Nueces Estuary Ecosystem Management Initiative

Publication CBBEP – 72
Project Number – 1018
July 2011

Prepared by:

Principal Investigator:
Paul A. Montagna, Ph.D., Principal Investigator
Lauren M. Hutchison, M.S.
Damon Scholz, M.S.
Terry Palmer, M.S.
Sandra Arismendez, Ph.D.
David Yoskowitz, Ph.D.

Harte Research Institute for Gulf of Mexico Studies
Texas A&M University-Corpus Christi
6300 Ocean Drive, Unit 5869
Corpus Christi, TX 78412-5869
361-825-2040 Telephone
361-825-2049 Facsimile

Submitted to:
Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd., Suite 205
Corpus Christi, TX 78401

Nueces Estuary Ecosystem Management Initiative

An Ecosystem Services-based Plan

Paul A. Montagna, Ph.D., Principal Investigator
Lauren M. Hutchison, M.S.
Damon Scholz, M.S.
Terry Palmer, M.S.
Sandra Arismendez, Ph.D.
David Yoskowitz, Ph.D.

TEXAS A&M UNIVERSITY CORPUS CHRISTI | HARTE RESEARCH INSTITUTE FOR GULF OF MEXICO STUDIES

6300 Ocean Drive, Unit 5869
Corpus Christi, Texas 78412-5869

Phone: 361-825-2040
Email: paul.montagna@tamucc.edu

Final report submitted to:

Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd., Suite 205
Corpus Christi, Texas 78401

CBBEP Project Number 1018

July 2011

Cite as:

P.A. Montagna, Hutchison, L.M., D. Scholz, T. Palmer, S. Arismendez, and D. Yoskowitz. 2011. Nueces Estuary Ecosystem Management Initiative: An Ecosystem Services-based Plan. Final Report submitted to the Coastal Bend Bays & Estuaries Program for project number 1018. Texas A&M University - Corpus Christi, Harte Research Institute for Gulf of Mexico Studies, 170 pp.

Table of Contents

LIST OF FIGURES v
LIST OF TABLES viii
ACRONYMS xi
ACKNOWLEDGEMENTS xiii
EXECUTIVE SUMMARY xiv
INTRODUCTION 1
Background/Project Description 1
Region Description 1
Ecoregion Summary 2
Project Area Description 3
Stakeholder Engagement 4
HABITATS OF PROJECT AREA 5
Habitat Types in the Project Area and their Importance 5
Seagrass Bed 6
Salt Marsh/Emergent Wetland 8
Intertidal Flat 9
Beach 10
Marine/Estuarine Open Water 11
Oyster Reef 13
Scrub-Shrub Wetland 14
Freshwater Wetland 14
Tree Canopy/Live Oak Motte 14
Rookery Island 15
Dune 15
THREATS AND RISKS TO THE AREA 16
Biological 16
Water Quality 17
Climatic Anomalies 18
Sea-level Rise and Shoreline Change 18

Development 20
Climate Change 20
Future Concerns 21
PROJECT APPROACH AND PROCESS 30
Existing Plans and Resources 30
Individual Meetings 32
Workshops 36
Workshop One 36
Workshop Two 39
ECOSYSTEM SERVICE VALUATION OF HABITATS 42
Ecosystem Services 42
Ecosystem Services Surveys 45
Incorporation of Stakeholder Input 49
Ecosystem Services Provided by Habitats 51
Freshwater Wetland 55
Salt Marsh Wetland 55
Tree Canopy/Live Oak Motte 56
Scrub-shrub Wetland 56
Seagrass Bed 56
Marine / Open Water 57
Oyster Reef 57
Dune habitat 57
Beach 58
Flat 58
Rookery Island 58
Heat Map of Ecosystem Services 59
GIS Methods 59
INVENTORY AND PRIORITIZATION OF AREAS FOR PROTECTION/RESTORATION/CREATION 71
Introduction of the Sub-regions 71
Status and Trends of Habitats 74

Nueces River and Delta Sub-region 77
Habitat Assessment 77
Priority Areas and Justification of Priorities 77
Future Activities 82
Nueces Bay Sub-region 83
Habitat Assessment 83
Priority Areas and Justification of Priorities 83
Future Activities 89
Corpus Christi Bay Sub-region 90
Habitat Assessment 90
Priority Areas and Justification of Priorities 90
Ecosystem Services 97
Future Activities 98
Mustang and North Padre Islands Sub-region 99
Habitat Assessment 100
Priority Areas and Justification of Priorities 100
Ecosystem Services 108
Future Activities 109
Oso Bay and Creek Sub-region 110
Habitat Assessment 110
Priority Areas and Justification of Priorities 110
Future Activities 121
Redfish and South Aransas Bay Sub-region 122
Habitat Assessment 122
Priority Areas and Justification of Priorities 122
Future Activities 131
Upper Laguna Madre Sub-region 132
Habitat Assessment 132
Priority Areas and Justification of Priorities 132
Ecosystem Services 132
Future Activities 136

General projects and/or concerns 137
Parks 137
Agriculture 144
Permitted Point Sources 147
Rookery Islands 152
FUTURE OUTCOMES AND NEXT STEPS 154
Implementation Tools 154
Governance structure, regulatory, policy and legal constraints 154
In Lieu Fee Program 155
Potential Financing Outcomes 156
Recommendations 157
Research and Monitoring Recommendations 157
Improvements to the Ecosystem Service Valuation Process 158
Action vs. Inaction 160
CBBEP's Responsibility to the Bays and Estuaries of the Coastal Bend 161
REFERENCES 163

LIST OF FIGURES

Figure 1. Boundary map of the EBMP area. 2
Figure 2. Level IV Ecoregions in the EBMP area (after Griffith et al. 2007). 3
Figure 3. Sea level at Rockport, TX with linear regression based on monthly mean sea level data from 1948 to 2006 (Graph from NODC 2010). 22
Figure 4. Annual averages and linear regressions of water quality variables in Corpus Christi Bay between 1976 and 2009. A) salinity, B) water temperature. 24
Figure 5. Annual averages linear, and non-linear regressions of water quality variables in Corpus Christi Bay between 1976 and 2009. C) turbidity and D) dissolved oxygen. 25
Figure 6. Tropical disturbances that came close to the EBMP area between 1869 and 2007 (Data NOAA). 26
Figure 7. Tropical storms and hurricanes that passed the area between Baffin Bay and Rockport Texas between 1869 and 2007. 28
Figure 8. Population growth in Nueces County and the City of Corpus Christi and linear regression of Nueces County population based on 1960-2009 populations. Data is US Census decennial data except for 2008 and 2009 data, which is estimated (www.census.gov). 29
Figure 9. Estuarine ecosystem conceptual model (From Montagna et al. 1996). 37
Figure 10. Percentage of stakeholders representing each stakeholder affiliation category. 41
Figure 11. Habitats and Related Ecosystem Service Survey completed by stakeholders at second workshop. 46
Figure 12. Snapshot of first page of the "Pair-wise Comparison of Ecosystem Services" survey. 48
Figure 13. Percentage of each Ecosystem Service Category providing the top four ecosystem services for all habitats included in the EBMP. 55
Figure 14. Heat map of average number of ecosystem services provided by habitats within the EBMP area. 60
Figure 15. NWI 2004 Data gaps in the EBMP area. 62
Figure 16. NWI 2004 Data gaps in the Redfish and South Aransas Bays sub-region. Pink areas had to be filled in with 1992 data. 63
Figure 17. NWI 2004 Data gaps in the Nueces River and Delta sub-region. Pink areas had to be filled in with 1992 data. 64
Figure 18. NWI 2004 Data gaps in the Upper Laguna Madre sub-region. Pink areas had to be filled in with 1992 data. 65
Figure 19. NWI 2004 Data gaps in the Oso Bay and Creek sub-region. Pink areas had to be filled in with 1992 data. 66
Figure 20. NWI 2004 Data gaps in the northwestern portion of Oso Bay and Creek sub-region. Pink areas filled in with 1992 data. 67

Figure 21. EBMP sub-regions: Nueces River and Delta, Nueces Bay, Corpus Christi Bay, Oso Bay and Creek, Upper Laguna Madre, Mustang and North Padre Islands, and Redfish and South Aransas Bays........ 73
Figure 22. Geographic areas (#s) from Status and Trends reports. Colors represent area of each EBMP sub-region represented by geographic areas of Status and Trends reports. See Table 26 for details. 76
Figure 23. Nueces River and Delta sub-region habitat map. 79
Figure 24. Nueces River and Delta sub-region heat map representing average number of ecosystem services provided by habitats. 80
Figure 25. Nueces River and Delta sub-region heat map including permitted wastewater outfall sites. 81
Figure 26. Nueces Bay sub-region habitat map. 85
Figure 27. Nueces Bay sub-region heat map representing average number of ecosystem services provided by habitats. 86
Figure 28. Nueces Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites........ 87
Figure 29. Nueces Bay sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover. 88
Figure 30. Corpus Christi Bay sub-region habitat map. 91
Figure 31. Corpus Christi Bay sub-region heat map representing average number of ecosystem services provided by habitats. 92
Figure 32. Corpus Christi Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with specific locations mentioned by stakeholders at the first workshop. 93
Figure 33. Corpus Christi Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites........ 94
Figure 34. Northern portion of Corpus Christi Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites. 95
Figure 35. Mustang and North Padre Island sub-region habitat map. 102
Figure 36. Mustang and North Padre Islands sub-region heat map representing average number of ecosystem services provided by habitats. 103
Figure 37. Mustang and North Padre Islands sub-region heatmap (representing average number of ecosystem services provided by habitats) with specific locations mentioned by stakeholders at the first workshop........ 104
Figure 38. Mustang and North Padre Islands sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites. 105

Figure 39. Mustang and North Padre Islands sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover. 106
Figure 40. Oso Bay and Creek sub-region habitat map. 111
Figure 41. Oso Bay and Creek sub-region heat map representing average number of ecosystem services provided by habitats. 112
Figure 42. Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) with specific locations mentioned by stakeholders at the first workshop. 113
Figure 43. Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites. 114
Figure 44. Northern portion of Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites. 115
Figure 45. Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover. 116
Figure 46. Redfish and South Aransas Bays sub-region habitat map. 123
Figure 47. Redfish and South Aransas Bays sub-region heat map representing average number of ecosystem services provided by habitats. 124
Figure 48. Redfish and South Aransas Bays sub-region heatmap (representing average number of ecosystem services provided by habitats) with specific location mentioned by stakeholders at the first workshop. 125
Figure 49. Redfish and South Aransas Bays sub-region (representing average number of ecosystem services provided by habitats) heat map with permitted wastewater outfall sites. 126
Figure 50. Redfish and South Aransas Bays sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover. 127
Figure 51. Upper Laguna Madre sub-region habitat map. 133
Figure 52. Upper Laguna Madre sub-region heat map representing average number of ecosystem services provided by habitats. 134
Figure 53. Upper Laguna Madre sub-region heatmap (representing average number of ecosystem services provided by habitats) with specific location mentioned by stakeholders at the first workshop. 135
Figure 54. Parks and refuges in the EBMP area. 139
Figure 55. Agriculture in the EBMP area. 146
Figure 56. Permitted outfalls in the EBMP area. 149
Figure 57. Rookery islands in the EBMP area. 153

LIST OF TABLES

Table 1. Status and trends in seagrass in 1999 at proposed conservation sites (Pulich et al. 1999). 7

Table 2. Forecasted changes of different drivers in Corpus Christi Bay calculated using extrapolations of linear regressions (y=y0+a*yr where y = driver value and yr=year). 22

Table 3. Tropical storms that passed between Baffin Bay and Rockport, Texas (Data NOAA).. 27

Table 4. Nueces County Population estimates for 2009 (www.census.gov). 28

Table 5. Future change projections of population and water demands in the Texas Coastal Bend region (TWDB 2007). 29

Table 6. Summary statistics of initial meetings. 33

Table 7. Organizations met during initial meeting stage of EBMP development. 34

Table 8. Proposed range of activities derived from stakeholder input to be included in the EBMP. 38

Table 9. Workshop two group number, facilitator name, and organization represented. 41

Table 10. Ecosystem services, description, and examples (Farber et al. 2006). 43

Table 11. Habitats not included in the ecosystem services surveys and reason for decision. 50

Table 12. Total number of stakeholders that perceive an ecosystem service is provided by a habitat (n = 53). 52

Table 13. Percentage of stakeholders that value ecosystem services provided by habitats. 52

Table 14. Habitats ranked based on average number of ecosystem services. Values have been rounded off to whole numbers. 54

Table 15. Top ecosystem services of Freshwater Wetland habitat. 55

Table 16. Top ecosystem services of Salt Marsh Wetland habitat. 56

Table 17. Top ecosystem services of Tree canopy/Live Oak Motte habitat. 56

Table 18. Top ecosystem services of Scrub-shrub Wetland habitat. 56

Table 19. Top ecosystem services of Seagrass Bed habitat. 57

Table 20. Top ecosystem services of Marine / Open Water habitat. 57

Table 21. Top ecosystem services of Oyster Reef habitat. 57

Table 22. Top ecosystem services of Dune habitat. 58

Table 23. Top ecosystem services of Beach habitat. 58

Table 24. Top ecosystem services of Flat habitat. 58

Table 25. Top ecosystem services of Rookery Island habitat. 59

Table 26. Summary of status and trends of habitats in the EBMP area based on Status and Trends reports (White et al. 2006 and Tremblay et al. 2008). 75

Table 27. Existing concerns and current assets in the Nueces River and Delta sub-region. 78

Table 28. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Nueces River and Delta sub-region. 82

Table 29. Current assets and existing concerns within the Nueces Bay sub-region. 84

Table 30. Specific locations in the Nueces Bay sub-region mentioned by stakeholders. 84

Table 31. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Nueces Bay sub-region. 84

Table 32. Current assets and existing concerns within the Corpus Christi Bay sub-region. 96

Table 33. Specific locations within the Corpus Christi Bay sub-region mentioned by stakeholders. 96

Table 34. Average number of ecosystem services provided by buffer zones surrounding sites mentioned by stakeholders at the first workshop. 97

Table 35. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Corpus Christi sub-region. 97

Table 36. Current assets and existing concerns in Mustang and North Padre Islands sub-region. 107

Table 37. Specific locations within the Mustang and North Padre Islands sub-region mentioned by stakeholders. 108

Table 38. Ecosystem service values for buffer regions surrounding areas mentioned by stakeholders at the first workshop. 108

Table 39. Ecosystem service values for buffer regions surrounding permitted wastewater outfalls in the Mustang and North Padre Islands sub-region. 109

Table 40. Current assets and existing concerns within the Oso Bay and Creek sub-region. 117

Table 41. Specific location in the Oso Bay and Creek sub-region mentioned by stakeholders and the first workshop. 118

Table 42. Ecosystem service values for buffer regions surrounding areas mentioned by stakeholders at the first workshop. Mean, minimum, maximum and range are included. 119

Table 43. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Oso Bay and Creek sub-region.................... 120

Table 44. Current assets and existing concerns within the Redfish and South Aransas Bay sub-region. 130

Table 45. Specific locations within the Redfish and South Aransas Bay sub-region mentioned by stakeholders.. 130

Table 46. Ecosystem service values for buffer regions surrounding area mentioned by stakeholders at the first workshop.. 131

Table 47. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Oso Bay and Creek sub-region.................... 131

Table 48. Current assets and existing concerns within the Upper Laguna Madre sub-region.... 136

Table 49. Ecosystem service values for buffer regions surrounding area mentioned by stakeholders at the first workshop.. 136

Table 50. Parks within the City of Corpus Christi, Texas. 140

Table 51. Agricultural statistics for 2010 in Nueces County from the AgriLife Extension Service (pers. com. J.R. Stapper, Nueces County Extension Agent).. 145

Table 52. Discharge permits in the EBMP for the Corpus Christi Bay area. Major category means the permit allows discharge > 1 million gallons per day; Minor category means the permit allows discharge < 1 MGD; NA means information not available.. 150

Table 53. Funding sources identified by stakeholders during the first workshop. 156

ACRONYMS

Acronym	Full Name
BAC	Beach Access Coalition
BMPs	Best Management Practices
CAMEO	Comparative Analysis of Marine Ecosystem Organization
CBBEP	Coastal Bend Bays & Estuaries Program
CBBF	Coastal Bend Bays Foundation
CCA	Coastal Conservation Association
CCBA	Corpus Christi Beach Association
CWA	Clean Water Act
DU	Ducks Unlimited
EBM	Ecosystem-based Management
EBMP	Ecosystem-based Management Plan
EPA	Environmental Protection Agency
ES	Ecosystem Services
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
GLO	Texas General Land Office
GOMF	Gulf of Mexico Foundation, Inc.
HPP	Habitat Priority Planner
HRI	Harte Research Institute
HUC	Hydrological Unit Code
IPCC	Intergovernmental Panel on Climate Change
MANPI	Mustang and North Padre Islands
MEA	Millennium Ecosystem Assessment
MGD	Million Gallons per Day
MSL	Mean Sea Level
NAIP	National Agriculture Imagery Program
NGO	Non-Governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NRA	Nueces River Authority
NRCS	Natural Resource Conservation Service
N-SPECT	Nonpoint Source Pollution and Erosion Control Tool
NWI	National Wetlands Inventory
PAHs	Polycyclic Aromatic Hydrocarbons

Acronym	Full Name
PCBs	Polychlorinated Biphenyls
POCCA	Port of Corpus Christi Authority
RFBSSA	Redfish Bay State Scientific Area
RMC	Resource Management Code
SEA	Saltwater Fisheries Enhancement Association
SEP	Supplemental Environmental Project
SRV	Submerged Rooted Vegetation
TAMU	Texas A&M University
TAMUCC	Texas A&M University- Corpus Christi
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
TXDOT	Texas Department of Transportation
US	United States
USACE	U.S. Army Corp of Engineers
UTBEG	University of Texas Bureau of Economic Geology
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UTMSI	University of Texas Marine Science Institute

ACKNOWLEDGEMENTS

Many people helped bring this project to a close. Jace Tunnell, in particular, contributed to every phase of the program, because he was the Project Manager for the Coastal Bend Bays & Estuaries Program (CBBEP). Jace helped develop the outline for this report, provided guidance on the direction of the project, provided presentations at the public workshop and wrote two sections ("In Lieu Fee Program" and "CBBEP Responsibility") for this report.

Much logistical support was provided for the second workshop by Carrol Simanek and Allison Knight. Dr. Elizabeth Smith, Dr. James Gibeaut and Dr. Blair Sterba-Boatwright provided guidance in the study design and implementation. Anthony Reisinger and William Nichols provided assistance in implementing the GIS analysis. Carlota Santos, Kathleen Welder and Brittany Bloomberg supported efforts to plan and execute the second workshop.

The following people acted as an advisory committee and reviewed the report prior to final acceptance by the CBBEP: Marc Woodin (USGS), Heather Young (NOAA -NMFS), Mark Garza (USACE-Galveston), Pat Clements (USFWS), Mark Fisher (TCEQ), Peggy Sumner (City of Corpus Christi), Leslie Williams (TPWD), Jorge Brenner (TNC), Jace Tunnell (CBBEP), Paul Carangelo (POCCA), Jack Carroll (Citgo), Manuel Freytes (GLO), and Barbara Keeler (EPA).

EXECUTIVE SUMMARY

The purpose of this project is to develop a Ecosystem-Based Management Plan (EBMP) that could be used to direct habitat preservation, creation and/or restoration activities in the Corpus Christi/Nueces Bay area and facilitate the application of fiscal opportunities and resources associated with coastal development, impact restitution, supplemental environmental, and community service projects and grants. The project was undertaken on behalf of the Coastal Bend Bays & Estuaries Program (CBBEP) and was performed in two phases: Phase I included a needs assessment (Palmer et al. 2009), stakeholder involvement (Brenner et al. 2009a), development of a boundaries map (Brenner et al. 2009b) and a preliminary management plan (Montagna 2009); Phase II included a process to synthesize results from Phase I and to develop an ecosystem-based management plan for the Corpus Christi/Nueces Bay area.

The project area for the EBMP was developed using criteria created after analyzing stakeholder input from Phase I of the project. The boundary map was created using an ecosystem-based perspective. The primary guidelines were natural hydrologic units and ecoregional boundaries. These natural guidelines were modified to include relevant socio-economic units. The resulting boundary merged both natural and human criteria and has an area of 247,363 hectares (611,247 acres). Therefore, the boundary represents the core planning area for representative habitats, and it comprises about 8% of the CBBEP project area. Major biophysical features included within the boundary are the Nueces River Delta, Corpus Christi, Nueces, Oso, Aransas, and Redfish Bays, in addition to parts of upper Laguna Madre. The cities of Corpus Christi, Robstown, Aransas Pass, and Port Aransas are entirely included within the boundary. Portland, Rockport and Ingleside are partially included in the EBMP boundary. Mustang Island and the Texas State owned waters in the Gulf of Mexico are also included in the project area. The boundary represents the spatial framework at an appropriate scale for the design and implementation of ecosystem-based projects.

The EBMP boundary was divided into sub-regions for organizational purposes. Sub-regions were labelled based on easily recognizable features with each sub-region. Sub-regions in the EBMP include the Nueces River and Delta, Nueces Bay, Corpus Christi Bay, Redfish and South Aransas Bays, Mustang and North Padre Islands, Upper Laguna Madre and Oso Bay and Creek.

A major objective of the EBMP project is to integrate stakeholder input; therefore, stakeholder engagement was constant and proactively pursued throughout plan development. Plan development consisted of three major parts. First, existing plans and resources were identified and reviewed to guide plan development. Second, individual meetings were conducted with stakeholders in the Corpus Christi/Nueces Bay area to solicit stakeholder input. Finally, two workshops were held to solicit and integrate stakeholder input into the plan development process.

Habitats are the elements of an environment that sustain an organism or a community of organisms. The populations of different species living in a habitat are called a community. In a

Texas bay and estuary ecosystem, typical habitats include riverine, salt marsh, algal mat, seagrass bed, water column, open bay bottom, oyster reef, beach and oceanic habitats (Day et al. 1989; Montagna et al. 1996). Energy can be transferred among habitats by physical movement of water or by movement of organisms between habitats. The interactions among and within habitats is partly responsible for the high diversity and productivity that is characteristic of estuaries.

The dominant habitats found in the EBMP project area are classified into the following groups for further description:

- Seagrass Bed,
- Salt Marsh Wetland,
- (Intertidal) Flat,
- Beach,
- Marine/Open Water,
- Oyster Reef,
- Scrub-Shrub Wetland,
- Freshwater Wetland,
- Tree Canopy/Live Oak Motte,
- Rookery Island, and
- Dune.

Threats and risks to the area include natural and anthropogenic processes in origin. These are identified using existing and obtainable information about risks that are changing the landscape now (e.g., development, pollution, storms, invasive species, etc.) and future risks that have the potential to change the landscape (e.g., climate change, population growth, etc.). While the risks due to threats is a real concern, no new analyses or studies were performed that would lead to a comprehensive risk analysis. Population growth and development are the main threats to habitats in the area. Climate change effects however, have the potential to be catastrophic should current warming and sea level rise trends continue in the future, because it would lead to severe degradation of water quality and drowning of habitats.

Invasive species are the main biological threats to natural habitats. Invasive species are species including its seeds, eggs, spores, or other biological material capable of propagating that species, that are not native to an ecosystem and whose introduction does or is likely to cause economic or environmental harm or harm to human health (CFR 64.25 1999). Invasive species often intentionally or unintentionally escape, are released, disseminated or placed into an ecosystem as a result of human activity. Invasive species are a threat to natural ecosystems and have been known to wreak havoc by out-competing native species, clogging waterways, and establishing monocultures where diverse ecosystems once existed.

Because of the lack of a comprehensive report of estuarine and coastal invasive species, little is known about the affect of invasive species in estuarine and coastal ecosystems. The available scientific literature documenting single species accounts is available only when aggregated in a piece-meal fashion. Invasive plant species seem to be better documented spatially; however few studies have addressed their effect on native plant communities. Therefore, threats from invasive species will be treated as an unknown or a data gap and should be further investigated. This preliminary synthesis of invasive species in the EBMP of the Corpus Christi Bay area indicates many invasive species do occur and many more may occur in the area and therefore the potential for invasive species being a threat to the Coastal Bend area is likely high.

Pollution is a primary cause of impaired water quality. The main water quality concerns in the Corpus Christ Bay area include: zinc in Nueces Bay, low dissolved oxygen in Oso Creek, Oso Bay, and Corpus Christi Bay, and high levels of bacteria at Ropes and Cole Parks located along the southwest shoreline of Corpus Christi Bay. There issues are currently being addressed in on-going total maximum daily load (TMDL) projects addressing these issues. More information regarding the status of the TMDL projects can be found at http://www.tceq.state.tx.us/implementation/water/tmdl/index.html.

Tropical storms, hurricanes, droughts, floods, and freezes are climatic disturbances that have strong effects on coastal habitats. The Coastal Bend has been fortunate in that it has not experienced a direct strike from a strong hurricane since the 1970's. While the Coastal Bend has been fortunate in dodging large tropical storms, it has suffered through extreme floods and droughts. The decade of the 1990's was extremely dry and the decade of the 2000's was extremely wet (Montagna et al. 2009b). The net result of droughts is to reduce marsh animal communities; floods however drown the marsh vegetation and kill it. The extreme variability of freshwater inflow related to the cycle of floods and droughts is likely the greatest natural threat to Coastal Bend habitats (Montagna et al. 1996).

The Coastal Bend area exhibits a semiarid to subtropical climate and associated flora and fauna. Therefore, when unusually cold winter freezes occur in the area, the biota are affected. Fish kills due to winter freezes have been documented as far back as the 1940s (Gunter 1941) and black mangrove die offs have also been attributed to unusually cold winter freezes (Sherrod and McMillan 1981). A combination of drought and back-to-back extended freezes in the late 1980s and early 1990s, respectively, have been attributed to the initiation of the brown tide event that occurred in the Laguna Madre for several years (DeYoe and Suttle 1994; Buskey et al. 1997). They attribute increased salinities coupled with a release of nitrogen from the decaying fish to the cause of the persistent brown tide from 1990 to 1997 in the Laguna Madre. The brown tide has also been documented to have had compounding effects on the decrease in aerial extent of seagrasses (Onuf 1996). Therefore, sporadic winter freezes, although natural, are known to have resulted in detrimental, lasting effects on ecological processes in the Coastal Bend area.

Rapid sea-level rise, however, may interact with habitat change to alter the trajectory of succession of coastal landscapes. It is not clear exactly what will happen. One possibility is that the rising sea level will simply drown wetland habitats, but as long as plant growth and soil stabilization by plant roots occur at a rate higher than apparent sea-level rise, the habitats can simply migrate as the shoreline migrates. Migration of shorelines can occur until man-made structures like roads or bulkheads impede this process. This is a threat to the Coastal Bend area because Mustang and North Padre Islands have roads dissecting them. There is no reason to conclude that shorelines will not change.

The Texas coast is likely to experience severe climate change impacts because of a synergy between the regional climate regime and the coastal geology (Montagna et al. 2007). Lying between about 26 and 30 degrees North latitude, the Texas coast is already in a relatively warm climate zone and subject to very high rates of evaporation. Thus, potential changes in rainfall or temperature will have great impacts on the Texas coastal hydrocycle (Montagna et al. 2010). The Texas coastal plain is relatively flat and low-lying, and the coast also has one of the highest rates of subsidence in the world (2.8 mm/yr in Rockport, Montagna et al. 2007). Thus, changes in sea level will be exacerbated on the Texas coast because the land is relatively flat and is rapidly sinking. The combined effects of these changes can affect the physical and biological characteristics of the Texas coast dramatically.

Although there are threats and risks from biological, climatic anomalies, water quality, and sea-level rise and shoreline change factors, the largest threat for habitat changes is nearly always from human activities, particularly development. Development in coastal regions is beneficial economically because of the increased property values near the water or near natural areas. The increased property value due to proximity to valued assets is called the hedonic value of property, which represents the difference between two similar properties when one is near a natural asset and one is not. There is great development pressure on coastal habitats because of the high hedonic values in coastal areas. However, development poses several threats to habitats. Increased land use near the water is associated with increased loads of nutrients because of fertilizer use, sediments because of erosion, and pollutants because of pesticide, herbicide, and hydrocarbon use. There is a simple and direct relationship between development, population increase and habitat loss.

Ecosystem services (ES) are the direct and/or indirect contributions that ecosystems make to the environment and human populations (CEQ 2010). Ecosystem services analysis is highly multidisciplinary, involving ecologists, physical scientists, modelers, economists, and social scientists. Large volumes of research and data, as well as input from communities of stakeholders, are required. Despite the difficulties, ES evaluations can convey the full value of ecosystems in common units (monetary or otherwise) to decision-makers and help them understand the trade-offs involved in altering landscapes, whether for development, restoration, or other activities. A list of services, descriptions of those services and examples are provided in (Farber et al. 2006).

The concept of ecosystem services is not new. Humans have benefitted from what the environment has provided for them for many millennia. However, 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 1960's in which all humans benefited from the existence of wildlife and not just the sportsman (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). Much of the work that has moved ecosystem services into the mainstream began in the late 1990's and early 2000's with attempts to value the world's ecosystem services (Costanza et al. 1997) and the beginning of a stronger linkage between ecology and economics (Daily 1997; de Groot et al. 2002). The early work culminated in the Millennium Ecosystem Assessment (MA), which was initiated under the auspices of the United Nations in 2001 and lasted through 2006 with numerous technical reports, assessments, and final reports (http://www.millenniumassessment.org/).

One of the goals of including stakeholder input in the development of the current EBMP was to determine the ecosystem services provided by habitats within the CBBEP area. The goal of the second workshop was to obtain ecosystem services valuation data from stakeholders. The data was collected as responses from stakeholders on survey forms. The survey entitled "Habitats and Related Ecosystem Services Survey" was designed to answer the question, "which ecosystem services are provided by which habitats?" This survey listed habitats as rows and ecosystem services as columns. Participants were asked to check off every ecosystem service a habitat provides. There were 23 ecosystem services and 12 habitats included on the survey. The ecosystem services chosen were based on stakeholder input from the first workshop and a priori knowledge. Habitats included in the surveys were based on input from stakeholders at the first workshop (Palmer et al. 2009).

The number of ecosystem services provided by habitats was determined based on the results of the "Habitats and Related Ecosystem Services Survey." For each habitat, a value for total number of ecosystem services provided to all stakeholders was calculated. This value was divided by the total number of stakeholders in order to derive an average number of ecosystem services per habitat type. The percentage of stakeholders whom perceived an ecosystem service was provided by a habitat was also determined. Freshwater and salt marsh wetland habitats ranked highly, as they were perceived to provide the most ecosystem services to stakeholders. Rookery island habitat was ranked the lowest of all habitats assessed. The average number of ecosystem services per habitat type was used to create a heat map of ecosystem services within the EBMP area. Dark blue represents lowest average number of ecosystem services and dark red represents highest average number of ecosystem services. Thus, dark red signifies "hot" areas on the "heat map" (Figure E1).

