacts and the Florida Reef Tract, and willingness-to-pay to protect the reef in Florida. In general, visitors and residents on beaches and those boating had good general knowledge of coral reefs, more so than the local Florida Reef Tract. A majority of beach visitors were willing-to-pay to protect reefs, while a majority of residents were not willing-to-pay an additional sales tax. Boaters were also noted as knowledgeable regarding the local fishing rules and regulations. Key findings from those surveyed are 1) coral reefs provide ecological and economic benefits, and 2) that reefs serve a recreational and food supply benefit more so than ecological benefit. Shivlani et al. (2003) surveyed visitors on their values along three beaches on Key Biscayne (Miami, Florida) as they relate to preference and quality and willingness-to-pay to protect the beaches. The top three uses of the beaches were sunbathing, swimming and walking. The top three reasons for visiting these particular beaches are space availability, other (e.g., taking dogs to beach), and distance from home. Beach nourishment, building a wider beach for either turtle nesting or recreational access,

was presented as a willingness-to-pay question (one or the other, not both options) and resulted in visitors expressing a greater willingness-to-pay for beach nourishment to achieve enhanced sea turtle nesting habitat and enhanced recreational access.

These studies not only illustrate the dependence of South Floridians on ecosystem services but also highlight the need for a systematic assessment that can be used to routinely adjust policy to protect these services.

Why do we need Human Dimensions indicators?

An indicator tells us that something is changing or has made a change. For MARES, indicators tell us about the biological, physical, economic or social aspects of the marine and coastal ecosystem. Often indicators are direct measures such as the number of people that live in a discrete area. However, they may also be proxies or measures we can make and use based on our knowledge of the relationship between what we can measure and the target that is harder or more expensive to measure, e.g., measuring the number of recreational tour guides can tell us about the change in desire of tourists for such experiences. Knowing that a change is taking place, the direction of the change and perhaps the degree of change allows us to mitigate negative impacts through policy or technology changes or allows us to develop 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.

Marine ecosystems provide a variety of important regional and national social services including tourism, recreation, fisheries, trade, and aesthetic and cultural values. The values and priorities of society as expressed by our social, political, and economic systems drive coastal management. Therefore, the way in which different shorelines and marine environments are managed should be a reflection of what society wants from those environments. Although this is the aim of most agencies and groups, management has largely been driven by an incomplete picture. Scientific information has been sought out for decision-making, but it often lacks the social sciences which would help guide this socially driven, value-based process. Large-scale management also encompasses 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. Lastly, decision-making happens within a context of a system that includes differing levels of capacity, commitment, mandates, economics, political pressures, and culture. While the value of this paper is in its applicability to produce indicators that inform a Drivers-Pressures-Ecosystem Services-Response (DPSE) model (see MARES Integrated Conceptual Ecological Model reports) for ecosystem-based management, it is important to recognize that the plausibility of success of actions may rely upon understanding the overall political context.

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) An ecosystem services approach moves beyond how people affect ecosystems to 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-market metrics, would reveal hidden benefits and costs to many current practices and yield 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 traded in markets, many ecosystem services are frequently neglected when decisions are made (Turner et al., 2003). They are off the ledgers of the public and policymakers, taken for granted, and yet nonetheless integral to human well-being. This contributes to the gradual erosion of some of the essential, communal life support services such as climate regulation, carbon storage, cultural heritage, aesthetics, erosion protection, and waste disposal.

Balancing the demands between public goods, private enterprise, development and protection has become the main natural resource management challenge. Instead of simply “protecting” ecosystems from development, an ecosystem approach also considers how to best invest in managing ecosystems for sustainable development. 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 & von Falkenhayn, 2009).

How are Human Dimensions Indicators used?

A DPSEER model is used to conceptualize the interactions of human dimensions with ecosystem services for management of South Florida resources, Figure 2. People are implicit throughout the model. The most direct relationship to humans is in the *Response* portion of the model.

Ecosystem services are the benefits that people derive from nature. These are the things we value, the goods and services that nature provides. For instance, we value the fish we catch in terms of high quality protein for nutrition, recreational benefits and jobs for fishers. We also value things we don't think about as often such as the clean water and the waste treatment that coastal ecosystems provide.

State describes the conditions of the marine environment and it can also refer to the state of the human environment. Is our human state changing from the ecosystem services we gain from the marine and coastal natural resources? For example, are we more vulnerable to the effects of storms or a weak economy when ecosystem services are disrupted or diminished?

Pressures are the mechanisms that cause change such as contaminants in the system. The drivers are often anthropomorphic, or caused by people, such as pollution that contains contaminants or changes in water flow that decreases the ability of coastal areas to function in waste treatment.

Responses are the changes in human activities in response to changes in services, state, pressure, and drivers. This is also where management actions come in to play. For instance a regulation that limits the number of fish that can be caught commercially may have a response in ecosystem services, such as increasing the number of fish in the water. This might increase the recreational value of fish, but decrease the amount of fish protein available at the market. It may also decrease the number of commercial fishers employed, but could increase the number of trades people manufacturing recreational vessels or the number of people employed in the fishing guide industry. An example of management need might be found in the example of an increased

number of people visiting a resource, threatening to “love to death” a view or animal. In this case, we might protect the valuable resources through limiting access to the area or directing some users to a different but similar location where they can find the experience they desire, therefore reducing the visitor impact to the state. Another example might be in establishing a management action that reduces pollution such as the use of a particular contaminant in household products. Although this might have a negative effect on an aspect of household life, it might serve to limit the effects of the contaminants on marine organisms including the humans that live near, work in or visit the ocean or consume the protein found there.

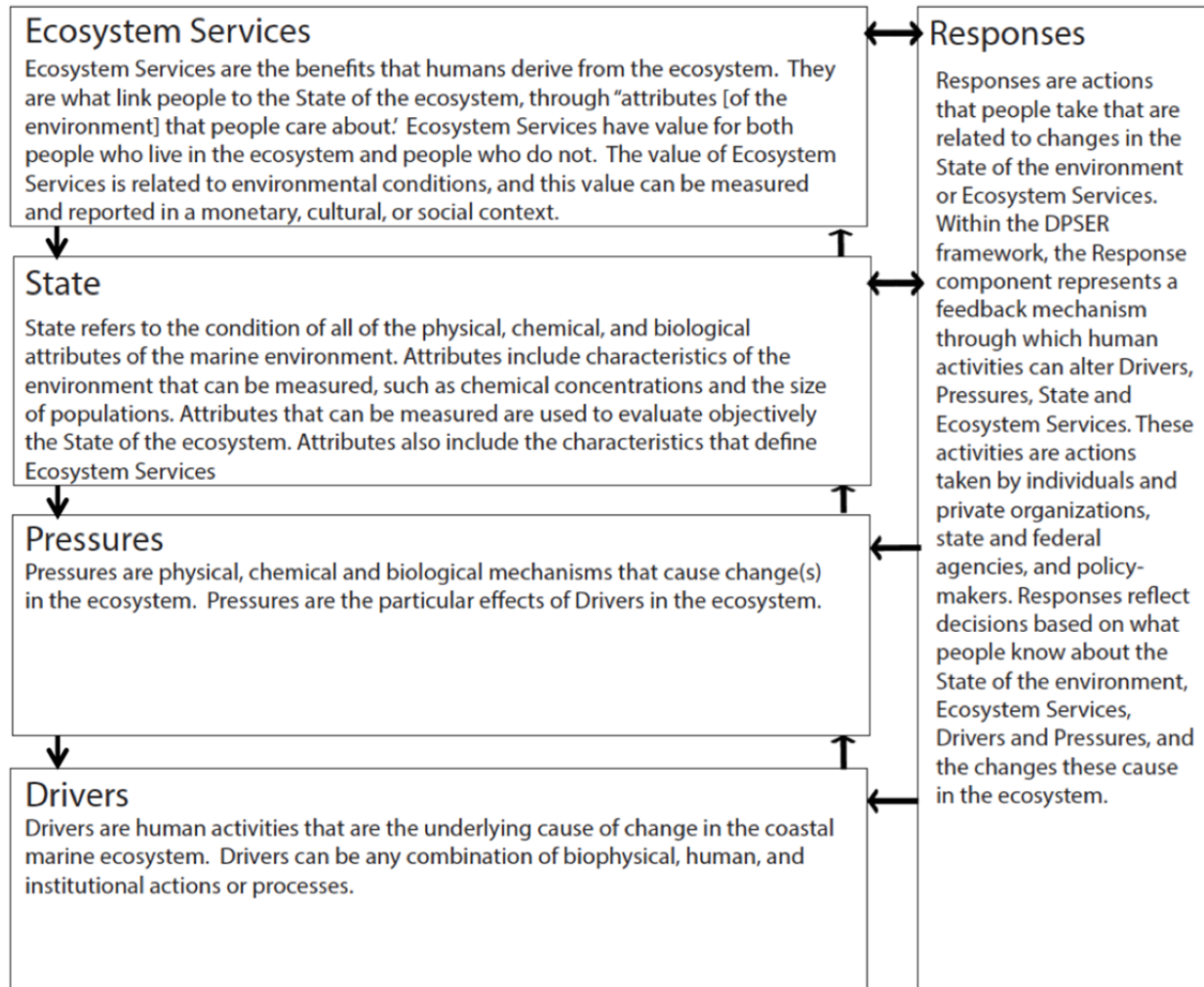
These are sophisticated interactions that ultimately involved in management trade-offs. Examples of this may be in-filling wetlands for development in a relatively degraded site to protect several acres of wetlands that form a contiguous relationship with other preserved areas, or providing a rural clinic in a medically underserved area. Choices do need to be made to direct development to best meet community needs, therefore it is important that we have a full range of information for making management choices while understanding the impacts of management decisions.

