Ecosystem Services Provided by the South Florida Coastal Marine Ecosystem

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Summary

This whitepaper identifies the ecosystem services provided by the south Florida coastal marine ecosystem and reviews some methods for evaluating these services. The list of ecosystem services used by the MARES project continues to evolve. Ecosystem services were first identified in workshops held to develop integrated conceptual ecosystem models (ICEM). Results of these workshops are documented in a set of technical reports now in preparation by NOAA. Subsequently, the list was revised for application in a workshop held jointly with Everglades National Park in August 2012. The list of ecosystem services presented here reflects further refinement in connection with preparation of a publication on the MARES project (Kelble et al. in review).

Background

The integrated conceptual ecosystem models developed for the South Florida coastal marine ecosystem are built around the DPSER framework comprising five elements: drivers, pressures, states, **ecosystem services,** and responses.[1] The ICEMs provide a foundation for implementing ecosystem-based management (EBM) of the region's coastal resources. The ecosystem services element provides the necessary link between the functioning ecosystem and human uses, and they are the focus for informing management decisions, establishing management goals, and evaluating management outcomes. The production of and trade-offs amongst ecosystem services when evaluating the relative merit of potential management strategies or responses.

Because ecosystem services describe the benefits that society derives from the ecosystem, both directly and indirectly (Costanza et al. 1997), they are a natural bridge between the biophysical and human dimensions sciences (Burkhard et al. 2010). Extensive scientific effort has been devoted to develop methodologies that identify, locate, and quantify the services we value (c.f. Costanza et al. 1997, Feld et al. 2010, Turner et al. 2003, Sherrouse et al. 2011). Despite these efforts, there are few examples employing ecosystem services to improve decision-making indicating they have yet to truly penetrate into the realm of resource management (Cowling et al. 2008). Ecosystem services will become a staple of resource management only when practical methodologies, including models, are developed that make consideration of ecosystem services tractable for decision-makers (Burkhard et al. 2010).

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[1] See MARES Whitepaper: Including HDS [online: http://sofla-mares.org/docs/MARES_White%20Paper1_DPSIR%20and%20HDS.pdf]

Ecosystem Services Related to Human Well Being

Ecosystem, ecosystem services reflect societal values, goals, desires, and benefits (Levin et al. 2009, MEA 2005, TEEB 2010). and contribute to human well-being. “Well-being” is used by human dimensions scientists as a measure of quality of life in many contexts and is typically broken into components related to economics, environment, basic human needs, and the subjective well-being of people. On a global level, the Millennium Ecosystem Assessment describes the following components of well-being: basic material needs, freedom, health, good social relations, and personal security (MEA 2005).

A distinction is often made between basic human needs and subjective well-being. Basic human needs are things required for survival such as food, water, and shelter. Subjective well-being, on the other hand, encompasses things that may not be absolutely necessary for immediate individual survival but are important to a positive emotional and psychological sense of life, such as culture and aesthetics, and may be important to long-term societal survival. Health is important to both. The absence of acute trauma and disease is a basic need, but chronic health issues contribute to subjective well-being. Developing countries focus on meeting basic needs, while countries where those basic needs are met, strive for higher levels of well-being in search of a good life (MEA 2005).

Aspects of well-being including ecosystem services have been addressed in the scientific literature (PCAST 2011) and have become the focus of assessments such as the Canadian Index of Well-being (Wellbeing CIo 2012) and the Organization for Economic Cooperation and Development’s Better Life Index (Kerenyi 2011). Ecosystem services that benefit people directly include food, recreation, and storm protection. These services provide life's basic needs and influence economic conditions, movement of people, regulation of climate and disease, recreation and cultural opportunities, and security. Changes in these ecosystem services have wide-ranging impact on human well-being (MEA 2005). EBM assumes that these ecosystem services influence well-being regardless of specific individual’s recognition of these services in their lives, and the service values can be measured through health, safety, economic security, effective governance, education, food/water, housing, access to critical services, social cohesion, social conflict and environmental use indicators (Lovelace et al. 2012). Indicators are included in EBM models to provide managers with information about social and economic status and their correlation with natural resource conditions.

Ecosystem Services Related to Attributes that People Care About

Ecosystem services are tied to the set of attributes of the coastal marine environment that people care about. The attributes are the beneficial outputs or outcomes that people derive from the environment. For example, worldwide recognition of the Florida Keys unique coastal environment is derived from the variety and quality of marine life. The integrity and ecological health of marine and terrestrial environments is critical to the economy of the Keys. In 2007-08, approximately 3.3 million visitor-trips were made to the Keys, totaling over 13.9 million person days. Recreating visitors accounted for 92% of the 3.0 million total visitors and 12.8 million person-days (Leeworthy, Loomis and Paterson 2010). Tourism by recreating visitors stimulated over $2.2 billion in local Keys production and supported over 32,000 local jobs (Leeworthy and Ehler 2010).

An "attribute that people care about" is a characteristic of an ecosystem service for which people can express their demand. One ICEM workshop facilitated a discussion of the "attributes people care about" as a prelude to identifying relevant ecosystem services. The workshop discussion results are summarized in Table 1. The "attributes people care about" were then used to identify relevant ecosystem services, those findings are shown in Table 2.

Ecosystem service values provide decision makers with critical information on the importance of marine ecosystems to people and the economy. Monetary values of ecosystem services can be used in benefit-cost analysis[2] to assess a project's economic worth. Methods for valuing services are identified in Table 3. Monetary values can be used with non-monetary measures to assess changes in human well-being.

Ecosystem services enter the DPSER framework through nested sub-models, c.f.[3] sub-models for the water column and major habitats including seagrass beds, fisheries, and coral reefs. The sub-models include pressures, ecosystem state attributes, and "attributes that people care about." The ecosystem state attributes in each sub-model are a parsimonious subset of descriptive characteristics used to represent its overall condition (Ogden 2005).

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[2] Benefit-cost analysis and other tools for decision-making are in described in Wegner and Pascual, 2011.

[3] The sub-models referred to are described in detail in the MARES integrated conceptual ecosystem model reports, currently in preparation as NOAA technical documents.