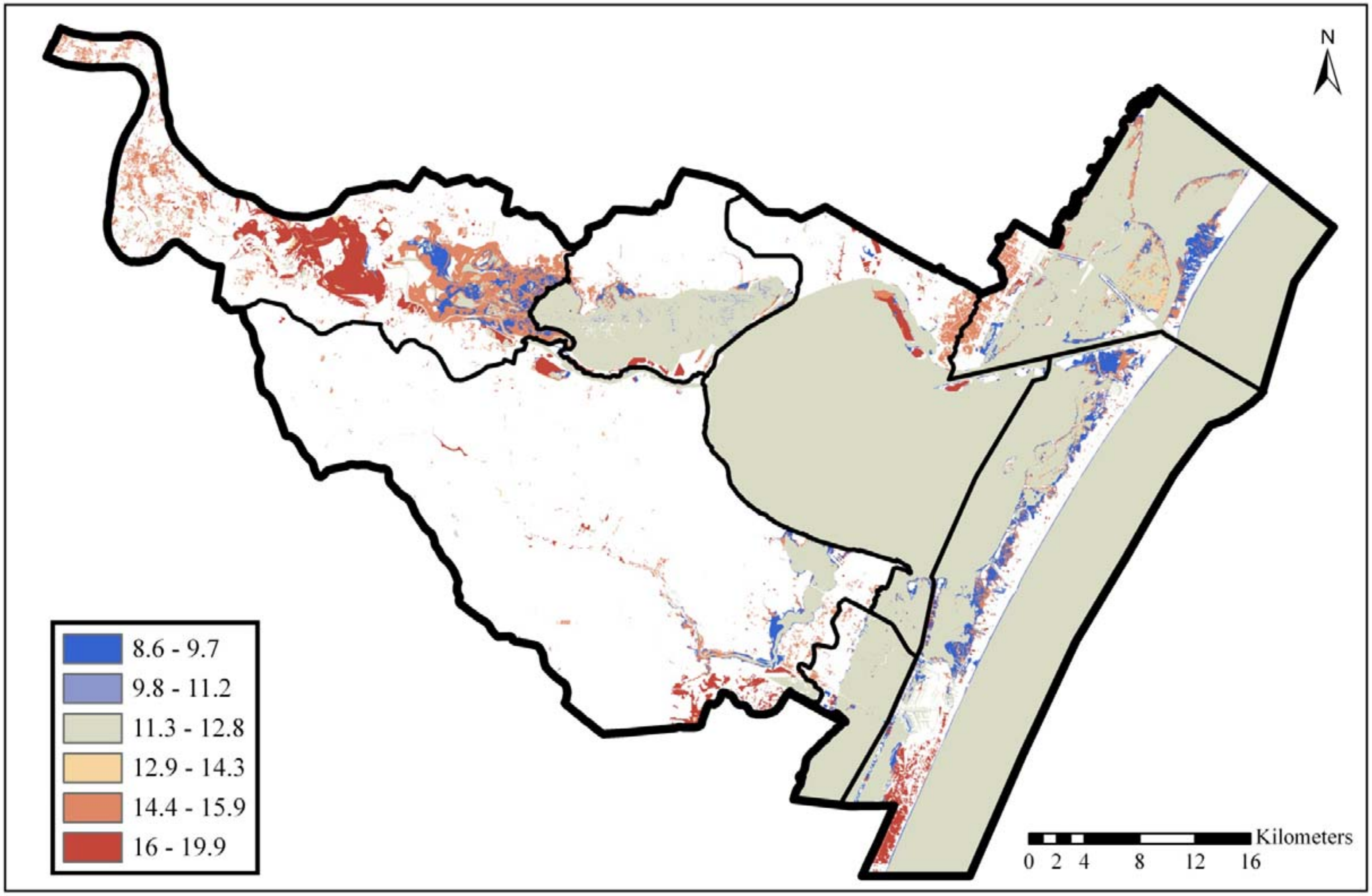

Figure E1. Heat map of average number of ecosystem services provided by habitats within the EBMP area.

The inventory and prioritization of areas for protection/restoration/conservation section has been summarized in Tables E1 and E2. The information on status and trends of habitats, stakeholder interests, and dominant habitat types can be used to guide decision-making concerning potential protection/conservation/restoration projects.

The number of ecosystem services (ES) provided by each habitat, gains and losses of habitats, dominant habitat types and input from stakeholders are included in Table E1. The information regarding gains and losses of the 11 habitats is based on wetland status and trends reports produced by Tremblay et al. (2008) and White et al. (2006). No new assessment of status and trends was attempted during the current study. The summary of these status and trends reports indicates that in all seven sub-regions, flat habitat is either stable or decreasing. Conversely, in every sub-region where seagrass bed habitat exists, it is either stable or increasing. Also, in all sub-regions where beach habitat exists, the habitat coverage is decreasing. Only five habitats (freshwater wetland, salt marsh wetland, seagrass bed, open water, and flats) occur in every sub-region. All 11 habitat types occur in only one sub-region: the Redfish Bay/South Aransas Bay sub-region. Two habitats (freshwater and salt marsh wetlands) provide the most ES (17 and 16 respectively) of all habitats found in the Nueces Estuary study region, which indicates that these wetlands in general are key priority habitats of the region.

Input from stakeholders used to identify priorities for the region is summarized in Table E2. Each of the sub-regions has different habitats and different priorities. Prioritization of areas for protection/restoration/creation based on ES is challenging where ecosystem service (ES) knowledge gaps exist, and this is true for many of the sub-region/habitat cells. Additional knowledge related to ES trade-offs (i.e., in-kind values), both temporally and spatially, is needed to make effective management decisions. Therefore, it is suggested that research be conducted regarding ES trade-offs. In the meantime, it is suggested that management decisions be made based on a precautionary principle, in which assets are protected until more informed decisions can be made. Effective decisions are ones in which benefits greatly outweigh costs. Thus, choosing to protect umbrella ES (i.e., services that encompass many other ES) is an effective way to manage until more information is available (Daily 2000). An example of an umbrella ES is water quality, which encompasses other ecosystem services, such as nutrient regulation and cycling, waste regulation, soil retention, and in some cases even aesthetics and recreation.

Table E1. Synthesis of average number of ecosystem services provided by habitat (#), increasing/decreasing/stable habitat (↑/↓/=), dominant habitats (by area) within sub-region (*), stakeholder interests/concerns (★), and sub-region where most of each habitat type exists (✓). Dark shaded boxes represent sub-regions where habitat does not exist based on data used for analysis (see GIS Methods section of report). Light Shaded boxes represent sub-regions where the habitat occurrence is very small or change data is lacking.

Sub-region[1]	**Fresh-water 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)	**Flat** (10)	**Beach** (9)	**Rookery Island** (9)
Nueces River/Delta	↓*★✓	↓↑*★✓	*★✓	★	★	↑			=★		
Nueces Bay	↓	↑↓*			↑★	↑*	*★✓		↓=		★
Corpus Christi Bay	↓	↑			↑=*	*			↓		*✓
Mustang/ North Padre Islands	↑★	↑★	★	★	↑*★	*✓		★✓	↓*★✓	↓★✓	
Oso Bay/Creek	↓=*	↑↓	★	★	↑	↑*			↓=*★		
Redfish/ South Aransas Bay	↑=	↑★	★	★✓	↑=*★✓	↑*	★		↓*	↓	
Upper Laguna Madre (only northern portion)	=↑	↑	*★		↑*★	*	★		↓*★	↓	★

[1] See Figure 21 for sub-region delineation.

Table E2. Summary of priorities for each sub-region. Each sub-region's priorities were developed and based on ecosystem services, stakeholder input, and status and trends of habitats. Additional information related to prioritization can be found in the sections covering each sub-region.

Sub-region	**Priority (issues)**	**Priority Areas (high # ES)**	**Decreasing Habitats**	**Existing Concerns (identified by stakeholders)**	**Future Activities (identified by stakeholders)**	**Locations of Interest (identified by stakeholders)**	**Current Assets (identified by stakeholders)**
Nueces River / Delta	▪ Protection of freshwater inflows ▪ Protection of riparian corridor and saltwater wetlands ▪ Erosion control	▪ Nueces Delta (especially the central portion, west of the intersection between Hwy 37 & Hwy 77 and the upper portion)	▪ Freshwater wetlands ▪ Salt marsh wetlands	▪ Importance of wetlands for: birds, fish nursery habitat, water quality & freshwater inflow ▪ Importance of Riparian bottom land and palmetto for: recreation & water quality ▪ Riparian habitat ▪ Erosion control ▪ Fresh water inflow ▪ Nursery grounds ▪ Nutrient source to bays	▪ Educational facilities ▪ Erosion control ▪ Improve freshwater inflow ▪ Water reuse ▪ Riparian habitat enhancements ▪ Sediment management ▪ River clean-ups ▪ Land runoff monitoring ▪ River water quality monitoring ▪ Kayak access	▪ Delta / bay interface	▪ CBBEP: Erosion control
Nueces Bay	▪ Protection of freshwater inflows ▪ Protection of tidal flats ▪ Enhancement and creation of rookery islands ▪ Ensuring erosion control for sensitive habitats ▪ Oyster reefs	▪ Gum Hollow Creek (including the Delta) ▪ Northern and southern shoreline of Nueces Bay ▪ Area surrounding Sunset Lake, including Indian Point (and area near shoreline on opposite side of Nueces Bay Causeway) ▪ White's Point (including marsh area to the east)	▪ Tidal flats ▪ Freshwater wetlands ▪ Salt marsh wetlands	▪ Oyster reefs ▪ Gum Hollow Watershed: freshwater inflow ▪ Wildlife Corridor: protects drainage ▪ Seagrass habitat: redhead ducks ▪ Agricultural runoff ▪ Open shoreline ▪ Rookery islands ▪ Shoreline erosion	▪ Erosion control ▪ Creating & raising rookery islands with dredge material ▪ Bird habitat enhancement/acquisition ▪ Planned marsh creation	▪ Area north of Nueces Bay causeway ▪ Gum Hollow ▪ North side of Bay ▪ Port of Corpus Christi	▪ Sunset Lake Park: wetlands bird habitat ▪ Pending CBBEP marsh restoration

Sub-region	Priority (issues)	Priority Areas (high # ES)	Decreasing Habitats	Existing Concerns (identified by stakeholders)	Future Activities (identified by stakeholders)	Locations of Interest (identified by stakeholders)	Current Assets (identified by stakeholders)
Corpus Christi Bay	▪ Creation / protection of rookery islands ▪ Hypoxia ▪ Bacteria ▪ Erosion control	▪ Northern portion of the Corpus Christi Bay sub-region (including area surrounding Kinney Bayou, and area just southwest of 361) ▪ Ingleside Point & La Quinta Island ▪ Rookery island south of Port Ingleside ▪ Live Oak Mottes in Ingleside, west of Hwy 361 ▪ Area surrounding drainage ditch east of Hwy 181 & south of Sunset Rd.	▪ Tidal flats ▪ Freshwater wetlands	▪ Artificial reef/shell pads ▪ Beds: fishing ▪ Dredge material management ▪ Erosion of hackberry rookeries ▪ Fishing pressure ▪ Hypoxia ▪ Industry ▪ Major rookery ▪ Open bay bottom ▪ Public bay/beach access ▪ Relevant sailing area ▪ Ship channel ▪ Shoreline erosion ▪ Trawling practice ▪ Wind turbine construction	▪ Beneficial use of dredge material ▪ Sediment management ▪ Hypoxic zone research & education & outreach ▪ Erosion control ▪ Acquisition and easements	▪ Kinney Bayou ▪ NAS Ingleside ▪ Portland shoreline ▪ Rookery islands along the ship channel	▪ Fish thermal refuge
Mustang & North Padre Islands	▪ Creation / protection of rookery islands ▪ Public access to beaches ▪ Dune protection	▪ Area south of Padre Isles & north of Padre Island National Seashore entrance ▪ Backside of Mustang Island ▪ Area on the backside of Mustang Island (including Coyote, Pelone and Salt	▪ Tidal flats ▪ Beach	▪ Tidal flats: bird habitat; potential loss due to sea level rise ▪ Seagrass beds ▪ Oak mottes ▪ Fish pass & Packery channels: sea turtles ▪ Willows ▪ Aesthetic ▪ Archeology ▪ Birds ▪ Boat Access ▪ Dunes and dune swales ▪ Fish	▪ Stop hazard stabilization ▪ Mitigate future flood loss ▪ Preserve scrub-shrub & upland habitat ▪ Protect & stabilize of dunes ▪ Allow natural retreat of marsh land & mud flats due to sea level rise ▪ New setbacks ▪ Stop the excavation of canals/channels through bayside habitats ▪ Create rolling easements ▪ Erosion control	▪ Backside of Mustang Island: marsh ▪ Barrier island uplands: prairies ▪ Beach ▪ Channelized housing ▪ Padre Island National Seashore ▪ Port Aransas ▪ Port Aransas	▪ Mollie Beattie Coastal Habitat Community ▪ Mustang Island State Park ▪ Packery Channel Park

Sub-region	Priority (issues)	Priority Areas (high # ES)	Decreasing Habitats	Existing Concerns (identified by stakeholders)	Future Activities (identified by stakeholders)	Locations of Interest (identified by stakeholders)	Current Assets (identified by stakeholders)
		Islands) ▪ Wetlands bordering Hwy 361 on Mustang Island ▪ Some rookery islands east of Intracoastal Waterway in the southern portion of the sub-region		▪ Fore dunes: storm surge protection ▪ Freshwater wetlands ▪ Need new setbacks ▪ Padre Island uplands ▪ Prairies and marshes ▪ Sea turtles	▪ Effective wastewater reuse ▪ *Sargassum* and freshwater pond management ▪ Create parks	jetties ▪ Scrub-shrub habitat ▪ Shamrock Island ▪ Temporary tidal inlets ▪ Washover channels	
Oso Bay and Creek	▪ Protect riparian zone ▪ Protect tidal flats ▪ Improve water quality	▪ Area surrounding Oso Creek (especially west/ northwest of Barney Davis Power Plant) ▪ Area surrounding and to the northwest of Tule Lake ▪ Southeast corner of the sub-region ▪ Area north/ northeast of the runway at the Naval Air Station	▪ Freshwater wetlands ▪ Salt marsh wetlands ▪ Tidal flats	▪ Riparian habitat: restoration ▪ Urban development: need for habitat acquisition ▪ Agriculture ▪ Birds ▪ Colonia's storm runoff and septic drainage into the Oso ▪ Drainages / buffers ▪ Enhance filtration & prevent construction ▪ Eutrophication ▪ Fresh water flows and sewage ▪ Mangroves ▪ Nursery grounds ▪ Soil / water conservation ▪ Tidal flats ▪ Wastewater plants	▪ Habitat restoration: land acquisition (along Ennis Joslin and Oso Bay) & riparian habitat restoration ▪ Education Initiatives: educate landowners on incentive programs, educate agricultural land owners and the public ▪ Water Quality Initiatives: convert septic systems to sewer systems, management agricultural runoff, soil and water conservation, enhance filtration, prevent construction ▪ Create recreation friendly initiatives: regional parks, hike & bike trails, install kayak access point at Highway 286 and Oso Creek, create a planned city park with a retention pond ▪ Protect mudflat habitat: limit ATV access ▪ Increase green space & parks in urban areas of Corpus Christi, enhance Hans Suter Wildlife Refuge & the Greenbelt, create a soft shoreline ▪ Storm drain retrofit for debris and contaminants	▪ Along Ennis Joslin ▪ Areas close to inlets to Corpus Christi Bay ▪ Oso Creek intersection with W. Rodd Field Rd. ▪ Botanical Gardens ▪ Flour Bluff ▪ Hans Suter Park ▪ Oso Creek intersection with 286 ▪ Mud flats ▪ Port of Corpus Christi ▪ Shoreline Drive	▪ Agriculture: crop land, Victoria clay soils, maintain drainage, erosion control ▪ City parks / land ▪ Botanical Gardens

Sub-region	Priority (issues)	Priority Areas (high # ES)	Decreasing Habitats	Existing Concerns (identified by stakeholders)	Future Activities (identified by stakeholders)	Locations of Interest (identified by stakeholders)	Current Assets (identified by stakeholders)
Redfish & South Aransas Bays	▪ Protect palustrine marsh, tidal flats, live oak mottes and coastal prairie ▪ Creation / protection of rookery islands ▪ Erosion control	▪ Backside of San Jose Island ▪ Mud, Talley, Traylor, Hog, and Shellbank Islands ▪ Live Oak Mottes in Aransas Pass & Ingleside	▪ Tidal Flats ▪ Beach	▪ Wetlands: high density ▪ Live Oak Mottes / Coastal Prairie ▪ Fresh water ponds ▪ Recreational boating: propeller scars ▪ Circulation ▪ Erosion control ▪ Flushing of system ▪ Industry ▪ Inlet ▪ Lighting of natural gas ▪ Rigs ▪ Spawning ▪ Transportation	▪ Habitat protection and restoration: seagrass beds, marshes, oyster reefs ▪ Erosion control and stabilization of sediments ▪ Easement establishment (intracoastal easements and land acquisition) ▪ Beneficial use of dredge material	▪ Aransas Pass (channel) ▪ Intracoastal easement ▪ Area just north of ship channel	▪ Mangroves: largest black mangrove extent in the area ▪ Aesthetic ▪ Birds ▪ Crabbing ▪ Dolphin nursery ▪ Fish ▪ Winter nursery habitat ▪Marsh ▪ Oysters ▪ Recreation
Upper Laguna Madre	▪ Creation / protection of rookery islands ▪ Seagrass management	▪ Pita Island and area west of Pita Island near the Barney Davis Power Plant	▪ Tidal Flats ▪ Beach	▪ Blue Hole (channel): fish habitat ▪ Tidal flats: water circulation restoration, tidal flats by Padre Island ▪ Erosion control ▪ Oak Mottes ▪ Removal of old obstructions ▪ Rookery islands ▪ Seagrass ▪ Sewage retrofit ▪ Water quality management	▪ Beneficial use of dredge material ▪ Use existing parks/field stations as enhancement areas ▪ Increase kayak access ▪ Education and outreach	▪ Western urban shore	▪ Parks ▪ Oysters ▪ Laguna Madre Field Station

A main area of concern identified by stakeholders and described in the "Initial Meetings Summary Report" (Brenner et al. 2009a) is the impact to natural habitats from anthropogenic structures and activities, e.g., development, agriculture, wastewater treatment plants, navigation channels, and dredged material placement areas. Stakeholders identified four types of manmade structures of concern including parks, agriculture, permitted point sources, and rookery islands. Available information related to the four types of manmade structures and associated activities and the impacts to natural habitats from the manmade structures was compiled and summarized.

Parks data was acquired from the City of Corpus Christi but only includes state, county and city parks within the City of Corpus Christi (Peggy Sumner pers. com.). Parks comprise approximately 26.4 km^2 (2,639 ha) within the City and they are managed by three levels of government including state, county and city governments. The state parks (2) are managed by the Texas Parks and Wildlife (TPWD), the county parks (3) are managed by Nueces County, and city parks (202) are managed by the City of Corpus Christi.

City parks are considered "urban" ecosystems. These urban ecosystems are documented as providing cultural ecosystem services such as education and recreation in addition to ecosystem services related to the mitigation of noise, heat and air pollution (Ernstson et al. 2008). The ecosystem services provided by these urban ecosystems are degraded when parks are isolated or fragmented (Ernstson et al. 2008). Management of these urban ecosystems can affect the ecosystem services provided (Ernstson et al. 2008). For example, city parks can be designed in a way that enhances ecosystem services, not only for users of the park, but also for residents who live in the area. Living infrastructure, such as functional landscapes, rainwater harvesting, outfall treatment, bioswale conveyances and stormwater ponds and wetlands are all options that try to mimic natural systems and provide and enhance ecosystem services.

There are approximately 561 km^2 (56,056 ha) of agriculture lands in the EBMP area, approximately 23% of the total EBMP area. The dominant crops cultivated in Nueces County within the Coastal Bend area include sorghum and cotton, with corn, wheat, and sunflowers coming in third, fourth and fifth respectively (pers. com. J.R. Stapper, Nueces County Extension Agent). Historically, agricultural lands were converted by humans from other habitat types. The conversion from native ecosystems to cultivated farmland has led to a loss in biodiversity (Swinton et al. 2007). Between the mid-1950s and early 1990s Texas lost about 98,000 acres of palustrine or inland, nontidal wetlands to agriculture (Moulton et al. 1997). Urbanization increased during this same period, "… mostly at the expense of agriculture and other upland land uses" (Moulton et al. 1997). Between 1996 and 2006 agriculture experienced a loss of 1.33 km^2 within the EBMP area. Thus, a recent trend is that agricultural lands are being converted to developed lands.

Based on input from local stakeholders, concerns exist within the EBMP area regarding impacts from agriculture such as the use of pesticides, fertilizers, and sediment erosion (Palmer et al. 2009). Management options exist to address these stakeholder concerns and include year round plant cover and conservation tillage (Swinton et al. 2007). These management options enhance the ecosystem services of groundwater recharge in addition to carbon sequestration (Swinton et al. 2007). Additionally, native communities and wetlands can be restored within agricultural lands, and in buffer zones near waterways, to further enhance the ecosystem services mentioned above in addition to providing habitat for pollinators and natural predators of crop pests (Swinton et al. 2007). An example of farming that incorporates native communities into agricultural practices is “wildlife-friendly farming” (Fischer et al. 2008).

The state agency responsible for regulating air, water, and waste is the TCEQ. One of the many roles of the TCEQ is to issue wastewater permits for point or ‘end of pipe’ and non-point or ‘diffuse’ sources of pollution. A total of 31 permitted industrial point sources and 16 domestic wastewater treatment facilities were identified. The industrial point sources include waste process water from the industrial facilities and in most cases storm water that drains from the facility’s footprint. It is not possible to distinguish between point and non-point sources because many permits include provisions for both sources in the same discharge permit without distinguishing between them. The domestic wastewater treatment facilities are required to disinfect the effluent using chlorination or ultra-violet light before the effluent is discharged. Facilities with a permit to discharge more than 1.0 MGD and use chlorination as a disinfectant must also dechlorinate to reduce negative effects on stream organisms.

The permitted entities are further categorized based on the amount of effluent they are allowed to discharge into the environment. A major discharger includes those entities allowed to discharge more than 1.0 MGD and a minor discharger includes those entities allowed to discharge less than 1.0 MGD. In total, there are 47 permitted outfalls in the EBMP area, 25 were major dischargers while 17 were minor. Five permitted entities had no established maximum daily average limit but instead had an intermittent and flow variable condition. The largest dischargers are the Nueces Bay and Barney Davis Power Stations with 500 and 540 MGD respectively. Excluding the City of Odem discharge, the total maximum permitted daily average discharge from the domestic wastewater facilities within the EBMP area is 57.5328 MGD.

Rookery island habitat was primarily created with sediment derived from dredging of navigation channels (Chaney and Blacklock 2003) such as the Gulf Intracoastal Waterway, Corpus Christi Ship Channel, La Quinta Channel, and other smaller channels located within the EBMP area. Sediment from dredging activities was placed in areas of the bay bordering navigation channels which created island chains. The islands created by the dredged material developed into productive habitat that support a diversity of highly valued colonial nesting waterbirds (Sims and Smith 2001). There are currently 286 mapped rookery islands within the EBMP area. Although initially most rookery islands served as dredged material placement areas and may have impacts on natural habitats, such as open bay bottom and seagrass beds, they are now considered habitats themselves experiencing impacts from anthropogenic activities. For example, rookery islands have experienced impacts from erosion and inundation due to natural and human induced phenomenon such as storms, boat traffic, vegetation changes, invasive species and sea level rise.

The Coastal Bend Bays & Estuaries Program's (CBBEP) responsibility to the bays and estuaries includes bringing the community (scientists, governments, industries, environmental groups, and other stakeholders) together to accomplish environmental and economic sustainability. The current ecosystem-based management plan uses a scientific process to identify the ecosystem services habitats provide to human health and well-being. Data gaps exist, ecosystem service valuation studies lag far behind routine monitoring, and the public has little knowledge of what ecosystem services are or why they should care about them. However, the uncertainty related to spatial distributions and ecosystem service values is no reason to avoid taking action to preserve, enhance or restore those habitats in the face of threats. The heat map and summary of habitats by sub-region can be used to identify priority areas where protection, conservation, or enhancement projects should be carried out. There are numerous activities that have been proposed during the workshops and stakeholders are ready and willing to participate in cooperative and collaborative efforts to implement the EBMP.

INTRODUCTION

Background/Project Description

The purpose of this project was to develop an Ecosystem-based Management Plan (EBMP) that can be used to direct habitat preservation, creation and/or restoration activities in the Corpus Christi/Nueces Bay area and facilitate the application of fiscal opportunities and resources associated with coastal development, impact restitution, supplemental environmental, and community service projects and grants.

The project was undertaken on behalf of the Coastal Bend Bays & Estuaries Program (CBBEP) and was performed in two phases, each taking about one year. Phase I included a needs assessment (Palmer et al. 2009), stakeholder involvement (Brenner et al. 2009a), development of a boundaries map (Brenner et al. 2009b) (Figure 1) and a preliminary EBMP (Montagna 2009). Phase II of the project included a process to synthesize results from Phase I to develop an ecosystem based management plan for the Corpus Christi/Nueces Bay area.

Past projects focused on identifying possible habitat creation opportunities in the program area (Smith et al. 1997, 2004) and determining habitat status and trends (White et al. 2006, Tremblay et al. 2008). However, these projects did not represent a consensus view of priority activities nor were they based on a system or landscape level approach. Lacking is a management plan that addresses how to link economic assets associated with development activities and attain regional ecological improvements and benefits for the environment. Thus, the objective of the current (Phase II) project is to include stakeholder involvement in developing a comprehensive EBMP based on the ecosystem services that benefit people, and which identifies habitat enhancement, creation, and conversion opportunities in the Corpus Christi/Nueces Bay area.

Region Description

The Texas coast includes seven major estuarine systems along 370 linear miles. Estuaries are transition zones between the land and sea where fresh water from rivers mixes with salt water from the ocean creating some of the most highly productive environments on Earth. The CBBEP program area includes three of these estuaries: the Mission-Aransas Estuary, Nueces Estuary, and Baffin Bay and Laguna Madre Estuary. The CBBEP ‘project area’ includes all of the open water, submerged habitat, emergent wetland, and upland environments of the 12-county area known as the Coastal Bend (Coastal Bend Bays Plan 1998). The 12 counties — Refugio, Aransas, San Patricio, Nueces, Kleberg, Kenedy, Bee, Live Oak, McMullen, Jim Wells, Duval, and Brooks — comprise more than 11,500 square miles and are home to over 550,000 residents. The term ‘bay system’ refers specifically to all marine and estuarine waters (saline and brackish waters) behind the Gulf surf line from the eastern edge of Mesquite Bay (in San Antonio Bay) to the ‘land cut’ south of Baffin Bay in the upper Laguna Madre (Coastal Bend Bays & Estuaries Program 1998).

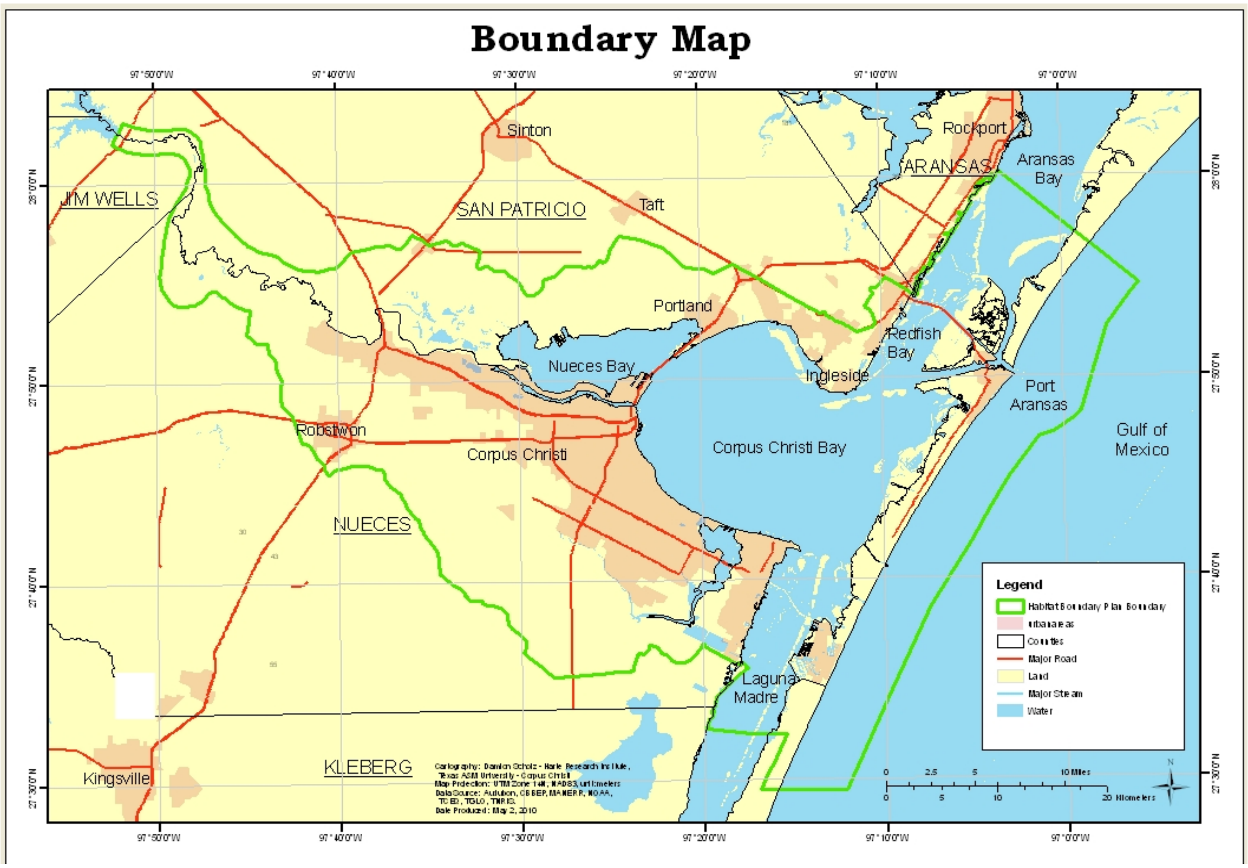

Figure 1. Boundary map of the EBMP area.

Ecoregion Summary

Ecoregions represent areas of similar ecosystems in type, quality, and quantity of environmental resources. Ecoregions constitute discrete spatial units that provide a spatial framework for assessment, management, and monitoring in ecosystem-based management (EBM) and are used extensively in conservation planning (Leslie 2005; The Nature Conservancy 2000). Natural characteristics including geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology define ecoregions hierarchically. Level I is the coarsest ecoregion, dividing North America into 15 ecological regions. Level II divides the continent into 52 regions. At level III, the continental United States contains 104 ecoregions. Level IV divides Texas into 56 ecoregions (Griffith et al. 2007).