How do we measure Human Dimensions indicators?

By monitoring HD indicators we can report on the status of the ecosystem as it is reflected in changes in society. These can be measured directly and indirectly through measurements of what people do, the status of their condition, or how society changes as a result of their actions. Primary data collections often use direct observation, focus groups, surveys, and other tools to assess in detail the use, values, and beliefs people subscribe to specific ecosystem services. This data can be either subjective or objective. Secondary data collections are those that have been collected for some other reason but these can be applied to ecosystem service uses. Usually, these are objective and the result of behaviors or circumstance. For example, national, state and county parks may collect visitation numbers to support their spending and this data also can be used as a proxy for measuring the changes in the number of local citizens accessing parks for recreational opportunities. The U.S. Census and the Department of Labor collect demographic and labor information required by and used by the federal government for a variety of purposes but it can also be used to determine changes in population, business patterns, and reliance on natural resources for jobs. Both methods of data collection are important to assess and understand society’s dependence on ecosystem services and preference for management. For monitoring purposes it is important that measures be repeatable.

When selecting measurable parameters, consideration should be given to content validity. Content validity is based on the extent to which a measurement (i.e., parameter) reflects the specific intended domain of content (i.e., stated goal and objective). In other words, how well does the parameter measure whether or not a particular project goal has been achieved. It is also important to keep in mind that while some parameters, on their own, may not serve as very good indicators of goal attainment, when used in combination with other parameters they may be very useful. Measuring multiple, often related, parameters for a particular goal (or objective) can help validate the measurement and strengthen any conclusions regarding goal attainment. Consultation between managers and human dimensions scientists will identify which of these indicators is the best for measuring specific outputs, needs, and uses in the future.

Figure 2: DPSER framework developed for MARES



Indicators may be measured with multiple metrics using multiple types of data collection to sharpen the understanding of societal changes (Figure 2). These indicators represent a series of measurable parameters, such as the number of marinas in the project area, as well as user observations, such as user satisfaction with access provided by marinas. Each of the indicators encompasses a range of concepts that will provide the best information for management. Using the example of satisfaction, measuring the perceptions and use limits of crowding, conflict, expectation/discrepancy acceptability and displacement will provide management with specific limits of what user groups find as acceptable ecosystem services. Therefore, each indicator listed in the matrix may have more than one metric (i.e. measurement method) associated with it. These metrics are critical to understand the range of social values and attitudes held across the population.

It must be recognized that there is a wide range of disciplines encompassed by the term human dimensions, including but not limited to sociology, geography, psychology, anthropology, outdoor recreation, political science, health, and public administration. The task of developing a completely comprehensive list of indicators for all ecosystem services specific to every discipline would be highly complex and the product would be virtually unusable. The authors acknowledge, therefore, that the indicators developed during the recent MARES project are a sub-set of a larger, effectively limitless pool of measures and metrics. Future work may also incorporate indicators derived from the literature or other projects, though managers will have to select which of these indicators are most pertinent to their needs. Research is needed to develop the most appropriate indicators for specific SFCME management challenges from those identified during the MARES project.

The MARES project identifies thirteen distinct Ecosystem Services provided by the SFCME (Table 2). These can be categorized as cultural, regulating, and provisioning services, following the approach taken in the Millennium Ecosystem Assessment (MEA) project (c.f. Farber et al. 2006). In this context, “Provisioning” services and goods are products obtained from ecosystems such as food, freshwater, fiber, biochemicals, and genetic resources. “Regulating” services and goods are benefits obtained from regulation of ecosystem processes such as climate regulation, disease regulation, water regulation, water purification and pollination. “Cultural” services and goods are defined as the non-material benefits obtained from ecosystems such as spiritual and religious, recreation and ecotourism, aesthetic, inspirational, educational, sense of place and cultural heritage. All are necessary for what the MEA defines as a good life. All are applicable to some degree within the coastal marine ecosystem of South Florida.

Table 2: Ecosystem services provided by the South Florida coastal marine ecosystem

<i>Cultural Services</i>	
Aesthetic and Existence	Provide aesthetic quality of aquatic and terrestrial environments (visual, olfactory, and auditory), therapeutic benefits, pristine wilderness for future generations
Recreation	Provide suitable environment/setting for beach activities, and other marine activities such as fishing, diving, snorkeling, motor, and non-motor boating
Science and Educational	Provide a living laboratory for formal and informal education and for scientific research
Cultural Amenity	Support a maritime way of life, sense of place, maritime tradition, spiritual experience
<i>Provisioning Services</i>	
Food/Fisheries	Provide safe-to-eat seafood
Ornamental Resources	Provide materials for jewelry, fashion, aquaria, etc.
Medicinal/Biotechnology Resources	Provide natural materials and substances for inventions and cures
<i>Regulating Services</i>	
Hazard Moderation	Moderate extreme environmental events (i.e. mitigation of waves and storm surge in the case of hurricanes)
Waste Treatment	Retain storm water, remove nutrients, contaminants, and sediment from water, and dampen noise
Climate Regulation	Moderate temperature and influence/control other processes such as wind, precipitation, and evaporation
Atmospheric Regulation	Exchange CO ₂ , O ₂ , mercury, etc.
Biological Interactions	Regulate species interactions to maintain beneficial functions such as seed dispersal, pest/invasive control, herbivory, etc.

Approach to Selecting and Evaluating Human Dimensions Indicators

The process used to develop HD indicators is a three-step process. Twelve ecosystem services were identified for the South Florida coastal marine ecosystem and through the workshop process a list of indicators that are linked to those services were identified, Table 3. Metrics to quantify each proposed indicator were developed. The metrics were split into primary collections and secondary collections to specify if data is not available at this time (primary), or readily available (secondary), Table 4. In general, primary data are those collected for a specific reason for a specific research project. They may be located in the literature and are often subjective in which they may tell us what people think. Often they are conducted in discrete areas. Secondary data is collected for other reasons though not always research. They are readily available, mostly free, easily monitored over regional scale and over time, provides big picture of what is happening (Lovelace, Godeke, Dillard, 2012). The final steps are to evaluate each measure as to its utility and methods for measurement and interpretation.

Table 3: Linking Human Dimensions Indicators to Ecosystem Services

Ecosystem Services → Human Dimensions Indicator ↓	Aesthetics and Existence	Recreation	Science and Educational	Cultural Amenity	Food/Fisheries	Ornamental Resources	Medicinal/Biotechnology Resources	Hazard Moderation	Waste Treatment	Climate Regulation	Atmospheric Regulation	Biological Interactions
Public Safety								X	X	X	X	
Recreation	X	X	X		X	X			X			X
Culture	X	X	X	X	X							
Education (Informal)		X	X	X			X				X	
Occupation Structure		X	X		X	X	X		X	X		
Aesthetics	X	X	X	X	X	X		X				X

Table 4: Human Dimensions Indicators and Measures

Indicator	Secondary Collections	Primary Collections
Public Safety		
	# storm events	
	# Beach closures/advisories	
	# beaches monitored	
	Access to medical care	
	Density of people living in floodplain	
	\$ personal property damage/number of storms	
Recreation		
	# boat ramps	Use of boat ramps
	# fishing, hunting, boat licenses	Quality of recreational activities
	# recreational areas	User satisfaction rating
	# dive trips, # participants	Annual visitor recreation days (combines 1° and 2° data)
		Acceptability of coral reef health
		social value mapping of specific areas
Culture		
	# cultural events (ex. Festivals)	Spiritual sites, spiritual services
	Attendance cultural events	Perceptions of marine related spirituality
	Historical or tribal designated sites	social value mapping of specific areas
	# of coastal/ocean environmental or civic groups	
	# arts /entertainment businesses	
Education, Informal		
	# nature tours, # participants	Learning experience/evaluations and comment cards
	# nature tour business	Quality of field experience
	# NGOs conducting tours	
	Miles of self-guided tours	Number and experience of self-guided tours
Occupation Structure		

