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Stakeholder Perceptions of Coastal Habitat Ecosystem Services

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Abstract The goal of the current study was to document local stakeholder perceptions of ecosystem services provided by coastal habitats and to incorporate values of ecosystem services into an ecosystem-based management plan. A second goal was to identify and quantify ecosystem service supply at the local level, which is a knowledge gap identified by the Millennium Ecosystem Assessment. Ecosystem services were quantified as stakeholder perceptions of values. To identify local stakeholder perceptions of coastal habitat ecosystem services, a workshop was conducted at which stakeholders were asked to complete surveys. Data from the surveys were used to create a spatial representation of the number of ecosystem services provided by habitats in the form of a heat map. Results of the study were incorporated into an ecosystem-based management plan to enable stakeholders and managers to make better-informed decisions regarding priority areas for conservation, preservation, and restoration. The methods used in this study can be expanded to develop future ecosystem-based management plans.

Keywords Laguna Madre · Nueces Bay · Corpus Christi Bay · Ecosystem services · Ecosystem-based management · Stakeholder analysis

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Introduction

Ecosystem services are components of "nature directly enjoyed, consumed or used to yield human well-being" (Boyd and Banzhaf 2006). Ecosystem services vary based on many factors, including their provision by habitat type, location of their provision, and consumption by humans (Tallis and Polasky 2009). The formal description and quantification of ecosystem services is fairly recent. The idea and introduction of the concept of services in the terrestrial environment can be traced back to two articles from the 1960s in which it was documented that all humans benefited from the existence of wildlife (Helliwell 1969; King 1966). Even earlier work took place in the Coastal Bend of Texas, where traditional and non-traditional marine resources were valued (Anderson 1960; Odum et al. 1959). Popularization of the idea of ecosystem services began in the late 1990s and early 2000s with attempts to assign monetary value to the world's ecosystem services (Costanza et al. 1997) and the establishment of a stronger linkage between ecology and economics (Daily 1997; De Groot et al. 2002). Early ecosystem service work led to the Millennium Ecosystem Assessment (MA), which was initiated under the auspices of the United Nations in 2001 (MA 2005). The goal of the MA was to assess ecosystem change and subsequent effects on human well-being. A lack of information regarding ecosystem service supply at the local level was identified to be a major knowledge gap according to the MA (2005).

More recently, decision makers and researchers in the field of ecosystem services have documented a need for spatially explicit ecosystem service analysis to be incorporated into decision making (Hogan et al. 2009). Using a geographic information system (GIS) to quantify ecosystem services in a spatial context is an ecosystem-based management tool that can be utilized to provide decision makers and resource managers with an easily understandable, yet quantifiable spatial representation of resources (Chen et al. 2009). Some marine protected areas and decision frameworks have incorporated ecosystem services into decision making, but often these are academic exercises and actual implementation in management rarely occurs. Very few, if any, management plans have incorporated protecting, sustaining or restoring ecosystem services into decision making. This is partially because the science does not exist to support the existing frameworks, and partially due to the complexity of integrating ecosystem services into an already multifaceted process of ecosystem management.

The goal of the current study is to incorporate ecosystem services into an ecosystem-based management plan for a local area. While management plans for habitats are common, management plans for ecosystem services are rare. So, it is necessary to create values for ecosystem services provided by habitats at small spatial scales. This also fills a knowledge gap identified by the MA regarding ecosystem service supply at the local level. The study focuses on the Nueces Estuary, located in the Coastal Bend region of Texas. The Nueces Estuary is one of the 28 nationally significant areas associated with the National Estuaries Program. Each National Estuaries Program is tasked to develop and implement a Comprehensive Conservation and Management Plan that addresses environmental, economic, and social issues surrounding an estuary. The Coastal Bend Bays & Estuaries Program (CBBEP) is an entity that implements local projects in an effort to research, restore, and protect the bays and estuaries in the Texas Coastal Bend. CBBEP funded the current study to ensure future economic development strategies are consistent with maintaining coastal habitat ecosystem services (Montagna 2009). Several management plans have been written to address local issues concerning the Nueces Estuary, including: the Coastal Bend Bays Plan (Corpus Christi Bay National Estuary 1998) and a Colonial Waterbird and Rookery Island Management Plan (Chaney and Blacklock 2003). None of the previous management plans incorporated ecosystem services.

The approach used in the current study is to identify perceptions of the value of ecosystem services provided by habitats in the Nueces Estuary by stakeholders who manage coastal habitats, research topics related to coastal habitats, or have a potential to have a significant impact on local coastal habitat ecosystem services. The study documents a methodology for assessing stakeholder knowledge of habitats and ecosystem services. The study also establishes a simple methodology for mapping the number of ecosystem services provided by habitats in the form of a "heat map." Results of the study were incorporated into an ecosystem-based management plan to enable stakeholders to make better-informed decisions regarding priority areas for conservation, preservation and restoration (http://www.cbbep.org/projects/ecomanagement.html). Stakeholders' survey results were integrated with habitat status and trends data, perceived threats and risks in the project area, and endangered species data to create a list of prioritized management activities. Stakeholder-identified priority issues, concerns, locations of interest, potential future activities, and current assets were also included in the management plan (Montagna et al. 2011).

Methods

Study Area

The Nueces Estuary is an urban-industrial estuary on the South Texas coast. Many urban areas, including the city of Corpus Christi surround the Nueces Estuary. As of 2010, Corpus Christi was the 60th ranked city in the United States in terms of population (U.S. Census Bureau). Corpus Christi supports the Port of Corpus Christi, which ranks as the 6th largest port in the United States for total tonnage traded (American Association of Port Authorities). The Nueces Estuary consists of a primary bay, Corpus Christi Bay, and two secondary bays. Corpus Christi Bay has two direct connections to the Gulf of Mexico. The secondary bays, Nueces Bay and Oso Bay, receive freshwater input from the Nueces River and Oso Creek, respectively.