All of the EBMP area falls within the Western Gulf Coastal Plains ecoregion, a Level III ecoregion with two distinguishing characteristics, a flat topography and primarily grassland potential natural vegetation (Griffith et al. 2007). Areas inland from this region are typically older, more irregular, and are comprised predominantly of forest or savanna-type vegetation. Most land in this ecoregion is cropland, compared to bordering ecological regions. In recent decades, urban and industrial land uses have expanded greatly together with oil and gas production. There are four Level IV ecoregions in the Western Gulf Coastal Plains in Texas including: Southern Subhumid Gulf Coastal Prairies, Floodplains and Low Terraces, Mid-Coast

Barrier Islands and Coastal Marshes, and Laguna Madre Barrier Islands and Coastal Marshes (Figure 2). A description of the Level IV ecoregions included in the EBMP area can be found at http://www.epa.gov/wed/ecoregions/tx/TXeco_Jan08_v8_Cmprsd.pdf.

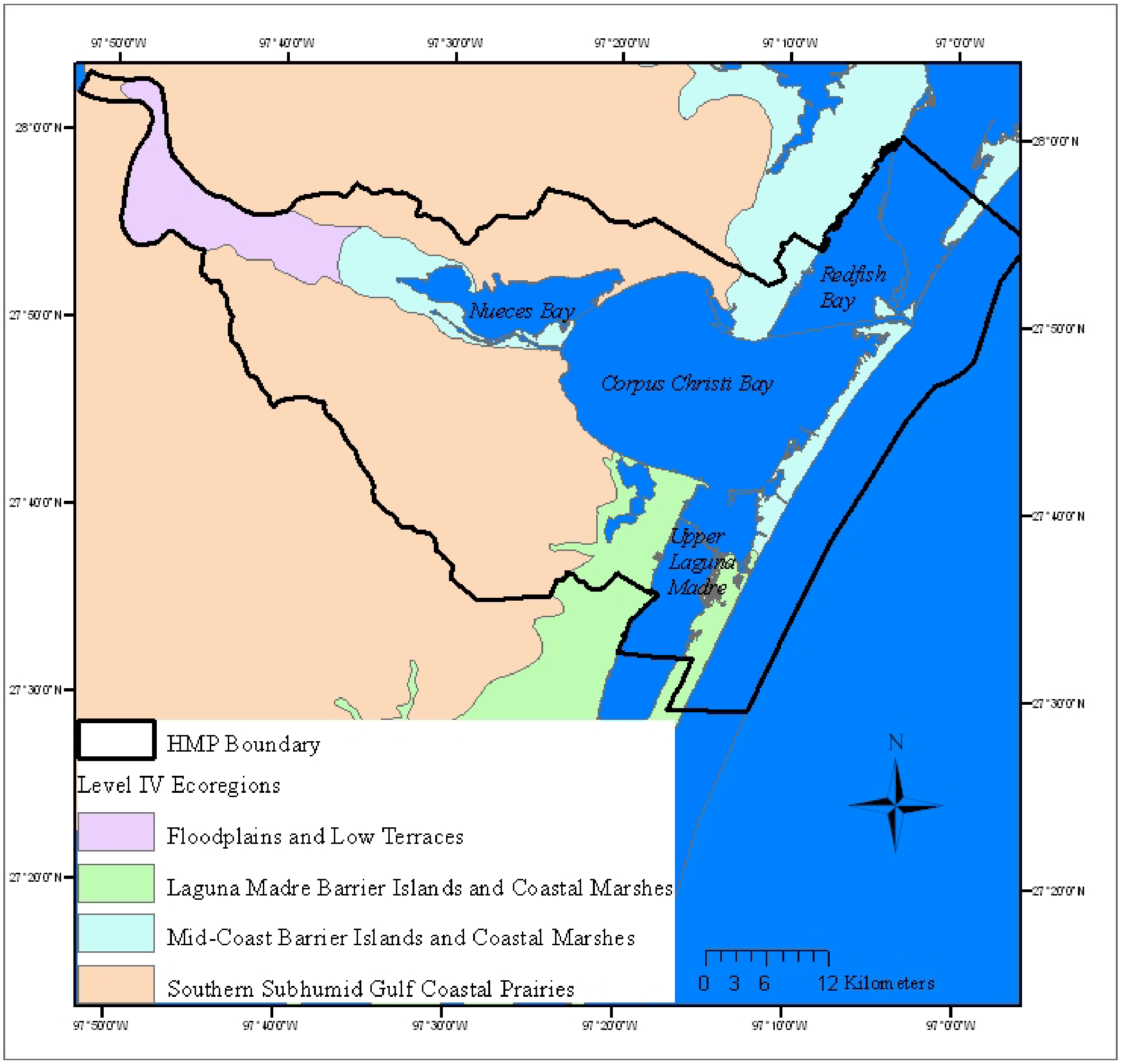

Figure 2. Level IV Ecoregions in the EBMP area (after Griffith et al. 2007).

Project Area Description

The project area for the EBMP was developed using criteria created after analyzing stakeholder input during Phase I of the project. The boundary map (Figure 1) was created using an ecosystem-based perspective. The primary guidelines were natural hydrologic units and ecoregional boundaries. These natural guidelines were modified to include relevant socio-economic units. The resulting boundary merged both natural and human criteria and has an area of 247,363 hectares (611,247 acres). Therefore, the boundary represents the core planning area for representative habitats, and it comprises about 8% of the CBBEP project area. Major biophysical features included within the boundary are the Nueces River Delta, Corpus Christi, Nueces, Oso, Aransas, and Redfish Bays, in addition to parts of the upper Laguna Madre. The cities of Corpus Christi, Robstown, Aransas Pass, and Port Aransas are entirely included within the boundary. Portland, Rockport and Ingleside are partially included in the EBMP boundary. Mustang Island and the Texas State owned waters in the Gulf of Mexico are also included in the project area. The boundary represents the spatial framework at an appropriate scale for the design and implementation of ecosystem-based projects.

Stakeholder Engagement

A major objective of the EBMP project was to integrate stakeholder input; therefore, stakeholder engagement was constant and proactively pursued throughout plan development. Plan development consisted of three major parts. First, existing plans and resources were identified and reviewed to guide plan development. Second, individual meetings were conducted with stakeholders in the Corpus Christi/Nueces Bay area to solicit stakeholder input. Third, two workshops were held to solicit and integrate stakeholder input into the plan development process. A detailed description of the steps involved in plan development is provided in the section of this report titled “Project Approach and Process.”

To summarize the findings of stakeholder involvement, there was a strong consensus among regional stakeholders that an ecosystem-based habitat management plan is needed for the region. There are numerous activities that have been proposed, and stakeholders are ready and willing to participate in cooperative and collaborative efforts to implement the EBMP.

HABITATS OF PROJECT AREA

Habitat Types in the Project Area and their Importance

Habitats are the elements of an environment that sustain an organism or a community of organisms. The populations of different species living in a habitat are called a community. In a Texas bay ecosystem, typical habitats include riverine, salt marsh, algal mat, seagrass bed, water column, open bay bottom, oyster reef, beach and oceanic habitats (Day et al. 1989; Montagna et al. 1996). Energy can be transferred among habitats by physical movement of water or by movement of organisms between habitats. The connection among habitats is partly responsible for the high productivity that is characteristic of estuaries.

Texas estuaries exhibit a geomorphology that is driven by physical processes in the area and is represented in estuaries within the EBMP area. Estuaries typically consist of a primary bay, e.g., Corpus Christi Bay, and secondary bay(s), e.g., Nueces and Oso Bays. The primary bay has a direct connection with the ocean while the secondary bay(s) are connected to a source of freshwater such as the Nueces River and Oso Creek. Barrier islands e.g., Mustang Island, typically provide a 'barrier' between the primary bay and the open ocean. Water exchange between the Gulf of Mexico and Corpus Christi Bay occurs through passes that bisect the barrier island, Aransas Pass at the northern end and Packery Channel at the southern end of Mustang Island. The leeward side of the barrier island is typically bordered by a lagoon environment, such as the Laguna Madre to the south and Redfish Bay to the north within the EBMP area. The lagoon environments connect Corpus Christi Bay to adjacent bays, therefore are important pathways for the transport of materials and recruitment between systems. The windward side of the barrier island consists of beach habitat. The characteristic geomorphology allows for establishment of a saltwater gradient from east to west that supports diverse estuarine habitats and associated flora and fauna.

The aerial extent of different habitat types varies depending on the location within the EBMP area. Corpus Christi Bay has a bay bottom that is predominantly a muddy habitat. However, there are patchy areas of sandy bottom or oyster reefs. Oyster reef habitats occur mostly in Nueces Bay because oysters depend upon freshwater brought by rivers. Marshes line the river sources of the EBMP areas' secondary bays, Nueces Bay and Oso Creek. Seagrass beds develop well in lagoon environments because of the higher salinities and water clarity. Algal mats develop on broad, supratidal tidal flats. Both algal mats and seagrass beds are common in Laguna Madre and Redfish Bay. Laguna Madre and Redfish Bay are well known for their large populations of fish, which are present, in part, because of the nursery habitat provided by extensive seagrass beds.

Estuary morphology plays an important role in species distribution, size and abundance. The Nueces Estuary has a gradient from muddy to sandy bottom from Nueces to Corpus Christi Bay. The nutrient storage in Nueces Bay is much higher than in Corpus Christi Bay because the

Nueces River and marsh provide Nueces Bay with intermittent fresh water (Whitledge 1989). Although there are more nutrients in Nueces Bay, chlorophyll *a* per unit area is higher in Corpus Christi Bay (Stockwell 1989). Correspondingly, higher zooplankton abundance is also found in Corpus Christi Bay (Buskey 1993). The sandier Corpus Christi Bay has higher abundance and species diversity of benthic mollusks than the muddier Nueces Bay. However, the mollusks in Corpus Christi Bay tend to be smaller than those in Nueces Bay (Montagna and Kalke 1995).

The dominant habitats found in the EBMP project area are classified into the following groups for further description:

- Seagrass Bed,
- Salt Marsh Wetland,
- (Intertidal) Flat,
- Beach,
- Marine/Open Water,
- Oyster Reef,
- Scrub-Shrub Wetland,
- Freshwater Wetland,
- Tree Canopy/Live Oak Motte,
- Rookery Island, and
- Dune.

Seagrass Bed

Much of Laguna Madre and shallow, fringing areas of Nueces Bay and Redfish Bay are covered with beds of seagrasses (Table 1). There is also a large seagrass bed in Corpus Christi Bay (East Flats). There are five species of seagrasses, but the thin-bladed shoal grass, *Halodule wrightii*, and the thick-bladed turtle grass, *Thalassia testudinum*, are the most common. *Halodule* grows rapidly in disturbed areas, but is usually out-competed by *Thalassia* over time. The areas in which seagrasses grow are characterized by strong currents and a shallow bottom. The sediments range from sandy to fine, and are usually reducing just below the surface due to high oxygen consumption rates of decomposers.

Seagrass beds support a very diverse and productive food web by providing a source of carbon for the food web, and a place for fish and invertebrates to hide from predators. The high amount of biomass from these plants leads to high rates of gross primary productivity and net community productivity. Seagrass is difficult to digest because of structural compounds. However, senescent seagrass is also an important contributor to the detrital food web. Seagrass is also a substrate for epiphytic algae (e.g., microalgae that grow on seagrass blades) and animals (e.g., crustaceans and polychaete worms). Seagrass beds serve an important role as nursery grounds for larval fish and invertebrates. Water current speeds are attenuated by the vertical leaf blades of seagrasses, therefore seagrass habitats provide a buffer against storms by stabilizing the bay

Table 1. Status and trends in seagrass in 1999 at proposed conservation sites (Pulich et al. 1999).

Bay	**1999 Area (ac)**	**Percent of Coastwide**	**Species***	**Trends**
Nueces	24,600	11.2	Hd, Rup	Fluctuates with inflow
Corpus Christi			Hd, Rup, Hph, Th, Syr	Acreage stable, some bed fragmentation
Redfish			Hd, Rup, Hph, Th, Syr	

*Hd = *Halodule*, Rup = *Ruppia*, Hph = *Halophila*, Th = *Thalassia*, Syr = *Syringodium*

bottom and improving water quality. The rhizomatous root system of seagrasses is also responsible for binding and filtering particles such as contaminants and sediments.

Many organisms can be found in the seagrass meadows. Among these are the tiny polychaete worm, *Spirorbis* sp., which filters plankton and organic matter from the water column. *Spirorbis* can be seen on seagrass blades as a small, white coil or circle. Grass shrimp graze on epiphytic algae and detrital matter. There are three types of grass shrimp, the dominant *Palaemonetes* sp., the arrow shrimp, *Tozeuma zostericola*, and the green, broken backed shrimp, *Hippolyte carolinensis*. The epiphytic algae are grazed by small snails, such as the white, sharp-pointed *Cerithium lutosum* and the brown, roundknobbed *Diastoma varium*.

Many animals are supported by detritus trapped by the seagrass blades or beneath the sediment. These include the tube-building amphipod, *Grandidierella bonneroides*, small snails, such as *Caecum pulchellum* and burrowing polychaetes. Polychaetes such as *Haploscoloplos foliosus* and *Capitella capitata* process bulk sediment, extracting organic matter from non-organic mud.

At the top of the foodweb are several generalist crustaceans, such as the striped hermit crab, *Clibinarius vittatus*, and the blue crab, *Callinectes sapidus*. These animals eat everything they can find, from detritus to grass shrimp and worms. Many kinds of fish live in the seagrass meadows, but particularly visible are the pinfish, *Lagodon rhomboides*. In the winter, a variety of duck species move into the seagrass meadows. The ducks feed on small meiofauna, grass shrimp, or the roots and rhizomes of the seagrass itself. Larger predatory fish, such as redfish, black drum, and spotted seatrout feed on the smaller fish and larger invertebrates that congregate in seagrass beds.

The Texas Parks and Wildlife Department (TPWD) currently operates a Seagrass Conservation Management Plan (Pulich et al. 1999). Redfish Bay was established as a scientific area under this conservation management plan. The Redfish Bay State Scientific Area (RFBSSA) was created in 2000 and extends 32,144 acres. In November 2005, the Texas Parks and Wildlife Commission amended the Texas Administrative Code §57.921 concerning the RFBSSA. This amendment defines a "seagrass plant" and prohibits uprooting or digging out seagrasses within the RFBSSA except as allowed under a General Land Office (GLO) coastal lease or otherwise permitted under state law. Enforcement of the amendment began May 1, 2006.

High priority ecosystem services provided by seagrass habitat include food, biological interactions, and water quality (Yoskowitz et al. 2010). Seagrasses also provide ecosystem services such as nutrient cycling and sediment stabilization, both of which affect water quality (Orth et al. 2006).

Salt Marsh/Emergent Wetland

Salt marshes are shallow or intertidal regions of the bay, often near a source of fresh water input, that are dominated by marsh grasses and plants, particularly *Spartina alterniflora*. In the EBMP area, salt marshes can be found along most of the shorelines, but are particularly abundant near the Nueces River mouth. Extensive salt marsh is also found in the Nueces Delta / Rincon Bayou area. Along the eastern coast of the United States (US), salt marshes extend for many kilometers because of the large intertidal range. In contrast, Texas has very small tidal ranges, so intertidal salt marshes in the EBMP area only extend for a few meters from the shoreline. In more tropical regions, mangroves, such as *Avicennia germinans*, gradually replace salt marsh grasses. The EBMP area is near the northern extent of the range of mangroves. However, in the period following several mild winters, mangroves are increasingly common, particularly along Redfish Bay (Montagna et al. 2010).

Intertidal wetlands act as sediment traps, where soft sediment and peat become trapped between the salt marsh plants. Beneath the plants are strong reducing conditions, and often low oxygen levels. Areas with a higher fresh water inflow (e.g., Nueces Bay and Delta) have higher producer diversity, higher rates of primary production and higher net community production. Because of the amount of dead and decaying plant matter, the detrital food web is important in salt marshes and other habitats near salt marshes. Biomass of producers and consumers can be high, but species diversity can be low because of fluctuating salinity. Like seagrass beds, salt marshes are important nursery and feeding grounds for a variety of invertebrates and fish.

The ubiquitous polychaete, *Streblospio benedicti* , can be found in salt marshes. *Streblospio* filters particles such as plankton from the water or browses detritus at the sediment surface with its tentacles. Another polychaete, common in salt marshes, and many other habitats, is the deposit feeder, *Mediomastus* sp. Unlike most marine habitats, salt marshes also support some insects, particularly when salinities are low. Midge larvae (Chironomidae) behave much like polychaetes, feeding on detritus from their tubes. Water boatmen (Corixidae) are active swimmers, but feed mostly on detritus. Many small fish can be found in salt marshes. The many species of killifish (*Fundulus* sp.) feed on the abundant soft-bodied invertebrates in the marsh.

These fish and their invertebrate prey are eaten by the diverse array of shore birds that frequent salt marshes, including rails, herons, egrets and ibis. Scurrying about on land, with the birds, are the fiddler crabs *Uca* sp. *Uca* dig burrows in the soft mud in the high intertidal zone. They feed on algae and detritus that they collect by scooping up the mud into a feeding ball and scraping organic matter off of the ball with their mouth parts. The epiphytic algae that grow on *Spartina* are grazed by several species of snail, including the small, white *Assiminea succinea* and the larger, striped periwinkle, *Littorina irrorata*.

The four global-scale beneficial functions of wetlands as outlined by Zedler and Kercher (2005) are: biodiversity support, water quality improvement, flood abatement and carbon management. A more recent and regionally focused publication on ecosystem services of Gulf of Mexico habitats includes priority ecosystem services by habitat type. Priority ecosystem services of saline and brackish marsh habitats include biological interactions, nutrient balance, soil and sediment balance, hazard moderation and recreational opportunities (Yoskowitz et al. 2010).

<u>Intertidal Flat</u>

Wind-tidal flats are found along the bay sides of San Jose Island and scattered along the bay margins of Redfish Bay. Wind-tidal flats are halophilic (i.e., salt-loving) ecosystems generally inundated by wind and storm tides and are found at elevations between mean sea level (MSL) and 1 m above MSL. The major primary producers of wind-tidal flats are mats of filamentous blue-green algae, which support a large array of consumers of the blue-green algae. These flats are one of the most significant feeding areas for aquatic bird life on the Gulf coast. Tidal flats also act as flood basins that protect vegetation in adjacent bay habitats (Withers and Tunnell 1998).

Algal mats are unusual features of the supratidal zone that occur in some locations around the EBMP area. They occur when rain or wave surge collects in low spots near the shore, often in areas with higher elevation than salt marshes. The trapped water is very shallow, and often becomes quite hot and saline. However, the water also promotes a bloom of photosynthetic bacteria, called cyanobacteria or blue-green algae, which live on the sediment surface. These producers are very important to the bay ecosystem, because they have the ability to fix atmospheric nitrogen (N_2) into an inorganic form (NH_4, NO_3 or NO_2) more usable by other producers and bacteria. When this material gets transported back into the estuaries, it represents a nutrient source that can enhance primary productivity in the estuary. However, aside from the cyanobacteria, there are not many species that are endemic specifically to the algal mats.

Not much information is available about the ecosystem services provided by flats. However, it is documented that flats provide supportive ecosystem services such as net primary production, nutrient cycling and soil formation (Zhao et al. 2004).

Beach

There are two types of beach habitat in the EBMP area. Bay shorelines that are not covered by vegetation such as salt marsh grasses are considered beaches. However, bay beaches are not as diverse and are not as distinct a habitat as are gulf beaches. Gulf beaches are found on the Gulf of Mexico side of Padre, Mustang, and San Jose Islands. While these habitats are not directly connected to the estuaries, there is interaction between the estuary and the adjacent beach. After storms, seagrass can be washed onto the beach, transporting energy from the bay to the gulf environment. Also, many mobile animals, such as fish and crabs, move freely between the two ecosystems.

Tidal passes and beaches are directly exposed to strong currents and waves. Because of the high energy imparted by the water, most mud-sized particles have been carried away. Furthermore, because of the constant exposure to high energy, beach habitats are well oxidized and have a constant oceanic salinity (about 35 psu). In the absence of mud and high organic detritus, these habitats are home mostly to filter feeders. The beach community is often highly diverse and has a high biomass and productivity, due to the transport of food by currents.

The larger, more obvious animals that comprise the Gulf beach habitat include the mole crab, *Emerita portoricensis*, a relative of the hermit crab. *Emerita* buries itself up to its head in the sand and filters plankton and organic matter with its feathery antennae. Some polychate species, such as the tentacle *Scolepis squamata*, also rely on plankton brought in by the waves. These filter feeders are eaten by many species of juveline fish, particularly postlarval jacks (Carangidae) that hide in shallow water to escape predation. The small polychaetes are also eaten by larger, predatory polychaetes, such as *Lumbrineris* sp. Another common and familiar resident of intertidal beaches is the colorful coquina clam, *Donax variablis*. *Donax* bury themselves using their muscular feet and probe for food with their long siphons. Because of the waves and tides, a lot of detritus piles up on the beach itself. This detritus is mostly plant material, particularly *Sargassum* seaweed or sea grasses that are transported by tides out of the bay area after storms. While this decomposing matter may smell offensive, and is often cleaned from the beaches by humans, it serves as an important source of food for near coastal environments. Detritus is food for animals such as the elusive ghost crab, *Ocypoda quadrata*, amphipods, meiofauna or insects. Some of these smaller animals are eaten by the numerous number of shorebird species, such as sanderlings, sandpipers, turnstones and seagulls. In addition, buried debris can trap sand and is partly responsible for the beach accretion process during the summer and prehurricane seasons.

Beach and dune habitat provide several priority ecosystem services including hazard moderation, aesthetic and existence and soil and sediment balance (Yoskowitz et al. 2010). The beach has an obvious recreational value, used by many for (but not exclusive to) swimming, sun bathing, surfing, fishing, shell collecting, jogging and strolling. Accretion of sediments during calm weather periods can assist in building up berms and sand dunes that act as natural barriers to small disturbance events such as storm surge and high wave activity.

Marine/Estuarine Open Water

Most recreationally and commercially important fish and invertebrates can be found in open water habitats although many also depend on other aquatic habitats such as seagrass and oyster beds. Open water of the bays is important both aesthetically and functionally. Functionally, open water acts as a playground for boaters, water skiers and fishermen among other groups, as well as a medium for transporting goods (port and ship channel) and people.

The marine and estuarine open water habitat can be divided into the water column and the bottom. The bottom can by subdivided into sandy and muddy bottom habitats.

High priority ecosystem services provided by open water habitat include food, recreational opportunities and climate regulation (Yoskowitz et al. 2010).

Sandy Bottom

Sand can support larger animals that might sink in the soft mud. Sandy bottoms are often accompanied by stronger currents and higher water transparency in comparison with muddy water habitats. Attached algae, such as macroalgae, and benthic diatoms can yield high productivity in sandy bottoms. Because of the clear water, there are also many filter feeders in sandy sediment.

One of these filter feeders is the sandy bottom version of the tentacled polychaete, *Spiophanes bombyx*. Like its relatives, *Spiophanes* uses their palps to capture food from the water, or gather it from the sediment surface. A larger polychaete is *Chaetopterus variopedatus*. *Chaetopterus* builds a tube that is completely buried in the sand. The worm stays inside the tube, using highly modified feet to pump in water and filter out organic matter. Another tube worm is the phoronid, that filter feeds by using a U-shaped brush, somewhat like a barnacle. Another filter feeder, less well known than the quahog, is the hemichordate, *Branchiostoma peridium*, that resembles a small fish. There are also deposit feeders in sandy sediment, such as the small clam, *Tellina* sp. Another deposit feeder is the sipunculid worm. Sipunculids sometimes live in discarded gastropod shells, much like hermit crabs.

Many filter and deposit feeders that inhabit sandy bottoms support several invertebrate and invertebrate predators. The red-gilled worm, *Diopatra cuprea* builds tubes of shells and detritus that are often found washed up on the beach. Despite the fact that it builds a tube, *Diopatra* is predatory, emerging from its tube to grab passing prey. The lightning whelk, *Busycon contrarium*, which in Texas has a backwards-curving shell, is a large, well known snail that uses the edge of its shell and a rasping radula to feed on large clams, such as *Mercenaria*. Blue crabs, *Callinectes sapidus* and *Callinectes similis*, can be found in many habitats, including sandy bottoms. They tend to be opportunistic, eating any animals or detritus they encounter. Another generalist predator is the naked goby, *Gobiosoma bocii*.

Muddy Bottom

By far, the most common benthic (i.e., bottom) habitat in the EBMP area is the muddy bottom. Sediment underlying deeper water in Corpus Christi, Nueces, Oso and Redfish Bays is predominantly mud. Muddy bottoms occur in portions of bays where there is a lack of other physical features, such as grasses or oyster reefs. Movement of the water over the surface of the mud keeps the sediment oxygenated to about one centimeter depth. Below this region is a strongly reduced, anaerobic environment due to the absence of oxygen-generating producers such as seagrasses. Mud is easily resuspended and muddy bottoms may experience erosion or deposition of sediment. Therefore, turbidity tends to be high, which restricts the presence of producers and filter feeders. Deposit feeders, however, can be present in high abundance and diversity. Deposit feeders can be high in biomass or live weight and also have high metabolism rates due to the relatively high biomass and abundance.

The muddy bottom ecosystem is driven by two sources of carbon: phytoplankton and detrital matter. The filter feeders may eat phytoplankton in the water column, or detritus that is particulate in the water. One of the dominant species is the dwarf surf clam, *Mulinia lateralis*. *Mulinia* is a small, white clam that can become so dense in certain areas that there is no space between a clam and its neighbors. Other filter feeders present are the bamboo worms of family Maldanidae, particularly *Clymenella torquata*. These polychaetes pump water through their tubes and extract food from it. An unusual characteristic of these worms is that their head is at the bottom of the tube. Because they pump water down to the bottom of the tube, these animals are important in turning over and aerating sediment, and returning sediment-bound nutrients to the food web. Another polychaete filter-feeder is the ubiquitous *Streblospio benedicti*. *Streblospio* uses its tentacle palps to capture organic matter in the water in strong currents or collect organic matter from the surface sediment when flow is lower.

Detritus, which can come from terrestrial organic matter transported by freshwater inflow, marine organic matter derived from marshes or seagrasses, and sedimented phytoplankton are the most important sources of carbon for muddy bottoms. There are three types of animals that utilize detritus: non-selective deposit feeders, selective deposit feeders, and omnivores. Nonselective deposit feeders include polychaetes such as *Mediomastus* sp., which resemble earthworms. These polychaetes process bulk sediment, extracting organic matter from the mud. Selective deposit feeders usually have tentacles to pick and choose specific particles of material for ingestion. In the EBMP area, the dominant selective deposit feeders include bivalves, such as *Tellina* sp. and *Macoma* sp., amphipods that build tubes, particularly *Ampelisca abdita*, and brittle stars (ophiruoids). Omnivores include animals such as the edible shrimp, *Penaeus* sp., that eat detritus, microphytes, or any small animals they can catch. Many animals, particularly fish, eat the numerous invertebrates on the bottom. The fish Spot, *Leiostomus xanthurus*, are well known for picking at animals in the sediment, particularly for biting off siphons or tentacles without killing the whole organism. The clam *Mulinia lateralis* is the primary food source for black drum, *Pogonias cromis*, which collect mouths full of sediment and grind up shells with their pharyngeal teeth. Shrimp are eaten by a diverse assemblage of fish, such as catfish, *Arius felis*, red drum, *Sciaenops ocellatus*, and various flatfish.

Oyster Reef

Oyster reefs are intertidal or subtidal areas of open bottom that have become covered with the living and dead shells of the oyster, *Crassostrea virginica*. In the EBMP area, oysters flourish in shallow water of intermediate salinity. In parts of Nueces Bay, oysters have formed extensive reefs. These reefs have two dramatic effects on the habitat. Both living oysters and dead shells provide a hard substrate for encrusting fauna, one of the only two natural hard bottom habitats in estuaries of the Texas coast. Furthermore, the physical structure of the reefs acts as a barrier to water flow, which can cause organic matter to settle out of the water on to the reef where it can fuel a detrital-based foodweb.

Many species in oyster reefs are filter feeders, including the oyster itself (*Crassostrea virginica*) and animals that encrust oyster shells. These include many species of barnacles, *Balanus* sp., that live in calcareous shells and filter water using modified feet. Some polychaetes, such as the members of the family Serpulidae, extend tentacles from calcaerous tubes. Other filter feeders, that actually pump water through their bodies, include various species of mussels (e.g. *Brachiodontes exustus*), and tunicates (sea squirts). Like the oysters, mussels filter plankton and organic matter out of the water using their gills as seives. Tunicates, which resemble lumpy bags with an incurrent and excurrent siphon, trap food from the water column using a fibrous net.

Deposit feeding, encrusting fauna are also very diverse. Several mollusks, such as the rock snail, *Thais haemastoma* and the slipper shell, *Crepidula fornicata*, attach to the oyster shells. Slipper shells settle on top of each other to facilitate reproduction. Slipper shells and rock snails graze on epiphytic algae that grow on oyster shells. Tube-building amphipods, *Corophium* sp., feed on detrital material that settles on the reefs. They also use the material to construct their protective tubes.

With such a high biomass and diversity of food sources, several omnivore - predators can be found in the vicinity of oyster reefs. Nereid polychaetes (*Nereis* sp.) and several species of crabs patrol the reefs searching for food. Nereids are large, highly developed worms that have well-developed eyes, tentacles, and large jaws. The crabs include the spider crab, *Libinia dubia* and the stone crab, *Menippe adina*. Stone crabs use their powerful claws to break open oyster and mussel shells, while spider crabs use their long arms to grab smaller prey. Fish also frequent oyster reefs, either to hide among the shells, or to find food. The black drum, *Pogonias cromis*, use their pharyngeal teeth to crush shells of a variety of bivalve mollusks.

High priority ecosystem services provided by oyster reef habitat include food, water quality, biological interactions and hazard moderation (Yoskowitz et al. 2010). Oysters benefit humans by filtering, and therefore cleaning, the water column, providing habitat for recreationally important fish, providing a food resource and accreting sediment. Accreting sediment is especially important as it mitigates effects of potential erosion and sea level rise.

Scrub-Shrub Wetland

Scrub-shrub wetland is defined as 'areas dominated by woody vegetation less than 6 m (20 ft) tall. The species include true shrubs, young trees and trees or shrubs that are small or stunted because of environmental conditions (Cowardin et al. 1979). Although there are some freshwater wetland related scrub-shrub species in the EBMP area, the dominant species by area is the black mangrove, *Avicennia germinans.* Dense stands of black mangrove are found on Harbor Island in Redfish Bay and dominates approximately 600 hectares on this island (Montagna et al. 2010). Black mangroves are also found in scattered stands on bay margins and islands in Redfish Bay as well as along the backside of Mustang Island. The Redfish Bay area is not only the northern limit of mangroves in the EBMP area, but the northern limit for mangroves in the US. Black mangrove stands are usually interspersed with *Spartina* spp., *Salicornia* spp., and *Batis* spp. (Sherrod and McMillian 1981). Seasonal freezes are the largest threat to black mangroves. A large freeze in 1989, decreased abundance of black mangrove stands, but since then populations have recovered (Everitt et al. 1996).