Indicator	Secondary Collections	Primary Collections
	Economic diversity (as measured by employment or earnings.)	Job dependence on coral reefs
	% Unemployment	Job dependence on other coastal attributes
Aesthetics	# water front hotel rooms	Content analysis of sales brochures/newspapers, web forums, google searches etc. for # and type of aesthetic descriptions by habitat or location
	# fish kills, # algal blooms	social value mapping of specific areas
	Miles of accessible shoreline	Species richness
	# dive trips, # participants (non-fishing)	Existence of megafauna
	# wildlife viewing areas	Acceptability of coral reef health
	Opportunities to see megafauna (dolphin trips)	How often you see megafauna on those trips?
Coastal Development	Amount or percent Impervious cover	
	# permits	

In order to develop a useful set of human dimensions indicators, it is important to impose a series of guiding principles around which all decisions were made. The principles established by the MARES human dimensions working group consist of the following:

1. To employ a total system approach that was not constrained by political or social boundaries.
2. To ensure that the indicators selected are pragmatic, useful and practical for managers and decision makers.
3. The selection of indicators and decisions made during the development of this component of MARES should not be constrained to use only existing data. Both primary and secondary collections should be considered to adequately monitor changes in societal conditions.
4. The multi-dimensional, overarching constructs of resilience, sustainability, and vulnerability were important considerations when selecting and developing final indicators.

Additionally, development of the indicators uses a series of questions to determine their appropriateness for communicating with managers. The process follows one used to create economic indicators (MARES White Paper No. 9) and restoration in the Everglades (Doren et al. 2009), Table 5.

It should be noted that the focus of this working group was specifically targeted at developing human dimensions non-economic indicators and measures. These may be developed for services that may be traditionally considered economic in nature, but it was acknowledged that these indicators can be measured using both economic and non-economic metrics to gain the full understanding needed for management. Therefore, there are specific measures that are included for both the economic and non-economic collections and that will serve as multiple indicators.

Table 5: Evaluation criteria for indicator measures

Criteria evaluation question	Abbreviation
Is the measure relevant? Is it linked to the condition of the ecosystem?	Linked
Is the measure responsive? Does it vary immediately when conditions change? Can it be used to signal changing conditions?	Quick
Is the measure response predictable?	Predictable
Is the measure credible? Is there scientific and managerial support for use of the indicator?	Credible
Is the measure feasible? Can it be quantified? Is the data already being collected? Is the collection regular, rigorous, and dependable into the foreseeable future?	Measureable
Does this measure a system-wide effect? Is it applicable for the entire ecosystem?	System-wide
Does the indicator denote value? Is it associated with human use or activity?	Value
Can the measure be explained easily? Does it resonate with the public?	Understood
Is the measure consistent? Will it show human gains only when the ecosystem condition improves?	Consistent
Can the measure be used for setting goals and targets?	Targets
Is the measure problem-specific? Can it provide direction for management?	Specific
Which ecosystem component within DPSEIR does the measure and ultimately the indicator address?	DPSEIR

Results: Indicator Descriptions

This section further describes the non-economic indicators selected for the South Florida coastal marine ecosystem.

Public Safety

The public safety indicator is described as protection from coastal hazards and recovery following events such as hurricanes, flooding, beach advisories, and fish kills. It relates to the population living in this area and their ability to recover from events taking into consideration the availability of medical assistance, insurance (home and health), and the density of people living in the coastal realm. The indicator is relevant in assessing changes in ecosystem services because the metrics used provide an overview of the overall health and resilience of coastal communities, both the built and natural environment. Measures such as *days under beach action* are directly tied to changes in ecosystem services. If harmful bacteria are present in the water, then humans do not derive the benefit of access for recreation or food such as shellfish. Measures such as *number of people per physician* measures access to health care. This access may mitigate the total effects of the contaminated water, that is, if someone becomes sick they may see a physician right away to receive treatment. This may mitigate the public safety risk to illness.

Public safety can be translated into management goals in several ways. For example, an increase in the occurrence of beach closures and/or fish kills may trigger a management response to increase the capacity of coastal water quality monitoring programs to address beach closures more quickly, and also to examine the causes of the events. Furthermore, managers may begin a more comprehensive, or integrated watershed program to improve water quality resulting in fewer beach closures. Another example is strengthening disaster planning and recovery efforts in more densely populated areas, or those that are determined to be more vulnerable.

Public safety data exists within secondary collections, that is, readily available data originally collected for another purpose. The data can be used to monitor change over time and may be collected at a larger spatial scale to provide a broad view of existing conditions. Available data includes the following metrics that can be used to calculate the public safety human dimensions indicator value:

- Access to medical care
- Number of storm events
- Personal property damage
- Density of people living in the floodplain
- Number of beaches monitored
- Days impacted by beach advisories/closures

These measures are responsive to both acute events such as a hurricane or chronic changes in ecosystem services such as those brought about by non-point source pollution. This indicator is integrative and includes measures to assess vulnerability to recovery from lost or interrupted ecosystem services.

Recreation

Recreation is the opportunity to engage in beach activities, wildlife viewing, and extractive and non-extractive uses of marine resources (e.g., SCUBA diving, snorkeling, fishing, boating). The ecosystem services benefit residents and visitors alike and include activities that have beneficial effects to individuals such as physical activity, aesthetic and therapeutic encounters, diet enhancement through seafood foraging and fun. Recreation measures both the opportunity which describes the benefits to people, but also relates to the users quality of the environment and recreational experience. It also creates jobs and business opportunities. Access to these services can be measured through secondary data sources, however it is important to conduct primary data collection activities such as surveys and observational studies to understand changes in recreational experiences and the beneficial uses people derive from specific locations. In the South Florida ecosystem, recreation is an important economic driver and is linked to management activities.

Activities are reported using visitation, licensing, access points such as boat ramps, the number of recreational areas, and use (concessions and commercial dive/fishing operations). These numbers are used to calculate the quantity of recreational opportunities. In some instances, user-satisfaction surveys have been conducted to capture perceptions of recreational experiences. The indicator is relevant for measuring changes in ecosystem services because the metrics represent recreation opportunities, and to some extent, the desirability to participate in those activities.

Recreation can be transferred into management goals as a response to user needs. For example, when user satisfaction ratings decline during visitation to boat ramps due to overcrowding, managers are faced with evaluating the need to propose, fund, and implement the construction of additional boat ramps or access points. Or if the dissatisfaction declines due to the excessive number of people on the water at specific locations it may be necessary to limit appropriate access points and redirect users to different areas. Another example is user perceptions of changes in the environment such as declining water quality in nearshore areas of the Florida Keys. Management actions prompted the evaluation and study of the causes of the change in water quality, sources and solutions, and improvements to encourage renewed recreation and visitation.

Recreation data exists in both primary and secondary formats. Primary collections consist of boat ramp use, quality of recreational activities (user-satisfaction surveys), annual visitor recreation days, acceptability of coral reef health, and social value mapping of specific recreational areas. Secondary data consists of the quantity of boat ramps, the number of fishing and hunting licenses issued, number of recreational areas available, number of dive trips available and their participants. Some of this information is available, while other information needs to be collected.

The recreation indicator responds to both chronic and event-related stressors. Biophysical impacts to the marine environment, such as poor water quality, can directly impact the frequency of recreational activities such as beach visitation. The loss of boat ramps or marine facilities due to storm damage prevents access for recreational opportunities. Additionally, higher recreational use occurs during seasonal fishing (e.g., mini sport season in the Keys, presence of highly valued fish – tournament fish). This indicator tells us that if the opportunity for recreation exists. It should be noted here that participant expectations can change over time. It is important to understand that opportunity for many forms of recreation may stay steady throughout declines in

ecosystem services until some tipping point is reached after which there may be steady declines. Relying on past studies or conducting additional work on the acceptable limits of services, the specific location of services, and the quality of current services will provide additional benefits in forecasting changes in this indicator.

Recreation can be integrative in the sense that it provides an overall status of the ecosystem structure, function and/or process. If individuals perceive changes in ecosystem health, they may alter participation in activities. Beach visitation may decrease when beach closures are issued. Recreational fishing may increase seasonally due to the presence of migratory fish. It may be important to investigate user perceptions of ecosystem structure and function to assess the knowledge-base of users to determine reasoning behind participation in recreational activities.