The study area encompasses over 2,430 km^2 (600,000 acres), including the Nueces Estuary (also known as the Corpus Christi Bay System). The study area boundary was developed using natural hydrologic units and ecoregional boundaries and then further delineated based on information provided by stakeholders (Brenner et al. 2009b). The study area was divided into sub-regions in an effort to divide the area into manageable units (Fig. 1). The sub-regions were: the Nueces Delta and River, Nueces Bay, Corpus Christi Bay, Mustang and North Padre islands, Oso Bay and Creek, Redfish and South Aransas bays, and part of the Upper Laguna Madre (Montagna et al. 2011).

Study Phases

The study was at the end of a two-phase project to develop a management plan for the Nueces Estuary (Montagna et al. 2011). During the initial phase of the project, meetings were conducted with stakeholders to explain project objectives, tasks, and expected deliverables and outcomes. During this phase, stakeholder interests and needs were documented and an advisory committee was established. The first phase of the project is summarized in an initial meetings report (Brenner et al. 2009a). The advisory committee members were asked to review the management plan at the end of the project timeline.

During the second phase of the project, two stakeholder workshops were conducted. At the first workshop, stakeholders were asked to identify priority habitats and ecosystem services, the preferred geographic coverage of the management plan, the range and scope of activities to include in the plan and

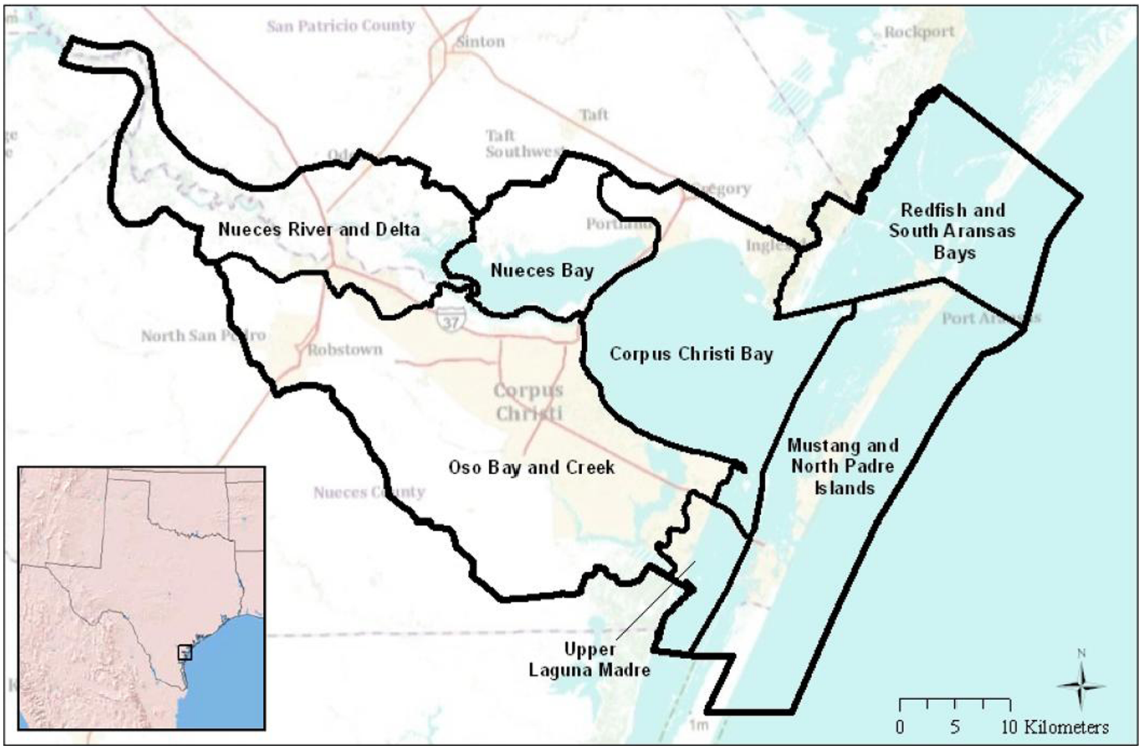

Fig. 1 Study area, including geographic sub-regions, in the Coastal Bend, Texas

mechanisms and resources needed to support the plan. Three documents were created as a result of the first workshop: a boundary map report (Brenner et al. 2009b), a workshop summary report (Montagna 2009), and a preliminary management plan (Palmer et al. 2009). The result of the first workshop was a well-defined study area and a better understanding of stakeholder concerns and priorities within the study area. The information from the first phase of the project and from the first workshop was used to develop methods for a second workshop, at which data for this study was collected. The objectives of the second workshop were to report results of the first workshop, describe and obtain feedback on the preliminary management plan, and assess valuation of ecosystem services in a quantifiable manner.

The goal of the current study was to document local stakeholder perceptions of coastal habitat ecosystem services and to incorporate ecosystem services into an ecosystem-based management plan. The data collected at the both workshops was used to develop the final management plan.

Data Collection

The second stakeholder workshop was conducted in June 2010. A total of 53 of the 57 stakeholders who attended the workshop completed surveys. Stakeholders represented agencies from three main levels of government (local, state, and federal) and private and public affiliations (Table 1). The largest group of stakeholders represented academia (Montagna et al. 2011).