Freshwater Wetland

Freshwater marshes receive tidal inundation primarily during extreme storm surges such as hurricanes, which increase water levels but may not change salinity levels (0 - 0.5 psu) (Tunnell et al. 1996). Large concentrations of freshwater marshes are found in the Nueces Delta, on North Padre Island and immediately south of Oso Creek. Freshwater marshes are composed of rushes, bulrush, cattail, and slough grass (Brown et al. 1976). Consumers found in freshwater marshes typically include *Melampus bidentatus*, Virginia Rail (*Rallas limicola*), and the King Rail *(Rallas elegans*) (Stewart 1951; Tunnell et al. 1996).

High priority ecosystem services provided by freshwater wetlands include nutrient balance, biological interactions and hazard moderation (Yoskowitz et al. 2010). The ability of wetlands to minimize the effects of floods is attributed to the water storage capacity they have and the decrease in current flow speed they cause on waters flowing through or over them. Wetlands also assist in carbon management by sequestering carbon because they continuously accrete and bury nutrient-rich sediments (Brevik and Homburg 2004; Choi and Wang 2004). In the EBMP area, freshwater wetlands are important habitat for waterfowl, amphibians and invertebrates, including insects. Shallow water wetlands are effective in removing nitrates (through denitrification) and phosphates (through sediment deposition) from rural and urban runoff, which would otherwise enter other waterways further downstream.

Tree Canopy/Live Oak Motte

Oak mottes are isolated groves of live oaks (*Quercus virginiana*) that exist as remnants of oak forests that occurred on sand sheets and barrier islands. Oak mottes are interspersed with little bluestem, yaupon (*Ilex vomitoria*), beauty berry (*Callicarpa americana*), greenbriar (*Similax* sp.), mustang grape (*Vitis mustangensis*), and muscadine (*Vitis rotundifolia*) (Chaney et al. 1996). The majority of the tree canopy/oak motte in the EBMP area exists in the Ingleside/ Aransas Pass area and the Nueces River and Delta sub-region. There are also moderate stands of tree canopy in Flour Bluff and an Oak Motte reserve on North Padre Island. The reserve on North Padre Island, named Packery Oak Motte Sanctuary, is a 3.7 ha (2.3 acre) reserve owned by the Audubon Outdoor Club of Corpus Christi. This sanctuary is deemed critical habitat for migratory and resident bird species (Gulf Coast Bird Observatory 2010). Tree canopy in the EBMP area, as in most areas, is important for carbon sequestration, oxygen generation, soil stability and retention, erosion control and aesthetic values.

Rookery Island

Natural and dredged spoil islands that have become bird rookeries are also present in the EBMP area. These islands are ideal nesting areas for several species of birds and often contain plant communities of mesquite, salt cedar (*Tamarix* spp.), popinac (*Leucaena leucocephala*), granjeno (*Celtis laevigata*), and oleander (*Oleander* spp.) (Chaney et al. 1996). Within the EBMP area, large rookery islands occur on the dredge spoil islands along the Gulf Intracoastal Water Way (GIWW), along the Aransas Pass Ship Channel and south of La Quinta Channel. Other locations of rookery islands include Shamrock Island(on the backside of Mustang Island), several locations in Redfish Bay and several small islands in eastern Nueces Bay.

Dune

Sand dunes stretch along the length of all three barriers islands (North Padre, Mustang and San Jose Islands) in the EBMP area. Sand dunes are naturally supplied with sediment from the inner continental shelf and riverine sources. Sediment is brought to the dunes by wind and waves. Humans alter the balance of sediment that is maintained in the dunes by removing and planting dune plants, building on the dunes and creating structures which interrupt the supply of sediment, e.g. jetties and piers. In comparison to other dunes along the Texas coast, the dunes in the EBMP area are relatively stable because of dense vegetation and limited shoreline development (Texas General Land Office 2003). Common dune plants along the Texas coast include bitter panicum (*Panicum amarum*), sea oats (*Uniola paniculata*), marshhay cordgrass (*Spartina patens*) and beach morning glory (*Ipomoea imperati*).

Beach and dune habitat provide several priority ecosystem services including hazard moderation, aesthetic and existence and soil and sediment balance (Yoskowitz et al. 2010). Aeolian (i.e., wind-blown) and biological soil-binding processes by plant roots assist in building and stabilizing sand dunes so that they form an effective barrier against large-scale climatic phenomena such as sea level rise over the long-term and storms over the short-term. Sand dunes also serve as a recreational zone for activities such as off-road driving and wildlife viewing.

THREATS AND RISKS TO THE AREA

Change happens. Thus, there are threats and risks to the area, some are natural and some are anthropogenic in origin. The focus of this section is on existing and obtainable information about risks that are changing the landscape now (e.g., development, pollution, storms, invasive species, etc.) and future risks that have the potential to change the landscape later (e.g., climate change, population growth, etc.). The information about present and future threats and risks is used to describe these interactions for the EBMP project area in a general way, because no new specific change analyses or the status and trends or analyses have been performed.

Biological

Invasive species are the main biological threats to natural habitats. Invasive species are species including its seeds, eggs, spores, or other biological material capable of propagating that species, that are not native to an ecosystem and whose introduction does or is likely to cause economic or environmental harm or harm to human health (CFR 64.25 1999). Invasive species often intentionally or unintentionally escape, are released, disseminated or placed into an ecosystem as a result of human activity. Invasive species are a threat to natural ecosystems and have been known to wreak havoc by out-competing native species, clogging waterways, and establishing monocultures where diverse ecosystems once existed.

State laws and regulations exist to control introductions of invasive species such as the Mexican fruit fly, fire ant, boll weevil, noxious weeds, forest pests, fish, shellfish, and aquatic plants under the Texas Administrative Code Title 4 Agriculture and Title 31 Natural Resources and Conservation (USDA 2010). But even though regulations exist, introductions of exotic species continue to occur. The Early Detection & Distribution Mapping System (http://www.eddmaps.org/) is a web-based mapping resource for reporting, documenting and mapping invasive plant species' distributions in the U.S. There are currently 88 documented invasive plant species in Nueces, San Patricio and Aransas Counties in the Coastal Bend area, with 13 of those listed as species of most concern across the U.S. (Early Detection & Distribution Mapping System 2010). Among the listed plant species are salt cedar (*Tamarix spp. L.*), Brazilian peppertree (*Schinus erebinthifolius* Raddi), and guinea grass (*Megathyrsus maximus* R. Webster).

The Texas Parks and Wildlife Department (TPWD) also maintains a list of invasive species in Texas (http://www.texasinvasives.org/invasives_database/). There are numerous birds, fish, shellfish, mammals, reptiles, insects, and aquatic plants listed on the TPWD invasive species list, however there are no marine species on this list. This list is incomplete because organisms like the Brown Mussel (*Perna perna*) (Hicks and Tunnell 1993), fire ants (Lofgren 1985), and Africanized honey bees (Winston 1992) are not included, yet are well-known invasive species in the Coastal Bend area. There are likely many more estuarine and marine invasive species on the Texas coast that are not accounted for on the TPWD list. Marine invasive species are known to be transported on ship hulls and in ballast water, so there are likely many marine invasive species in the Coastal Bend area that have not been documented.

Because of the lack of a comprehensive report of estuarine and coastal invasive species, little is known about the affect of invasive species in estuarine and coastal ecosystems. The available scientific literature documenting single species accounts is available only when aggregated in a piece-meal fashion. Invasive plant species seem to be better documented spatially; however few studies have addressed their effect on native plant communities. Therefore, threats from invasive species will be treated as an unknown or a data gap and should be further investigated. This preliminary synthesis of invasive species in the EBMP area indicates many invasive species do occur and many more may occur, therefore the potential for invasive species being a threat to the Coastal Bend area is likely.

Water Quality

Pollution is a primary cause of impaired water quality. The issues facing the Corpus Christ Bay area include: zinc in Nueces Bay, low dissolved oxygen in Oso Creek, Oso Bay, and Corpus Christi Bay, and high levels of bacteria at Ropes and Cole Parks located along the southwest shoreline of Corpus Christi Bay. There are currently on-going total maximum daily load (TMDL) projects addressing these issues. More information regarding the status of the TMDL projects can be found at http://www.tceq.state.tx.us/implementation/water/tmdl/index.html.

Recurring summer hypoxia (low dissolved oxygen concentration) in Corpus Christi Bay is another water quality issue of concern (Nelson and Montagna 2009). Hypoxia has occurred in bottom waters in the southeast corner of Corpus Christi Bay each summer since its discovery in 1988 (Ritter and Montagna 1999). The Texas Commission on Environmental Quality (TCEQ), Surface Water Quality Monitoring Program monitors surface water quality, therefore since hypoxia in Corpus Christi Bay occurs in bottom waters it is not listed as an impaired water body on the Clean Water Act 303d List of Impaired waters (TCEQ 2010). Hypoxia is associated with salinity stratification, and salty water entering Corpus Christi Bay from both Oso Bay and Laguna Madre contribute to hypoxia. There are also three major wastewater treatment plants discharging (more than one million gallons per day) into Oso Creek and Oso Bay which are also a source of nutrients. Hypoxia in Corpus Christi Bay can begin as early as the first week of June, and occurs as late as the last week of August and can extend from Ward Island to Shamrock Island. Nutrient concentrations in the hypoxic area are not at high levels relative to other adjacent bays. However, ammonium levels are higher in the hypoxic zone and this is likely due to microbial remineralization. At the present time, it appears that salty water driven by prevailing winds into Corpus Christi Bay is the main cause of water column stratification resulting in hypoxia, but a contribution of nutrients is not to be dismissed.

Storm water runoff is another issue of concern because it can load the bays with various pollutants including oil and grease from roadways; fertilizers, herbicides and pesticides from residential homes, and industrial pollutants from the industries adjacent to the bay (Carr et al.

2000). In the study by Carr et al. (2000), toxicity (amphipod and mysid solid phase and sea urchin pore-water fertilization and embryological development) was significantly correlated with contaminant concentrations (metals, polycyclic aromatic hydrocarbons [PAHs], polychlorinated biphenyls [PCBs], and pesticides). Four of the five most degraded sites in the study were storm-water outfall sites. The results were similar to what has been observed for other heavily urbanized bay systems along the Texas and Gulf coast.

Climatic Anomalies

Tropical storms, hurricanes, droughts, floods, and freezes are climatic disturbances that have strong effects on coastal habitats of the Texas coast.

The Coastal Bend has been fortunate in that it has not had a direct strike from a strong hurricane since the 1970's. Galveston Bay has not been so lucky. Hurricane Ike (4 September 2008) in particular destroyed nearly all the oyster reefs in Galveston Bay. The TPWD plans large restoration of oyster reefs using emergency relief funds. Also, erosion caused by tidal surge destroyed sand dunes and wetland habitats. It is likely that the same climatic effects will occur when a major storm hits the Corpus Christi Bay area.

While the Coastal Bend has been fortunate in dodging large tropical storms, it has suffered through extreme floods and droughts. The decade of the 1990's was extremely dry and the decade of the 2000's was extremely wet (Montagna et al. 2009b). The net result of droughts is to reduce marsh animal communities; floods however drown the vegetation and kill it. The extreme variability of freshwater inflow related to the cycle of floods and droughts is likely the greatest natural threat to Coastal Bend habitats (Montagna et al. 1996).

The Coastal Bend area is in a semiarid to subtropical climate zone with associated flora and fauna, therefore when unusually cold winter freezes occur in the area the biota are affected. Fish kills due to winter freezes have been documented as far back as the 1940s (Gunter 1941) and black mangrove die offs have also been attributed to unusually cold winter freezes (Sherrod and McMillan 1981). A combination of drought and back-to-back extended freezes in the late 1980s and early 1990s, respectively, have been attributed to the initiation of a brown tide event that occurred in the Laguna Madre for nearly a decade (DeYoe and Suttle 1994; Buskey et al. 1997). They attribute increased salinities coupled with a release of nitrogen from the decaying fish to the initial cause of the brown tide, and the high salinities and lack of micrograzer control was the cause of the persistence of the brown tide in the Laguna Madre. Because of the shading provided by the brown tide, there were also compounding effects causing a decrease in the aerial extent of seagrasses (Onuf 1996). Therefore, sporadic winter freezes, although natural, are known to have resulted in detrimental, lasting effects on ecological processes in the Coastal Bend area.

Sea-level Rise and Shoreline Change

Rapid sea-level rise, however, may interact with habitat change to alter the trajectory of succession of coastal landscapes. It is not clear exactly what will happen. One possibility is that the rising sea level will simply drown wetland habitats, but as long as plant growth and soil stabilization by plant roots occur at a rate equal to or higher than apparent sea-level rise, the habitats can simply migrate as the shoreline migrates. Migration of shorelines can occur until man-made structures such as roads or bulkheads impede this process. This is a major threat to the Coastal Bend area because Mustang Island and North Padre Island have roads dissecting them and canal communities on the bay side of the islands. Thus, bay shorelines will change.

Most of the sandy Gulf of Mexico beach shoreline of South Texas has probably been retreating for several thousand years and definitely since the mid to late 1800's (Montagna et al. 2007). An analysis of multiple Gulf of Mexico shorelines from the 1930 to 2000 time period and from the Colorado River to the U.S. – Mexico border shows that 56% of the shoreline retreated at a mean rate of 2.2 m/yr, 36% was essentially stable, and only 8% advanced seaward. The advancing shoreline sections were associated with impoundment of sand by jetties or spit progradation caused by engineering alterations affecting Pass Cavallo. A section a few miles long in the central Padre Island area also advanced because of the natural convergence of littoral drift in the Gulf of Mexico.

Bay shorelines have been retreating for at least 10,000 years as sea-level rose from the low stand of 18,000 years ago and flooded paleo-river channels running through the bays. Inundation, waves, and tidal action eroded the river banks, and the resulting shoreline retreat largely shaped the bays as they exist today. Generally, these bay shorelines continue to retreat with the erosion of marshes and flats, clay bluffs, sandy slopes, and sand and shell beaches. In some areas, extensive shore protection structures such as rip rap and bulkheads have been installed. Paine and Morton (1993) determined an average retreat rate for the Copano, Aransas, and Redfish Bay systems of 0.24 m/yr from 1930 to 1982 (Gibeaut and Tremblay 2003).

Changing sea level relative to the elevation of the land (relative sea-level change) and the change in sand supply to the coast causes shorelines to retreat or advance over a period of 100 years or more (Gibeaut and Tremblay 2003). The rise in relative sea level during the last 100 years (5.2 mm/yr) along the South Texas coast has moved the Gulf and bay shorelines through inundation and by shifting the erosive energy of waves and currents landward (Gibeaut et al. 2010). This has happened because, overall, the rate of new sediment delivered to the littoral zone has not been sufficient to counter-balance the effects of relative sea-level rise. Localized exceptions to this are where rivers form deltas at the heads of the bays, such as the Nueces and Mission deltas, and where creeks erode bluffs and enter the bays (Paine and Morton 1993) and where dunes have migrated and advanced the shoreline (Gibeaut and Tremblay 2003). Because of this sediment deficit and the low-lying and gently sloping shores of much of the South Texas coast, relative sea-level rise has had and will continue to have a profound effect on coastal habitats. Increases in the rate of global sea-level rise, as projected by global climate modeling, and coastal development will very likely result in further decreases of coastal wetland habitats.

Development

Although the previous four subsections identified threats and risks from biological, climatic anomalies, water quality, and sea-level rise and shoreline change factors, the largest threat for habitat changes is nearly always from human activities, particularly coastal development.

Development in coastal regions is beneficial economically because of the increased property values near the water or near natural areas. The increased property value due to proximity to valued assets is called the hedonic value of property, which represents the difference between two similar properties when one is near a natural asset and one is not. There is great development pressure on coastal habitats because of the high hedonic values in coastal areas.

Development poses several threats. Wetlands, seagrass beds, oyster reefs, open water, dunes, and tidal flats are destroyed during construction of canals, docks, homes, and roads. Increased land use near the water is associated with increased loads of nutrients because of fertilizer use, sediments because of erosion, and pollutants because of pesticide, herbicide, and hydrocarbon use. There is a simple and direct relationship between development, population increase and habitat loss. In fact, 50% of all wetland habitats have been lost since the founding of the United States.

Development is correlated to population growth and economic prosperity. Nearly all civic organizations and local governments will be promoting growth and economic development in the region. The Corpus Christi region has grown slowly over the past two decades. Between 1990 and 2000 the city grew 8%, but growth slowed to 4% between 2000 and 2009. This is a rather slow growth rate, especially when compared with other coastal cities or other Texas cities. The slow growth rate may be one reason why habitats in the Corpus Christi region are in relatively good condition. The slow population growth rate actually represents an opportunity for the Corpus Christi region to manage habitats in a proactive manner.

Climate Change

The Texas coast is likely to experience severe climate change impacts because of a synergy between the regional climate regime and the coastal geology (Montagna et al. 2007). Lying between about 26 and 30 degrees North latitude, the Texas coast is already in a relatively warm climate zone and subject to very high rates of evaporation. Thus, potential changes in rainfall or temperature will have great impacts on the Texas coastal hydrocycle (Montagna et al. 2010). The Texas coastal plain is relatively flat and low-lying, and the coast also has one of the highest rates of subsidence in the world (2.8 mm/yr in Rockport (Montagna et al. 2007)). Thus, changes in sea level will be exacerbated on the Texas coast because the land is relatively flat and is rapidly sinking. The combined effects of these changes can affect the physical and biological characteristics of the Texas coast dramatically.

Climate change is not a future event, it has been happening at an accelerated pace since the 1970's. There are at least three indicators of change (temperature, dissolved oxygen, species distribution) and all show a strong signal along the Texas coast (Montagna et al. 2010).

There has been a long-term trend of increasing water temperature along the entire Texas coast. The patterns over time differ among the estuary systems. The main difference is a higher rate of increase in Lower and Upper Laguna Madre than in the other seven estuarine ecosystems. The overall average rate of increase in temperature is 0.0428°C per year, which translates into an increase of 1°C in 23 years (1°F every 13 years).

In contrast, dissolved oxygen has decreased in these coastal ecosystems over the long term. Again, the patterns differ among the estuaries. The main difference is a higher rate of decrease in Galveston Bay and Upper Laguna Madre than in the other seven estuarine ecosystems. The overall average rate of decrease in dissolved oxygen is approximately at a rate of 0.06 milligrams per liter per year (mg/L/y), or 0.7 percent per year. At this rate, dissolved oxygen in surface waters of Corpus Christi Bay will not meet exceptional aquatic life standards (≤5 mg/L) in the year 2032. This may be one of the greatest threats to the bay systems.

Species that are sensitive to changes in any one or more of these factors, or reside at the edge of their distribution range, are indicator species. One potential indicator species is the black mangrove (*Avicennia germinans*), because its distribution and survival in Texas are limited by winter temperature. Black mangroves, which are sensitive to freezes, are expanding northward. Species that are even more sensitive to cold, such as the red mangrove (*Rhizophora mangle*), are now showing up on the Texas coast. There is a population of red mangroves in the Lighthouse Lakes area.

Future Concerns

The future will present significant challenges and consequences related to climate change, sea-level rise, human population growth, and increased water demands on habitats and the natural resources of the Coastal Bend. Climate predictions along the Texas Gulf coast include a 2 °C (3.6 °F) increase in air temperature and a 5 percent decrease in precipitation between the years 2000 and 2050 (Ward 2009). A 30 cm relative sea-level rise has been documented in the Coastal Bend area between 1948 and 2006, which equates to an increase of 5.16 mm/y (1.69 ft/100 y, Figure 3, Table 2). Sea level is predicted to rise approximately 50 cm over the next 100 years based on extrapolation of the 1948 to 2006 sea level rise rate (NODC 2010, Gibeaut et al. 2010).

Relative sea-level rise is attributed to landward migrating shorelines and coastal habitats. A more pronounced effect of shoreline and habitat migration has been projected along the Texas coastal plains due to the small topographic relief that exists in this area (Twilley et al. 2001). In addition, a sediment deficit coupled with coastal development has contributed to a retreating shoreline along the Texas Gulf coast for the past one hundred years (Montagna et al. 2007). The Intergovernmental Panel on Climate Change has projected a continued increase in the rate of global sea-level rise, which means that the losses of coastal habitats and shoreline retreat will likely continue (IPCC 2007).

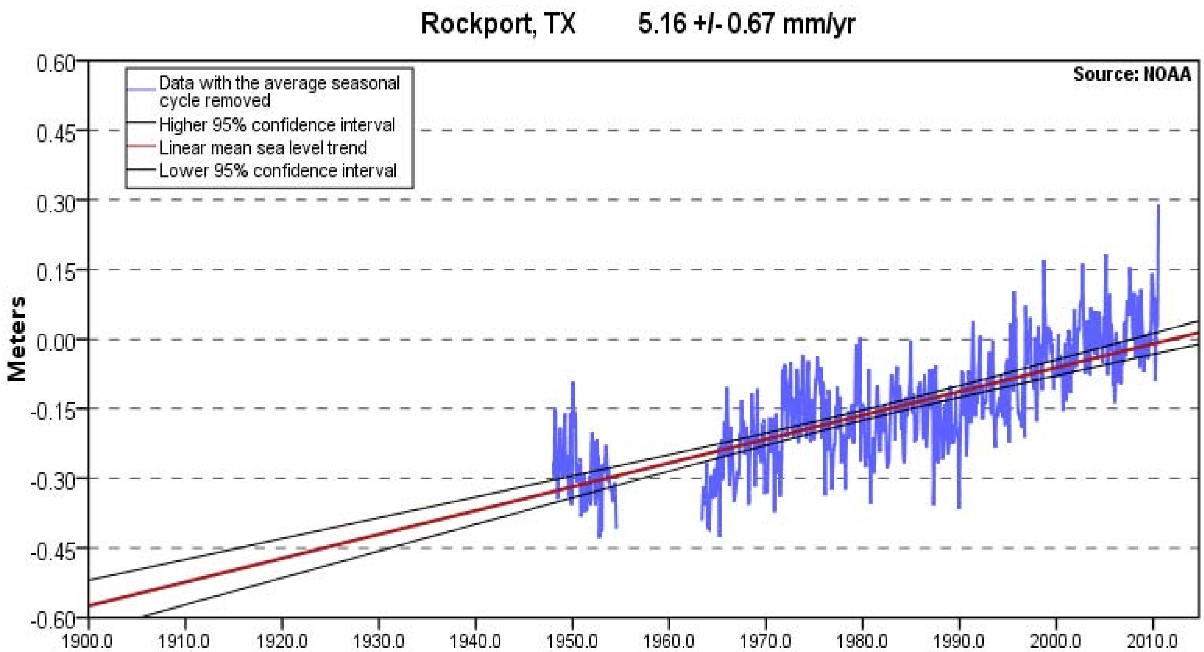

Figure 3. Sea level at Rockport, TX with linear regression based on monthly mean sea level data from 1948 to 2006 (Graph from NODC 2010).

Table 2. Forecasted changes of different drivers in Corpus Christi Bay calculated using extrapolations of linear regressions (y=y0+a*yr where y = driver value and yr=year).

Driver	**Year**				**Linear Equation Parameters**	
	2010	**2020**	**2040**	**2060**	**y_0**	**a**
Sea Level (m)[1]	-0.01	0.04	0.14	0.25	-10.382	0.00516
Temperature (°C)[2]	24.2	24.7	25.8	26.9	-83.522	0.05359
Turbidity (NTU)[2,3]	12.9	8	3.1	1.2		
DO (mg/L)[2]	6.6	6	4.9	3.8	117.58	-0.05522
Nueces County population (10^3)[4]	329	350.4	393.2	436.1	-3974.8	2.14117
Coastal Bend population (10^3)[5]	617	694	811	886		
Coastal Bend water demand (10^6/m^3/yr)[5]	280	309	345	381		
Coastal Bend water demand (10^3 ac-ft/yr)[5]	227	250	280	309		

[1] Sea level data is for Rockport, TX; data from NODC (2010).
[2] Linear regression based on data from Montagna et al. (2010).
[3] Turbidity forecasting uses a exponential decay model rather than a linear regression model.
[4] Regression used U.S. Census Bureau Nueces County data from 1960 to 2009.
[5] Data from TWDB (2007)

Climatic changes in temperature and precipitation can result in degraded estuarine water quality. An increase in temperature, for example, would decrease the solubility potential of gas in water leading to decreased dissolved oxygen concentrations and potential occurrences of hypoxia. A decrease in precipitation could compound the hypoxia effect by reducing the dilution effect provided by freshwater inflows and increasing the salinity and further reducing the solubility potential of gas in water. The overall effect would be warmer, saltier estuarine water with lower dissolved oxygen concentrations. In Corpus Christi Bay, there has been a significant increase in temperature and significant decreases in turbidity and dissolved oxygen between 1976 and 2009 (Figure 4 and Figure 5) (Montagna et al. 2010). Salinity has not significantly changed however. Estimates of changes in water quality between 2010 and 2060 include a 2.7 °C increase in water temperature, a 11.7 NTU decrease in turbidity, and a 2.8 mg/L decrease in dissolved oxygen (Table 2). An exponential decay regression ($y = a^{(-b*x)}$)was used for turbidity data. A dashed regression line indicates a significant relationship ($p < 0.05$), whereas a dotted line indicates a non-significant relationship.

Another consequence of climate change is a predicted change in frequency and intensity of tropical disturbances in Texas (Nielsen-Gammon 2010). Although many tropical disturbances have passed close to the EBMP area over the last 140 years (Figure 6, Table 3), there is no significant correlation of hurricane frequency over time (Figure 7).

The human population in Texas is expected to more than double from 20.9 million in 2000 to 45.6 million by 2060 (TWDB 2007). The majority of the people that reside in the EBMP area live in Nueces County, in particular the city of Corpus Christi (Table 4). Nueces County and Corpus Christi have experienced 41 and 31 percent increases in population growth respectively between1960 and 2008 (Figure 8). If population growth rates stay the same, it is estimated that the population of Nueces County will increase by 107,000 people between 2010 and 2060 (Table 5). In the Coastal Bend, a human population increase of 30 percent between the years 2010 and 2060 corresponds to an increase in water demand of 27 percent over the same period. The resulting challenges and consequences of these future changes will require concerted, thoughtful and perhaps unconventional approaches that minimize impacts to natural resources.

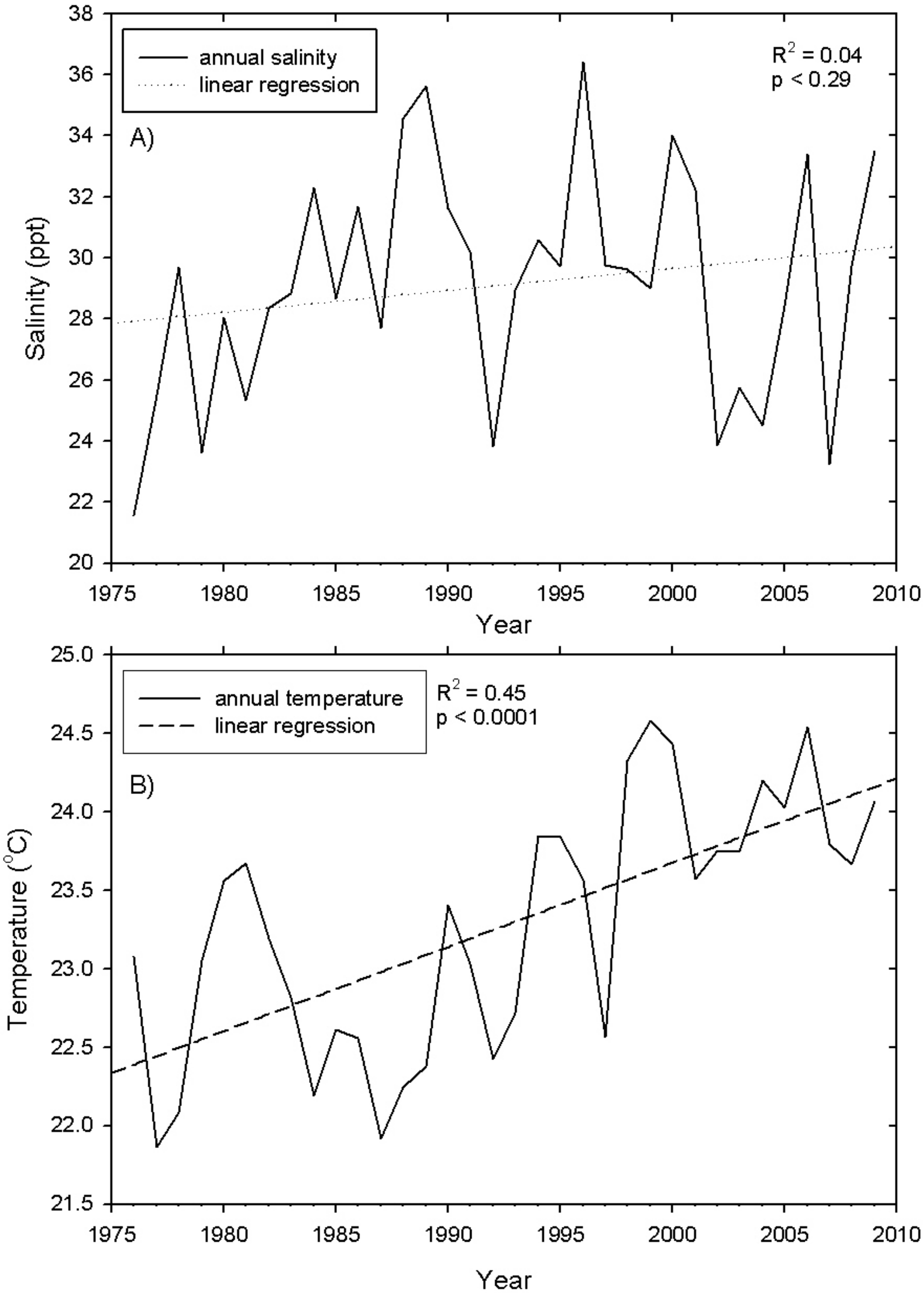

Figure 4. Annual averages and linear regressions of water quality variables in Corpus Christi Bay between 1976 and 2009. A) salinity, B) water temperature.