Recreation is sensitive to ecosystem drivers and pressures. The effects can be tied to local, regional, and global impacts. A local pressure, excess nutrients suspended in the water column may affect SCUBA divers seeking to view corals and reef fish. Divers may be disappointed if they visit sites with low visibility and little or no coral and algal overgrowth caused by increased nutrients suspended in the water column. These visitors may not return to South Florida for future dive-related vacations, or may choose to visit another dive site in the region.

Currently available data includes the following metrics that are examples of those that can be used to calculate the recreation human dimensions indicator value:

- Number of boat ramps
- Number of fishing, hunting and boating licenses
- Number of recreational areas such as local, county, state and federal parks and natural areas
- Number of commercial dive trips and number of participants

Culture

Culture encompasses the many facets of community life and historical activities that center around marine and coastal ecosystems. Activities within the MARES context are those that include the opportunity to attend events related to coastal ecosystem services and activities, protection of historic sites or sacred tribal areas and spiritual activities related to the ocean and coast. The indicator is relevant because it reflects the relationship of humans with their environment. These relationships vary from participation in seafood festivals, religious ceremonies (weddings, meditation, etc.), and tribal events. The frequency and type of cultural activities offer a broader view of how people connect to the environment, and to some extent, the enrichment in understanding of marine and coastal systems through visitation.

In general, these measures are integrative in that they depend on vibrant ecosystem services to move people to use these resources as inspiration for other activities. Culture indicators can be linked to management goals. The Waterfronts Florida Program provides assistance to revitalize areas with a maritime tradition. Environmental and cultural resource protection is one of the Program's priority areas. The program supports community visualization to identify alternatives for revitalization, which is then followed by an implementation plan to carry out that vision. Within the MARES project area, one port, Port Salerno in Martin County received assistance from the program. Other working waterfronts, such as Marathon Marina, Marathon, Florida

Keys, did not receive the Waterfronts Florida designation. However, a revitalization project to maintain and expand the marina began implementation in the late 1990s as a grassroots effort.

Cultural data exists in both primary and secondary data collection in a variety of ways. Primary research consists of spiritual sites and services, perceptions of marine related spirituality, and social value mapping tied to specific areas of the marine/coastal environment. Secondary data is measures in the number of cultural events, attendance at those events, the number of designated sites of tribal or historical importance, the number of environmental or civic groups, and the number of arts and entertainment maritime-related businesses located within the coastal region.

Culture responds to stressors with changes in the frequency and participation in events and the quantity of maritime sites. Stressors affecting participation in events may be tied to economic impacts in a region, or may be more closely influenced by ecosystem state. Lower than normal participation rates may be due to habitat quality, severe weather, or competing events in an area. Maritime sites may change in number due to a decline in the number of fishing vessels in a fleet. The initial decline in fishing licenses may be tied to fishery management regulations reducing the amount of available catch, thus, impacting the ability for fishers to stay in business.

Available data includes the following metrics that are examples of those that can be used to calculate the culture human dimensions indicator value:

- Number of cultural events (e.g., Festivals)
- Attendance cultural events
- Number of historic or tribal designated sites
- Number of coastal/ocean environmental or civic groups
- Number of arts /entertainment businesses

These measures show how people value services as well as their concern for adequate protection of services. Opportunities that rely on access to resources, biodiversity of resources or capture of seafood depend on the supply of services. Select measures such as the number of environmental groups in an area are already counted, reported and available for collection. Others, such as cultural events will require additional collection. A fuller understanding of the places people value for their cultural services or the perceptions people have of marine-related spirituality will require the design and conduct of new studies.

Education (Informal)

The education indicator consists of the opportunity to explore and tour marine and coastal areas. Living laboratories can be used for both learning and scientific research. The relevance of the indicator to ecosystem services is the existence of these environments, healthy or unhealthy, restored or injured. They present real-world examples for participants to experience (see, touch, and feel) components of the marine ecosystem. The term “informal” only implies that this is not K-12 or university education, not that it is any less rigorous in content and pedagogy.

Education is linked to management goals in South Florida. The Florida Keys National Marine Sanctuary and Florida Department of Environmental Protection work together to implement Sanctuary’s Education and Outreach plan. The focus is to build knowledge of the region’s marine and coastal resources. Teacher trainings, educational/visitor centers, and classroom

activities comprise some of the projects to implement education within the management goal. Managers can use enforcement data to identify trends in compliance with fishing regulations, boating regulations, anchoring and use of protected areas (Special Protected Areas, Ecological Reserves, etc.). This can then be transferred into education programs that target enforcement issues.

Science and education data is found in both primary and secondary collections. Primary collections consist of the opportunity for learning experiences, quality of field experiences, and the number and experiences of guided tours. Secondary collections consist of the number of nature tours and participants, the number of nature tour businesses and non-governmental organizations conducting tours, and the quantity/length of self-guided tours. Some of this information exists and is easily accessible, such as the number of operators and businesses. *Other information such as learning experiences and quality of field experiences is more difficult to locate and deserves a more comprehensive evaluation in the future.*

Science and education respond to stressors, however, these stressors and changes in the ecosystem state are often used as educational opportunities. A negative impact on the environment can be turned into a learning experience. Lionfish, an invasive marine species from the Indo-pacific is found throughout the Florida Reef Tract. In response, educators develop programs to inform participants about the impacts to the marine environment, changes in the food web on the reef caused by Lionfish. Educators also include information to deter individuals from releasing plants and animals into the environment that are not native to Florida. Science and education presents an interesting facet of the how indicators and ecosystem services are linked. Science and education opportunities will continue so long as there is no risk of harm to participants, and these opportunities, even if detrimental, present opportunities for learning.

Science and education is integrated in a sense that it can be coupled with most all of the other indicators. Changes in ecosystem state by their nature present opportunities for learning. Formal education opportunities, studying changes to the ecosystem components helps explain why changes are occurring in the ecosystem.

Available data includes the following metrics that are examples of those that can be used to calculate the Education (informal) indicator.

- Number of nature tours, number of participants
- Number of nature tour businesses
- Number of non-profit groups providing tours and classes
- Miles of self-guided tours (vehicle, foot and bicycle traffic)

Marine Occupation Structure

The occupation structure indicator is the opportunity for those activities associated with generating income from marine and coastal resources. These opportunities are associated with marine dependent people, these include but are not limited to people who are directly or indirectly tied to the coastal marine environment. This may include people who work in the following industries; commercial fishing, recreational guides, boat ramp operators, coastal hotels, restaurants that depend on local seafood, marine fuel stations, gas stations for land-based access (driving), dive shops, fish bait shops, etc. Data is available from the U.S. Bureau of Labor Statistics pertaining to employment and wages in a variety of service sectors however it will take more work to separate, for instance, restaurants from those dependent on local seafood versus those who do not. An example of commercial fishers is provided below however it will be important to monitor total job diversity and devise means to interpret changes.

In MARES, we identified three distinct but related classes of users of the coastal marine environment were identified to further develop the MARES models and are used here to illustrate the breadth and depth of the occupation structure indicator:

Primary users are those individuals or groups that actively engage in activities in or on the water, and that are directly dependent on the marine resource. Examples are commercial fishers, beach goers, anglers, divers and swimmers, and beachfront hotel owners.

Secondary users are those one step removed from direct interaction with the marine resource, but who provide enabling support for the primary users. Examples include marina operators, dive shops or bait and tackle shops.

Tertiary users are those who don't directly interact with the coastal marine environment, but whose activities support the primary and secondary users in an indirect fashion. Examples would include hotels, restaurants, souvenir shops, linen companies, lawn maintenance for hotels, transportation, etc.

The marine occupation standard indicator can be used to assess ecosystem services. Changes in ecological state cascade across the occupation structure with the potential for far-reaching impacts. Fish abundance may reflect the ability to catch fish (primary users), a change in the need for vessel maintenance or marina use (secondary users), and the availability of seafood products for purchase in grocery stores and markets (tertiary users). Also included in primary users are owners of beachfront resorts, restaurants, and vendors (e.g., beach chairs, water sports equipment, etc.), boat builders and public and private organizations that study and management marine and coastal areas. Marine occupational structure contains a larger and diverse group of businesses and individuals.

Marine occupation structure is linked to management goals. In the commercial fishery example, if catch limits are implemented, fewer fish may be caught and fisher incomes may be reduced, again with impacts on both the secondary and tertiary users. Management alternatives vary in scope, some options used are limited entry into fishing grounds, length of fishing season, gear restrictions, and reductions in the number of fishing licenses issued.