Habitats assessed were identified at the first workshop (Palmer et al. 2009). Over 30 habitat types were mentioned as important habitat types within the study area. This habitat list was aggregated into more concise habitat descriptions. Some habitats were eliminated from inclusion in the survey. Reasons for elimination included: (a) broad nature of the terminology, (b) habitat suggested is either not actually a habitat or is not accurately represented by available data, and (c) lack of presence in the study area. Habitats assessed were classified into the following groups: seagrass bed, salt marsh wetland, (intertidal) flat, beach, marine/open water, oyster reef, scrub-shrub wetland, freshwater wetland, tree canopy/Live Oak motte, dune habitat, and rookery islands. Rookery islands were chosen as a habitat type to include in assessment based on stakeholder input and the abundance of dredge material disposal areas in the study area. These spoil islands, which also serve as rookeries, are abundant within the study area as a result of various dredging activities associated with oil and gas exploration, shell dredging in the mid twentieth century, access channels to development, ship channel maintenance and expansion and the ongoing maintenance of the Gulf Intracoastal Waterway.

Ecosystem services assessed were derived from Farber et al. (2006). Ecosystem services fall into four broad categories: supportive functions and structures,

Table 1 Stakeholder affiliation and category

Stakeholder affiliation	Category of affiliation
Center for Coastal Studies, Texas A&M University—Corpus Christi	Academia
Conrad Blucher Institute, Texas A&M University—Corpus Christi	Academia
Harte Research Institute, Texas A&M University—Corpus Christi	Academia
Mission Aransas NERR, University of Texas Marine Science Institute	Academia
Texas A&M University—Corpus Christi	Academia
University of Texas Marine Science Institute	Academia
HDR Inc./Shiner Moseley	Development
U.S. Army Corps of Engineers	Federal Government
U.S. Environmental Protection Agency	Federal Government
U.S. Fish and Wildlife Service	Federal Government
U.S. Geological Survey	Federal Government
Port of Corpus Christi Authority	Industry
City of Corpus Christi—Environmental Services	Local Government
City of Corpus Christi—Parks and Recreation Department	Local Government
Nueces River Authority	Local Government
Coastal Bend Bays and Estuaries Program	Non-profit
Gulf of Mexico Foundation	Non-profit
Saltwater Fisheries Enhancement Association	Non-profit
Texas Coastal Conservation Association	Non-profit
Texas Commission on Environmental Quality	State Government
Texas Department of Transportation	State Government
Texas General Land Office	State Government
Texas Parks and Wildlife Department	State Government

regulating services, provisioning services, and cultural services. Supportive functions and structures support the other three categories, which have more direct contributions to human well-being.

A survey was designed to answer the question "Which ecosystem services are provided by targeted habitats?" Data were collected from survey responses. The survey listed habitats in rows and ecosystem services in columns (Fig. 2). Participants were asked to check off every ecosystem service a habitat provides. Stakeholders were provided with three supplements in order to complete surveys. The first supplement was a packet of color maps. Each map represented one habitat within the management plan boundary. A second supplement listed ecosystem services by category and included a description and example of each ecosystem service. A third supplement listed each habitat, the components of the habitat, and species of interest within the habitat (Hutchison 2011).

Data Analysis

Surveys were digitized and represented in binary form, i.e., a check in a box was represented as a value of one and a lack of a check in a box was represented as a value of zero. For each habitat, a numeric value for average number of ecosystem services provided to all stakeholders was calculated using the following equation:

$$\mathrm{ES} = \mathrm{ES}_{\mathrm{hab}} \Big/ n$$

where $\mathrm{ES}_{\mathrm{hab}}$=total number of ecosystem services provided to all stakeholders for a specific habitat (hab) and n=total number of stakeholders who completed surveys.

The percentage of stakeholders who identified the provisioning of an ecosystem service by a habitat was calculated and expressed as a consensus value. Higher agreement among stakeholders translated to a higher consensus value. The top four ecosystem services provided by each habitat were also derived. If there was a tie for fourth place, both ecosystem services were included in the top four.

A spatial representation of the average number of ecosystem services provided by habitats was created as a *heat map*. The most current and highest resolution data were determined to be of utmost importance to incorporate into the creation of the heat map. Data sources considered to represent habitats within the study area included: National Wetlands Inventory (NWI) data, National Oceanic and Atmospheric Administration (NOAA) benthic habitat data, U.S. Geologic Survey Landuse and Landcover (LULC) data, and CBBEP rookery island data.

Habitats and Related Ecosystem Services Survey

Which ecosystem services are provided by each habitat? Put a check mark in ALL boxes that apply.
Please see Supplements for a Description of Ecosystem Services AND Components of Habitats.

HABITAT	SUPPORTIVE ECOSYSTEM SERVICE					REGULATING ECOSYSTEM SERVICE								PROVISIONING ECOSYSTEM SERVICE						CULTURAL ECOSYSTEM SERVICE			
	Net Primary Production (1)	Hydrological Cycle (2)	Nutrient Cycling (3)	Pollination & Seed Dispersal (4)	Soil Formation (5)	Water Regulation (6)	Disturbance Regulation (7)	Soil Retention (8)	Waste Regulation (9)	Nutrient Regulation (10)	Gas Regulation (11)	Biological Regulation (12)	Climate Regulation (13)	Food (14)	Water Supply (15)	Raw Materials (16)	Genetic Resources (17)	Medicinal Resources (18)	Ornamental Resources (19)	Recreation (20)	Aesthetic (21)	Science & Education (22)	Spiritual & Holistic (23)
Live Oak Peninsula	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Scrub Shrub	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Park / refuge	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Dune	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Beach	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Flat	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Salt Marsh Wetland Complex	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Freshwater Wetland Complex	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Seagrass Bed	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Oyster Reef	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Marine / Open Water	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□
Rookery Island	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□

Fig. 2 Habitats and Related Ecosystem Services Survey. Habitats are listed in *rows* and ecosystem services in *columns*. Ecosystem Services are grouped by category. Instructions are provided at the *top* of the survey

The NWI data was slightly newer (2004) than the LULC data (2001), and existed at a higher resolution, so the NWI data was used. However, the 2004 NWI data had three major limitations: (a) the 2004 data did not cover the entire study area, (b) many disclaimers exist regarding the accuracy of the data with regard to water habitats, such as oyster reefs and seagrass beds, and (c) the dataset did not include all habitats assessed in the current study (specifically tree canopy/Live Oak motte and rookery island habitats). Areas not covered by the 2004 NWI data were filled in with 1992 NWI data (Scholz 2010). Additional datasets were used to represent habitats not assessed within the NWI datasets. The deciduous forest attribute classification was extracted from the LULC dataset and used to represent the tree canopy/Live Oak motte habitat type (Scholz 2010). Since the LULC data is at 30-meter resolution, it was converted to a false one-meter grid for incorporation into the heat map at the same resolution as the other habitats. CBBEP rookery island data was used to represent the rookery island habitat because it was the only known rookery island data that exists for the area (Scholz 2010).