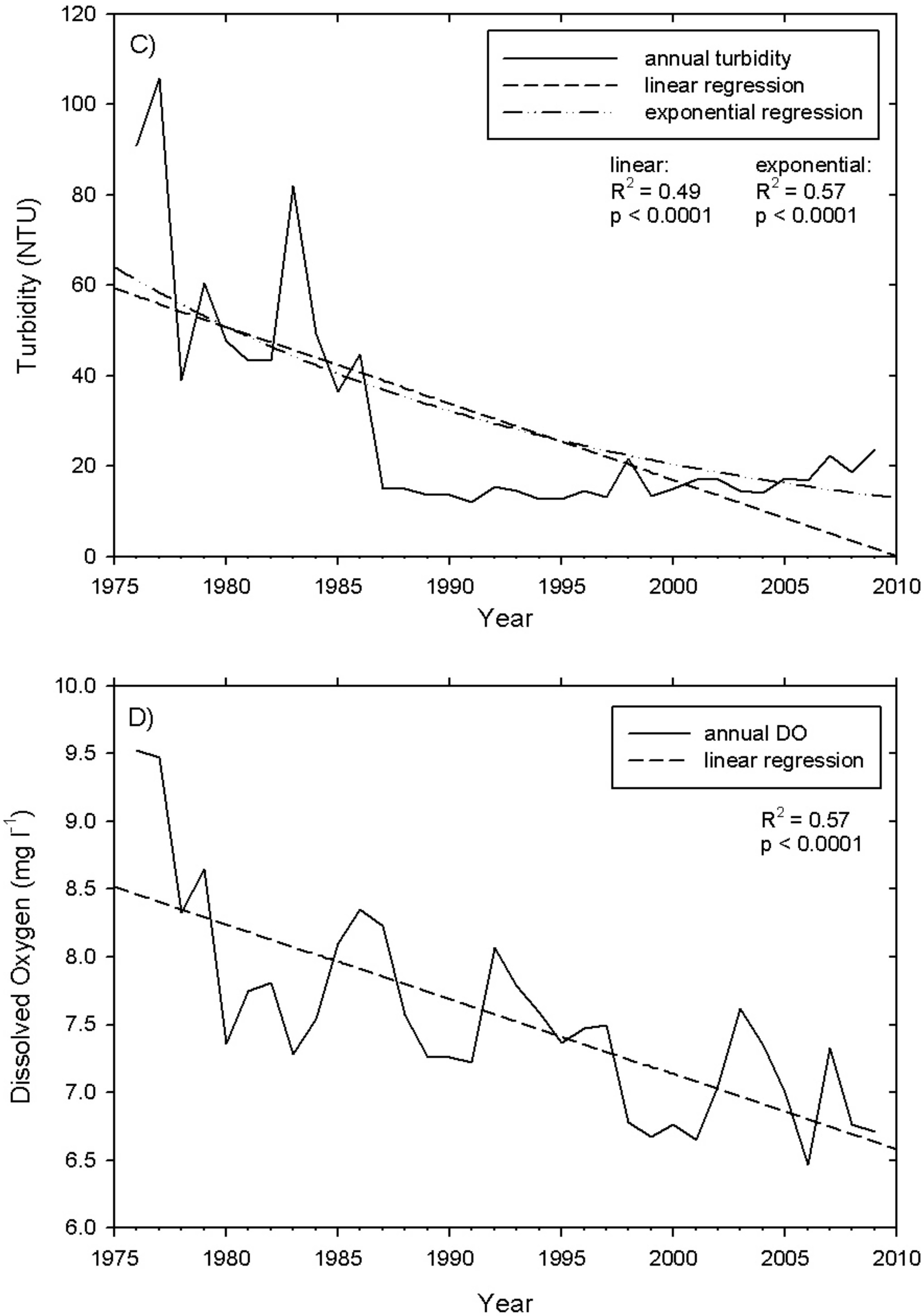

Figure 5. Annual averages linear, and non-linear regressions of water quality variables in Corpus Christi Bay between 1976 and 2009. C) turbidity and D) dissolved oxygen.

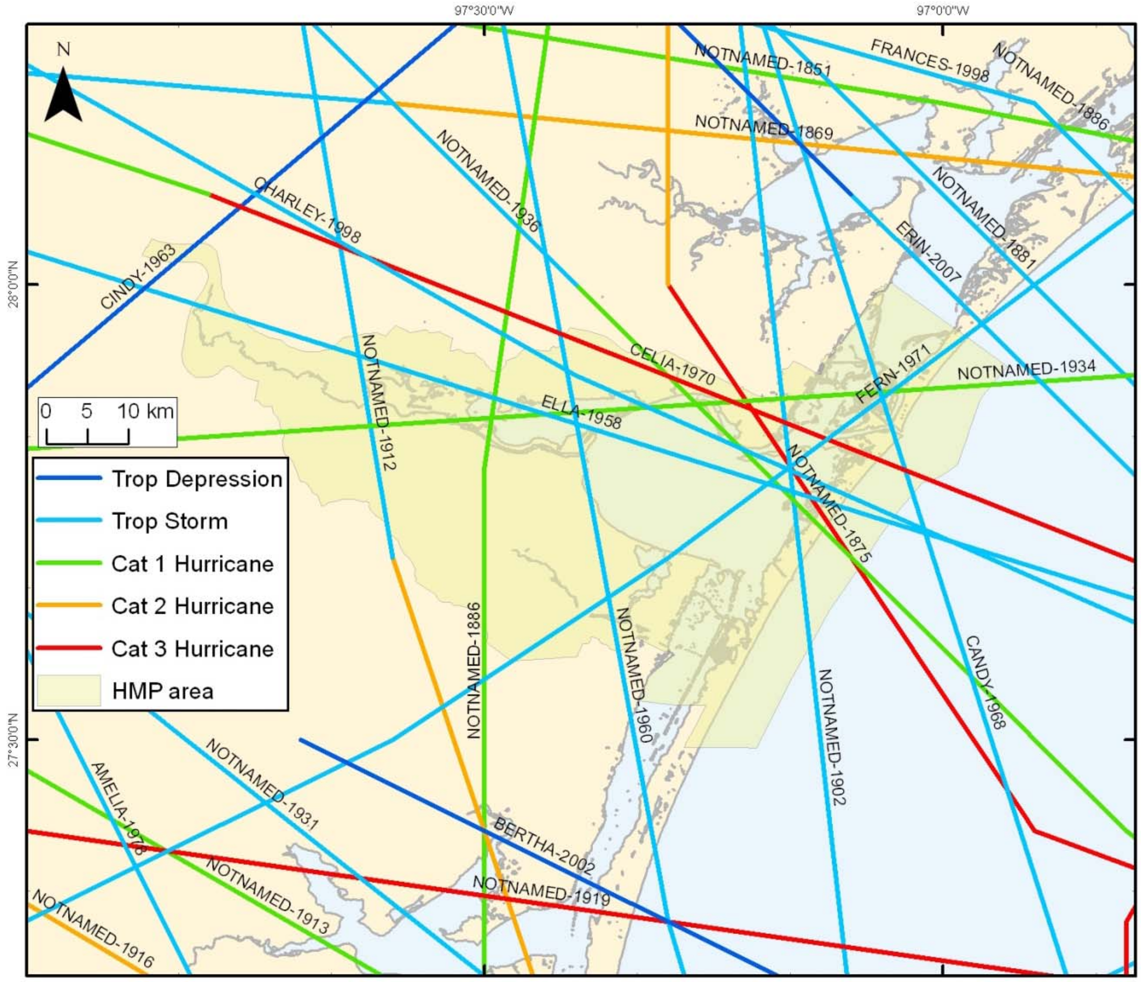

Figure 6. Tropical disturbances that came close to the EBMP area between 1869 and 2007 (Data NOAA).

Table 3. Tropical storms that passed between Baffin Bay and Rockport, Texas (Data NOAA).

Year	Month	Day	Name	Sustained Wind (kts)	Barometric Pressure (mb)	Category
1869	8	17	Not named	90		Cat 2 Hurricane
1875	9	16	Not named	100		Cat 3 Hurricane
1881	8	13	Not named	40		Tropical Storm
1886	9	23	Not named	75		Cat 1 Hurricane
1902	6	26	Not named	60		Tropical Storm
1912	10	16	Not named	85		Cat 2 Hurricane
1913	6	28	Not named	65		Cat 1 Hurricane
1919	9	14	Not named	75		Cat 1 Hurricane
1931	6	28	Not named	35		Tropical Storm
1934	7	25	Not named	65		Cat 1 Hurricane
1936	6	27	Not named	70		Cat 1 Hurricane
1958	9	6	Ella	40		Tropical Storm
1960	6	24	Not named	35	1002	Tropical Storm
1963	9	19	Cindy	25		Tropical Depression
1968	6	23	Candy	45	1001	Tropical Storm
1970	8	3	Celia	110	945	Cat 3 Hurricane
1971	9	11	Fern	55	988	Tropical Storm
1998	8	22	Charley	60	1002	Tropical Storm
2002	8	9	Bertha	20	1011	Tropical Depression
2007	8	16	Erin	35	1005	Tropical Storm

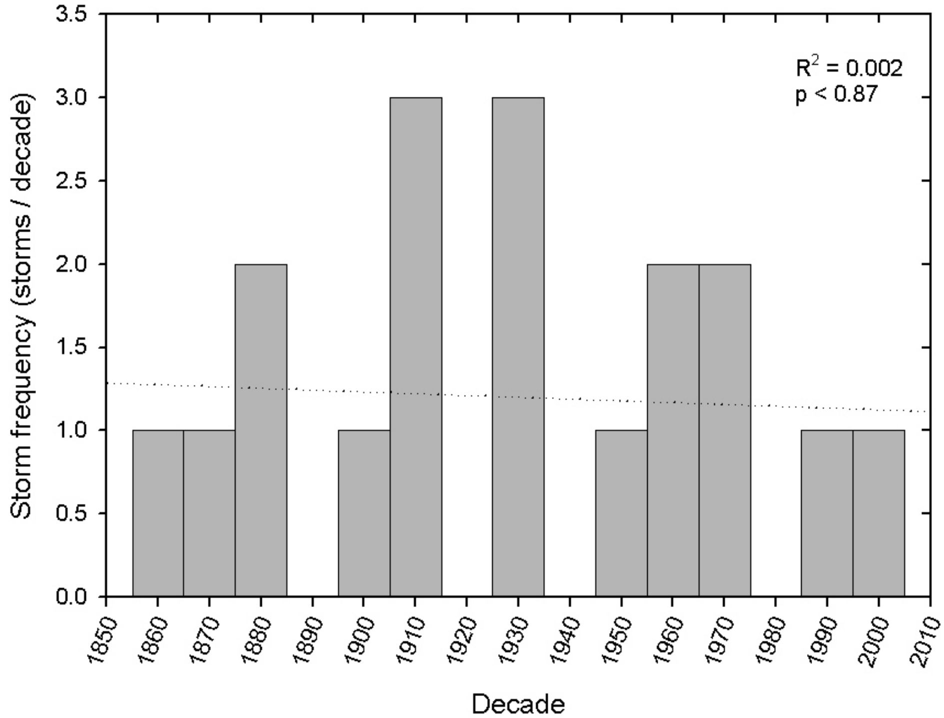

Figure 7. Tropical storms and hurricanes that passed the area between Baffin Bay and Rockport Texas between 1869 and 2007.

Table 4. Nueces County Population estimates for 2009 (www.census.gov).

City*	Population
Agua Dulce city	715
Aransas Pass city (pt.)	97
Bishop city	3,126
Corpus Christi city (pt.)	287,212
Driscoll city	805
Ingleside city (pt.)	0
Petronila city	79
Port Aransas city	3,905
Portland city (pt.)	0
Robstown city	12,169
Balance of Nueces County	14,938
Total for Nueces County	323,046

*City and town populations include only those parts (pt.) of each place found within this county.

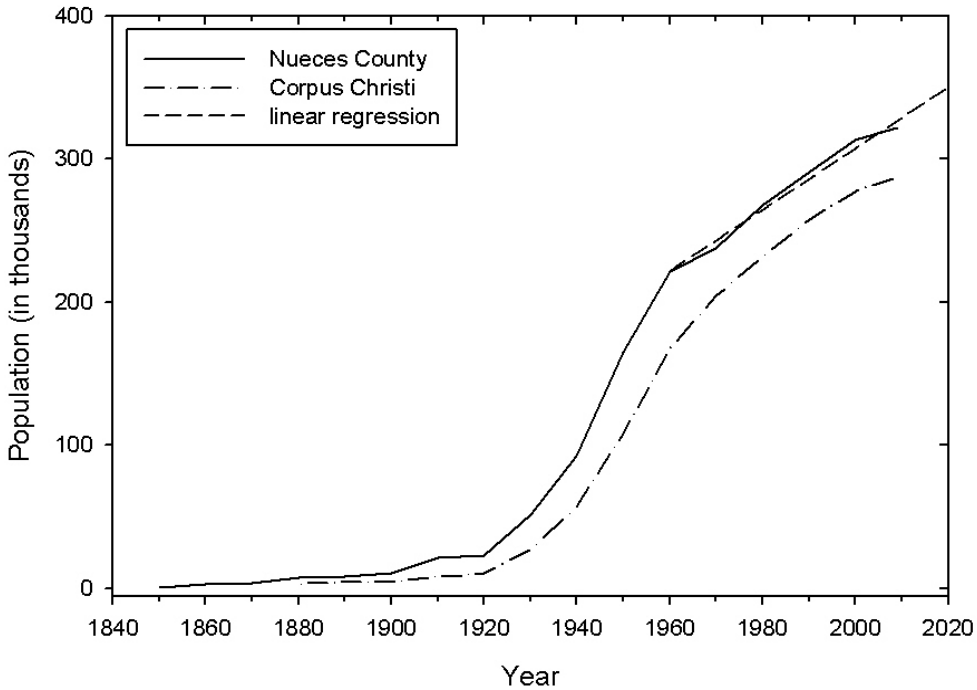

Figure 8. Population growth in Nueces County and the City of Corpus Christi and linear regression of Nueces County population based on 1960-2009 populations. Data is US Census decennial data except for 2008 and 2009 data, which is estimated (www.census.gov).

Table 5. Future change projections of population and water demands in the Texas Coastal Bend region (TWDB 2007).

Future changes	**2020**	**2030**	**2040**	**2050**	**2060**
Human population growth	693,940	758,427	810,650	853,964	885,665
Increased water demands (acre-feet/year)	250,401	265,212	279,510	293,254	308,577

PROJECT APPROACH AND PROCESS

Development of the EBMP was approached by taking a series of steps. First, existing plans and resources were identified and reviewed to guide plan development. Second, individual meetings were conducted with stakeholders in the Corpus Christi/Nueces Bay area to solicit stakeholder input into the EBMP development process. Third, two workshops were held to integrate stakeholder input into development of the EBMP. The three steps are described below.

Existing Plans and Resources

Existing plans, particularly Texas plans, were useful in providing past priorities and management strategies for similar (and sometimes the same) habitats to those found in the EBMP area. The following plans and resources were identified as being useful in the development of the current EBMP:

- Galveston Bay Plan
- Galveston Bay Foundation - Galveston Bay Habitat Conservation Blueprint, 1998, in revision
- USFWS - Strategic Plan for the Texas Coast, 2006
- TNC – Gulf Coast Prairies & Marshes Ecoregional Plan, 2002
- TNC – Mustang Island Conservation Action Plan, 2001
- TNC – Laguna Madre Conservation Action Plan, 2001
- CBBEP - The Coastal Bend Bays Plan, 1998
- City of Corpus Christi – Mustang-Padre Island Area Development Plan, 2003
- TCEQ – Watershed Protection Plan for Arroyo Colorado – Phase 1, 2007
- USFWS - Strategic Plan for the Coast Program, 2006

Existing Texas Background Data Resources:

- CBBEP - Status and Trends of Inland Wetland and Aquatic Habitats in the Corpus Christi Area, 2008
- GLO – Status and Trends of Wetland and Aquatic Habitats on Barrier Islands, Coastal Bend, 2006
- USFWS - Whooping Crane Recovery Plan, 1994
- USFWS – Attwater's Prairie Chicken Recover Plan, 1992
- Joint Venture - Gulf Coast Joint Venture Texas Mid-Coast Initiative Plan, 2002
- TPWD - Texas Comprehensive Wildlife Conservation Strategy, 2005, in revision
- TPWD - Seagrass Conservation Plan for Texas, 1999, in revision
- Gulf Coastal Prairie Working Group - U.S. Shorebird Conservation Plan Lower Mississippi/Western Gulf Coast Shorebird Planning Region, 2002
- CBBEP - Potential Sites for Wetland Restoration, Enhancement, and Creation: Corpus Christi/Nueces Bay Area, 1997

- CBBEP - Chaney/Blacklock - Colonial Waterbird and Rookery Island Management Plan, 2002
- CBBEP – Identification of Potential Conservation, Restoration, and Enhancement Sites in CBBEP area, 2003
- Texas Sea Grant Program - The Resilient Coast: Policy Frameworks for Adapting the Built Environment to Climate Change and Growth in Coastal Areas of the U.S. Gulf of Mexico, 2007
- Nueces River Authority – 2008 Basin Summary Report, 2008
- USGS – Suspended Sediment Project in Lower Nueces River, ETA late 2010
- GLO - Coastal Texas 2020: a clear vision of the Texas coast, 2005
- TPWD - Land and Water Resources Conservation and Recreation Plan 2005
- TSSWCB - Texas State Soil and Water Conservation Board Agency Strategic Plan, Fiscal Years 2007-2011 Period, 2006
- Texas Sea Grant College Program Strategic Plan , 2006
- TCEQ - Strategic Plan Fiscal Years 2005-2009
- UTBEG - Determining recent sedimentation rates of the Nueces River system Texas, 1996

Existing National Plans as Resources:

- Louisiana Department of Natural Resources – Coast 2050: Toward a Sustainable Coastal Louisiana, 1998
- New York Ocean and Great Lakes Ecosystem Conservation Council - Transitioning the Ocean and Great Lakes to a Sustainable Future: Implementation of Ecosystem-Based Management in New York State, 2007
- Hudson River Foundation - Target Ecosystem Characteristics for the Hudson Raritan Estuary: Technical Guidance for Developing a Comprehensive Ecosystem Restoration Plan, 2007
- Humbolt Bay Harbor, Recreation, and Conservation District – The Humbolt Bay Management Plan, 2006
- Natural Resources Service – Linking Land and Sea: a Northern California Coastal Conservation Needs Assessment, 2006
- EPA - Chesapeake Bay Program – Chesapeake Action Plan, 2008
- USGS - National wetlands research center strategic plan 2005 - 2009
- TNC - Northern Gulf of Mexico Ecoregional Plan, 2000
- TNC-Mid-Atlantic Seascape IL Draft Plan
- EPA - Identifying planning and financing beneficial use projects using dredge material, 2007

Existing Tools as Resources:

- Ecosystem-Based Management Tools Network (EMBTN) www.ebmtools.org
    - CommunityViz (socioeconomics),
    - NatureServe Vista (ecological values and impacts), and
    - Nonpoint Source Pollution and Eroxion Control Tool (N-SPECT) (predict sedimentation and pollution changes).
- The Comparative Analysis of Marine Ecosystem Organization (CAMEO) http://cameo.noaa.gov/
- Marxsam (ecosystem based management software)
- Gulf of Mexico Regional Collaborative (developing EMB tools for the Gulf of Mexico Region)
- Texas Sustainable Coastal Initiative & Coastal Atlas (TAMU)

Individual Meetings

Individual meetings to solicit input to the EBMP were conducted with Corpus Christi/Nueces Bay stakeholders from universities, federal, state, and local government agencies, development, industry, citizen, environmental and conservation groups (Table 6 and Table 7) (Brenner et al. 2009a). The individual meetings were scheduled in advance by e-mail and they lasted about one hour. At each meeting, project objectives, tasks, expected outcomes and deliverables were presented along with a handout with background information. Whenever needed, slides were presented using a computer and projector.

A one-page summary report of each meeting was produced for further reference with participants' name, location, comments, concerns, suggestions for other contacts, agreements, and willingness to participate on an Advisory Committee for the EBMP. Reports were sent to all participants for comments and edits and resubmitted if needed. When it was not possible to have an individual meeting with stakeholders the report was substituted by a summary of phone or e-mail conversations. Meetings were conducted by Jace Tunnell and Leo Trevino from CBBEP, Paul Carangelo from the Port of Corpus Christi Authority (POCCA) and Jorge Brenner of Harte Research Institute (HRI).

Table 6. Summary statistics of initial meetings.

Organizations and people	**N**
Number of organizations met	43
Number or people met	101
Number of potential members of the Advisory Committee*	12
Meetings:	
Number of one to one meetings	21
Number of phone conversations	3
Number of e-mail conversations	14
Organization type:	
Governmental:	
Federal	9
State	5
City	4
Non-governmental:	
Industry	7
Conservation and other advocacy groups	13
Consulting firm	2
Academic	3
TOTAL	*43*

*As expressed explicitly in the reports/conversations.

Table 7. Organizations met during initial meeting stage of EBMP development.

Organization Type	Organization Name
Governmental:	
Federal	US Army Corps of Engineering (USACE) US Coast Guard US Department of Agriculture US Environmental Protection Agency (Region 6) (EPA) US Geological Survey (USGS) US National Marine Fisheries Service (NOAA / NMFS) US National Oceanic and Atmospheric Administration (NOAA) US Fisheries and Wildlife Service (USFWS) Mission-Aransas National Estuarine Research Reserve (UTMSI/NOAA)
State	Texas Commission on Environmental Quality (TCEQ) Texas Department of Transportation (TXDOT) Texas General Land Office (GLO) Texas Parks and Wildlife Department (TPWD) Texas State Soil and Water Conservation Board (TSSWCB)
City	City of Corpus Christi City of Ingleside City of Portland The Port of Corpus Christi Authority (POCCA)
Non-governmental:	
Industry	Citgo Elementis Flint Hills LyondellBasell Industries Mark West Javeline Port Industries of Corpus Christi Valero
Conservation, and other advocacy groups	Audubon Outdoor Club Beach Access Coalition (BAC) Coastal Bend Bays and Estuary Program, Maritime Commerce & Dredging Implementation Team Coastal Bend Bays Foundation (CBBF) Coastal Conservation Association (CCA) Corpus Christi Audubon Society Corpus Christi Beach Association (CCBA) Ducks Unlimited (DU) Gulf of Mexico Foundation (GOMF) Nueces River Authority (NRA) Saltwater Fisheries Enhancement Association (SEA) Sierra Club Surfrider Foundation The Nature Conservancy (TNC)
Consulting firm	HDR	Shiner Mosley

Organization Type	Organization Name
	Naismith Engineering
Academic	AgriLIFE Extension-TAMU System Center for Coastal Studies-TAMUCC Harte Research Institute-TAMUCC Conrad Blucher Institute - TAMUCC

In general, stakeholders agreed that creation of the Plan was a good idea and that the Plan would provide helpful guidance for the conservation of Coastal Bend habitats. The most frequent comment given by stakeholders was the need to make the Plan accessible and applicable to other bay systems. This may include creating a "how to" template on developing ecosystem-based management plans, as well as placing the final Plan into the Texas Digital Library (https://www.tdl.org/) for access by other groups seeking to develop similar plans. Stakeholders were also interested in expanding the scope of the Plan to include important areas such as reservoirs, neighboring bay systems, riparian areas, beaches, and bird sanctuaries. Other important topics of interest were the impacts of climate change, beneficial uses of dredge materials, ecosystem services, beach and bay access, and beach raking.

Stakeholders suggested the plan incorporate adaptive management strategies, including scheduled review and update periods every 5-10 years to adjust to current scenarios. Incorporation of broader audience participation was also suggested, as were potential avenues for presenting the Plan, such as CBBF Seminars. Stakeholders also discussed end-products of the Plan that would be beneficial to their goals and missions, including GIS map products of habitat changes over various time scales that could be made available online.

Workshops

<u>Workshop One</u>

Representatives from local stakeholder groups were invited to participate in a joint workshop titled "Outlining an Ecosystem–Based Management Plan for Corpus Christi Bay" (Palmer et al. 2009). The workshop was held on February 18th 2009 at the HRI. The workshop generated information important in developing the EBMP for the Corpus Christi Bay area. The information gathered at the first workshop guided the creation of the project area boundary (Figure 1) and a preliminary management plan titled "Preliminary Habitat Management Plan for the Corpus Christi Bay Area." Input was received from sixty-three (63) stakeholders, not including the seven (7) breakout group facilitators. The stakeholders represented agencies from three main levels of government (local, state, federal) and private and public organizations. Objectives of the workshop were to collectively identify:

1) Priority habitats and associated ecosystem services
2) Management plan's geographic coverage, e.g. project area boundary
3) Range and scope of activities that should be part of the overall plan
4) Mechanisms and resources needed to support the plan.

Participants added twenty-two (22) priority habitats in the Nueces Estuary region to the eleven priority habitats already identified (Figure 9). The priority habitats most commonly listed were freshwater wetland, man-made structure, rookery island and dune habitats. Twenty-one (21) ecosystem services were reported in the workshop. The services supported by the greatest number of different habitats included habitat, water regulation, disturbance regulation, soil retention, food and recreation.

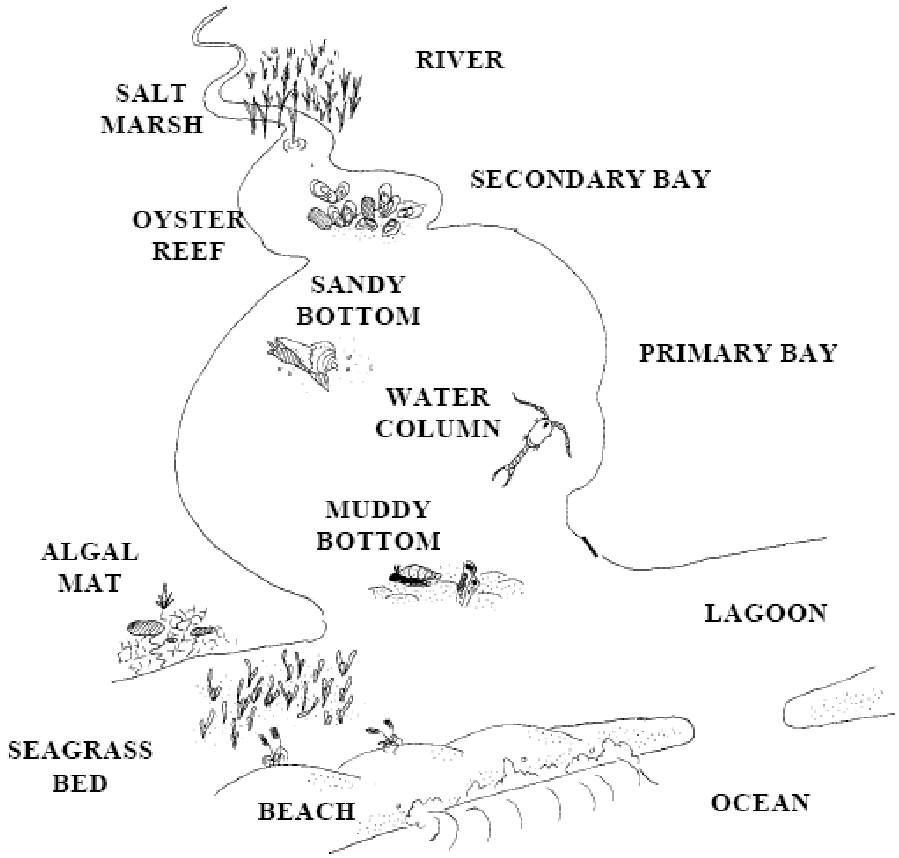

Figure 9. Estuarine ecosystem conceptual model (From Montagna et al. 1996).

Over sixty-five (65) locations were suggested for inclusion in the EBMP. The most commonly suggested locations were Packery Channel, the backside of Mustang Island (incl. Marsh) and Mustang Island sand dunes. When grouped into larger areas, the most frequently mentioned areas were Oso Creek Watershed and Upper Laguna Madre. Many ideas for the areal extent of the EBMP such as including the local watersheds for each bay, the area out to ten miles offshore and the Nueces watershed up to the Wesley Seale Dam were also discussed.

Table 8. Proposed range of activities derived from stakeholder input to be included in the EBMP.

Activity Type	Activity	Count
Communication	Education	7
	Youth / Community Programs	2
	Legislative Outreach	1
	Public Service Announcement	1
	Community Involvement	1
Regulatory / Planning	Best Management Practices (agricultural, wastewater treatment)	5
	Smart Growth	4
	Parks/ Green-space Planning / Buffer Zones	4
	Conservation Easement	2
	Mitigation Banks	2
	Riparian Zones	2
	Regulatory Success / Monitoring	1
	Sediment Management Plan	1
	Adaptive Management	1
	Wetland Ordinance	1
	Carbon Credits	1
	Rolling Easement	1
	Land Reuse	1
Specific Habitat Management	Marshes	2
	Water Quality	2
	Wetlands	2
	Dunes	1
	Inlet Maintenance	1
	Invasive Species Management	1
	Oyster Reef	1
	Rookery Islands	1
	Sargassum	1
	Seagrass Conservation	1
	Soft Shoreline	1
Other	Acquisition	3
	Fresh Water Inflow	3
	Incentives	3
	Monitoring	3
	Restoration	3
	Drainage	2

Activity Type	Activity	Count
	Erosion Control	2
	Technology	1
	Xeriscaping	1
	Prioritized List Projects	1
	Litter	1
	Modeling (Geohazard)	1
	Economic Valuation	1
	Debris Management	1

Suggestions for the range and scope of activities to be included in the overall plan were determined by asking stakeholders 'what activities promote sustainable production of goods and services?' Forty-three potential activities were generated and divided into four categories; communication, regulatory / planning, specific habitat management and other activities (Table 8). There was consensual agreement that education was an important activity in promoting the sustainable production of goods and services. Three other activities, all categorized as regulatory/planning activities, also deemed important include the implementation of best management practices (BMP's), smart growth, and park space planning.

Several federal, state, city and other funding opportunities were identified in the EBMP workshop. Other sources of support for implementing activities were also identified (Brenner et al. 2009b). Many private and public barriers were identified that may hinder implementation of actions (Palmer et al. 2009). Over forty-five (45) potential partners from governmental, educational, non-profit and private organizations were identified as being potential partners in accomplishing the proposed activities in the EBMP.

<u>Workshop Two</u>

A second workshop titled: "Nueces Estuary Ecosystem Management Initiative: An Ecosystem Services Based Plan" was conducted on June 14, 2010. The overall goal of the second workshop was to obtain stakeholder input on valuing ecosystem services provided by habitats. Objectives of the second workshop were to:

1) Report results of the first workshop
2) Describe the preliminary management plan
3) Assess valuation of ecosystem services provided by habitats
4) Obtain feedback on scope and direction of the preliminary plan.

The second workshop started with a short presentation by Jace Tunnell, CBBEP project manager, describing the development of an ecosystem-based management plan that will direct habitat preservation, creation and/or restoration activities in the Corpus Christi/Nueces Bay area.

Next, Dr. Paul Montagna addressed the process involved in creating the Preliminary Management Plan, including initial meetings, the first workshop, and establishment of the project boundary.

Dr. David Yoskowitz presented information about ecosystem services. The concept of ecosystem services stems from the idea that humans are a part of the environment and receive numerous benefits from the environment. These benefits, known as ecosystem services, are the direct and indirect contributions made by the environment that impact human well-being. Ecosystem services are not accounted for in traditional “market” systems, yet these “non-market” services are no less valuable. The four general categories of ecosystem services established by the Millennium Ecosystem Assessment (MEA) are supportive, regulating, cultural and provisioning and encompass 24 ecosystem services (Millennium Ecosystem Assessment 2005).