Table 1: Identification and description of attributes that people care about for South Florida coastal marine ecosystems

Attributes that people care about	Description
Aesthetics – on land	Healthy mangroves, sea grass beds, and other submerged aquatic vegetation support the quality of ocean views due to their natural beauty and their processing of nutrients and waste products that would otherwise pollute the marine waters. These services provide high quality open space aesthetics, and positive recreational experiences, including wildlife viewing, fishing, diving and boating activities.
Aesthetics – on water (water quality)	Water quality is one of the main attributes of the coastal marine environment that people care about. General characteristics of the water column, like clarity and cleanliness, i.e. the general absence of objectionable odor, nuisance, or disease-causing organisms, contributes to the aesthetic appeal of the coastal marine environment, as a whole, the enjoyment of the beaches and other activities on the water, and the safety of seafood.
Lots of healthy coral	Intact coral habitat and trophic structure: (1) maximizes the long-term sustainability of the system, (2) increases the likelihood of recovery of threatened species like acroporid corals (in particular the staghorn coral (Acropora cervicornis) has important populations on the SE Florida reef tract), and (3) increases the system's ability to recover from damage and disease. Diverse, productive, and healthy coral reef and hard bottom habitats also provide maximum enjoyment for snorkelers, and divers. The recreational value of coral reef and hard bottom will increase if a wide variety of different habitat types is widely distributed. This will provide a large number of diverse enjoyment opportunities for repeat visitors, as well as spread the impacts of excessive use over a wider area.
Lots and a large variety of fish	This attribute encompasses many characteristics of fisheries that people care about. For example, recreational fishers may care about the success in catching a certain species of fish while divers and snorkelers may care about seeing a variety of fish and shellfish. The importance of this attribute to ecosystem services is best illustrated using the Ten Thousand Islands in southwest Florida. The spectacular wilderness and teeming waters of the Ten Thousand Islands make fishing a major tourist attraction. Enthusiasts from around the world travel to the Ten Thousand Islands to enjoy the labyrinth of inner bays, passes, and outside waters for pristine back-country fishing. Desirable species include tarpon, snook, red drum, pompano, snappers, groupers, and other large sport fish, as well as pink shrimp and stone crabs. Most fishers understand the importance of a diverse and abundant prey base and connect undisturbed productive nursery habitats with good fishing. Recreational fishing in the Ten Thousand Islands area includes guide boat fishing, tournament fishing, and fishing from private vessels. Backcountry fishing guides provide valuable expertise on what, where, and when to fish.

Attributes that people care about	Description
	Guides experienced with the geography of the area easily navigate the many confusing passes, interisland channels, back bays, and tidal creeks, where the newcomer to the area can easily become lost. Tournaments such as the Red Snook Charity Tournament and other tournaments announced periodically on the internet, by fishing clubs, or by sport fishing magazines attract many sports fishing participants to the Ten Thousand Islands. Offshore fishing also is popular in the area. Legal-size snapper and grouper can be found offshore over hard bottom areas in waters 40 to 50 ft deep or more, where gray and lane snapper are mixed with red grouper. Commercial fisheries in the Ten Thousand Islands are focused on blue crab inshore and pink shrimp, stone crab, snapper, and grouper offshore. The two major shrimp trawling grounds are offshore near the Dry Tortugas and near Sanibel-Captiva. Shrimp trawling also occurs in waters where there is an absence of reefs between the two main grounds. Passage of the Endangered Species Act and the Critical Habitat component of the Magnuson-Stevens Fishery Conservation and Management Act suggest that people care about species that are imperiled. The Ten Thousand Islands area provides important habitat for two fish species, one marine mammal, and five turtle species that are endangered, threatened, or otherwise of special concern. The threatened Wood Stork, *Mycteria americana*, also forages in the Ten Thousand Islands (Browder 1984).
Lots and a large variety of marine wildlife	In Florida there are close to 2000 species of birds, fish, mammals and other animals (Estevez 1998). Viewing this diverse wildlife enhances the visitor experience for all tourists, even those who did not travel specifically to view wildlife. The coastal wetlands and mangrove forests of the southwest Florida coast provide prime opportunities for viewing a diverse range of animals that utilize the wetland habitat (Estevez 1998; Montague and Wiegert 1990; Odum et al. 1982).
Beach and shoreline quality	Florida Statute 161.053 identifies beaches as "one of the most valuable natural resources of Florida." Florida has 8,426 miles of tidal shoreline, second only to Alaska, and 1,350 miles of sandy beaches.[b] Florida has about 166 public beaches owned by the State of Florida or by a Florida city or county.[c]
Erosion and storm protection	Mangroves and coastal marshes are a natural barrier to shoreline erosion because the plants trap, hold and stabilize sediments (Carlton, 1974; Estevez 1998; Montague and Wiegert 1990; Odum et al. 1982). In addition, they buffer waves and storm surges providing natural protection for developed inlands (Badola and Hussain 2005; Montague and Wiegert 1990; Odum et al. 1982). In a worldwide study of mangroves, Barbier et al. (2008) found mangroves protected coastal communities from tropical storms up to 5 km inland exponentially decreasing wave height with mangrove distance inland from the shoreline. Salt marshes provided natural protection for coastal communities decreasing wave height four-fold with increasing distance inland from the shoreline.

Attributes that people care about	Description
	Oyster reefs protect sea grasses and mangroves from erosion by reducing wave height, current velocities, and sediment re-suspension. The reduction in turbidity, sedimentation and erosion aids the ecology and maintains the economic benefits and ecosystem services derived from these habitats. The three-dimensional structure provided by coral reefs provides protection from the impacts of storm waves, surge and tides, protecting both natural shorelines and property from physical damage. Coral reefs also provide much needed protection for beaches and natural shorelines from erosion. In South Florida, many beachfront hotels and other real estate benefit from the indirect protection that coral reefs provide to their beaches and buildings by providing a barrier to offshore migration of sand.
Air quality – odor	Clean, clear, unpolluted air is an important environmental amenity needed to enjoy outdoor activities.
Environmental education and research	Healthy habitats benefit the education and research sectors by serving as living laboratories for scientists, teachers, students, and the general public. SE Florida Universities with marine-based curricula and laboratories include FIU-Biscayne campus, FAU Ocean Engineering Campus, RSMAS Virginia Cay campus, NSU Dania Beach campus. Broward County maintains a marine high school magnet program.
Seafood safety	In 2010, Florida's commercial marine fishers landed 50 million pounds of finfish, 22 million pounds of crabs, lobsters and oysters and 19 million pounds of shrimp for a total dockside value of $186 million.[a] The predominant harvested species groups by weight and value are grouper, mackerel, mullet, snapper, swordfish, crab, lobster, oysters and shrimp.
Variety and number of birds	Of all wildlife viewing activities, bird watching is among the largest (Carver 2009). The coastal wetlands and mangrove forests of the southwest coast provide prime opportunities for viewing the diverse bird communities (Estevez 1998; Montague and Wiegert 1990; Odum et al. 1982). Waterfowl and birds of prey are abundant in the southwest coastal marshes and are the largest categories of birds watched away from the home (Carver, 2009).
Critical habitat for protected species	All but two of the State sub models directly provide critical habitat for protected species. The other two sub models are indirect providers of critical habitat in that they support the other sub models. Coastal wetland plants provide critical habitat for a number of vertebrate and invertebrate species (Odum et al. 1982), including seven species and four sub-species listed by U.S. Fish and Wildlife Service as endangered, threatened or of concern (Odum and McIvor 1990).
Carbon sequestration	All marine plant communities are carbon reservoirs. Twilley et al. (1986) measured litter fall in the fringing mangrove swamps of south Florida of 1.86 to 12.98 metric tons per hectare per year yielding carbon sequestration of 210 grams CO_2 per square meter annually. This is ten times larger than the