Habitat datasets were aggregated in GIS. The 2004 NWI dataset contained 51 habitat categories relevant to the study area and the 1992 NWI dataset contained 13 relevant habitat categories. All habitats, except for tree canopy/Live Oak motte habitat, were originally represented in vector format and converted to raster format in GIS. Results from the survey were then incorporated into one-meter habitat rasters. The average number of ecosystem services per habitat type was used as the unit of weight in a weight sum overlay calculation (Scholz 2010). The result was a raster that represented average number of ecosystem services per grid cell for the entire study area. This raster was then represented in the form of a heat map.

Results

The average number of ecosystem services provided to all stakeholders by each habitat was calculated based on the survey (Table 2). Freshwater wetlands, salt marsh wetlands, and tree canopy/Live Oak motte habitats were perceived to provide the greatest number of ecosystem services to stakeholders. Rookery island habitat ranked lowest of all habitats assessed.

The top four ecosystem services and a consensus value for each habitat type were determined (Table 3). Cultural ecosystem services made up almost half of the top four ecosystem services of habitats. Supportive and regulating ecosystem services each comprised between 20 % and 30 % of services. Provisioning ecosystem services made up less than five percent of the top ecosystem services. The science and education ecosystem service was a top ecosystem service of all habitats assessed. Marine/open water and oyster reef were the only two habitats in which the provisioning ecosystem service of food was in the top four ecosystem services.

Table 2 Rank of habitats based on average number of ecosystem services provided. Values rounded off to whole numbers

Habitat	Average number of ecosystem services
Freshwater wetland	17
Salt marsh wetland	16
Tree canopy/Live Oak motte	15
Scrub-shrub wetland	14
Seagrass bed	12
Marine/open water	12
Oyster reef	11
Dune	11
(Intertidal) Flat	10
Beach	9
Rookery island	9

Values rounded off to whole numbers

Freshwater Wetland

Freshwater wetland habitat provided an estimated 17 out of 23 ecosystem services (Table 2). The consensus value for the top freshwater wetland ecosystem services was 92 % (Table 3). Three of the top ecosystem services of freshwater wetlands were supportive services (Table 4). The top freshwater wetland ecosystem service was water regulation. Net primary production and hydrological cycle ranked second. Freshwater wetland was the only habitat in which hydrological cycle and water regulation were in the top 4 ecosystem services.

Salt Marsh Wetland

Salt marsh wetland habitat provided an estimated 16 out of 23 ecosystem services (Table 2). The consensus value for the top services provided by salt marsh wetlands was 89 % (Table 3). The top ecosystem service provided by salt marsh wetland was science and education (Table 4).

Tree Canopy/Live Oak Motte

Tree canopy/Live Oak motte habitat provided an estimated 15 out of 23 ecosystem services (Table 2). The consensus value for the top services of tree canopy/ Live Oak motte habitat was 89 % (Table 3). The top ecosystem services were climate regulation and aesthetics (Table 4). Tree canopy/Live Oak motte habitat was the only habitat assessed in which climate regulation was in the top 4 ecosystem services.

Scrub-Shrub Wetland

Scrub-shrub wetland habitat provided an estimated 14 ecosystem services (Table 2). The consensus value for the top ecosystem services of scrub-shrub wetlands was 81 % (Table 3). The top ecosystem service provided by scrub-shrub wetlands was soil retention (Table 4).

Seagrass Bed

Seagrass bed habitat provided an average of approximately 12 ecosystem services (Table 2). The consensus value for the top services of seagrass bed habitat was 79 % (Table 3). The top ecosystem service of seagrass beds was net primary productivity (Table 4).

Marine/Open Water

Marine/open water habitat also provided an estimated 12 ecosystem services (Table 2). The consensus value for the top services of marine/open water habitat was 85 % (Table 3). Three of the top four services of marine/open water habitat were cultural services. Recreation was the top ecosystem service to stakeholders, and food and science and education ranked second (Table 4).

Oyster Reef

Oyster reef habitat provided an estimated 11 out of 23 ecosystem services (Table 2). The consensus value for the top services of oyster reef habitat was 74 % (Table 3). The top ecosystem service of oyster reef habitat was food, followed by science and education (Table 4).

Dune

Dune habitat provided an estimated 11 out of 23 ecosystem services (Table 2). The consensus value for the top services of dune habitat was 77 % (Table 3). The top service of dune habitat was disturbance regulation (Table 4). Dune habitat was the only habitat assessed in which the disturbance regulation ecosystem service was in the top 4 ecosystem services.