Damion Scholz introduced the twelve (12) habitats to be assessed at the workshop and referred to habitat maps provided to workshop participants in both digital and paper form. Stakeholder input was obtained using surveys, which were explained in a presentation by Lauren Hutchison.

A total of fifty-seven (57) stakeholders attended the second workshop. Stakeholders represented agencies from the three main levels of government (local, state, and federal). Additionally, stakeholders represented both private and public organizations. The largest group of stakeholders represented academia (Figure 10).

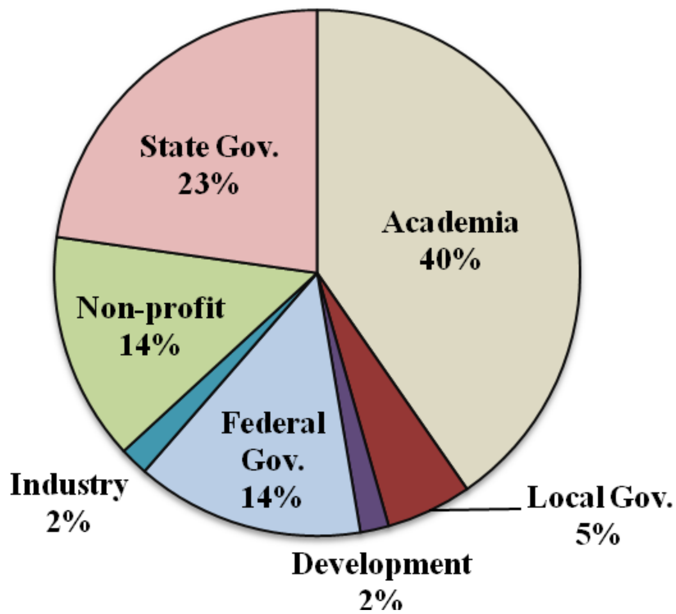

Figure 10. Percentage of stakeholders representing each stakeholder affiliation category.

Stakeholders were seated at eight tables. Each table had a workshop facilitator present (Table 9). The main job of the facilitator was to make sure everyone was aware of the process for filling out surveys and to report results from their table to the workshop participants and to the technical advisory team after the workshop. At the workshop, the facilitators tallied up the results for their table and put these results on a white board. Facilitators took notes on main topics discussed at this point and questions and/or concerns stakeholders brought up while completing surveys. These concerns were addressed at the workshop and are included in the Incorporation of Stakeholder Input section below.

Table 9. Workshop two group number, facilitator name, and organization represented.

Group	Facilitator	Organization
1	Leslie Adams	HRI
2	Sandra Arismendez	HRI
3	Lauren Hutchison	HRI
4	Terry Palmer	HRI
5	Carlota Santos	HRI
6	Damion Scholz	HRI
7	Jace Tunnell	CBBEP
8	Kathleen Welder	HRI

ECOSYSTEM SERVICE VALUATION OF HABITATS

The overarching objective of the EBMP is to guide decision-making through the use of ecosystem services (ES) as currency for prioritizing habitat management options. This section provides background information on what ES are, how they were assessed, and how the assessed ES were used to create a map of priorities called a 'heat map'.

Ecosystem Services

Ecosystem services (ES) are the direct or indirect contributions that ecosystems make to the environment and human populations (CEQ 2010). Ecosystem services analysis is highly multidisciplinary, involving ecologists, physical scientists, modelers, economists, and social scientists. Large volumes of research and data, as well as input from communities of stakeholders, are required. Despite the difficulties, ES evaluations can convey the full value of ecosystems in common units (monetary or otherwise) to decision-makers and help them understand the trade-offs involved in altering landscapes, whether for development, restoration, or other activities. A list of services, descriptions of those services and examples are provided in Table 10 (Farber et al. 2006).

The concept of ecosystem services is not new. Humans have enjoyed what the environment has provided for them for many millennia. However, 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 all humans benefited from the existence of wildlife and not just the sportsman (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). Much of the work that has moved ES into the mainstream began in the late 1990's and early 2000's with attempts to value the world's ES (Costanza et al. 1997) and the beginning of a stronger linkage between ecology and economics (Daily 1997; de Groot et al. 2002). The early work culminated in the Millennium Ecosystem Assessment (MA), which was initiated under the auspices of the United Nations in 2001 and lasted through 2006 with numerous technical reports, assessments, and final reports.

The foundation of concepts about ES that was laid in 1990s and 2000s and the work of the MA spurred an entirely new way we look at the management of our natural resources in light of the services they provide. For example, the EPA has initiated the Ecosystem Services Research Program with several place based study sites for the application of ES in decision making. The U.S. Department of Agriculture (USDA), and the Forest Service specifically, has recently opened the Office of Ecosystem Services and Markets in order to advance markets and payments for ecosystem services. Many other federal agencies as well as NGOs are incorporating ES into their agendas.

Table 10. Ecosystem services, description, and examples (Farber et al. 2006).

Ecosystem Service	Description	Example
Supportive Functions and Structure	Ecological structures and functions that are essential to the delivery of ecosystem services	
Nutrient Cycling	Storage, processing, and acquisition of nutrients within the biosphere	Nitrogen cycle; phosphorus cycle
Net primary production	Conversion of sunlight into biomass	Plant growth
Pollination and Seed Dispersal	Movement of plant genes	Insect pollination; seed dispersal by animals
Habitat	The physical place where organisms reside	Refugia for resident and migratory species; spawning and nursery grounds
Hydrological Cycle	Movement and storage of water through the biosphere	Evapotranspiration; stream runoff; groundwater retention
Regulating Services	Maintenance of essential ecological processes and life support systems for human well-being	
Gas Regulation	Regulation of the chemical composition of the atmosphere and oceans	Biotic sequestration of carbon dioxide and release of oxygen; vegetative absorption of volatile organic compounds
Climate Regulation	Regulation of local to global climate processes	Direct influence of land cover on temperature, precipitation, wind and humidity
Disturbance Regulation	Dampening of environmental fluctuations and disturbance	Storm surge protection; flood protection
Biological Regulation	Species interactions	Control of pests and diseases; reduction of herbivory (crop damage)
Water Regulation	Flow of water across the planet surface	Modulation of the drought-flood cycle; purification of water
Soil Retention	Erosion control and sediment retention	Prevention of soil loss by wind and runoff; avoiding buildup of silt in lakes and wetlands
Waste Regulation	Removal or breakdown of non-nutrient compounds and materials	Pollution detoxification; abatement of noise pollution
Nutrient Regulation	Maintenance of major nutrients within acceptable bounds	Prevention of premature eutrophication; maintenance of soil fertility
Provisioning Services	Provisioning of natural resources and raw materials	

Ecosystem Service	Description	Example
Water Supply	Filtering, retention, and storage of freshwater	Provision of freshwater for drinking; medium for transportation; irrigation
Food	Provisioning of edible plants and animals for human consumption	Hunting and gathering of fish, game, fruits, and other edible animals and plants; small-scale subsistence farming and aquaculture
Raw Materials	Building and manufacturing; Fuel and energy; soil and fertilizer	Lumber, skins, plant fibers, oils and dyes; Fuel wood, organic matter (ex: peat); Topsoil, frill, leaves, litter and excrement
Genetic Resources	Genetic Resources	Genes to improve crop resistance to pathogens and pests and other commercial applications
Medicinal Resources	Biological and chemical substances for use in drugs and pharmaceuticals	Quinine; Pacific yew; echinacea
Ornamental Resources	Resources for fashion, handicraft, jewelry, pets, worship, decoration and souvenirs	Feathers used in decorative costumes; shells used as jewelry
Cultural Services	Enhancing emotional, psychological, and cognitive well-being	
Recreation	Opportunities for rest, refreshment, and recreation	Ecotourism; bird-watching; outdoor sports
Aesthetic	Sensory equipment of functioning ecological systems	Proximity of houses to scenery; open space
Science and Education	Use of natural areas for scientific and educational enhancement	A natural field laboratory and reference area
Spiritual and historic	Spiritual or historic information	Use of nature as national symbols; natural landscapes with significant religious values

Ecosystem Services fall into four broad categories: Supportive functions and structures, regulating services, provisioning services, and cultural services. Supportive functions and structures are exactly that, they support the services in the other three categories that more directly make contributions that impact human well being. The other three services would not exist without stocks that combine with human built capital that then impact human well-being. Simply, if there is no natural capital, then there is no human well-being (Costanza et al. 1997).

Research and application of ES in the terrestrial environment has progressed at a faster rate than that of the coastal and marine environments. Coastal and marine ES are no less important than their terrestrial counterparts. In fact they are becoming more important as people are increasingly moving to coastal counties. Twenty-nine percent of the United State's population

(87 million) now lives in coastal counties and five of the top ten most populous cities are on the coast (Wilson and Fischetti 2010). In the Gulf of Mexico alone the population of coastline counties has grown 150 percent from 1960 to 2008 (Wilson and Fischetti 2010). These increased populations will place greater demand on ES while at the same time potentially affecting their supply as a result of development and overuse.

Ecosystem Services Surveys

The goal of the second workshop as described above was to obtain ES valuation data from stakeholders. The data was collected as responses from stakeholders on survey forms. The surveys addressed the following questions:

1) Which ecosystem services are provided by which habitats?

2) Which ecosystem services are most valued by stakeholders?

The first survey entitled "Habitats and Related Ecosystem Services Survey" was designed to answer the first question (Figure 11). This survey listed habitats as rows and ecosystem services as columns. Participants were asked to check off every ecosystem service a habitat provides. There were twenty-three (23) ecosystem services and twelve (12) habitats included on the survey. Stakeholders were provided with three supplements in order to complete the survey. The first supplement was a packet of color maps, each map representing one habitat within the Management Plan boundary. Additionally, a supplement describing ecosystem services by category including a description and example of each ecosystem service was provided (Table 10). The third supplement was a table that listed each habitat, the components of the habitat and species of interest within that habitat. Stakeholders were instructed to add information to the third supplement, if time permitted, by filling in specific ecosystem services provided by specific species.

The second survey entitled "Pair-wise Comparison Survey" was designed to address the second research question "Which ecosystem services are most valued by stakeholders?" (Figure 12). There are two important concepts that guided development of the pair-wise survey. First, a simple pair-wise comparison forces the respondent to choose between two ES for a habitat. Second, the technical advisory team was forced to make decisions as to which ES should be paired together for each habitat. The ES chosen were based on stakeholder input from workshop one and a priori knowledge.

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	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□

Figure 11. Habitats and Related Ecosystem Service Survey completed by stakeholders at second workshop.

Pair-wise comparison results can be used to obtain relative weights of ecosystem services. Methods for creating pair-wise comparisons were derived from publications addressing stakeholder analysis (Accorsi et al. 1999; Fichtner 1986; Hosseini and Brenner 1992). When comparing *n* number of services, there are [n(n-1)]/2 possible comparisons. Thus, because there are 23 ES, there are 253 possible pair-wise comparisons for each habitat. This extends to 3,036 possible combinations for all 12 habitats. This was an impossibly long survey. Thus, the goal in survey design was to have an equal number of pair-wise comparisons for each habitat and a survey that could be completed at workshop two in a short period of time.

At the first workshop, stakeholders were asked to identify ecosystem services provided by habitats. These suggestions, based on a compilation of stakeholder input, were used to develop a first draft of the pair-wise survey. Because these lists were incomplete and sometimes technically incorrect, we determined that only the top four or five ES for each habitat should be included in a survey. Therefore, the survey was finalized using expertise of the technical advisory team. To complete the survey, stakeholders were asked to estimate the relative importance of ecosystem services for each habitat.

Pair-wise Comparison of Ecosystem Services Provided by Habitats

Please estimate the relative importance of the ecosystem service on the left as compared with the ecosystem service on the right for each of the following habitats.

Circle the number associated with the value of each ecosystem service.

Freshwater Wetland Complex

	← More Important			|	More Important →			
	Extreme	Strong	Moderate	Equal	Moderate	Strong	Extreme	
Recreation	4	3	2	1	2	3	4	Soil Retention
Water Regulation	4	3	2	1	2	3	4	Recreation
Recreation	4	3	2	1	2	3	4	Waste Regulation
Water Supply	4	3	2	1	2	3	4	Recreation
Soil Retention	4	3	2	1	2	3	4	Water Regulation
Waste Regulation	4	3	2	1	2	3	4	Soil Retention
Soil Retention	4	3	2	1	2	3	4	Water Supply
Water Regulation	4	3	2	1	2	3	4	Waste Regulation
Water Regulation	4	3	2	1	2	3	4	Water Supply
Water Supply	4	3	2	1	2	3	4	Waste Regulation

Figure 12. Snapshot of first page of the "Pair-wise Comparison of Ecosystem Services" survey.

Incorporation of Stakeholder Input

Habitats included in the surveys were based on input from stakeholders at the first workshop (Palmer et al. 2009). Table 11 includes habitat names that were specifically mentioned at the first workshop and how they were aggregated into more concise habitat descriptions. These new habitats were assessed for inclusion in the ecosystem services surveys. Some of these habitats were eliminated from consideration for inclusion in surveys. Reasons for elimination included: broad nature of the terminology, habitat suggested is either not actually a habitat or is not accurately represented by available data and lack of presence in the EBMP area.

The habitats included in the surveys were: Live Oak Peninsula, Scrub-shrub, Park/Refuge, Dune, Beach, Flat, Salt Marsh Wetland, Freshwater Wetland, Seagrass Bed, Oyster Reef, Marine/Open Water and Rookery Island. There was confusion amongst many stakeholders related to three habitats: Park/Refuge, Scrub-Shrub and Live Oak Peninsula. Stakeholders also expressed concern regarding several issues. Some of these issues were expressed to the group, while others were discussed amongst table participants and facilitators. Some stakeholders stressed the importance of manmade structures (jetties, dams, channels, etc.) and agriculture (row crops and grazing) and were concerned by the fact that these entities were not included in the surveys. The HRI technical advisory team addressed these issues and came to the following conclusions.

Man-made structures and agriculture were not incorporated into the ecosystem services surveys because the purpose of the surveys was to establish ecosystem service values provided by natural habitats within the study area. Because manmade structures and agriculture are not part of the natural capital of the ecosystem they were not included in the creation of the heat map. However, manmade structures and agricultural areas are an important component of the landscape and will be addressed in the EBMP under the section titled "General Projects and/or Concerns.

For the same reason as above, the Parks/Refuge category was eliminated from the list of natural habitats and from survey analysis. Most of the parks within the study area are parks that are urbanized and heavily altered by man. Further, parks and refuges are geographic locations, not habitats. The natural habitats at these locations were still included in the surveys and thus were incorporated into the heat map. Additionally, some stakeholders expressed concern that grouping parks and refuges into one category made it difficult to assess ecosystem services on the surveys because heavily altered parks provide different ecosystem services than refuges.

Table 11. Habitats not included in the ecosystem services surveys and reason for decision.

Habitat	**Action**	**Reason for Action**
Whole System	eliminated	broad nature of terminology / not useful for spatial analysis
Atmosphere	eliminated	broad nature of terminology / not useful for spatial analysis
Basin	eliminated	broad nature of terminology / not useful for spatial analysis
Agriculture	eliminated	not a habitat
Live Oak		
Thorn Scrub		
Coastal Prairie		
Dune		
Park / refuge		
Beach		
Mangrove	*aggregated*	moved to scrub-shrub because of data accuracy
Flat		
Man made structure	eliminated	not a habitat
Platform in Bay	eliminated	not a habitat
Wetland	eliminated	broad nature of terminology
River delta	eliminated	broad nature of terminology / not useful for spatial analysis
Salt marsh wetland		
Freshwater wetland		
Riparian	*aggregated*	moved to Freshwater Wetlands
Near shore bar	*aggregated*	moved to Beach
Tidal inlet	eliminated	not a habitat
Open bay	*aggregated*	moved to Marine / Open Water
Reservoir	eliminated	lack of presence in Management Plan area
Seagrass Bed		
Oyster Reef		
Muddy Bottom / dredged channel	eliminated	not a habitat
Submerged dredged material	eliminated	not a habitat
Worm reef	eliminated	lack of presence in Management Plan area
River	*aggregated*	moved to Marine / Open Water
Barrier Island	eliminated	broad nature of terminology / not useful for spatial analysis
Rookery		
Subsurface Soil	eliminated	lack of relevance / not a habitat
Groundwater	eliminated	lack of relevance / not a habitat

There was also confusion amongst stakeholders regarding the definition of Scrub-shrub habitat. This confusion stemmed from a database issue. In some datasets scrub-shrub refers to the woody vegetation of wetlands, such as mangroves, and in other datasets scrub-shrub refers to mesquite-like vegetation in terrestrial settings. Within the EBMP boundary, the entire coastal habitat listed as scrub-shrub was in wetlands. Thus, the habitat should have been referred to as Scrub-shrub Wetland. These two habitats are very different and have different roles in the environment, thus they should have different associated ecosystem services. Because of the way in which some stakeholders may have interpreted the definition of scrub-shrub, the number of ecosystem services provided by the scrub-shrub wetland habitat may not accurately reflect the stakeholders' intentions. Additionally, because some stakeholders thought that mangroves were aggregated into salt marsh wetland habitat, and not into scrub-shrub wetland habitat, it is possible that the number of ecosystem services provided by salt marsh wetland habitat might have been different.

Finally, the Live Oak Peninsula category was mislabeled and should have been labeled Tree Canopy/Live Oak Motte. Again, the word peninsula is a geographic place not a habitat, and this word was mistakenly included in the description. This habitat includes all forested upland tree species. It is possible that stakeholders may have associated a different number of ecosystem services to the tree canopy/live oak habitat if it had not been mislabeled. All of these changes were incorporated into the methods moving forward.

There was also confusion amongst many stakeholders regarding a few ecosystem services. The definition for soil formation was accidently left off the ecosystem services supplement definition guide. Additionally, stakeholders wanted better examples of some of the ecosystem services listed. Some stakeholders specifically requested examples that were related to the coastal environment.

Ecosystem Services Provided by Habitats

The number of ecosystem services provided by habitats was determined based on the results of the "Habitats and Related Ecosystem Services Survey." For each habitat, a value for total number of ecosystem services provided to all stakeholders was calculated (Table 12). This value was divided by the total number of stakeholders in order to derive an average number of ecosystem services per habitat type. The percentage of stakeholders that perceived an ecosystem service was provided by a habitat was also determined (

Table 13). All stakeholders agreed that beach habitat provides a recreation ecosystem service. This was the only case in which all stakeholders agreed.

Freshwater and Salt Marsh Wetland habitats ranked highly, as they were perceived to provide the most ecosystem services to stakeholders. Rookery Island habitat was ranked the lowest of all habitats assessed (Table 14).

Table 12. Total number of stakeholders that perceive an ecosystem service is provided by a habitat (n = 53).

HABITAT	SUPPORTIVE ES					REGULATING ES								PROVISIONING ES						CULTURAL ES				
	Net Primary Production	Hydrological Cycle	Nutrient Cycling	Pollination & Seed Dispersal	Soil Formation	Water Regulation	Disturbance Regulation	Soil Retention	Waste Regulation	Nutrient Regulation	Gas Regulation	Biological Regulation	Climate Regulation	Food	Water Supply	Raw Materials	Genetic Resources	Medicinal Resources	Ornamental Resources	Recreation	Aesthetic	Science & Education	Spiritual & Holistic	**TOTAL**
Tree Canopy/ Live Oak Motte	44	41	37	44	34	36	42	47	27	29	44	28	49	21	19	37	19	11	23	40	49	47	36	804
Scrub-shrub Wetland	43	39	42	46	37	36	37	50	30	32	43	28	41	26	15	22	17	10	11	31	40	46	24	746
Dune	34	30	27	32	18	31	27	30	26	21	27	25	31	16	17	6	15	4	14	53	53	52	43	632
Beach	34	27	21	29	28	23	50	41	11	14	19	21	26	8	9	9	9	5	14	39	48	49	31	565
Flat	9	19	21	10	20	18	32	17	10	10	8	22	15	17	1	14	5	4	39	53	52	52	46	494
Salt Marsh Wetland	37	29	38	16	20	27	25	21	15	32	30	24	20	13	6	3	8	3	7	30	31	47	21	503
Freshwater Wetland	49	44	48	42	35	45	42	44	44	43	47	35	43	39	16	9	17	8	11	47	46	50	32	836
Seagrass Bed	50	50	49	43	37	52	42	43	46	46	47	36	42	36	47	11	15	9	9	47	47	49	30	883
Oyster Reef	50	16	46	28	30	23	29	37	26	42	35	30	20	38	5	4	16	4	6	42	30	48	19	624
Marine/ Open Water	15	12	43	3	18	28	37	25	35	36	14	30	8	52	6	36	16	7	32	39	23	47	22	584
Rookery Island	40	34	35	16	9	25	11	2	20	25	32	27	39	47	13	17	14	16	18	51	45	47	35	618

Table 13. Percentage of stakeholders that value ecosystem services provided by habitats.

HABITAT	SUPPORTIVE ES					REGULATING ES								PROVISIONING ES						CULTURAL ES			
	Net Primary Production	Hydrological Cycle	Nutrient Cycling	Pollination & Seed Dispersal	Soil Formation	Water Regulation	Disturbance Regulation	Soil Retention	Waste Regulation	Nutrient Regulation	Gas Regulation	Biological Regulation	Climate Regulation	Food	Water Supply	Raw Materials	Genetic Resources	Medicinal Resources	Ornamental Resources	Recreation	Aesthetic	Science & Education	Spiritual & Holistic
Tree Canopy/ Live Oak Motte	83	77	70	83	64	68	79	89	51	55	83	53	92	40	36	70	36	21	43	75	92	89	68
Scrub-shrub Wetland	81	74	79	87	70	68	70	94	57	60	81	53	77	49	28	42	32	19	21	58	75	87	45
Dune	64	51	40	55	53	43	94	77	21	26	36	40	49	15	17	17	17	9	26	74	91	92	58
Beach	17	36	40	19	38	34	60	32	19	19	15	42	28	32	2	26	9	8	74	100	98	98	87
Flat	70	55	72	30	38	51	47	40	28	60	57	45	38	25	11	6	15	6	13	57	58	89	40
Salt Marsh Wetland	92	83	91	79	66	85	79	83	83	81	89	66	81	74	30	17	32	15	21	89	87	94	60
Freshwater Wetland	94	94	92	81	70	98	79	81	87	87	89	68	79	68	89	21	28	17	17	89	89	92	57
Seagrass Bed	94	30	87	53	57	43	55	70	49	79	66	57	38	72	9	8	30	8	11	79	57	91	36
Oyster Reef	28	23	81	6	34	53	70	47	66	68	26	57	15	98	11	68	30	13	60	74	43	89	42
Marine/ Open Water	75	64	66	30	17	47	21	4	38	47	60	51	74	89	25	32	26	30	34	96	85	89	66
Rookery Island	43	26	47	58	30	17	45	43	9	30	32	58	30	13	2	8	26	6	34	85	85	91	51

Table 14. Habitats ranked based on average number of ecosystem services. Values have been rounded off to whole numbers.

Habitat	Average # 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
Flat	10
Beach	9
Rookery Island	9

The top four ecosystem services provided by each habitat were determined based on the total number of ecosystem services provided to stakeholders (Table 12). If there was a tie for fourth place, both ecosystem services were included in the top four. Thus, some habitats have five (5) ecosystem services listed in the top four (4). Cultural ecosystem services made up almost 50 percent of the top four ecosystem services provided by habitats and supportive and recreational ecosystem services each comprised between 20 and 30 percent. Provisioning ecosystem services made up only about 4 percent of the top ecosystem services provided by habitats (Figure 13). Marine/Open Water and Oyster Reef habitat were the only two habitats in which provisioning ecosystem services were in the top four. In both cases, food was the ecosystem service provided. Each habitat and the top four services provided are described below in descending order by number of ecosystem services provided.

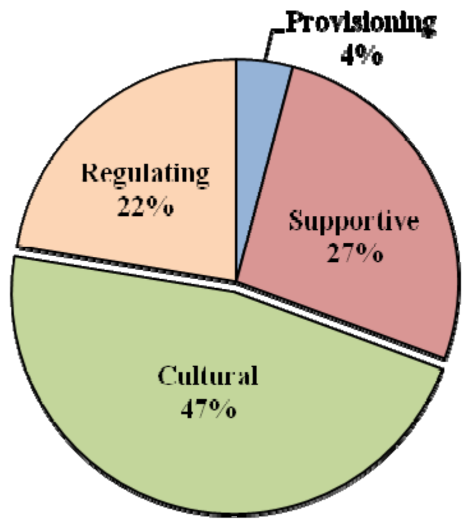

Figure 13. Percentage of each Ecosystem Service Category providing the top four ecosystem services for all habitats included in the EBMP.

Freshwater Wetland

Freshwater wetland habitat provides an average of approximately 17 out of 23 ecosystem services. The top ecosystem services provided by freshwater wetlands include water regulation, net primary production, hydrological cycle, science and education and nutrient cycling (Table 15).

Table 15. Top ecosystem services of Freshwater Wetland habitat.

Category	**Ecosystem Service**	**Stakeholder Rating**
Regulating	Water Regulation	1
Supportive	Net Primary Production	2
Supportive	Hydrological Cycle	2
Supportive	Nutrient Cycling	3
Cultural	Science & Education	3

Salt Marsh Wetland

Salt marsh wetland habitat provides an average of approximately 16 out of 23 ecosystem services to stakeholders. Top ecosystem services provided by salt marsh wetlands include science and education, net primary productivity, nutrient cycling, recreation and gas regulation (Table 16).

Table 16. Top ecosystem services of Salt Marsh Wetland habitat.

Category	Ecosystem Service	Stakeholder Rating
Cultural	Science & Education	1
Supportive	Net Primary Production	2
Supportive	Nutrient Cycling	3
Regulating	Gas Regulation	4
Cultural	Recreation	4

Tree Canopy/Live Oak Motte

Tree canopy/Live Oak Motte habitat provides an average of approximately 15 out of 23 ecosystem services to stakeholders. Top ecosystem services provided include climate regulation, aesthetic, science and education and soil retention (Table 17).

Table 17. Top ecosystem services of Tree canopy/Live Oak Motte habitat.

Category	Ecosystem Service	Stakeholder Rating
Regulating	Climate Regulation	1
Cultural	Aesthetic	1
Regulating	Soil Retention	2
Cultural	Science & Education	2

Scrub-shrub Wetland

Scrub-shrub Wetland habitat provides an average of approximately 14 ecosystem services to stakeholders. Top ecosystem services provided include soil retention, science and education, pollination and seed dispersal, net primary production and gas regulation (Table 18).

Table 18. Top ecosystem services of Scrub-shrub Wetland habitat.

Category	Ecosystem Service	Stakeholder Rating
Regulating	Soil Retention	1
Supportive	Pollination & Seed Dispersal	2
Cultural	Science & Education	2
Supportive	Net Primary Production	3
Regulating	Gas Regulation	3

Seagrass Bed

Seagrass Bed habitat provides an average of approximately 12 ecosystem services to stakeholders. Top ecosystem services include net primary productivity, science and education, nutrient cycling and regulation and recreation (Table 19).

Table 19. Top ecosystem services of Seagrass Bed habitat.

Category	**Ecosystem Service**	**Stakeholder Rating**
Supportive	Net Primary Production	1
Cultural	Science & Education	2
Supportive	Nutrient Cycling	3
Regulating	Nutrient Regulation	4
Cultural	Recreation	4

Marine / Open Water

Marine / Open Water habitat also provides an average of approximately 12 ecosystem services. Top ecosystem services provided include recreation, science and education, food and aesthetic. For the Marine / Open Water habitat, three of the top four services provided are cultural services (Table 20).

Table 20. Top ecosystem services of Marine / Open Water habitat.

Category	**Ecosystem Service**	**Stakeholder Rating**
Cultural	Recreation	1
Provisioning	Food	2
Cultural	Science & Education	2
Cultural	Aesthetic	3

Oyster Reef

Oyster Reef habitat provides an average of 11 out of 23 ecosystem services to stakeholders. Top ecosystem services provided include food, science and education, nutrient cycling and recreation (Table 21).

Table 21. Top ecosystem services of Oyster Reef habitat.

Category	**Ecosystem Service**	**Stakeholder Rating**
Provisioning	Food	1
Cultural	Science & Education	2
Supportive	Nutrient Cycling	3
Cultural	Recreation	4

Dune habitat

Dune habitat also provides an average of approximately 11 ecosystem services. Top services provided include disturbance regulation, science and education, aesthetic and soil retention (Table 22).

Table 22. Top ecosystem services of Dune habitat.

Category	Ecosystem Service	Stakeholder Rating
Regulating	Disturbance Regulation	1
Cultural	Science & Education	2
Cultural	Aesthetic	3
Regulating	Soil Retention	4

Beach

Beach habitat provides an average of approximately 9 ecosystem services. Top ecosystem services provided include recreation, aesthetic, science and education and spiritual and holistic. Beach is the only habitat in which the spiritual and holistic ecosystem service rated in the top 4 ecosystem services provided by a habitat (Table 23). All of the top four ecosystem services provided by Beach habitat are cultural ecosystem services.

Table 23. Top ecosystem services of Beach habitat.

Category	Ecosystem Service	Stakeholder Rating
Cultural	Recreation	1
Cultural	Aesthetic	2
Cultural	Science & Education	2
Cultural	Spiritual & Holistic	3

Flat

Flat habitat provides an average of between 9 and 10 ecosystem services to stakeholders. Top services include science and education, nutrient cycling, net primary production and nutrient regulation (Table 24).

Table 24. Top ecosystem services of Flat habitat.

Category	Ecosystem Service	Stakeholder Rating
Cultural	Science & Education	1
Supportive	Nutrient Cycling	2
Supportive	Net Primary Production	3
Regulating	Nutrient Regulation	4

Rookery Island

Rookery Island habitat provides the least number of ecosystem services, an average of less than 9, to stakeholders. Top ecosystem services provided include science and education, recreation, aesthetic, pollination and seed dispersal and biological regulation (Table 25). The top three ecosystem services provided by rookery islands are all cultural services.

Table 25. Top ecosystem services of Rookery Island habitat.

Category	Ecosystem Service	Stakeholder Rating
Cultural	Science & Education	1
Cultural	Recreation	2
Cultural	Aesthetic	2
Supportive	Pollination & Seed Dispersal	3
Regulating	Biological Regulation	3

Heat Map of Ecosystem Services

Habitats were assigned values based on results from the Habitats and Related Ecosystem Services Survey (Figure 11). The average number of ecosystem services per habitat type was calculated and used to create a heat map of ecosystem services within the EBMP area (Figure 14). Dark blue represents lowest average number of ecosystem services and dark red represents highest average number of ecosystem services. Thus, dark red signifies "hot" areas on the "heat map".

GIS Methods

Creating the heat map consisted of seven steps:

1) Creating sub-regions

2) Acquiring datasets

3) Aggregating data into the EBMP habitats

4) Converting habitats to raster files

5) Calculating weights of each habitat

6) Performing weighted sum overlay operation to habitat raster files

7) Finalizing the raster mosaic

Each step is explained within the following subsections 1 - 7.