Attributes that people care about	Description
	sequestration of freshwater marshes and peat lands (20 to 30 g of CO_2 per square meter) with less methane gas release due to the abundance of sulfates (Chmura et al. 2003). In Florida's estuaries, oysters absorb CO_2 from the water column to produce hard calcium carbonate shells. Over time the shells accumulate very large amounts of CO_2.
Ecosystem resilience to disturbance	In general, people care about the sustainability of the coastal marine ecosystem. A sustainable ecosystem is required as home to particular species that people are interested in, such as sport fish, marine birds, and large animals like sea turtles, dolphins, and mantees that people find engaging and interesting to watch in their native habitat. The attribute of sustainability requires a well-functioning, whole ecosystem in which all elements are healthy and functioning well; the water column, the fish and shellfish populations, coastal wetlands, oyster reefs, seagrasses, and other benthic communities. Fish make use of the entire mosaic of benthic habitats over their life spans. And, in turn the communities of organisms responsible for maintaining these habitats require just the right combination of characteristics in the water column, i.e. temperature, salinity, clarity, and nutrient concentrations, in order to thrive.
Natural filter/ nutrient reduction	The quality of marine coastal waters is a key factor in determining the quality and quantity of many of the ecosystem attributes that people care about. Mangroves and coastal marsh systems filter and trap nitrogen, phosphorus, trace elements and heavy metals through combined interactions of the plants, soils, and living organisms protecting estuaries and marine ecosystems. These interactions reduce the nutrient and pollution loads into marine waters (Odum and McIvor 1990; Estevez 1998; Sklar and Browder 1998). Elements may be stored in the wetlands for many years (Estevez 1998; Sklar and Browder 1998). Oyster reefs filter and trap organic matter, detritus, phytoplankton, contaminants and bacteria from the water column. Oysters have a tremendous capacity, according to Newell (1981) an individual oyster can filter up 40 liters of water per hour.
Human health	Assuring human health is a principal goal in environmental management, and it is included in the list of attributes that people care about for that reason. Human health is a factor in other attributes that people care about, such as the quality of beaches and shorelines, seafood safety, water quality, air quality, and harmful algal blooms.

Attributes that people care about	Description
Recreation	The barrier islands in Lee County include over 50 miles of beaches that are enjoyed by visitors and residents and provide a significant income from tourism (Murley et al. 2003). The salt marshes in this region provide a sense of wilderness (Montague and Wiegert 1990) that also is valued by visitors and residents. The mangrove shorelines of the Ten Thousand Islands, Everglades and Whitewater Bay regions provide a scenic vista for visitors enjoying the waterways of the southwest coast while boating, fishing or wildlife viewing (Odum et al. 1982; Odum and McIvor 1990).
Harmful algal blooms	Residence times of dissolved and particulate matter on the Florida Shelf can be on the order of weeks to months. This creates conditions that favor the occurrence of harmful algal blooms, e.g. red tides dominated by the toxic dinoflagellate *Karenia brevis* (Steidinger et al., 1998), and 'blackwater' events (Hu et al., 2003). Red tides occur almost every year (Steidinger et al., 1998). When they occur, red tides threaten the health of marine life and affect air quality along the coast. In three of the last five years, bloom initiation has occurred in the nearshore coastal waters adjacent to Fort Myers. The Florida Department of Agriculture surveys seafood for health risks related to red tides, and shellfish beds are closed when concentrations of the concentration of Karenia brevis, the toxic dinoflagellate responsible for neurotoxic shellfish poisoning (NSP) get too high. Consumers are also concerned about the effects of pollution on safety of seafood.
Water clarity	Water quality is one of the main attributes of the coastal marine environment that people care about. General characteristics of the water column, like clarity and cleanliness, i.e. the general absence of objectionable odor, nuisance, or disease-causing organisms, contributes to the aesthetic appeal of the coastal marine environment, as a whole, the enjoyment of the beaches and other activities on the water, and the safety of seafood.

[a] Florida Fish and Wildlife Conservation Commission, Marine Fisheries Information System, 2010 Annual Landings Summary. According to the website: "Commercial fisheries include any species that are harvested and sold for human consumption, for medical use, in aquarium or souvenir trades, or for any other for-profit purpose. The state of Florida collects data from commercial harvesters and dealers to generate statistics on the types of species and quantities landed, as well as the size, weight, and age distribution of harvested species."
[b] Florida Department of Health website: http://www.doh.state.fl.us/environment/community/aquatic/beach_index.html.
[c] From a list of Florida beaches provided by Wikipedia.org and author expertise.

Table 2: Attributes that people care about related to ecosystem services

Attributes that people care about	Ecosystem Services
Air quality	Aesthetic quality of aquatic and terrestrial environments
Water quality	
Lots of healthy coral	
Lots and large variety of fish	
Lots and large variety of wildlife	
Water quality	Beach activities and wildlife recreation activities
Beach and shoreline quality	
Critical habitat for protected species	
Large variety and number of birds	
Lots and large variety of large wildlife	
Harmful algal blooms	
Lots and large variety fish	Recreational fishing
Lots and large variety of large wildlife	
Ecosystem resilience to disturbance	
Water clarity	Scuba diving and snorkeling
Lots of healthy coral	
Lots and large variety of fish	
Lots and large variety of large wildlife	
Ecosystem resilience to disturbance	Living laboratory for education
Lots and large variety of fish	Cultural identity
Lots and large variety of large wildlife	
Ecosystem resilience to disturbance	
Aesthetics – on land	
Seafood safety	
Ecosystem resilience to disturbance	Wildlife abundance, diversity and habitat
Critical habitat for protected species	
Erosion and storm protection	Protection of property from coastal storm damages
Seafood safety	Seafood safety
Human health	

Attributes that people care about	**Ecosystem Services**
Natural filter / nutrient reduction	Pollution treatment
Climate regulation	Climate stability
Lots and large variety of fish	Commercial fish and shellfish harvest and consumption
Seafood safety	
Ecosystem resilience to disturbance	
Lots and large variety of fish	Recreational and commercial ornamental harvest and culture
Lot of healthy coral	
Ecosystem resilience to disturbance	
Lots and large variety of fish	Subsistence fishing
Seafood safety	
Ecosystem resilience to disturbance	
Ecosystem resilience to disturbance	Natural materials needed for inventions and cures

Valuing Ecosystem Services

Ecosystem services have value which can be measured by human dimensions scientists. Quantitative and qualitative analytical methods can be used to produce data and tools for decision-making and to estimate the relative importance of different natural resources to particular human populations. Knowing the values that people place upon ecosystem services informs decisions that involve tradeoffs between environmental and other societal goals and between competing objectives. Assessing the value of ecosystem services can occur within either economic or social contexts. While there is great utility in monetization for cost-benefit analyses (Turner et al. 2003, Loomis et al. 2000, Hein et al. 2006), the monetary ecosystem service value may represent only a partial valuation of the ecosystem (Pimm 1997). Recreational services, for example, have value to society beyond monetary which can be quantified and interpreted using common methods (Wegner and Pascul 2011). Identifying an appropriate approach for valuing each ecosystem is important for making well-informed management decisions (Wegner and Pascul 2011).