Table 3 Stakeholder consensus values (percentage of stakeholders that perceive an ecosystem service is provided by a habitat)

		Tree canopy/Live Oak motte	Scrub-shrub wetland	Dune	Beach	(Intertidal) Flat	Salt marsh wetland	Freshwater wetland	Seagrass bed	Oyster reef	Marine/ open water	Rookery island
Supportive	Net primary production	83	**81**	64	17	**70**	**92**	**94**	**94**	28	75	43
	Hydrological cycle	77	74	51	36	55	83	**94**	30	23	64	26
	Nutrient cycling	70	79	40	40	**72**	**91**	**92**	**87**	**81**	66	47
	Pollination and seed dispersal	83	**87**	55	19	30	79	81	53	6	30	**58**
	Soil formation	64	70	53	38	38	66	70	57	34	17	30
Regulating	Water regulation	68	68	43	34	51	85	**98**	43	53	47	17
	Disturbance regulation	79	70	**94**	60	47	79	79	55	70	21	45
	Soil retention	**89**	**94**	**77**	32	40	83	81	70	47	4	43
	Waste regulation	51	57	21	19	28	83	87	49	66	38	9
	Nutrient regulation	55	60	26	19	**60**	81	87	**79**	68	47	30
	Gas regulation	83	**81**	36	15	57	**89**	89	66	26	60	32
	Biological regulation	53	53	40	42	45	66	68	57	57	51	**58**
	Climate regulation	**92**	77	49	28	38	81	79	38	15	74	30
Provisioning	Food	40	49	15	32	25	74	68	72	**98**	**89**	13
	Water supply	36	28	17	2	11	30	89	9	11	25	2
	Raw materials	70	42	17	26	6	17	21	8	68	32	8
	Genetic resources	36	32	17	9	15	32	28	30	30	26	26
	Medicinal resources	21	19	9	8	6	15	17	8	13	30	6
	Ornamental resources	43	21	26	74	13	21	17	11	60	34	34
Cultural	Recreation	75	58	74	**100**	57	**89**	89	**79**	**74**	**96**	**85**
	Aesthetic	**92**	75	**91**	**98**	58	87	89	57	43	**85**	**85**
	Science and education	**89**	**87**	**92**	**98**	**89**	**94**	**92**	**91**	**89**	**89**	**91**
	Spiritual and holistic	68	45	58	**87**	40	60	57	36	42	66	51

Bolded percentages represent top four (or five if there is tie) ecosystem services provided by a habitat. Ecosystem service categories are included on the left

Table 4 Stakeholder rank of ecosystem services provided by habitats

Habitat	Category	Ecosystem service	Rank
Freshwater wetland	Regulating	Water regulation	1
	Supportive	Net primary production	2
	Supportive	Hydrological cycle	2
	Supportive	Nutrient cycling	3
	Cultural	Science and education	3
Salt marsh wetland	Cultural	Science and education	1
	Supportive	Net primary production	2
	Supportive	Nutrient cycling	3
	Regulating	Gas regulation	4
	Cultural	Recreation	4
Tree canopy/Live Oak motte	Regulating	Climate regulation	1
	Cultural	Aesthetic	1
	Regulating	Soil retention	2
	Cultural	Science and education	2
Scrub-shrub wetland	Regulating	Soil retention	1
	Supportive	Pollination and seed dispersal	2
	Cultural	Science and education	2
	Supportive	Net primary production	3
	Regulating	Gas regulation	3
Seagrass bed	Supportive	Net primary production	1
	Cultural	Science and education	2
	Supportive	Nutrient cycling	3
	Regulating	Nutrient regulation	4
	Cultural	Recreation	4
Marine/open water	Cultural	Recreation	1
	Provisioning	Food	2
	Cultural	Science and education	2
	Cultural	Aesthetic	3
Oyster reef	Provisioning	Food	1
	Cultural	Science and education	2
	Supportive	Nutrient cycling	3
	Cultural	Recreation	4
Dune	Regulating	Disturbance regulation	1
	Cultural	Science and education	2
	Cultural	Aesthetic	3
	Regulating	Soil retention	4
(Intertidal) Flat	Cultural	Science and education	1
	Supportive	Nutrient cycling	2
	Supportive	Net primary production	3
	Regulating	Nutrient regulation	4
Beach	Cultural	Recreation	1
	Cultural	Aesthetic	2
	Cultural	Science and education	2
	Cultural	Spiritual and holistic	3
Rookery island	Cultural	Science and education	1
	Cultural	Recreation	2
	Cultural	Aesthetic	2
	Supportive	Pollination and seed dispersal	3
	Regulating	Biological regulation	3

(Intertidal) Flat

Flat habitat provided an estimated 10 ecosystem services (Table 2). The consensus value for the top ecosystem services was 60 % (Table 3). The top service provided by flat habitat was science and education, followed by nutrient cycling (Table 4).

Beach

Beach habitat provided approximately 9 ecosystem services (Table 2). The consensus value for the top services of beach habitat was 87 % (Table 3). The recreation ecosystem service ranked highest for beach habitat. The only case in which all stakeholders agreed was that beach habitat provided a recreational service. Beach was also the only habitat for which the spiritual and holistic ecosystem service ranked in the top four ecosystem services (Table 4).

Rookery Island

Rookery island habitat provided the least number of ecosystem services, less than 9 (Table 2). A consensus value of 59 %, the lowest of all consensus values for habitats assessed, existed for the top services of rookery islands (Table 3). The top three ecosystem services of rookery islands were all cultural services. The highest ranked ecosystem service was science and education (Table 4). Rookery island habitat is the only habitat assessed for which the biological regulation ecosystem service was in the top 4 ecosystem services.

Heat Map

A heat map was created to spatially represent the average number of ecosystem services provided by habitats (Fig. 3). Colors on the heat map range from dark red to dark blue. Dark red represents highest average number of ecosystem services provided by habitats and thus signifies “hot” areas on the heat map. Dark blue represents lowest average number of ecosystem services. The Nueces River and Delta subregion provided the most ecosystem services in the study area. The high value of this sub-region was due to the abundance of freshwater wetlands, salt marsh wetlands and tree canopy/Live Oak motte habitat. There were also many high value areas along the backside of North Padre, Mustang, and San Jose Islands due to the large expanses of salt marsh wetlands in these areas.