1. Creating sub-regions. Sub-regions were created using the 12-digit hydrological unit code (HUC) polygons obtained from the USDA Geospatial Data Gateway. These HUC polygons were used as a guide to establish internal boundaries based on the prominent features they encompass. Prominent features were used to name the sub-regions in a manner easily recognizable to stakeholders and future project coordinators. Because prominent natural features are the defining characteristic of each sub-region, some of the HUC polygons were merged to prevent the splitting of these features.

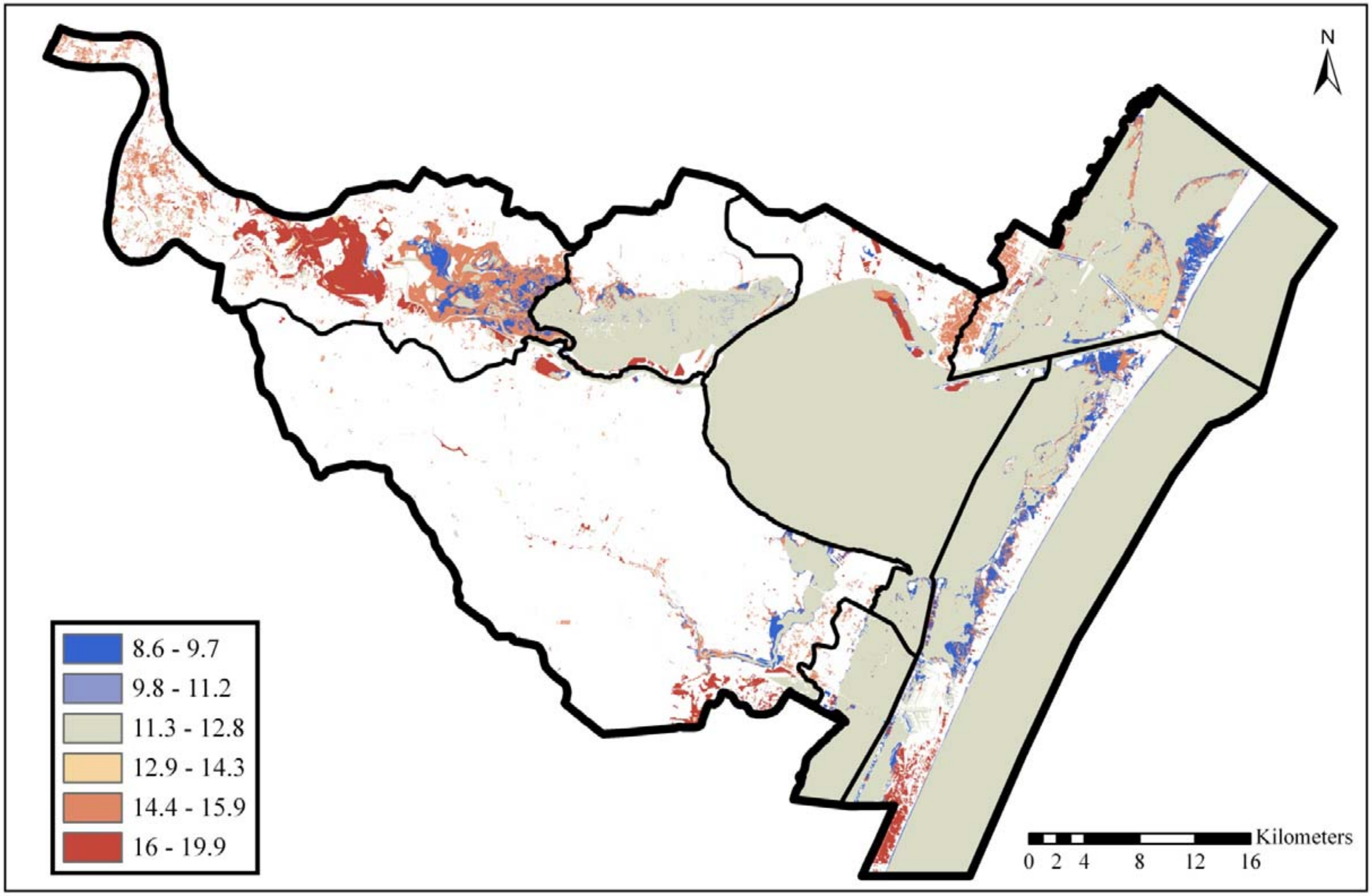

Figure 14. Heat map of average number of ecosystem services provided by habitats within the EBMP area.

2. Acquiring datasets. Several data sources were considered to represent habitats. These were:

- National Wetland Inventory (NWI) data
- NOAA benthic habitat data
- USGS land cover data
- CBBEP Rookery Island dataset

The 2004 NWI dataset was selected because of its high resolution (1 meter) and because it was the most current dataset available that covers most habitats assessed. For our purposes, this dataset has some limitations:

- It does not cover the entire EBMP area
- There are many disclaimers regarding the data and its accuracy in representing water habitats, such as oyster reefs and seagrass beds
- It does not include the terrestrial habitats, such as tree canopy/live oak motte and it does not include rookery island data

To address the data limitations, the areas within the EBMP area, not covered by the NWI 2004 data, were filled in with the NWI 1992 data. Some areas in the Gulf of Mexico were filled in with the open water data from the NWI 1992 dataset (Figure 15). Additionally, the major areas filled in with NWI 1992 data are: the Redfish and Aransas Bays sub-region (Figure 16), the western half of the Nueces River and Delta sub-region (Figure 17), much of the Upper Laguna Madre sub-region (Figure 18), a small portion of the southern part of the Oso Bay and Creek sub-region near the Upper Laguna Madre (Figure 19), and additional small areas in the western section of Oso Creek sub-region (Figure 20).

The NOAA benthic dataset (2006) was considered for incorporation into the analysis to better represent the oyster reef and sea grass bed habitats in the EBMP area. However, the incorporation of many datasets is complicated and can lead to overlap errors. Because of various technical difficulties, this dataset was not incorporated into analysis. However, with greater resources, time and effort, these technical problems can likely be resolved.

Rookery island data was obtained from the CBBEP and was used to represent the rookery island habitats.

The USGS land cover dataset (2001) was used to represent the tree canopy/live oak motte habitat. The USGS land cover data is at a different resolution (30 meter) than the NWI dataset (1 meter).

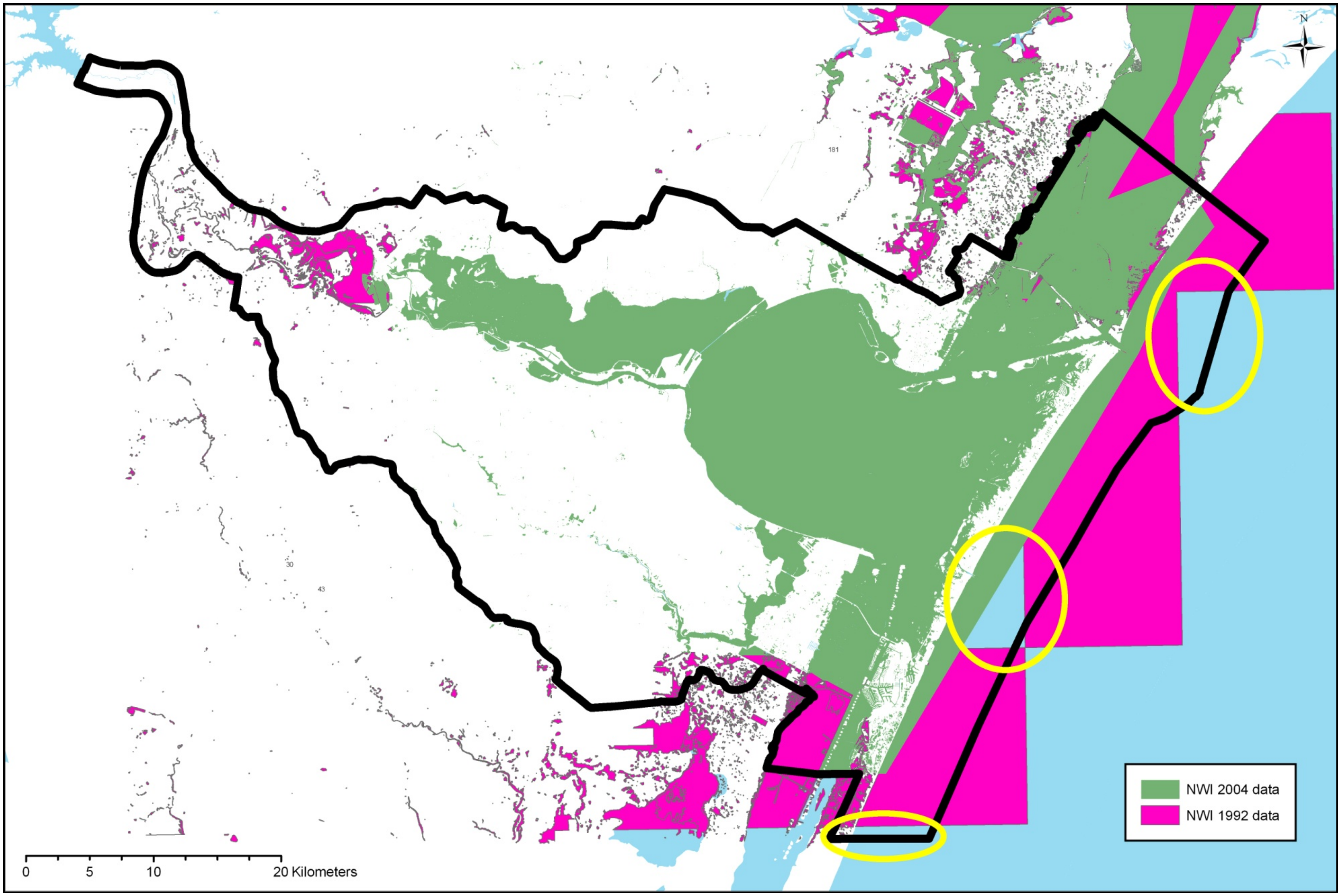

Figure 15. NWI 2004 Data gaps in the EBMP area.

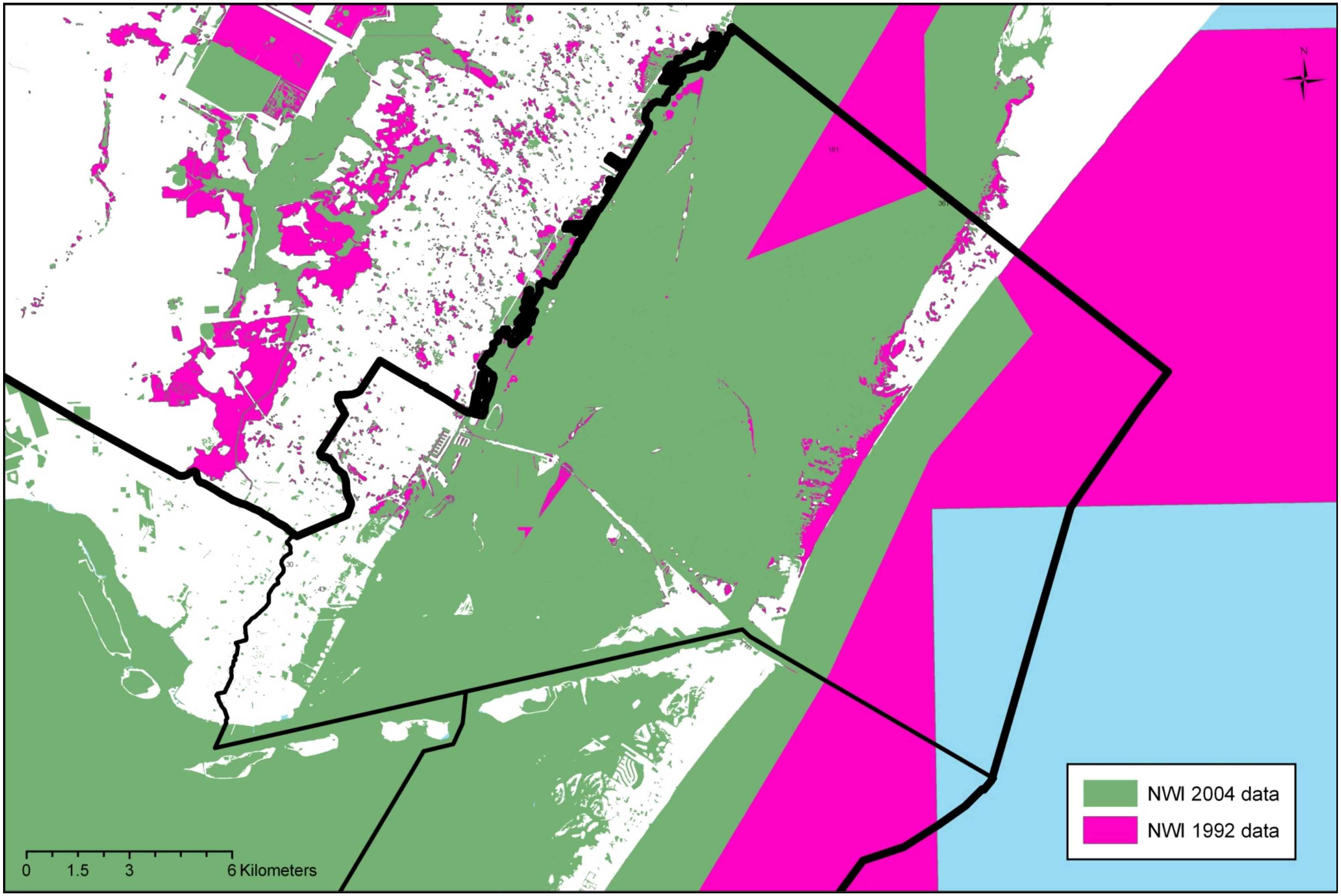

Figure 16. NWI 2004 Data gaps in the Redfish and South Aransas Bays sub-region. Pink areas had to be filled in with 1992 data.

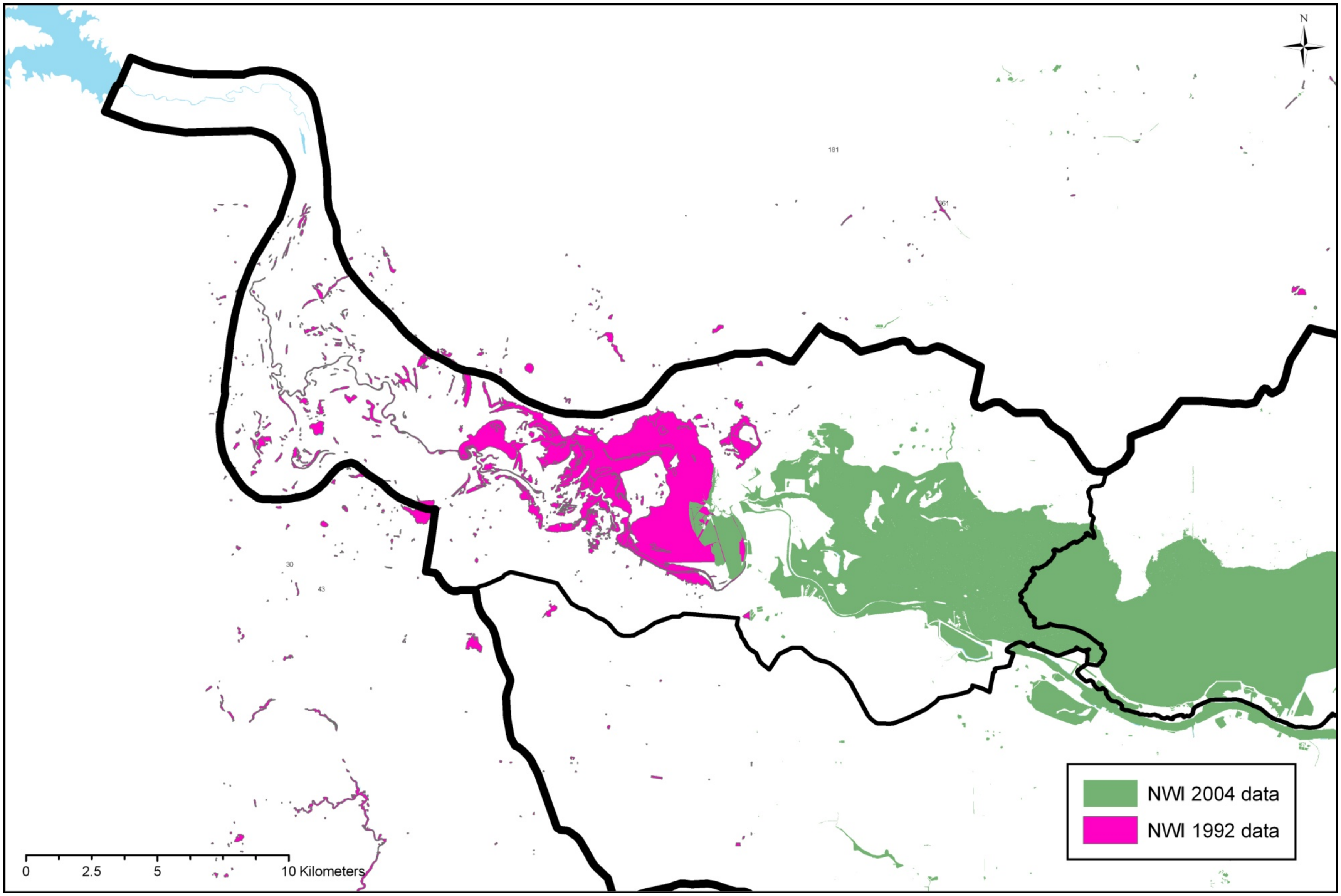

Figure 17. NWI 2004 Data gaps in the Nueces River and Delta sub-region. Pink areas had to be filled in with 1992 data.

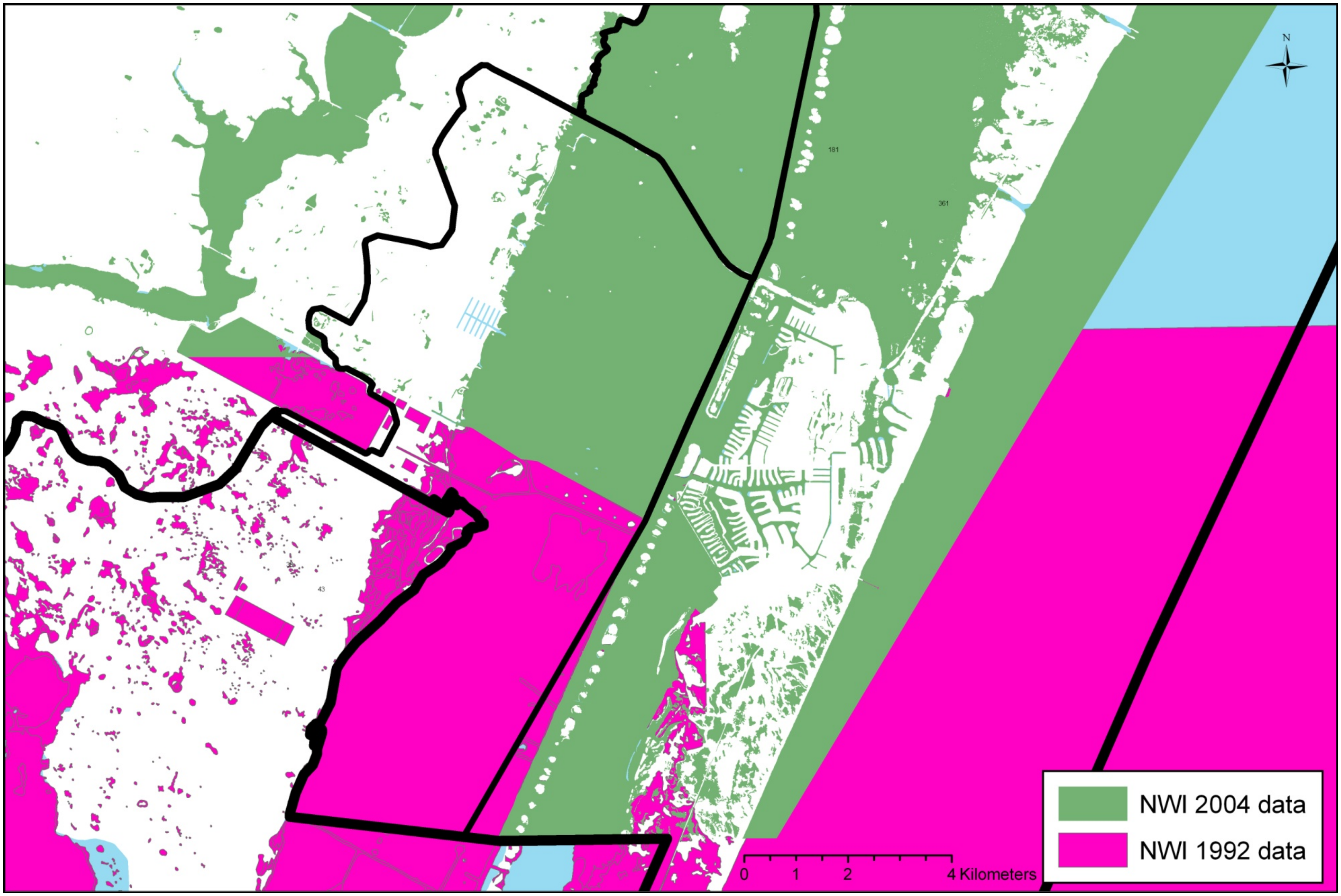

Figure 18. NWI 2004 Data gaps in the Upper Laguna Madre sub-region. Pink areas had to be filled in with 1992 data.

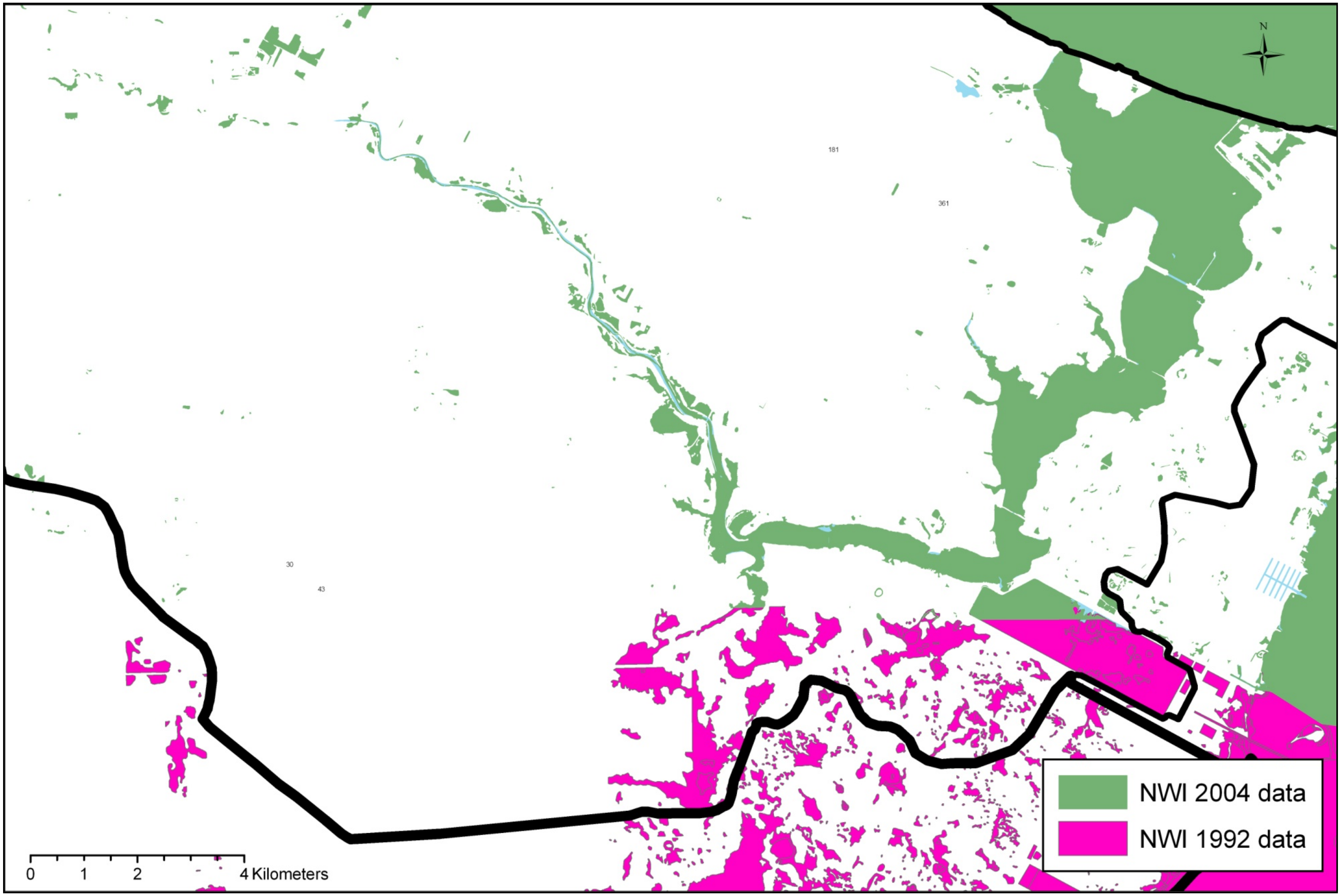

Figure 19. NWI 2004 Data gaps in the Oso Bay and Creek sub-region. Pink areas had to be filled in with 1992 data.

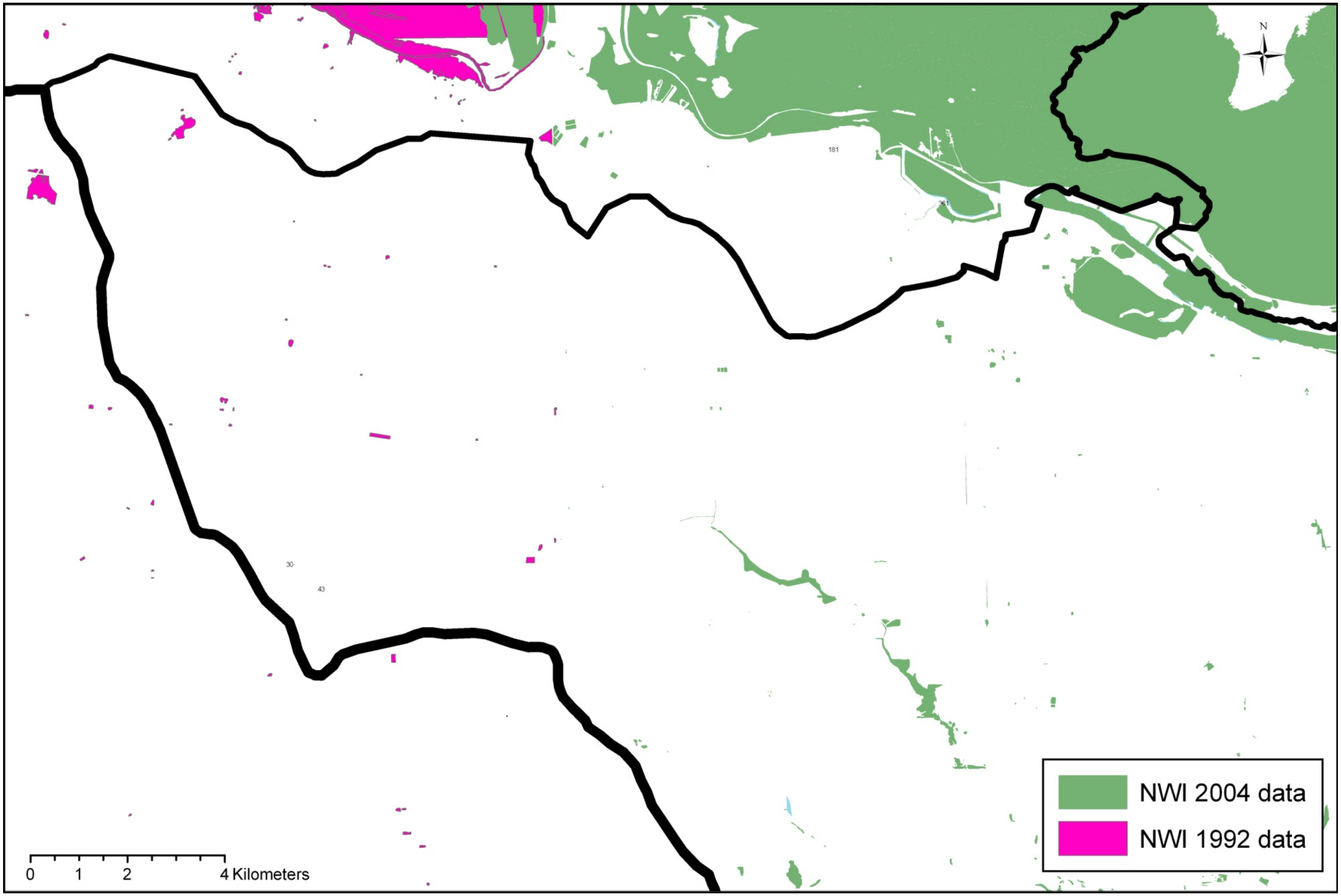

Figure 20. NWI 2004 Data gaps in the northwestern portion of Oso Bay and Creek sub-region. Pink areas filled in with 1992 data.

In order to incorporate the USGS land cover dataset into the framework used to assess all other habitats, a false one meter raster file was created. Because of the difference in scale, the area of this habitat is potentially overrepresented on the heat map (Figure 14).

Aggregating data into the Management Plan habitats. Habitat datasets were aggregated using a prioritization tool developed by NOAA called the Habitat Priority Planner (HPP). The HPP was run as an extension of ArcINFO. Each habitat dataset in need of aggregation was aggregated separately.

NWI 2004 dataset. The NWI 2004 dataset was mapped by the University of Texas, Bureau of Economic Geology. Mapping was based on color infrared aerial photographs from 2002-2004 (White et al. 2006, Tremblay et al. 2008). The Corpus Christi area of the data was mapped using National Agriculture Imagery Program (NAIP) georectified color infrared aerial photographs at a scale of 1:5,000. The dataset contains 51 habitat categories that are relevant to the study area, and these habitat classifications were aggregated into nine habitat categories including: Beach, Dune, Flat, Freshwater Wetland, Marine/Open Water, Oyster Reef, Salt Marsh Wetland, Scrub-shrub Wetland and Seagrass Bed. The dune, beach, and oyster reef habitats required no aggregation and were simply renamed for consistency. Scrub-shrub Wetland, Marine/Open Water, Flat, and Seagrass Bed were aggregated by name because the EBMP name was a component of the NWI 2004 name. For example, scrub shrub broad leaved evergreen and scrub shrub were aggregated into Scrub-shrub Wetland.