Other considerations such as distributive justice (the fairness associated with allocating scarce resources), sustainability, ecological stewardship, human well-being, and cultural and ethical values are important to consider in the decision-making process (Costanza and Folke 1997, Deutsch 1975). Equity analysis (one approach to allocating scarce resources) requires an estimation of the differences between groups who receive benefits and those who lose benefits under different management alternatives. There are other allocation norms associated with who does or does not receive ecosystem service benefits in the amount they want or feel they deserve, such as equality or need based allocations (Loomis and Ditton 1993). Sustainability and stewardship analyses focusing on the past, present, and future distribution of those services consider additional layers of complexity. Cultural and ethical considerations may place further constraints on the acceptability of different management decisions (Farber et al. 2006). Human societies are complex with diverse perspectives on the use of ecosystem services depending on circumstances at the global-regional-local level of political or societal organization.

Categories of Economic Benefit Values

The benefits provided by ecosystem services can be measured in dollar amounts that capture the willingness to pay for the service. The types of measurements include: (1) use value; (2) income, including profit; and non-use values including (3) option value; (4) passive use value; and (5) quasi-option value. Each is discussed in turn.

Use value is the value to an individual of an actual or planned use of the ecosystem service. For example, a day trip to a sea grass bed in the Florida Keys to canoe or dive with the manatees, or a planned trip to snorkel the coral reefs. *Use value* is the value of the trip or the willingness of the individual to pay to participate in the activity. The value is dependent on the condition of the resource, in this case the sea grass bed and the coral reef.

Use value is the sum of the expenditures made to participate in the activity and consumer surplus. Consumer surplus is the difference between the maximum amount of money that the consumer would have been willing to pay for a certain quantity of a good or service and the amount that was actually paid. For recreation, the amount actually paid is the recreation expenditures including transportation to the recreation site, purchases of fishing, diving and snorkeling excursions, bait, ice, food and drink, boat rentals, lodging costs, etc. For seafood purchases, the amount actually paid is the amount paid to purchase the fish. Thus, *use value* is the maximum amount of money that the consumer would have been willing to pay to participate in the recreation activity or to obtain seafood and is the sum of consumer surplus and expenditures.

The *use value* of certain ecosystem services can be imbedded in real estate values. For example, some households are willing to pay to live next to an aesthetically-pleasing shoreline. This willingness to pay is reflected in a portion of the market value of the land and house. This portion can be derived using hedonic modeling which uses statistical analysis and data on market prices and the values of factors that influence this price, including the proximity of the real estate to a water body of a certain quality. Hedonic modeling provides an estimate of the impact of a shoreline of certain quality on the market value of the real estate. This impact is the use value of the shoreline as it is enjoyed by those who live on it.

Income is the money provided to individuals and businesses from their use or provision of the ecosystem service. This is the income generated throughout the region as people spend money to participate in marine-related recreation and as people sell fish and shellfish harvested from the south Florida marine waters. It is the economic contribution as measured by salaries, wages, proprietor's income, and profit that are estimated using an economic input-output model of the region and data regarding the itemized recreation expenditures and retail sales of fishery products. Profit, also called producer surplus, is the seafood sales (market value) minus all costs of production including opportunity costs and includes profits accruing to commercial fishers, wholesalers and retail stores that supply the fish to consumers. Opportunity cost is the value of the production inputs to the producer if they were put to their next most valuable use and it is typically represented by the interest that would have been paid if the money had been invested in a certificate of deposit or other financial instrument.

Option value is the amount that individuals are willing to pay to know that the ecosystem service will be available for use in the future apart from any planned uses. For example, some individuals may not have plans to travel to sea grass beds in the Florida Keys but they appreciate manatees in the wild and enjoy knowing that sea grass beds will be there in the future in case they (or others) decide to visit and view the manatees. The *option value* is the value an individual obtains from having an ecosystem service perpetuated and can be thought of as an investment that ensures the resource is maintained in a healthy condition for use in the future.

Passive Use Value is the value individuals place on the assurance that the ecosystem will continue to provide services separate from actual, planned, or future uses. For example, some individuals, although they don't travel to the sea grass beds, still have an appreciation for manatees in the Florida Keys and enjoy knowing the species will continue to winter in the Florida Keys. In the economics literature, this value was categorized according to people's motives (even though people's motives are irrelevant to the legitimacy of the values; economists don't question people's motives for consuming a good or service). The categories are *existence value* or the willingness to pay to ensure that something exists in a certain condition and *bequest value* or the willingness to pay to ensure future generations have the opportunity to experience the resource in a certain condition. In recent literature, economists have adopted the terminology *passive use value* to encompass these two categories because people need to know something about the resource they are valuing. Passive users learn about the condition of resources through media sources (e.g. TV, radio, magazines, newspapers, internet, newsletters, etc.) and they consume these resources passively by learning and thinking about them.

Quasi option value is the amount of money individuals are willing to pay to postpone decisions that will irreversibly diminish or eliminate the ecosystem service. Here there is uncertainty about both future supply and demand. It can be thought of like an investment to perpetuate the resource until more information can be learned about the future supply and demand for the services.

Techniques for Valuing Ecosystem Services

There are many techniques for valuing ecosystem services. The information below provides a brief introduction to some of these methods.

Travel cost is a method that utilizes visitor trips, visitor expenditures and visitor origins and destinations to quantify the recreational use value of a site visit. The Random Utility Model (RUM) estimates how values change with changes in site characteristics and attributes.

Contingent valuation is a stated preferences method that uses survey questions to ascertain individuals' willingness to pay to retain or increase the quantity or quality of an ecosystem service or willingness to accept a loss or reduction in the quantity or quality of an ecosystem service.

Hedonic modeling is a method that uses the market price of a traded good whose market value is dependent on the existence, quality and/or quantity of the ecosystem service to infer the value of the ecosystem service.

Choice modeling is a stated preferences method that uses survey questions to ascertain individuals' tradeoff between levels of an ecosystem service, levels of competing uses of the resource, and cost. This method can integrate the physical/natural sciences in defining the service change to be valued, and can be directly tied to management actions. The method also allows for non economic rankings of preferences.

The method used will depend on the type of ecosystem service being valued. Professionally accepted methods used to estimate the value of ecosystem services are summarized in Table 3. These methods can be used to show how the value of ecosystem services varies with changes in the quality of the attributes that people care about.