Discussion

This study presents insight into stakeholder perceptions of coastal habitat ecosystem services in the Nueces Estuary and surrounding area. Salt marsh wetlands (relatively highly ranked) and (intertidal) flats (relatively poorly ranked) often occur adjacent to each other in the landscape. Further, rookery islands ranked lowest, but often support the growth of highly valued salt marsh and freshwater wetland habitats.

Ecosystem Services at the Local Level and Relevance to Ecosystem-Based Management

Lack of incorporation of ecosystem services into decision making has been documented (Farber et al. 2006) and a need exists for better understanding human values within an ecosystem-based management framework (Endter-Wada et al. 1998). A knowledge gap regarding ecosystem service supply at the local level has also been documented (MA 2005). Results of the present study were incorporated into an ecosystem-based management plan to enable stakeholders to make better-informed decisions regarding priority areas for conservation, preservation and restoration and to attempt to address the need to understand ecosystem service supply at the local level (http://www.cbbep.org/projects/ecomanagement.html). The heat map was used to spatially represent number of ecosystem services provided by habitats. Buffer zones around specific areas identified by stakeholders were created in GIS. An ecosystem service value for each area was extracted. Areas were then ranked and listed in tables. This information was presented in tandem with a description of the area, habitats and public lands in the area, stakeholder-identified priority issues, areas of interest, and areas of concern in the area, gains and losses of habitats in the area, and endangered species habitat in the area. Presenting information in this way enables stakeholders to make consensus-based management decisions. The usability of a product such as the heat map can be enhanced via modeling techniques and the incorporation of other data types. Additionally, creating a web-based interactive product would make the heat map more user-friendly and accessible. A web-based interactive product would allow decision makers to make better-informed decisions regarding tradeoffs and the provision of ecosystem services based on stakeholder-specific questions.

Methods used to conduct the present study can be refined and expanded upon to effectively incorporate ecosystem services into decision making. There is a need to establish the links between ecosystem structure and function, and ecosystem services and human well-being (Rosenberg and McLeod 2005; Maynard et al. 2010; Jordan et al. 2010). Quantifiable metrics and indicators are also necessary for decision makers to make justifiable decisions (Jordan et al. 2010). Cowling et al. (2010) provide a theoretical model for mainstreaming ecosystem services to ensure effective ecosystem-based management. An example of a practical application of ecosystem-based management that incorporates ecosystem services into a decision making framework

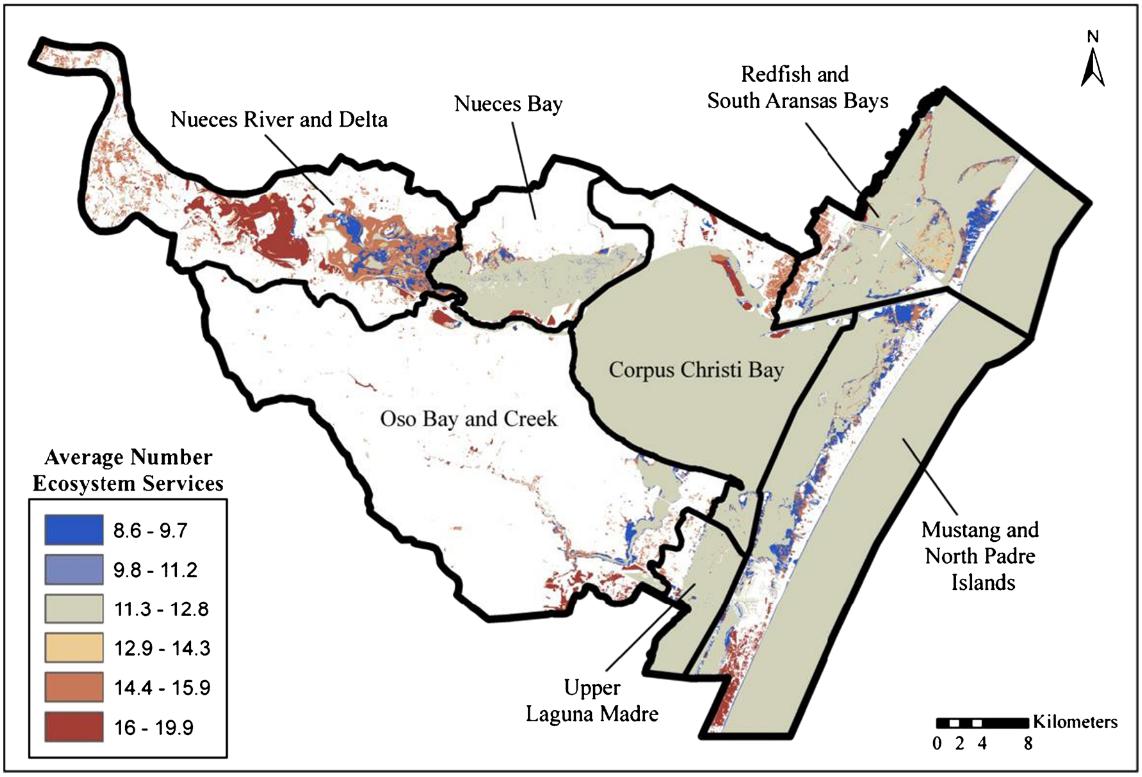

Fig. 3 Heat map of average number of ecosystem services provided by habitats within the study area

has been developed and implemented by Maynard et al. (2010) in Australia. The framework needs refinement, but is a good (if not the only) example of a practical application of ecosystem-based management that incorporates ecosystem services into decision making.