Marine occupation structure data can be captured as primary and secondary data. Primary data consists of job dependence on coral reefs and marine and coastal environments. Secondary data includes the number and earnings of people associated with different areas of work as coded by the U.S. Bureau of Labor Statistics, percent unemployment and economic diversity. Various measures of the intensity of activities by primary marine dependent people, and secondarily by the number people participating in these activities can be explored through data collected by the NOAA National Marine Fisheries Service or primary data collection. Using commercial fishing as a primary user, information is collected on the types and amount of fish harvested and “landed” in port. Additional information can be collected to estimate the effort expended by commercial fishers in acquiring their catch, and this leads to the calculation of catch per unit effort, which is often taken as a measure of the abundance of the fished stock. Information collected can be analyzed to estimate the magnitude, or value, of their activities in economic terms. This allows for comparisons to be made about the scale of the activities of marine dependent people versus other sectors of the marine and other sectors of the general regional economy as viewed in unemployment numbers.

Marine occupation structure responds to *Drivers* and *Pressures* of change impacting ecological *State*. The most obvious example is commercial fishing impacts due to a reduction in the amount of fish available to catch. This reduction may be the result of reduced numbers of fish or restrictions on harvest due to protection placed on populations of targeted commercial species. Lower income may cause fishers to leave the industry, no longer needing a marina to store and service their vessel(s), and no longer providing fish to processing plants, grocery stores and restaurants. Improved conditions may result with increases in the hotel and restaurant service sector. The marine occupation structure indicator and impacts that range from ecology to economy are closely linked and the fishing example provided the sensitivity of this indicator to monitor change in the stressor-indicator relationship.

The indicator is integrative into most of the ecosystem models. MARES project teams openly debated the application of fisheries-related occupation structure, termed marine dependent people during several workshop sessions and should be further evaluated. Two options surfaced, to include marine dependent people in every state ecological model, or to have a single marine dependent people model that included the relationship with all state ecological models. No single solution was developed, however, this illustrates the strength of the relationship between this indicator and all of the state ecological models.

Available data includes the following metrics that are examples of those that can be used to calculate the Marine Occupation Structure indicator:

- Number of beachfront rooms
- Number of insurance claims or dropped policies

Aesthetics

The aesthetics indicator is the opportunity to access marine and coastal areas including for wildlife viewing, recreation, and the existence of the coastal marine ecosystem. Ecosystem services tied to this indicator are comprised of the quality of aquatic and terrestrial environments, open space and the associated visual, olfactory, and auditory components, and the abundance and diversity of wildlife. Changes in these services directly impact the indicator. For example, fewer 'pristine' environments and the presence of wildlife in those habitats translates to fewer visitor opportunities.

The aesthetics indicator can be interpreted into management goals. One example of aesthetics is flats fishing in Florida Bay. Boats designed to move through shallow water are equipped with a raised platform (~5ft high) along the back end of the boat. The platform is used to stand on when the engine is off and the only form of movement is to pole-and-troll. The boat moves quietly over seagrass beds, mud flats, and among mangrove islands in search of prize fish-bonefish and tarpon-solely by the movement of the person pushing the boat along with a long pole. Flats fishermen tend to appreciate the quietness of their environment both for aesthetics, but more so because noises can scare away fish. The group of fishers frequent areas of Florida Bay in search of their target species. Disturbances, such as a boat passing at high rates of speed cause fish to scatter, and sometimes, shallow seagrass beds that serve as nursery grounds for fish are destroyed by boat propellers (seagrass scarring). These impacts affect the aesthetic quality of the fishing experience and leave lasting impacts on the ecosystem. Using this example, the aesthetics indicator is closely linked to management goals that both allow use of natural resources and protection from damage. Another example is found in the desire for residents and visitors to access the beach for enjoying the view of oceans and bays. Policies to obtain land for public access and parking allows access the beach, just as stormwater best management practices protect water quality and clarity.

Aesthetics indicator data is collected in primary and secondary formats. Primary data consists of content analysis of sales (brochures and newspapers), web forums, google searchers for the number and type of aesthetic descriptions by habitat or location, social value mapping, species richness, existence of megafauna, acceptability of resource health, and how often megafauna are spotted during visits. Limited primary information is available at this time. Secondary data consists of the number of waterfront hotel rooms, number of fish kills or algal blooms, miles of accessible shoreline, number of SCUBA trips and participants (non-fishing), number of wildlife viewing areas, and opportunities to see megafauna (dolphins, turtles, etc.), attendance at beach-front parks. Some of the secondary data exists and is available on the internet or by contacting agency offices (Tourism Development offices, Fish and Wildlife Conservation Commission).

The aesthetics indicator responds to stressors on the ecological state. Water quality, habitat, and disturbance (development, boating activity, etc.) contribute to 'pristine' qualities of the environment that is typically associated with aesthetics. A reduction or loss of these elements results in lower quality of aesthetics. A loss of seagrass habitat can limit the potential for wildlife viewing (manatees, sea turtles, and prize fish) and also can impact water quality (reduced sediment retention and lower visibility).

The aesthetics indicator is sensitive to change both directly and indirectly. A loss of habitat directly affects the quality of the environment (visual, olfactory and auditory). For example,

direct changes following a hurricane, trees lose their leaves, debris accumulates in coastal creeks and tributaries, and familiar places can be hard to locate without the aesthetic context clues. Indirect changes, such as upstream development can alter freshwater flows impacting water quality. The changes can be both visual (water clarity) and also chemical where changes in salinity can vary the presence of fish species, that might otherwise be typically found in an area. It should be noted here that participants expectations can change over time so it is important to understand that opportunity for many forms of recreation may stay steady throughout declines in ecosystem services until some tipping point is reached after which there may be steady declines. Relying on past studies or conducting additional work on the acceptable limits of services, the specific location of services and the quality of current services will provide additional benefits in forecasting changes in this indicator.

The aesthetics indicator is integrative. Aesthetics are most closely related to the economic indicators associated with tourism and recreation in the region. They can also be tied to ecological states. If change in habitat occurs, it is likely that the regulating services provided by these 'aesthetic' environments is changed and there are some implications for biophysical interactions and resilience of the ecosystem.

Available data includes the following metrics that are examples of those that can be used to calculate the Aesthetics indicator:

- Number of fish kills or algal blooms
- Miles of accessible shoreline
- Number of dive trips
- Number of participants (non-fishing)
- Number of wildlife viewing areas
- Opportunities to see megafauna (e.g., dolphin and/or manatee viewing trips)

Discussion

Indicator measurement and change over time: Public Safety Example

The public safety indicator has been worked out as an example of how the other indicators may be operationalized in the future. This example of measurement is prepared using data collected for another project, but uses many of the same measures. The county data available for analysis did not perfectly match up with the counties used in MARES, however, they are close enough to provide an understanding of how this indicator may be measured and used (Table 6).` Secondary data is used in this example though additional studies targeted specific questions related to further refine the indicator could be used. Two time points are used to show change over time, in this example between 2000 and 2008. These are aggregated at the county level. The components of this indicator are:

- Access to medical care
- Number of storm events
- Personal property damage
- Density of people living in the floodplain
- Number of beaches monitored
- Days impacted by beach advisories/closures

Table 6: Counties used in analysis and those of MARES study area.

Counties used in overall analysis (MARES and reference)	Counties used to measure MARES area	MARES Counties	Region of Mares
Escambia			
Santa Rosa			
Okaloosa			
Walton			
Bay			
Gulf			
Franklin		Lee	Southwest
Wakulla		Collier	
Monroe	Monroe	Monroe	
			Keys
Miami-Dade	Miami-Dade	Miami-Dade	Southeast
Broward	Broward	Broward	
Palm Beach	Palm Beach	Palm Beach	
Martin	Martin	Martin	
		St. Lucie	

Method

Initial measures for the public safety index were determined through review of scientific literature and other well-established indices, expert recommendations acquired through a workshop focused on indicators and measures of community well-being for coastal counties (Lovelace, et al. 2012) and statistical analyses on a dataset collected for coastal counties of the southeast and Gulf of Mexico (Lovelace et al., in press). The candidate measures were examined using statistical analyses, including correlation analysis and principle components analysis (PCA), to identify the best performing measures of public safety for the pre-selected time points. Based on the results of these analyses and the ability of measures to meet the criteria of being responsive, meaningful, and easy to understand, the component measures of public safety were selected. The measures include: (1) number of rural health clinics, (2) number of individuals per hospital bed/number of individuals per physician, (3) total tropical storm and hurricane events, (4) total tornado events, (5) total property damage from tropical storms and hurricanes, (6) total property damage from tornados, (7) housing density in Federal Emergency Management Agency (FEMA) special flood hazard area (SFHA) zone (2010 data used for second time point), (8) percent days under a beach action such as closing or advisory, and (9) percent beaches in the county that are monitored. Though not available across all time points, the variables for total number of hospital beds and physicians in a county are used as indicators of access to medical care, alongside the number of rural health clinics, for the two time points analyzed. The number of physicians was used in place of number of hospital beds for the second time point due to the strong, significant correlation between the measures. Measures were adjusted for population size, when necessary (e.g. hospital beds and physicians). The measures are summarized in Table 7.