Table 3: Methods for Valuing Ecosystem Services

Ecosystem Service*	Value of Service	Methods to Estimate Value
Aesthetic quality of aquatic and terrestrial	Use Value – willingness of residents and visitors to pay for the level of visual, olfactory and auditory amenities provided by the south Florida marine ecosystem	Hedonic analysis of real estate market values and survey-based research such as contingent valuation or choice stated preferences focused on residents and visitors in south Florida
Beach activities and wildlife recreation activities	Use Value – willingness to pay to maintain or improve beach conditions and wildlife habitat conditions	Travel cost modeling and/or survey-based research such as contingent valuation or choice stated preferences focused on management measures to protect or improve conditions
	Economic Contribution – income, employment, and tax revenue generated as visitors and residents spend money to participate in these activities in south Florida.	Survey-based research focused on residents and visitors who participate in beach and/or wildlife-recreation activities in south Florida and an economic input-output model of the region
Recreational fishing	Use Value – willingness to pay to maintain or improve marine fishing conditions	Travel cost modeling or survey-based research such as contingent valuation or choice stated preferences focused on fishing success by species
	Economic Contribution – income, employment, tax revenues generated as visitors and residents spend money to fish for recreation in south Florida.	Survey-based research focused on resident and visitor recreational fishers in south Florida and an economic input-output model of the region
SCUBA diving and snorkeling	Use Value – willingness to pay to maintain or improve coral reef conditions	Travel cost modeling or survey-based research such as contingent valuation or choice stated preferences focused on management measures to protect or improve coral reefs
	Economic Contribution – income, employment, and tax revenue generated as visitors and residents spend money to SCUBA and snorkel in south Florida	Survey-based research focused on residents and visitors who SCUBA and snorkel in south Florida and an economic input-output model of the region
Living laboratory for education	Use Value – willingness of students to pay for the educational experience provided by south Florida's marine ecosystem	Survey-based research such as contingent valuation or choice stated preferences focused on Florida students
	Non-Use Value – willingness of all households in Florida (and in U.S.) to	Survey-based research such as contingent valuation or choice stated

Table 3: Methods for Valuing Ecosystem Services

Ecosystem Service*	Value of Service	Methods to Estimate Value
	pay for the educational opportunities provided by the south Florida marine ecosystem	preferences focused on all Florida (or U.S.) households
Cultural identity – maritime way of life	Use Value – willingness of marine-dependent businesses and households and other residents who live in the area to pay preserve their maritime cultural identity; willingness of visitors to pay to learn about maritime heritage Economic Contribution – income, employment and tax revenues generated by visitors to museums	Survey-based research such as contingent valuation or choice stated preferences focused on marine-dependent businesses and households and other residents who live in the area and visitors. Survey-based research focused on visitors who visit museums to learn about maritime heritage and an economic input-output model of the region
Wildlife abundance, diversity, and habitat	Non-Use Value – willingness of all households in Florida (and in U.S.) to pay for management measures focused on protecting marine ecosystems in south Florida over what they would pay to directly use the wildlife resources	Survey-based research such as contingent valuation or choice stated preferences focused on all Florida (or U.S.) households
Protection of property from coastal storm damages	Avoided cost of damages and property loss; or cost to replace service	Estimation of avoided or replacement cost / Hedonic price analysis of real estate values
Seafood safety	Avoided cost of illness or willingness to pay to avoid illness	Avoided cost estimation or choice stated preferences method with reductions in the probabilities of suffering illness.
Pollution treatment	Avoided cost of alternative waste management such as wastewater treatment plants and storm water systems	Avoided cost estimation Changes in consumer's surplus with changes in water quality
Climate stability	Change in the U.S. or world economy from an unstable climate	Change in consumer and producer surplus associated with the change in production and consumption Change in income, employment and tax revenue as land uses change
Commercial fish / shellfish harvest and consumption (Commercial, Recreational, and Ornamental)	Consumer and producer surpluses of harvested fish, shellfish, tropical fish, live rock and other ornamentals	Surplus values estimated through consumer demand functions and producer supply functions for fishery species harvested and consumed or for ornamental resources.
	Economic contribution - income, employment, and tax revenue generated as commercial fishers spend money to	Ex vessel value of commercial species and ornamental resources harvested and an economic input-

Table 3: Methods for Valuing Ecosystem Services

Ecosystem Service*	Value of Service	Methods to Estimate Value
	harvest marine fishery species and ornamental resources in south Florida	output model of the region
Subsistence fishing	Consumer surplus of harvested fish	Estimated through consumer demand functions for fishery species and surveys of those who fish for the sole purpose of acquiring food.
	Economic contribution - income, employment, and tax revenue generated as subsistence fishers spend money to harvest marine fishery species in south Florida	Survey based research focused on the fishing-related expenditures made by subsistence fishers and an economic input-output model of the region
Natural materials for inventions and cures	Because the medical or other uses for these materials are not identified, the non-use value would be most relevant here. Non-Use Value – willingness of all households in Florida (and in U.S.) to pay for the potential of the south Florida marine ecosystem to provide natural materials for inventions and cures	Survey-based research such as contingent valuation or choice stated preferences focused on all Florida (or U.S.) households

Note: Refers to an earlier version of ecosystem services identified for the South Florida coastal marine ecosystem.

Ecosystem Services Identified by the MARES Project

The definition for ecosystem services used by the MARES project is:
Ecosystem Services are the benefits that humans derive from the ecosystem. They are what link people to the State of the ecosystem, through "attributes [of the environment] that people care about.' Ecosystem Services have value for both people who live in the ecosystem and people who do not. The value of Ecosystem Services is related to environmental conditions, and this value can be measured and reported in a monetary, cultural, or social context.

Following the example of Farber et al. (2006), we categorize these services by the benefit they provide: cultural, regulating, and provisioning (Table 3). In this context, "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. "Regulating" services and goods are benefits obtained from regulation of ecosystem processes such as climate regulation, disease regulation, water regulation, water purification and pollination. "Provisioning" services and goods are products obtained from ecosystems such as food, fresh water, fiber, biochemicals and genetic resources.

"Supporting ecosystem services," as defined by Farber et al. (2006) are captured in the EBM-DPSER model as state-to-state interactions. For example, the seagrass sub-model connects to nutrient concentrations in the water column sub-model, thus capturing the supporting service of nutrient cycling by seagrass. Because supporting services are captured in this manner, we opted not to include them in the ecosystem services module. The services that constitute the ecosystem services module are adapted from Farber et al. (2006). The cultural ecosystem services furnished by the Florida Keys and Dry Tortugas marine ecosystem are aesthetics and existence, recreation, science and education, and cultural amenity. The provisioning ecosystem services furnished by the Florida Keys and Dry Tortugas marine ecosystem are food/fisheries, ornamental resources, and medicinal and biotechnology resources. The regulating ecosystem services furnished by the Florida Keys and Dry Tortugas marine ecosystem are hazard moderation, waste treatment, climate regulation, atmospheric regulation, and biological interactions. All of these ecosystem services result in benefits to society that can be evaluated and therefore used to determine the efficacy of specific responses.

Table 3. Ecosystem services provided by the Florida Keys marine ecosystem.

Cultural	*Aesthetics & Existence*	Provide aesthetic quality of aquatic and terrestrial environments (visual, olfactory,and auditory), therapeutic benefits, and pristine wilderness for future generations
	Recreation	Provide a suitable environment/setting for beach activities and other marine activities such as fishing, diving, snorkeling, motor, and non-motor boating
	Science & Education	Provide a living laboratory for formal and Informal education, and scientific research
	Cultrual Amentity	support a maritime way of life, sense of place, maritime tradition, spiritual experience
Provisioning	*Food/Fisheries*	Provide safe-to-eat seafood
	Ornamental Resources	Provide materials for jewelry, fashion, aquaria, etc.
	Medicinal/Biotechnology Resources	Provide natural materials and substance for inventions and cures
Regulating	*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. with the atmosphere
	Biological Interactions	Regulate species interactions to maintain beneficial functions such as seed dispersal, pest/invasive control, herbivory, etc.