Weighting Ecosystem Services and Ecosystem Service Trade-Off Analysis

A weakness of the present study is that all ecosystem services were valued equally. Ecosystem service trade-off analysis is needed to make effective management decisions. Pair-wise comparison (PWC) surveys can be used to weight ecosystem services and determine weighted preference scores. A PWC survey forces a stakeholder to choose between specific ecosystem services. Methods to create and analyze PWC surveys can be derived from stakeholder analysis publications (Accorsi et al. 1999; Hosseini and Brenner 1992; Fichtner 1986). PWC surveys were tested at the workshop, but results were not incorporated into the management plan. One interesting finding was that cultural ecosystem services usually ranked lower than regulating and provisioning ecosystem services when stakeholders were forced to choose between them (Hutchison 2011). Other techniques for assessing relative importance include simple scoring systems and the expected value method (Maynard et al. 2010).

Improvements to Surveying Method and the Participatory Process

The surveying method and participatory process can be improved in many ways. Potential improvements include: (a) pretesting surveys, (b) tracking the identity and/or affiliation of respondents, (c) allowing stakeholders to relay that they do not know enough to answer a survey question, (d) only assessing stakeholder knowledge in relation to the habitat(s) about which they are most knowledgeable, and (e) making sure all stakeholder questions and concerns are addressed before the surveying process begins.

The importance of pretesting surveys cannot be emphasized enough. Stakeholder confusion occurred during the surveying process at the workshop. For example, a description of one of the supportive ecosystem services, soil formation, was left off of a supplement to the surveys. This is also the only ecosystem service in the supportive category was not in the top four ecosystem services for any of the habitats assessed. Additionally, some workshop participants were confused about the naming of some habitats. For example, on the surveys, freshwater wetland and salt marsh wetland habitat both included the word “complex” at the end of the title. Some stakeholders felt this could create bias by making these two habitats sound more important than the other habitats. Additionally, tree canopy/Live Oak motte habitat was labeled “live oak peninsula” instead of live oak motte. Live Oak Peninsula is a physical location within the study area and could have been perceived to represent an entire area, rather than a specific habitat. Also, the descriptor for scrub-shrub wetland habitat did not include the word “wetland” at the end, which caused confusion as well. Further, some stakeholders expressed concern regarding whether or not mangroves were included in the scrub-shrub habitat category. Stakeholders referencing supplements, such as maps and habitat descriptions, would have eliminated some of the confusion regarding naming conventions. However, some of the mistakes and subsequent confusion could have been eliminated if repeated pre-testing was conducted prior to the workshop. Further, uncertainty exists when attempting to define and assess ecosystem services. Thus, future studies could set aside time, either in focus groups or at the beginning of the workshop, for stakeholders to discuss and agree on definitions of ecosystem services and habitats before proceeding to the assessment portion of the study. This type of approach was used at a workshop that addressed ecosystem services provided by Gulf of Mexico habitats (Yoskowitz et al. 2010) and seemed to work well to ensure consensus.

Tracking the identity of respondents might also improve this type of surveying method. Two benefits of tracking the identity of stakeholders are: (a) the ability to follow-up with stakeholders post survey analysis and (b) the ability to group stakeholders based on affiliations and other socio-economic information. The ability to follow-up with respondents after the surveys have been completed is imperative to better understanding stakeholder perceptions. Because the concept of stakeholder analysis of ecosystem service provision is a relatively new area of research, the ability to follow-up with stakeholders regarding why they assessed certain habitats as they did is essential to understanding the stakeholder perceptions of ecosystem services. Additionally, establishing an iterative process in which stakeholders are allowed to change their minds based on new knowledge obtained would also be insightful. Additionally, attempting to better understand value systems and potential conflicts based on stakeholder affiliation would be useful information to incorporate into analysis.

Lack of stakeholder knowledge was not explicitly captured in surveys and could have created information bias. Thus, future studies could allow stakeholders to relay the fact that they do not know whether or not a service is provided. For example, an option could be provided to the stakeholder to not answer a survey question, and instead check a box that states, “I don’t know.” This would not only eliminate information bias, it would also give a clear indication of a need for education and a need for research related to specific ecosystem services and habitats. This type of information could then be used to guide targeted education and research campaigns.

In order to minimize respondent fatigue and error associated with answering survey questions stakeholders do not feel qualified to answer, respondents could be asked to assess only habitats with which they are most familiar. The knowledge of experts can be used to gain information quickly when there is a lack of time or resources. However, it is important to note that potential bias, known as strategic bias, can occur when an expert knows a potential outcome will take place as a result of his or her assessment.

Inclusion of a Wide Range of Stakeholders

Representation of a more diverse group of stakeholders (and thus a larger sample size) could be incorporated into future experimental designs. The concept of including all relevant stakeholders in decision making is a fundamental aspect of stakeholder analysis (Grimble and Wellard 1997). Sustainable solutions to natural resource management depend on including local users rather than formally educated experts in the participatory process (Menzel and Teng 2010). That the general public was not included in the study could also be perceived as a weakness. Further, because we are dealing with a coastal system, at the bottom of a watershed, it could also be beneficial to involve stakeholders from the entire watershed. The perspectives of individuals residing at the top of the watershed might be less informed about coastal habitats. However, simply involving these stakeholders in research may enhance their understanding of the important role coastal habitats play in the ecosystem, including effects on human well-being throughout the watershed.

Stakeholders from industry and development were relatively underrepresented at both workshops (Montagna et al. 2011; Palmer et al. 2009). At the second workshop, local government was relatively underrepresented and academics were relatively overrepresented. Data collected at the second workshop showed that the science and education ecosystem service, defined as use of natural areas for scientific and educational enhancement, was in the top four ecosystem services provided by all habitats assessed. This is probably due to the abundance of academics and science-oriented stakeholders at the workshop. Results might have been much different if local users were surveyed rather than experts.