The criteria (Table 5) were applied to this indicator and measures to determine their ability to inform management. The result of working through the series of questions is a summary, or short list of the most important HD information to be considered for management actions required by this target audience. (Table 8.) Each response is highlighted based on their utility for measuring this indicator. *Yes* responses are highlighted in green; the *maybe* responses in yellow and; the *no* responses in red or orange fill. It is important to note that those highlighted in orange are measures needed to fully understand the level of safety for residents and even though they don't have a direct link to the quality of the ecosystem service it is necessary to include them in the analysis. For instance, a high level of available physicians may mitigate health impacts from a degraded environment as residents or visitors might quickly visit a health care provider if they become ill. Or, a low number of housing units in the flood plain reduces the impact from flooding events compared to a county that has more residences in a flood plain even if there is ecosystem degradation. These evaluation responses are for illustration and remain open for further discussion and debate.

Table 7: Description and sources of measures and data for public safety example.

Measure	Description	Source
percent days under a beach action such as closing or advisory	This is the percent of days in the number of beach days available (depends on the local description of the beach season) that there was a beach closing or advisory. More information at http://water.epa.gov/type/oceb/beaches/	EPA
percent beaches in the county that are monitored	This is the percent of beaches in a county that are regularly monitored. This varies by year. A list of beaches can be found at: http://water.epa.gov/type/oceb/beaches/list_index.cfm	EPA
number of rural health clinics	This is the number of rural health clinics available in a county per 1000 people of the county population. More information at http://arf.hrsa.gov/ and http://muskie.usm.maine.edu/Publications/rural/RHChartbook03.pdf	HHH- Area Resource File
number of individuals per hospital bed	This is the number of hospital beds available within a county per 1000 people in the county population. More information at http://arf.hrsa.gov/	HHH- Area Resource File
number of individuals per physician	This is the number of individuals per each physician practicing in a county. Physicians are the total number of non-federal MDs and Dos under age 75 who are not hospital residents and whose major activity is classified as patient care.	AMA (compiled by Census)
housing density in FEMA special flood hazard area (SFHA) zone	This is the number of housing units per square mile of area in the Special Floodplain Hazard Area as designated by FEMA. (2010 data was used for second time point) http://www.floodsmart.gov/	FEMA, Census
total tropical storm and hurricane events	This is the total number of events as determined by the National Weather Service. http://hurricanes.noaa.gov/pdf/hurricanebook.pdf	NOAA National Weather Service
total property damage from tropical storms and hurricanes	This is the total dollars in property damage summed from the total events per year per county. http://hurricanes.noaa.gov/pdf/hurricanebook.pdf	NOAA National Weather Service
total tornado events	This is the total number of events as determined by the National Weather Service. http://www.spc.noaa.gov/faq/tornado/	NOAA National Weather Service
total property damage from tornados	This is the total dollars in property damage summed from the total events per year per county. http://www.spc.noaa.gov/faq/tornado/	NOAA National Weather Service

Table 8: Evaluation of candidate measures for Public Safety indicator

Ecosystem Service	Public Safety									
	Secondary Collection	Days under beach action	beaches being monitored	Individual per hospital bed	Individuals per physician	Rural clinics	Housing density in SFHA flood zone	Total tropical storm and hurricane events	Total property damage from tropical storms and hurricanes	Total tornado events
Measurement units	percent	percent	number	number	number	ratio	number	dollars	number	dollars
Linked	Y	Y	N	N	N	Y	M climate	Y	M climate	Y
Quick	Y	Y	N	N	N	M	M	Y	M	Y
Predictable	Y	Y	N	N	N	Y	Y	Y	Y	Y
Credible	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Measureable	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
System-wide	Y	Y	Y	Y	Y	Y	M	M	M	M
Value	Y	Y	Y	Y	Y	Y	M	Y	Y	Y
Understood	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Consistent	Y	Y	N	N	N	Y	M	N	M	N
Targets	Y	Y	M	M	M	Y	M	Y	M	Y
Specific	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
DPSEER	E	E/R	P	P	P	D	E	E/R	E	E/R

Y=yes, N=no, M=maybe, somewhat, or depends, DPSEER – Driver, Pressure, Ecosystem Service, Response

Using the MARES economic index compilation as an example, each of the index components was recoded into an ordinal variable with a score of 1 to 5 based on the distribution of values for the 13 Florida coastal counties for which data was readily available. Variables were scored such that higher values represent higher risk, i.e. the more tropical storm and hurricane events, the higher the score. When necessary, variables were reverse-scored so that the increase of score was synonymous with higher risk. For example, the more rural health clinics, the lower the county's score as the population has easier access to health care. Index values were computed by summing the values of the component measures. The final index values have a potential range of 9 to 45. Likewise, percent change in index score between time points was calculated for each county in the sample using the equation: $(t2-t1)/(t1) * 100$. A t-test was then conducted for the larger sample of Florida coastal counties to assess the significance of the change. Although this method of scoring and computing the index was satisfactory for this example other methods might produce more reliable and meaningful results and should be pursued in the future.

Results

Public safety is reported for two time points as both 1) component measures and 2) additive index scores. The scores are reported as high score/high risk, lower score/lower risk. Results are reported for MARES counties specifically, and for a broader sample of Florida coastal counties. First, the component measures for each of the MARES counties are presented for each time point (Figure 3, 2000 and Figure 4, 2008). The counties used represent the Florida Keys and southeastern regions of the state. (Monroe County straddles the Keys and southwestern regions.) At the 2000 time point, the total property damage from tropical storms and hurricanes is low, due to the low number of tropical storm and hurricane storm events that year. The risks to public safety resulting from tornados, housing density in flood plain, and percent days under a beach action are high. This is not mitigated by access to healthcare in most counties, as the score for lack of access is also high demonstrating an increased risk for public safety. At the 2008 time point, there is an increase in tropical storm and hurricane events for Monroe and Miami-Dade Counties, while fewer days were impacted by beach actions. The improvement in beach health represents a positive change in the ecosystem services available, which contributes to public safety.

Composite scores are sums of the component measure scores much as the MARES economic indicators are additive to a single score. The index values are useful for generalizing a single indicator such as public safety, in this case, between two time points. When there is a significant change in the indicator, then it will be useful to look at the individual component scores to provide information on the particular dimensions that have created the change in risk. In most cases, an understanding of the causes and consequences of the change will require additional research.

This is evident in the composite graph for the southeast counties, Figures 5 and 6. Palm Beach County saw a slight decrease in risk while Monroe County had an increase in risk. To learn more it is necessary to look at the measures for each time point, Figures 3 and 4. Palm Beach County experienced a decrease in the number of tornado events and beach actions. Alternately, for Monroe County, the increased hurricane and tornado events led to greater risks to public safety. Figure 7 shows the change in risk for all of the counties analyzed. Except for Monroe County, MARES counties are more stable than the reference counties in terms of change over

time. This is largely due to the increase in tropical storm and hurricane events on the west coast of Florida during this time period.

Additional Considerations, A Note About Well-being

Well-being is utilized as a measure of quality of life in many countries, cities, and localities, and is typically broken into components related to economics, environment, basic human needs, and the subjective well-being of people. Many definitions of well-being include the following key components: basic material needs, freedom, health, good social relations, and personal security so it is generally comprised of the indicators used in the MEA to link the reliance of well-being on ecosystem services. More recently, aspects of well-being have been documented in the scientific literature (President's Council of Advisors on Science and Technology 2011). In this case, the concept of well-being can be aggregated to a regional perspective.

Changing conditions in the natural environment and the corresponding changes to ecosystem components or processes can have a positive or negative impact on the benefits accrued to people. As a result, changes in ecosystem conditions can result in changes to the well-being and quality of life for people who value those benefits the most. When ecosystems that are stressed or compromised fail to provide people with desired benefits, the loss, particularly if the impairment is sustained, will likely become noticeable to people and communities and may serve to reduce well-being. For example, technological disasters that lead to some negative outcome for people or the environment, such as contamination of the natural environment with toxins, chemicals or other contaminants, can greatly reduce or eliminate some ecosystem services of value to people. Thus, this concept measures response to changes in ecosystem services within the regional population. The demonstrated indicator, public safety, is one aspect of well-being.