Discussion

By highlighting ecosystem services the MARES DPSER model framework emphasizes the extent to which society relies upon and benefits from the ecosystem. This inclines EBM towards proactive intervention rather than strictly reactive management. The linking of pressures to states to ecosystem services permits at a minimum the qualitative assessment of the cumulative impacts of pressures upon ecosystem services and captures the direct and indirect effect of multiple human uses on ecosystem services, as well as the loss of ecosystem services to human society. This is an important first step towards quantifying these complex interactions. As shown in the example applications, the EBM-DPSER model can assist in bridging the communication gap between human dimensions scientists, biophysical scientists, and resource managers thereby providing EBM with a useful operational tool.

The MARES project defines Ecosystem Services as the benefits that humans derive from the ecosystem. They are what link people to the State of the ecosystem, through “attributes [of the environment] that people care about.” Ecosystem Services are valued by people who live in the ecosystem and by people who do not. The value of Ecosystem Services is related to certain environmental conditions, and this value can be measured and reported in a monetary, cultural, or social context.

Ecosystem services have value to the people who benefit from them. The dollar value of each ecosystem service is dependent on the quantity and/or quality of the associated bundle of environmental attributes that people care about. For South Florida’s coastal ecosystems, 15 environmental attributes that people care about were identified and mapped to Ecosystem Services. Attributes identified were based on peoples’ ability to perceive and enjoy them and therefore potentially express a value or a demand for the ecosystem service given the qualities of the attributes. Ecosystem service values provide decision makers with critical information on the importance of marine ecosystems to people and the economy.

Economic methods can be used to monetize the value of ecosystem goods and services. The values of the ecosystem services include recreational use value; value to the economy; value of commercial fish and shellfish to consumers; non-use values including option, passive use, and quasi-options values; avoided flood damages and property loss; avoided damages from illness; and replacement cost of ecosystem services. Ecosystem service values reflect the impact of changes in the quantity and/or quality of the attributes that people care about on the provision of services. Valuation studies have been conducted in Florida over the past thirty years. A compilation of resource values from past work appears on the NOAA National Ocean Economics Program website[4], however it is our opinion that some of the values for South Florida are outdated and of limited use to management today.

Economic values for South Florida coral reefs in 2001 were reported in “Socioeconomic Study of Reefs in Southeast Florida” and “Socioeconomic Study of Reefs in Martin County, Florida” (Johns, Leeworthy, Bell and Bonn, 2001 and Hazen and Sawyer, 2004). These studies provide

[4]http://www.oceaneconomics.org/nonmarket/valEstim.asp#recfish

estimates total reef use of residents and visitors in each of the five counties as measured in terms of number of person-days by recreation activity (fishing, diving, snorkeling, glass bottom boats); economic contribution of the natural and artificial reefs as residents and visitors spend money in each of the five counties to participate in reef-related recreation; willingness of reef users to pay to maintain the natural and artificial reefs of southeast Florida in their existing conditions; willingness of reef users to pay for additional artificial reefs in southeast Florida; and socioeconomic characteristics of reef users. Economic contribution is measured by total value of production, income, and employment generated within each county from residents and visitors who use the reefs. In addition, the opinions of residents regarding the existence or establishment of "no-take" zones as a tool to protect existing artificial and natural reefs are presented.

The "Socioeconomic Study of Reefs" studies found that residents and visitors spent 29 million person-days recreational fishing, snorkeling and SCUBA diving on the coral and artificial reefs of southeast Florida in 2001. Southeast Florida includes the counties of Martin, Palm Beach, Broward, Miami-Dade and Monroe, including the Florida Keys. One-half of the person-days were spent fishing on the reefs and one-quarter each were spent snorkeling and SCUBA diving. The use value of coral and artificial reefs to those who fish, snorkel and SCUBA dive is \$3.33 billion per year which includes \$3.0 billion in reef-related recreation expenditures and \$330 million in willingness to pay to protect the reefs in their existing condition. Reef users would be willing to pay an additional \$31 million per year to fund the development and maintenance of new artificial reefs in southeast Florida. Southeast Florida coral and artificial reef-related recreation expenditures generated \$4.4 billion in local production, \$2.0 billion in resident income, and 70,000 jobs in the five county area in 2001. The studies did not estimate the non-use value associated with the reefs of southeast Florida. However, this value is expected to be significant given the non-use values of natural resources used for recreation estimated in other studies throughout the U.S. and in Florida (see for example, Hazen and Sawyer, 2008).

A recent study has estimated the "Total Economic Value (TEV)" of Hawaii's coral reef ecosystem at almost \$34 billion per year (Bishop et al, 2011). In this study, TEV includes consumer's surpluses from all uses and from non use or passive economic use value. The study was based on a sample of more than 3,100 household in the U.S. and the overwhelming majority have never visited or plan to visit Hawaii in the future, so most of the value is non use or passive economic use value.

Use and Non-Use values and avoided costs can be estimated and used in benefit-cost analysis of management actions deemed necessary to protect the quality of the environment. For example, the cost to improve wastewater and storm water treatment in the Florida Keys to improve the quality of ecosystem services is in the neighborhood is at least \$1 billion based on Leeworthy and Bowker (1997) estimate of the non-market use value (or consumer surplus) to Florida Keys' visitors who participated in natural resource-based recreation activities. Non-market use value is the use value net of the expenditures made to use all of the natural resources in the Keys. They estimated that the overall nonmarket use value to Florida Keys' visitors is \$1.2 billion annually, of which \$910 million is attributed to enjoyment of the Keys' natural resources. Based on this figure, the total asset value of the Keys' natural resources to tourists is estimated to range between \$18.2 billion and \$30.4 billion depending on the discount rate used to convert future streams of value to present values (discount rates between 3% and 5% per year). Therefore, although the $1 billion price tag for improved wastewater treatment seems high, it is small relative to the asset value from improved wastewater treatment. Wiley and Leeworthy (1999) conducted a benefit-cost analysis of a proposed wastewater treatment plant in the Florida Keys and found that the benefits exceeded the costs under a broad range of estimates of value elasticities (how the value of recreation and treatment services change with changes in water quality).

In some circumstances it may be necessary to construct values indirectly by tying ecosystem services to goods that people value directly using hedonic modeling. For example, the value of a house in the Florida Keys or near marine waters is directly influenced by the quality and extent of marine ecosystems and the services that they provide. The portion of the house's value that reflects household willingness to pay for these ecosystem services can be estimated using a statistical method called hedonic modeling.

An important economic value is the economic contribution of the ecosystem as it is enjoyed for recreation and to produce goods such as fish and shellfish harvests. Economic contribution is the impact of an ecosystem on recreation expenditures and fish and shellfish purchases including the multiplier effect as this money moves through the local, regional, State and U.S. economies. This economic contribution includes the value of production (output), income, employment, and tax revenues generated in local, regional, State, and U.S. economies.