Importance of Long-Term and Accurate Datasets

The ability to accurately represent and calculate change in habitat area over time is essential for calculating changes in ecosystem services. This type of information is critical for decision makers to be able to make justifiable decisions regarding protection of certain areas. Availability of long-term habitat coverage datasets in the study area and throughout the Coastal Bend of Texas is limited to the recent past. The calculation of actual change in habitat for the entire study area is only available at 30×30 meter pixel resolution for years 1996, 2001, and 2005 through the NOAA Coastal Change Analysis Program (C-CAP). The continued collection of C-CAP data and similar data at an even higher spatial and temporal resolution is imperative for monitoring and effective adaptive management and decision making at the local level. Other data currently available for habitats within the study area, such as NWI data, are at higher spatial resolution than C-CAP data, but are only useful when determining general trends in habitat changes over time (Tremblay et al. 2008; White et al. 2006). Further, data used to delineate and assess open water habitats, such as seagrass beds and oyster reefs, is highly affected by water turbidity and tide levels. Efforts to better map these habitats, such as NOAA's Benthic Habitat Mapping and work conducted by members within the Seagrass Monitoring Work Group and Texas Parks and Wildlife Department, are currently underway and necessary for effective monitoring and potential conservation of these habitat types.

Several stakeholders expressed concern related to a couple of hot areas on the heat map that do not appear to be accurate. These misrepresented areas are within dredge placement areas and the rookery island habitat designation. An example of such an area is the southern shore of Nueces Bay, which is an active dredge placement area that is turned over with a machine on a regular basis. Another example of misrepresented areas on the heat map are rookery islands within the upper portions of Nueces Bay that are represented in red, even though it was determined by stakeholders that these areas do not provide as many ecosystem services as other habitats. This exaggeration of rookery islands is related the fact that the rookery island layer was separate from all other datasets, which accounted for some overlap during raster processing. These types of misrepresentations due to inadequate data on temporal and spatial scales can be addressed via more intensive data collection and through the use of local stakeholder knowledge combined with a tool such as a heat map. Further, the decision to incorporate rookery islands into analysis as a habitat type complicated the process due to a lack of available data and issues associated with other habitat types colonizing rookery islands.

Need for Education

A key finding of the first workshop was the need for education to promote sustainable production of ecosystem goods and services (Montagna 2009). A similar need was also identified at the second workshop. Many stakeholders at the second workshop were unfamiliar with the specific definitions related to ecosystem services and thus relied heavily on supplements provided to them. Many stakeholders also requested coastal examples of ecosystem services. This is essentially the information gap the researchers were seeking to fill by conducting the study. Thus, there is a need for documentation and education related to (Texas) coastal habitat ecosystem services, even for individuals who are knowledgeable about these habitat types. Lack of understanding ecosystem services, and the resiliency of ecosystem services, will continue to hinder effective decision making.

At the second workshop, stakeholders cited specific examples of confusion regarding definitions of ecosystem services. In some cases, this confusion related to a specific ecosystem service, and in other cases, this confusion stemmed from a lack of understanding regarding how ecosystem services are organized into broader categories. For example, some stakeholders could not determine the difference between water supply and water regulation. These two services are under the umbrella of different ecosystem service categories. Water supply is defined as a provisioning ecosystem service and water regulation as a regulating ecosystem service. A provisioning ecosystem service is provided to humans through the *direct* consumption of natural resources and raw materials. Regulating ecosystem services are *indirectly* consumed by humans and involve the maintenance of systems and natural processes (Farber et al. 2006). Thus, humans directly consume the water supply ecosystem service, whereas the water regulation ecosystem service is indirectly provided to humans through the flow of water across the landscape. The water regulation ecosystem service affects the quality of water humans consume and use for other purposes, such as sustaining healthy animal and plant communities.

At the second workshop, some stakeholders expressed reservation related to specific ecosystem services. For example, some stakeholders expressed doubt related to the genetic and medicinal resource ecosystem services. The stakeholders understood what this ecosystem service was, but were not confident enough to determine whether or not a habitat in the study area provided this type of service. For this reason, it could be that some ecosystem services were documented as not being provided, not because the service was lacking, but because the knowledge regarding the provision of service was lacking. This type of confusion can be eliminated through research and education that incorporate ecosystem services.

Education needs related to ecosystem services have previously been documented and thus many suggestions for enhancement of ecosystem service education exist. Suggestions for educational endeavors related to ecosystem services include the use of existing agencies to educate the public and inclusion of ecosystem services in school textbooks (Hogan et al. 2009). Additionally, the movement away from static maps (Villa et al. 2009) and the development of interactive, web-based tools would be useful to enhancing the ecosystem service knowledge of decision makers and the general public. Some researchers suggest the use of participatory research in which stakeholders are tasked with gathering ecosystem service data (Menzel and Teng 2010) and thus educating themselves. Further, publication of information, such as the information gathered in this study, will help to enhance the understanding of ecosystem service provision by coastal habitats.

Conclusion

This study documents a methodology for assessing knowledge and perceptions of local stakeholders regarding ecosystem services provided by coastal habitats. This study also describes one method to incorporate ecosystem services into an ecosystem-based management plan. There are three main benefits of the current study: (a) suggestions for enhancement of ecosystem-based management implementation related to the incorporation of ecosystem services into decision making, (b) documentation of ecosystem services provided by targeted habitats so identification, quantification, and valuation of ecosystem services provided by coastal habitats, including habitats surrounding the Nueces Estuary, can proceed in a better informed manner, and (c) identification of education and research needs related to ecosystem services. The current study progresses the knowledge of local ecosystem service provision by expanding upon simply theorizing about local stakeholder perceptions of the provision of ecosystem services. More detailed studies using quantifiable metrics of how these services are linked to ecosystem structure and function and human well-being should be conducted. The current study establishes a baseline assessment of what stakeholders think. "Value results from its beholder, not from the 'thing' itself" (Menzel and Teng 2010). It is important to note that people act based on what they think, not based on truth. Thus, the current study identifies the interests and priorities of stakeholders that affect decision making at the local level.

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