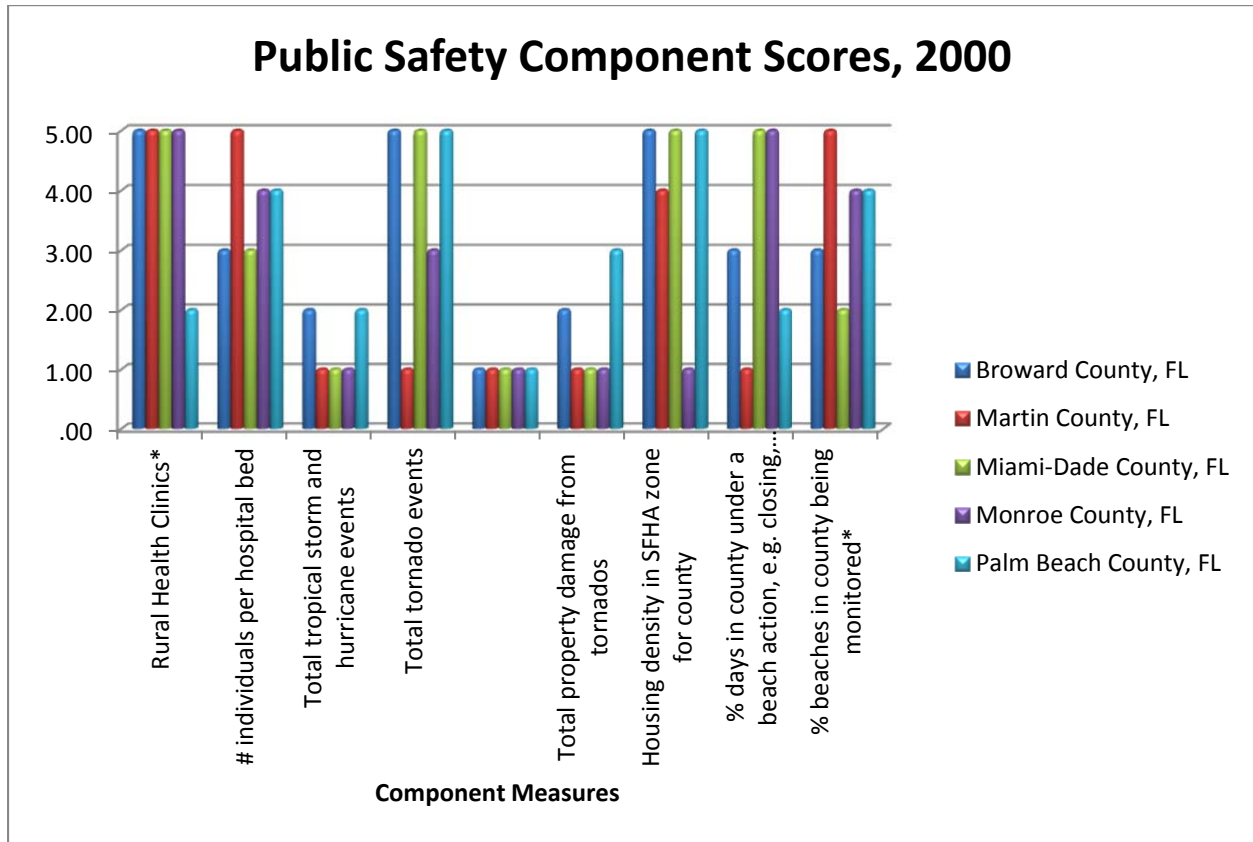
When do we need HD indicators?

While historic data can be used to show past trends, experts assert that for best use, data collection, analysis, and monitoring should begin before impacts occur and in advance of restoration.

In order to support management activities that will conserve ecosystem services that lead to vibrant and resilient coastal communities it will be important to understand and measure how humans drive and pressure the system as well as how they respond in the system, i.e. are humans deriving the services needed for a quality life? The ultimate goal will be to anticipate and prepare for the types of ecosystem or social disruption most likely to accompany acute changes in management options.

Establishing a strategy for monitoring social and economic changes at this regional level will allow researchers and public managers to assess the impacts of changing environmental conditions (e.g., water quality, changing shorelines, and rising sea levels), to human health and well-being. Additionally, such monitoring can inform the development of tools to predict socioeconomic changes to the region given particular environmental scenarios and to identify where resources might be applied to conserve societal benefits and to evaluate the success of management activities.

**Figure 3: Public safety component scores for southeast Florida counties in 2000. High score(5)=high risk, lower score (0)=lower risk.
 *higher scores are equivalent to fewer rural clinics and beaches monitored **housing density in the SFHA zone measured for 2010**



**Figure 4: Public safety component scores for southeast Florida counties in 2008. High score(5)=high risk, lower score (0)=lower risk.
 *higher scores are equivalent to fewer rural clinics and beaches monitored **housing density in the SFHA zone measured for 2010**

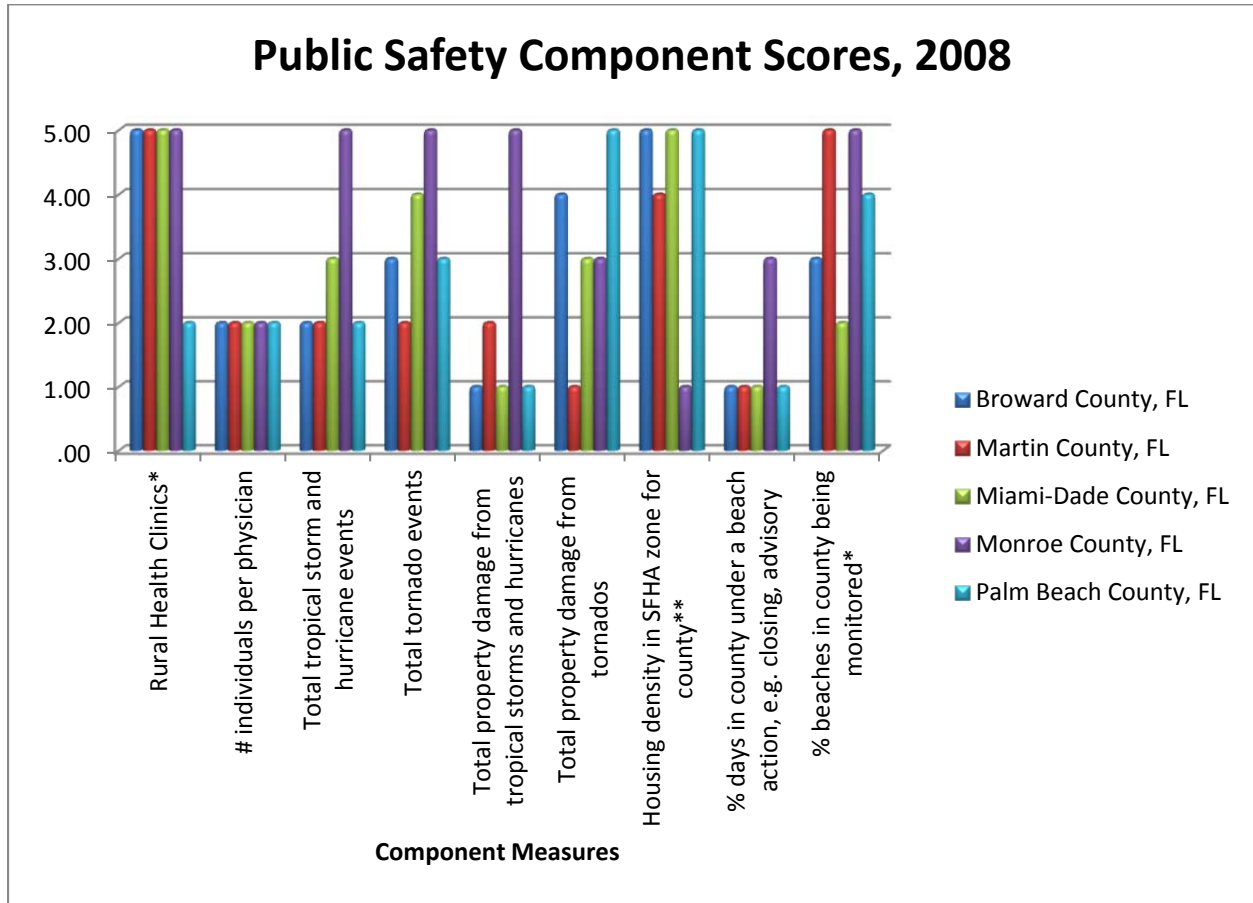


Figure 5: Composite scores of public safety in southeast Florida between two time points (2000 and 2008).