Non-monetizing methods do not require a connection between values and money, but still provide information about relative values, equivalencies, or rankings. The equivalencies and relative rankings can be used to weigh changes in ecological services resulting from management decisions. A simple conceptual model of the economics of natural resource and environmental change is provided in Leeworthy and Bowker (1997). This model shows how actual and perceived changes in environmental attributes and ecosystem services can change the demand for and economic value of outdoor recreation and tourism. Economic values include market and nonmarket values received by users (those participating in recreation activities) and non users.

While benefit-cost analysis using these economic values is an important criterion for measuring the impacts of management alternatives on social welfare, other considerations including equity, sustainability, ecological stewardship, and cultural and ethical values are also important to consider in the decision making process (Costanza and Folke 1997). Equity analysis requires an estimation of who receives the benefits and who pays the costs of management alternatives. Sustainability and stewardship analyses focus on the intertemporal distribution of those services. Cultural and ethical considerations may place constraints on acceptable management decisions (Farber et al 2006).

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Appendix: Other Compilations of Coastal Marine Ecosystem Services

Farber et al. (2006)

A list of twenty-three ecosystem services compiled by Farber et al. (2006) provided the starting point in compiling the list of ecosystem services for the Gulf of Mexico. The list by Farber et al. expands on the list of ecosystem services used by Costanza et al. (1997) to estimate the value of ecosystem services world-wide. Farber et al. define ecosystem services this way:

> *Ecosystem services are the benefits humans receive, directly or indirectly, from ecosystem (Costanza et al. 1997, Daily 1997). Alterations of ecosystems change the mix of services through changes in ecosystem structures and processes. Services may increase or decrease; for example, increasing the land mass of wetlands for storm protection may diminish fishery habitat by reducing the marsh-water edge. Ecosystem management decisions inevitably involve trade-offs across services and between time periods, and weighing those trade-offs requires valuations of some form.*

Comparison of the list of ecosystem services defined by the MARES project[5] with the list by Farber et al. is provided in Tables A1 through A4. These tables provide some insight into how the MARES approach differs from that taken by Costanza et al. (1997) and various studies that derive from that work. Differences between the two lists derive from two sources.

First, the MARES project is more focused on describing the particular ecosystem of the South Florida coastal marine waters. As a result, some services identified by Farber et al. do not apply, such as (fresh) water supply. Other services, such as medical resources and ornamental resources, may apply to the South Florida coastal marine ecosystem, but these are not as important economically as, say, recreation, which the MARES project breaks down into four separate ecosystem services. The scale of study also plays a role; although (atmospheric) gas regulation is an important function of ecosystems at the global scale, the region's coastal marine waters play a relatively minor role in regulating atmospheric composition for south Florida.

The second source of differences relates to how the MARES project conceptualizes ecosystem services. The DPSER framework separates Ecosystem Services from State, which describes key attributes of the coastal marine environment. This separation eliminates from consideration the whole category of "support services," identified by Farber et al. (2006) as "ecological structure and functions that are essential to the delivery of [other] ecosystem services." In the MARES integrated conceptual ecosystem models, based on the DPSER framework, these services, e.g. nutrient cycling, habitat, and net primary production, are inherent in the key attributes and interrelationships that comprise the definition of the State of the environment. The "support services" category needs to connect the State of the Ecosystem with the attributes that people care about. For example, the Gulf of Mexico Alliance lists "Nutrient Balance" as an ecosystem service but it does not qualify as an ecosystem service under the MARES definition. While

[5] Note: The comparison here uses an earlier version of the list of ecosystem services provided by the South Florida coastal marine ecosystem.

"Nutrient Balance" is important, it is an intermediary service using the MARES definition. To convert it to an ecosystem service requires we take it a step further and answer the question of what attributes that people care about are the result of "Nutrient Balance". Water clarity is one. Snorkelers, SCUBA divers, glass-bottom boat riders and sight fishermen care about water clarity. This connects the state of the physical/natural system with the human system and thus an ecosystem service.

Table A1: Cultural services*

Ecosystem functions and services	Description	Ecosystem Services
Farber et al. 2006		**MARES**
Recreation	Opportunities for rest, refreshment, and recreation	2. Beach activities 3. Wildlife recreation activities 4. Offshore marine recreational activities
Aesthetic	Sensory enjoyment of functioning ecological systems	1. Aesthetic quality of aquatic and terrestrial environments
Science and education	Use of natural areas for scientific and educational enhancement	5. Living laboratory for education 15. Natural materials for inventions and new cures for illness
Spiritual and historic	Spiritual or historic information	6. Cultural identity – maritime way of life 7. Wildlife abundance, diversity and habitat

*Enhancing emotional, psychological and cognitive well-being

Table A2: Regulating services*

Ecosystem functions and services	Description	Ecosystem Services
Farber et al. 2006		**MARES****
Gas regulation	Regulation of the chemical composition of the atmosphere and oceans	
Climate regulation	Regulation of local climate processes	11. Climate stability
Disturbance regulation	Dampening of environmental fluctuations and disturbance	8. Protection of property from storm damages
Biological regulation	Species interactions	9. Safe-to-eat seafood
Water regulation	Flow of water across the planet surface	10. Storm water retention, water treatment, nutrient cycling, and regulatory compliance
Soil retention	Erosion control and sediment retention	9. Protection of property from coastal storm damages
Waste regulation	Removal or breakdown of non-nutrient compounds and materials	10. Storm water retention, water treatment, nutrient cycling, and/or regulatory compliance
Nutrient regulation	Maintenance of major nutrients within acceptable bounds	11. Storm water retention, water treatment, nutrient cycling, and/or regulatory compliance

*Maintenance of essential ecological processes and life-support systems for human well-being

Table A3: Provisioning services*

Ecosystem functions and services	Description	Ecosystem Services
Farber et al. 2006		**MARES**
Water supply	Filtering, retention, and storage of fresh water	
Food	Provisioning of edible plants and animals for human consumption	12. Opportunity to harvest and consume commercial fishery species 13. Opportunity to catch and consume recreational fishery species 14. Opportunity for subsistence fishing
Raw materials	Building and manufacturing, Fuel and energy, Soil and fertilizer	
Genetic resources	Genetic resources	
Medical resources	Biological and chemical substances for use in drugs and pharmaceuticals	15. Natural materials for inventions and new cures for illness)
Ornamental resources	Resources for fashion, handicraft, jewelry, pets, worship, decoration, and souvenirs	12. Opportunity to harvest and consume ornamental marine resources

* Provisioning of natural resources and raw materials

Table A4: Supporting functions and structures*

Ecosystem functions and services	Description	Ecosystem Services
Farber et al. 2006		**MARES**
Nutrient cycling	Storage, processing, and acquisition of nutrients within the biosphere	10. Pollution treatment - storm water retention, water treatment, nutrient cycling, and regulatory compliance
Net primary production	Conversion of sunlight to biomass	
Pollination and seed dispersal	Movement of plant genes	
Habitat	The physical place where organisms reside	4. Opportunity for offshore marine recreational activities - fishing, diving, snorkeling, & boating (Healthy, functioning ecosystem)
Hydrologic cycle	Movement and storage of water through the biosphere	

*Ecological structure and functions that are essential to the delivery of ecosystem services

Gulf of Mexico Alliance

The Gulf of Mexico (GoM) Alliance is a partnership among the states of Alabama, Florida, Louisiana, Mississippi, and Texas. Initiated in 2004, the intent of this Alliance is to significantly increase regional collaboration to enhance the ecological and economic health of the Gulf of Mexico. In 2010, the first ecosystems services workshop was held in Mississippi to gain consensus on how to define, identify and approach ecosystem services in the Gulf of Mexico and the steps to be taken toward the initiation of a case study (Yoskowitz, et al. 2010). The GoM Alliance defines ecosystems services for the GoM as:

"The Gulf of Mexico Alliance defines ecosystem services as the contributions from Gulf of Mexico marine and coastal ecosystems that support, sustain, and enrich human life. Ecosystem services quantification provides standard metrics for expressing benefits of the services provided by the ecosystem. The metrics might be monetary or non-monetary."

An Alliance workshop in the summer of 2010 compiled a list of ecosystem services for the Gulf of Mexico. This list is provided in Table A5.

Table A5: Ecosystem Services of the Gulf of Mexico	
1. Nutrient Balance	11. Medicinal Resources
2. Hydrological Balance	12. Ornamental Resources
3. Climate Balance	13. Science and Education
4. Pollutant Attenuation	14. Biological Interactions
5. Gas Balance	15. Soil and Sediment Balance
6. Water Quality	16. Spiritual and Historic
7. Water Quantity	17. Aesthetics and Existence
8. Air Supply	18. Recreational Opportunities
9. Food	19. Hazard Moderation
10. Raw Materials	

The ecosystem services developed by this MARES project describe the benefits derived from the south Florida marine ecosystem that can be valued directly. Relative to the Gulf of Mexico Alliance list provided in Table A5, the ecosystem services list developed by the MARES project provides categories of ecosystem services that include many of the Gulf of Mexico Alliance categories listed above. In addition, the MARES project further identifies the ecosystem services of south Florida by providing additional detail regarding how the ecosystem is used by or provides benefits to humans and links actual services and goods to the values that humans place on them. The Gulf of Mexico Alliance list describes attributes of the ecosystem that benefit humans. These attributes may be assigned to the MARES-developed ecosystem services as provided in Table A6 which demonstrates that more than one attribute contained in the Gulf of Mexico Alliance list of ecosystem services is associated with each MARES-developed ecosystem service[6].

Table A6: List of Gulf of Mexico Alliance Ecosystem Services Under Each MARES South Florida Ecosystem Service

1. Aesthetic quality of aquatic and terrestrial environments including visual, olfactory, and auditory

I. Nutrient Balance	VIII. Air Supply
II. Hydrological Balance	XIV. Biological Interactions
III. Climate Balance	XV. Soil and Sediment Balance
IV. Pollutant Attenuation	XVI. Spiritual and Historic
VI. Water Quality	XVII. Aesthetics and Existence

2. Beach activities, including swimming, picnicking, sunning, and enjoying the shoreline views

II. Hydrological Balance	VI. Water Quality
IV. Pollutant Attenuation	XVIII. Recreational Opportunities

3. Wildlife related recreation activities including viewing manatees, dolphins, fishes & birds in their habitats

I. Nutrient Balance	VI. Water Quality
II. Hydrological Balance	XIII. Science and Education
III. Climate Balance	XIV. Biological Interactions
IV. Pollutant Attenuation	XVIII. Recreational Opportunities

4. Offshore marine recreational activities including fishing, diving, snorkeling, & motor and non-motor boating

I. Nutrient Balance	XIII. Science and Education
II. Hydrological Balance	XIV. Biological Interactions
III. Climate Balance	XV. Soil and Sediment Balance
IV. Pollutant Attenuation	XVI. Spiritual and Historic
VI. Water Quality	XVIII. Recreational Opportunities

[6] Note: The table refers to an earlier version of the list of ecosystem services provided by the South Florida Coastal marine ecosystem.

Table A6: List of Gulf of Mexico Alliance Ecosystem Services Under Each MARES South Florida Ecosystem Service

5. Living laboratory for education at the K-12 and college levels

I. Nutrient Balance	VI. Water Quality
II. Hydrological Balance	XIII. Science and Education
III. Climate Balance	XIV. Biological Interactions
IV. Pollutant Attenuation	XV. Soil and Sediment Balance

6. Cultural identity – The geographic area supports a maritime way of life

I. Nutrient Balance	XVI. Spiritual and Historic
II. Hydrological Balance	VI. Water Quality
III. Climate Balance	XIV. Biological Interactions
IV. Pollutant Attenuation	XV. Soil and Sediment Balance

7. Wildlife abundance, diversity and habitat

I. Nutrient Balance	XIII. Science and Education
II. Hydrological Balance	XIV. Biological Interactions
III. Climate Balance	XV. Soil and Sediment Balance
IV. Pollutant Attenuation	XVI. Spiritual and Historic
VI. Water Quality	XVII. Aesthetics and Existence
XI. Medicinal Resources	

8. Protection of property from coastal storm damages

XIX. Hazard Moderation

9. Provides Safe-to-Eat Seafood

IV. Pollutant Attenuation	IX. Food
VI. Water Quality	

10. Provides storm water retention, water treatment, nutrient cycling, and/or regulatory compliance

I. Nutrient Balance	VI. Water Quality
IV. Pollutant Attenuation	

11. Climate stability

III. Climate Balance

Table A6: List of Gulf of Mexico Alliance Ecosystem Services Under Each MARES South Florida Ecosystem Service

12. Opportunity to harvest and consume commercial fishery species

I. Nutrient Balance
II. Hydrological Balance
III. Climate Balance
IV. Pollutant Attenuation
VI. Water Quality
XII. Ornamental Resources
XIV. Biological Interactions

13. Opportunity to catch and consume recreational fishery species

I. Nutrient Balance
II. Hydrological Balance
III. Climate Balance
IV. Pollutant Attenuation
VI. Water Quality
IX. Food
XIV. Biological Interactions
XVIII. Recreational Opportunities

14. Opportunity for subsistence fishing

I. Nutrient Balance
II. Hydrological Balance
III. Climate Balance
IV. Pollutant Attenuation
VI. Water Quality
IX. Food
XIV. Biological Interactions

15. Natural materials needed for inventions and new cures for illnesses

I. Nutrient Balance
II. Hydrological Balance
III. Climate Balance
IV. Pollutant Attenuation
VI. Water Quality
XI. Medicinal Resources
XIII. Science and Education
XIV. Biological Interactions
XVII. Aesthetics and Existence

16. Opportunity to collect and culture ornamental marine resources

I. Nutrient Balance
II. Hydrological Balance
III. Climate Balance
IV. Pollutant Attenuation
VI. Water Quality
IX. Food
XIV. Biological Interactions