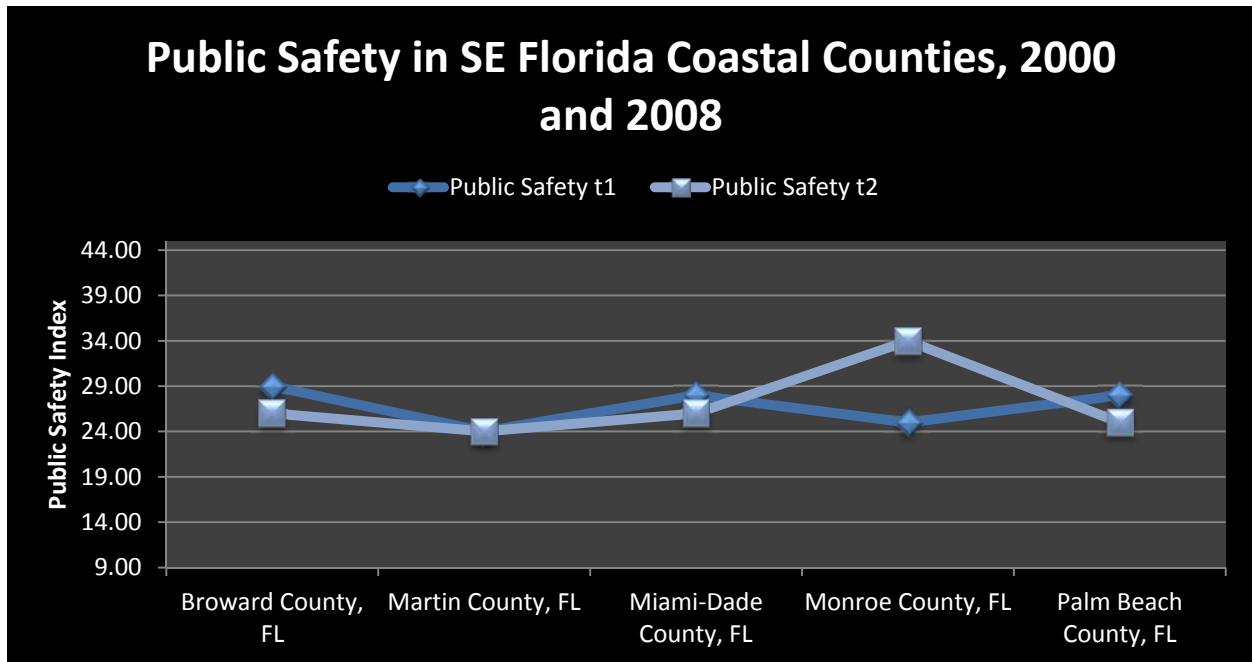


Figure 6: Change in composite score of public safety in southeast Florida between two time points (2000 and 2008). Note, tropical cyclone events caused the significant change in Monroe County results.

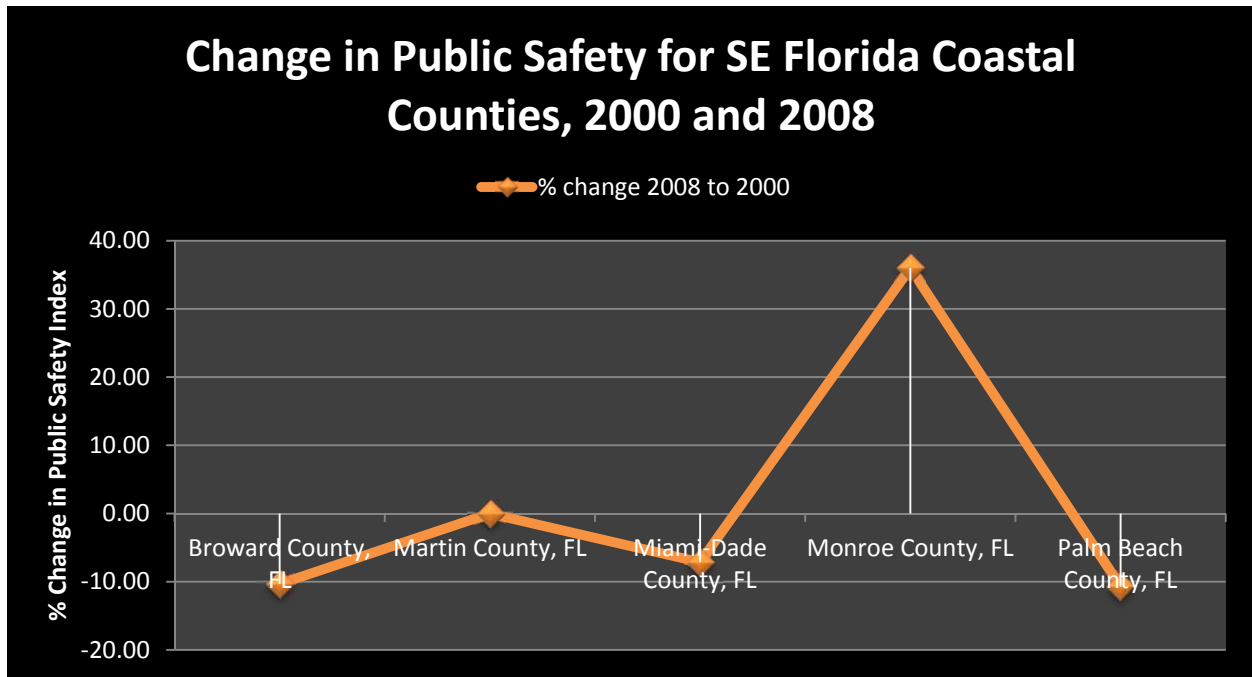
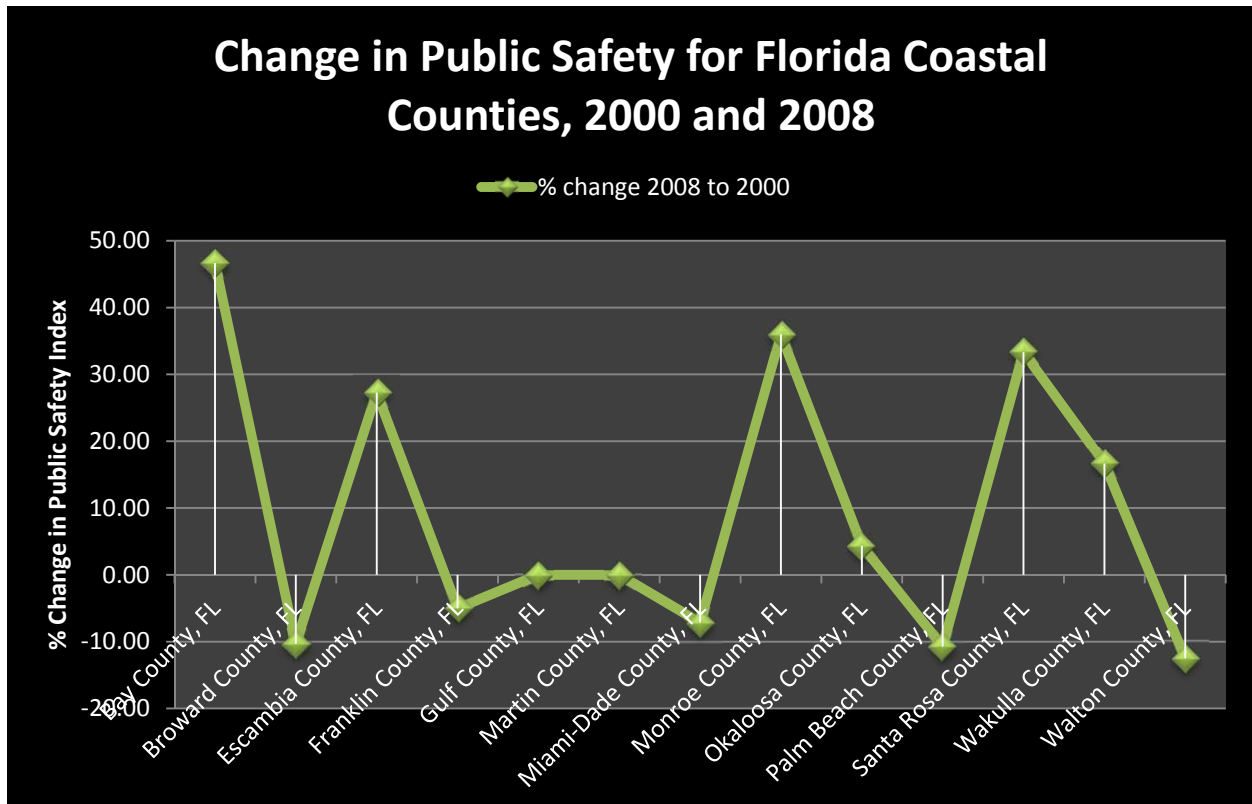


Figure 7. Change in composite score of public safety in selected Florida counties between two time points (2000 and 2008). Note, tropical cyclone events caused significant change in Bay, Escambia, Monroe, Santa Rosa counties and is reflected in their results.



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