The Salt Marsh Wetland habitat was aggregated based on Cowardin's classification system (Cowardin et al. 1979), a commonly used wetlands and deepwater habitats classification system (White et al. 2006). The Salt Marsh Wetland habitat is by definition an estuarine classification. Salt marsh wetlands are tidal ecosystems that are usually semi-enclosed by land and have varying salinities due to freshwater runoff and evaporation (Moulton and Dall 1998). In this regard, and through visual clarification, the salt marsh wetland habitat was an aggregate of the NWI 2004 categories of high marsh, reef, algae, high marsh on spoil, low marsh, low marsh on spoil, and aquatic bed floating vascular semi-permanently flooded.

The fresh water wetlands habitat was represented in the NWI 2004 dataset by palustrine and lacustrine classifications. The remaining NWI 2004 habitat classifications of seasonally flooded marsh diked / impounded, temporarily flooded, temporarily flooded drained or ditched, semi-permanently flooded marsh excavated, semi-permanently flooded, seasonally flooded, and marsh seasonally flooded drained or ditched were included in the freshwater wetland priority habitat through visual inspection and adjacent habitat categories.

NWI 1992 dataset. The NWI 1992 dataset, mapped by the USFWS, was delineated from 1992-1993 aerial photography of various scales. The NWI 1992 dataset contains 13 habitat categories that are relevant to the study area. These include: estuarine marsh, estuarine shrub, shrub wetland, mangrove marsh, algal vegetation, floating vegetation, submerged vegetation, bald cypress forest, palustrine marsh, forested wetland, open water, flats (mud/sand), and impounded area. These NWI 1992 habitat classifications were aggregated into the Management Plan habitat categories: Flat, Freshwater Wetland, Marine / Open Water, Salt Marsh Wetland, Scrub-Shrub Wetland and Seagrass Bed. The NWI 1992 dataset followed Cowardin's classification system, as did the NWI 2004 dataset. Thus, the process of aggregating NWI 1992 habitats follows a similar process used in aggregating NWI 2004 habitat data.

NOAA Benthic Habitats dataset. The NOAA benthic habitats dataset was processed using 2004 NAIP digital multi-spectral imagery at a one meter resolution in coordination with the TPWD and the Texas A&M University-Corpus Christi, Center for Coastal Studies. This dataset was considered for incorporation into the Management Plan because it was developed to more accurately represent Seagrass Bed habitat. The Seagrass Bed and Oyster Reef datasets included in this study also support the state's Seagrass Monitoring program. In this regard, the Seagrass Bed and Oyster Reef NWI 2004 priority habitats were replaced with the NOAA data while the NOAA priority habitats. For aggregation, the NOAA habitat category of bivalve reef was renamed Oyster Reef as this name is considered more familiar to stakeholders. Continuous submerged rooted vegetation (SRV) and patchy SRV were aggregated into a single Seagrass Bed priority habitat. Unfortunately, because of overlap topology errors this dataset was removed from the analysis for the final heat map.

USGS Land cover dataset 2001. The USGS 2001 land cover dataset was used to extract tree canopy/live oak motte data. Tree Canopy/Live Oak Motte data was extracted from the deciduous forest attribute classification.

CBBEP Rookery Island data. Rookery Island data were acquired from David Newstead of the CBBEP. No aggregation was necessary for this habitat type.

4. Converting habitats to raster files. All Management Plan habitats, except for Tree Canopy/Live Oak Motte habitat, were represented in vector format and converted to raster format. Conversion from vector to raster format consisted of three steps:

Step 1: Extent Raster Creation

The extent of the EBMP area was used to define the extent of the habitat rasters. The Management Plan boundary shapefile was converted to a raster file with decimal values removed. This was done because no raster in this study had a resolution higher than one meter.

Step 2: One Meter Resolution Raster Files

Before raster conversion of the habitats, each habitat was extracted from its respective HPP generated feature class into a feature dataset. A field was created for each habitat feature class called "VALUE" and all were assigned a value of one. This was done through a batch process using Arc Toolbox. Habitats required a one meter resolution to prevent data loss.

Step 3: No Data Values Reclassified as Zero.

Once the habitat rasters were created, a batch process was run in which the values of each raster were reclassified to change no data values to zero. This reclassification created raster files that had a value of one if the habitat fell within a one meter cell and zero if the habitat did not.

5. Calculating stakeholder weights of each habitat. Results from the Habitats and Related Ecosystem Services Survey were then incorporated into the habitat rasters. The average number of ecosystem services per habitat type was the value used as the unit of weight for the weight sum overlay calculation.

6. Performing weighted sum overlay operation to habitat raster files. Using a python script, the value of a habitat was automatically added as an attribute to the habitat raster. This was done for all habitat rasters. With values added to the habitat raster files, the Arc tool weighted sum overlay was run for each grid to produce a score raster in the form of a heat map.

7. Finalizing the raster mosaic. Because small subsets were created for each habitat raster, to allow for efficiency in the creation of rasters, the raster subsets then had to be combined into a mosaic. To accomplish this, the raster files were exported into a raster catalog. This raster catalog formed a mosaic of the raster files which was then exported in the IMAGINE format, standardizing the visual representation of values.

INVENTORY AND PRIORITIZATION OF AREAS FOR PROTECTION/RESTORATION/CREATION

Introduction of the Sub-regions

The sub-regions included in the EBMP are Nueces River and Delta, Nueces Bay, Corpus Christi Bay, Redfish and South Aransas Bays, Mustang and North Padre Islands, Upper Laguna Madre and Oso Bay and Creek (Figure 21).

Information about each sub-region is provided below including a brief introduction to the sub-region, a series of maps, habitat assessments, priority areas and future activities. Maps created for each sub-region include a habitat map, heat map of priority areas based on ecosystem services, and heat maps incorporating specific locations mentioned by stakeholders at the first workshop, permitted wastewater outfalls and USFWS habitat data for the federally endangered piping plover, *Charadrius melodus*. In some sub-regions, one or more of these maps does not exist due to lack of relevant data for that specific sub-region. Further, there are numerous threatened and endangered species, other than the piping plover, within the EBMP area. However, spatial data could not be obtained for these species and thus was not incorporated into the heat map. A list of threatened and endangered species, by county, can be found on the TPWD's website at www.tpwd.state.tx.us/landwater/land/maps/gis/ris/endangered_species/.

Existing concerns, current assets and future activities were established by stakeholders at the first workshop. Ecosystem services provided by habitats were established by stakeholders at the second workshop. Areas can be prioritized based on gains and losses of habitats and input from stakeholders. The gains and losses of habitats information is primarily based on wetland status and trends reports produced by Tremblay et al. (2008) and White et al. (2006). Input from stakeholders is included for each sub-region. Stakeholders identified existing concerns, future activities and current assets. Prioritization of areas for protection/restoration/creation based on ES is difficult because ecosystem service knowledge gaps exist. Knowledge related to ecosystem service trade-offs, both temporally and spatially, is needed to make effective management decisions. Therefore, it is suggested that research be conducted related to ES trade-offs. In the meantime, it is suggested that management decisions be made based on a precautionary principle, in which assets are protected until more informed decisions can be made. Effective decisions are ones in which benefits greatly outweigh costs. Thus, choosing to protect umbrella ecosystem services (services that encompass many other ES) is an effective way to manage until more information is available (Daily 2000). An example of an umbrella ES is water quality, which encompasses other ecosystem services, such as nutrient regulation and cycling, waste regulation, soil retention, and in some cases even aesthetic and recreation.

Stakeholder input and ecosystem service data were used to create heat maps and analyzed in GIS in an effort to prioritize areas. Buffers of 0.3 km were created around all point data. Zonal statistics were extracted from the heat map and average number of ecosystem services was calculated for these buffered areas. Areas with higher average number of ecosystem services were prioritized over areas with lower average number of ecosystem services.

These topics, discussed in detail for each sub-region, should be used cohesively to guide decision-making concerning potential protection/conservation/restoration projects.

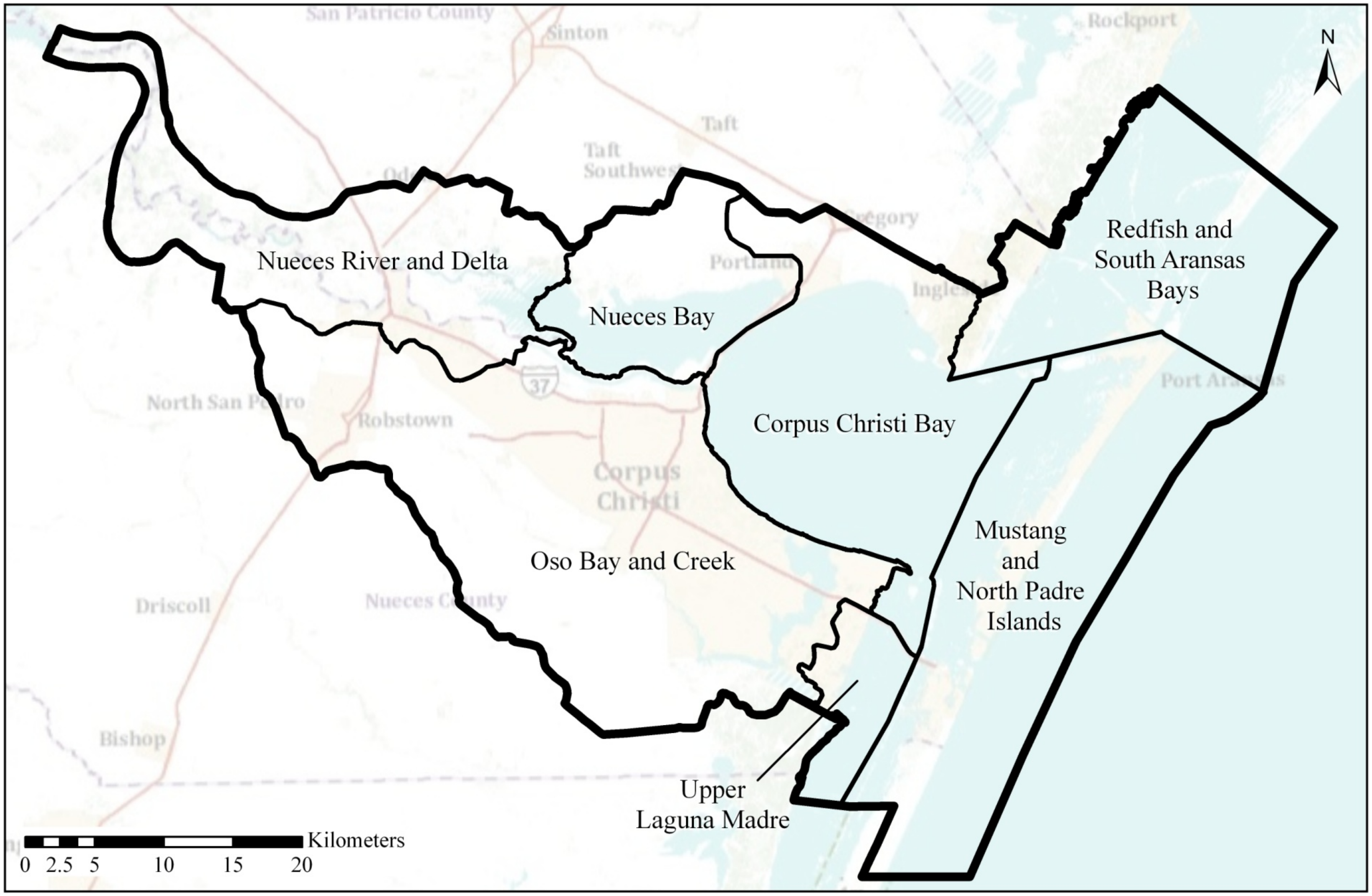

Figure 21. EBMP sub-regions: Nueces River and Delta, Nueces Bay, Corpus Christi Bay, Oso Bay and Creek, Upper Laguna Madre, Mustang and North Padre Islands, and Redfish and South Aransas Bays.

Status and Trends of Habitats

Two reports describe changes in habitat coverage within the EBMP area from the 1950's to the mid 2000's: Status and trends of inland wetland and aquatic habitats in the Corpus Christi area and Status and trends of wetland and aquatic habitats on barrier islands, Coastal Bend (White et al. 2006 and Tremblay et al. 2008).

The status and trends reports were summarized and included in the EBMP for each sub-region under a section entitled Gains and Losses of Habitats. The information within these status and trends reports was also summarized for the entire EBMP area (Table 26). The status and trends reports address changes in habitats by dividing large areas into smaller areas called geographic areas. The intersections between EBMP sub-regions and these geographic areas were determined using GIS (Figure 22). The percentage of EBMP sub-region area that status and trends geographic areas comprise was then calculated in GIS (Table 26). Several trends in habitat change are documented in the EBMP area. Throughout the study area, seagrass habitat is either stable or increasing, marine/open water habitat is increasing, and flat habitat is stable or decreasing. Beach habitat is also decreasing. It should be noted that the habitat categories within the EBMP and the status and trend reports do not always represent the same classification system. For example, the status and trends reports include scrub-shrub wetland in the both freshwater and salt marsh wetland habitat. In the EBMP, scrub-shrub wetland was defined as a separate habitat from freshwater and salt marsh wetland habitat. Further, in the status and trends reports, oyster reef habitat was not assessed by geographic area; dune, tree canopy/live oak motte and rookery island habitats were not assessed at all.

Table 26. Summary of status and trends of habitats in the EBMP area based on Status and Trends reports (White et al. 2006 and Tremblay et al. 2008).

EBMP Sub-region	% of EBMP Sub-region Covered by Status & Trends Reports	Status and Trends Geographic Area (# on map)	% of EBMP Sub-region Covered by Status & Trends Geographic Area	Freshwater Wetland	Salt Marsh Wetland	Tree Canopy/ Live Oak Motte	Scrub-shrub Wetland	Seagrass Bed	Marine/ Open Water	Oyster Reef	Dune	Flat	Beach	Rookery Island
Nueces River Delta	43	Coastal Prairie (2)	18.6	↓	↑									
		Nueces River Delta (1)	24.8	↓	↓				↑			=		
Nueces Bay	100	Coastal Prairie (2)	48.4	↓	↑									
		Nueces River Delta (1)	8.8	↓	↓				↑			=		
		CC Bay & Estuary (3)	42.8		↑			↑				↓		
Corpus Christi Bay	100	Coastal Prairie (2)	11.6	↓	↑									
		Port Bay (5)	2.4	↓	↑			↑				↓		
		Live Oak Ridge & Peninsula (4)	5.2	↓	↑			=				↓		
		CC Bay & Estuary (3)	80.7		↑			↑				↓		
Mustang & North Padre Islands	61	Mustang Island (6)	49.5		↑			↑				↓	↓	
		North Padre Island (7)	11.6	↑				↑				↓	↓	
Oso Bay & Creek	80	Encinal Peninsula & Oso Creek (8 & 9)	10	=	↑			↑				↓		
		Coastal Prairie (2)	67.3	↓	↑									
		CC Bay & Estuary (3)	1.5		↑			↑				↓		
		Nueces River Delta (1)	1.1	↓	↓				↑			=		
Redfish & South Aransas Bay	77	Redfish Bay (10)	22.8		↑			=				↓		
		Harbor Island (11)	19.5		↑			↑	↑			↓		
		San Jose Island (12)	24.2	↑	↑			↑				↓	↓	
		Live Oak Ridge & Peninsula (4)	10.8	=	↑									
Upper Laguna Madre	66	CC Bay & Estuary (3)	42		↑			↑				↓		
		Encinal Peninsula (8)	16.2	=	↑									
		North Padre Island (7)	8	↑				↑				↓	↓	

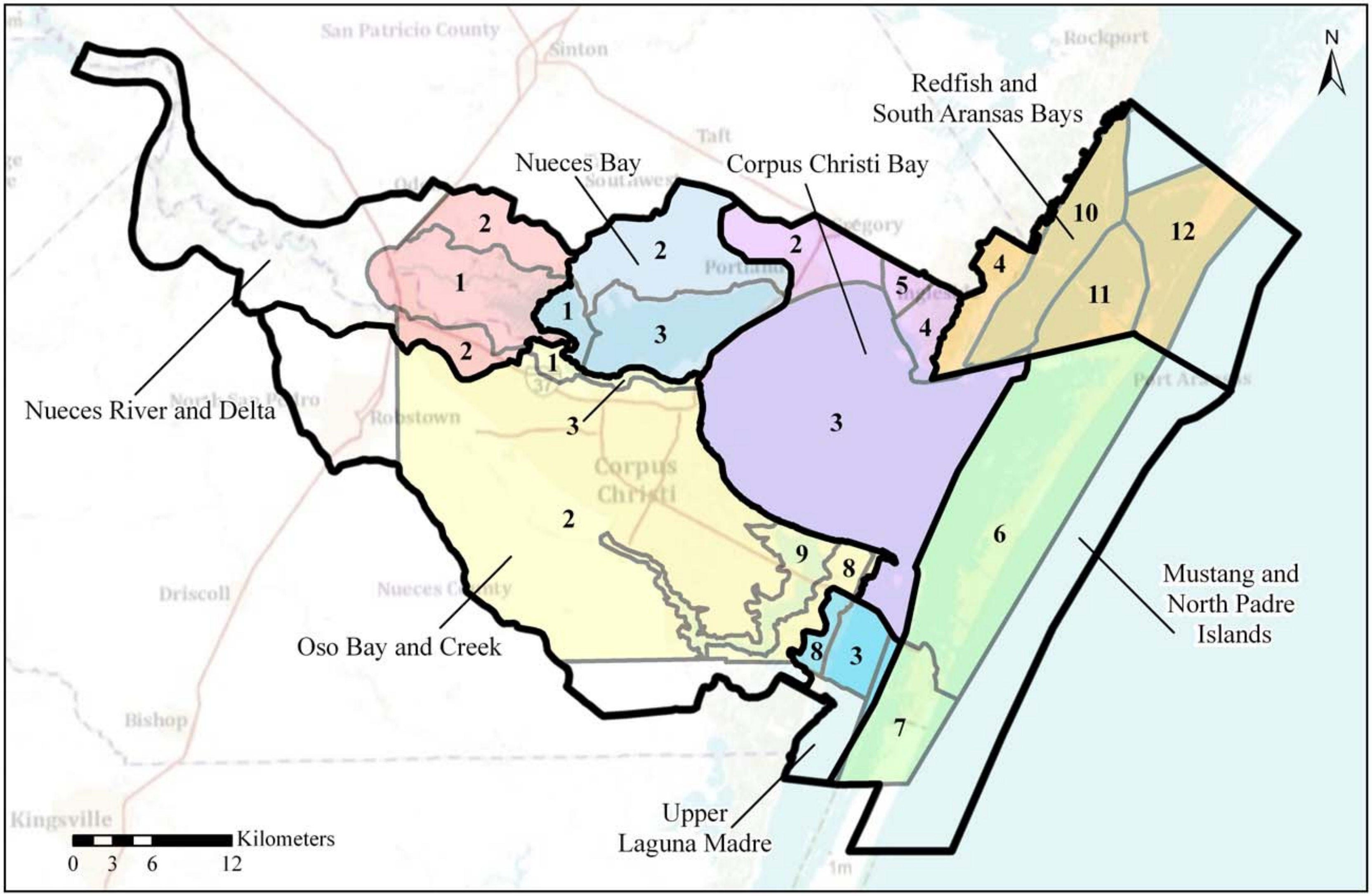

Figure 22. Geographic areas (#s) from Status and Trends reports. Colors represent area of each EBMP sub-region represented by geographic areas of Status and Trends reports. See Table 26 for details.

Nueces River and Delta Sub-region

The Nueces River and Delta sub-region is within the Nueces River Watershed and encompasses the Nueces River and Delta. The Nueces River empties into Nueces Bay below the delta. Rincon Bayou is a creek connecting the tidal segment of the Nueces River to the delta during flood events. The bayou runs down the main stem of the Nueces Delta. The Nueces River provides drinking water for the City of Corpus Christi and the surrounding Coastal Bend area.

The northwestern edge of the boundary borders the Wesley Seale Dam. The Wesley Seale Dam impounds Lake Corpus Christi. This reservoir, along with the Choke Canyon Reservoir, controls almost all of the flow from the Nueces River Basin and regulates freshwater inflow into the Nueces Estuary (Montagna et al. 2009).

The Nueces River Basin Reconnaissance Study conducted by the Army Corps of Engineers is a useful resource for both characterizing this sub-region and developing restoration projects (*http://www.swf.usace.army.mil/pubdata/notices/nueces_river_study.asp*).

Three maps were created for the Nueces River and Delta sub-region: habitats within the sub-region (Figure 23), a heat map of habitats within the sub-region (Figure 24), and a heat map including locations of outfalls and permitted discharges within the sub-region (Figure 25).

Habitat Assessment

Habitats within the Nueces River and Delta sub-region include: Scrub-shrub Wetland, Freshwater Wetland, Salt Marsh Wetland, Marine/Open Water, Flat, Rookery Island, Tree Canopy/Live Oak Motte and Seagrass Bed (Figure 23).

The Nueces River flows into Nueces Bay and is the major form of freshwater inflow into the Nueces estuary (Tremblay et al. 2008). Historically the Nueces River Delta receives two pulses of freshwater inflow events per year, in May and September. The Nueces River supports palustrine emergent marshes and forested wetlands (Smith et al. 1997). There are extensive estuarine emergent wetlands on the Nueces River Delta and at the mouth of the Nueces River (Tremblay et al. 2008). Tidal mats and algal mats are also extensive on the Delta (Tremblay et al. 2008).

Priority Areas and Justification of Priorities

All of the priority issues with the Nueces River and Delta sub-region (Table E2) can be addressed by protecting/conserving land in the Nueces Delta, including riparian habitat along the river. ES within all four categories will be protected by protecting this land. Protected ES include nutrient cycling and regulation, water supply and regulation, recreation and aesthetic values. Priority areas, based on number of ecosystem services, include the central and northern portion of the Nueces Delta.

Gains and Losses of Habitats

Between the 1950's and 2004, palustrine marsh habitat experienced the greatest losses on the Delta (Tremblay et al. 2008). Estuarine marsh is extensive in the Nueces River Delta, but nevertheless, decreased between the mid 1950's and 2004 (Tremblay et al. 2008). Estuarine flat habitat area has remained stable in that same time period, but the spatial distribution has changed drastically (Tremblay et al. 2008).

Stakeholder Areas of Interest and Concern

Existing concerns and current assets were addressed by stakeholders at the first workshop (Brenner et al. 2009b). Habitats mentioned within the Nueces River and Delta sub-region include wetland and riparian habitats.

Ecosystem Services

Stakeholder valuation of ecosystem services was used to create a heat map for the Nueces River Delta sub-region (Figure 24). Freshwater wetland habitat provides the highest number of ecosystem services of all habitats assessed and the largest expanse of freshwater wetlands in the EBMP area is found within the Nueces River and Delta sub-region. Large expanses of salt marsh wetland habitat also exist within the Nueces River and Delta sub-region and provide a high number of ecosystem services.

Table 27. Existing concerns and current assets in the Nueces River and Delta sub-region.

Reason for inclusion	**Information provided by Stakeholders**	**Further Description**
Current assets	Coastal Bend Bays & Estuaries Program	Erosion control
Existing concern	High diversity of wetland types	Submerged vegetation Birds Nursery for fish Water quality Fresh water inflow
Existing concern	Riparian bottom land and palmetto	Unique due to recreation and water quality
Existing concern	Erosion control	
Existing concern	Fresh water inflow	
Existing concern	Nursery grounds	
Existing concern	Nutrient source to bays, Gulf of Mexico	
Existing concern	Riparian habitat	Limited resource

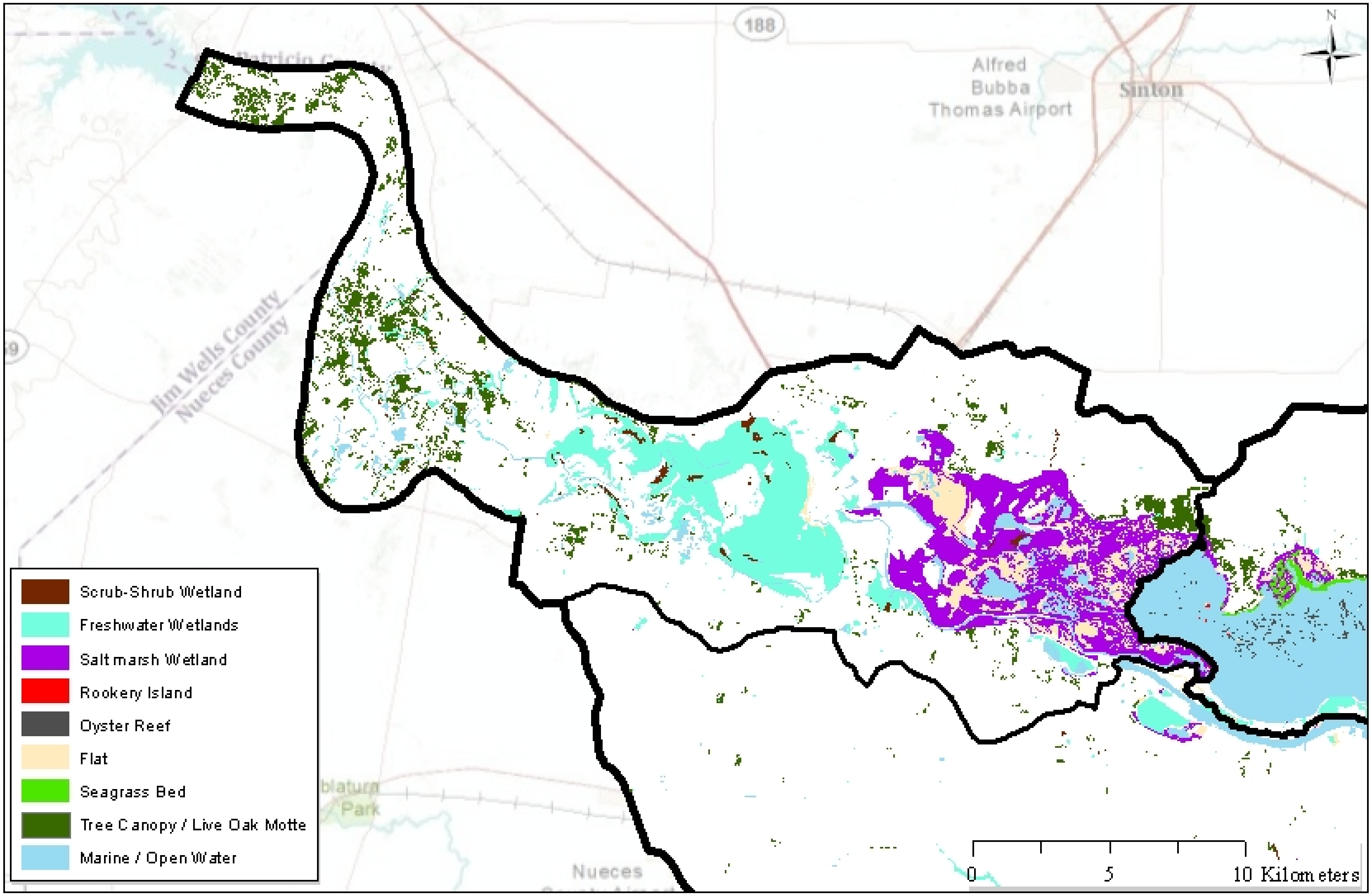

Figure 23. Nueces River and Delta sub-region habitat map.

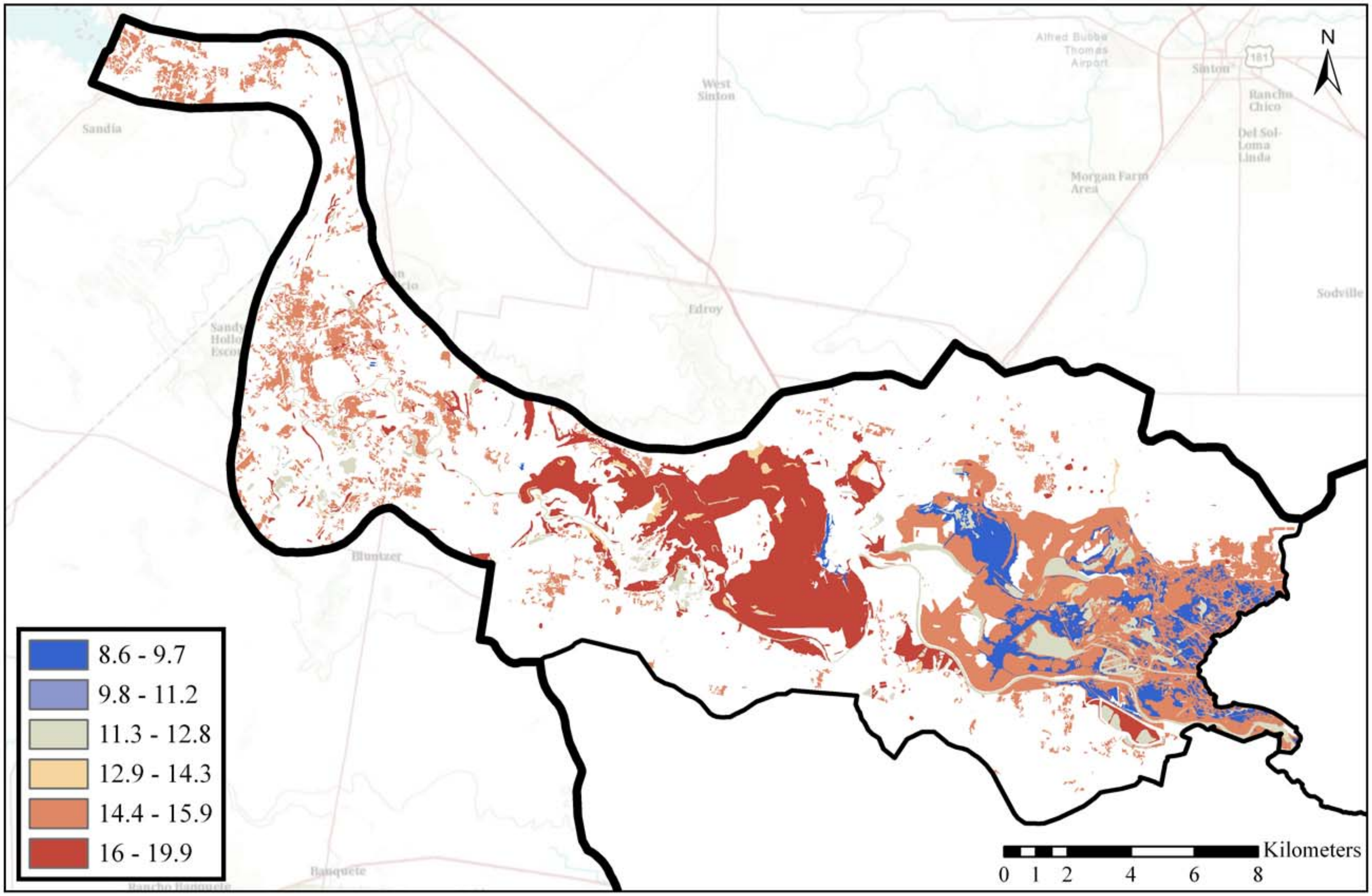

Figure 24. Nueces River and Delta sub-region heat map representing average number of ecosystem services provided by habitats.

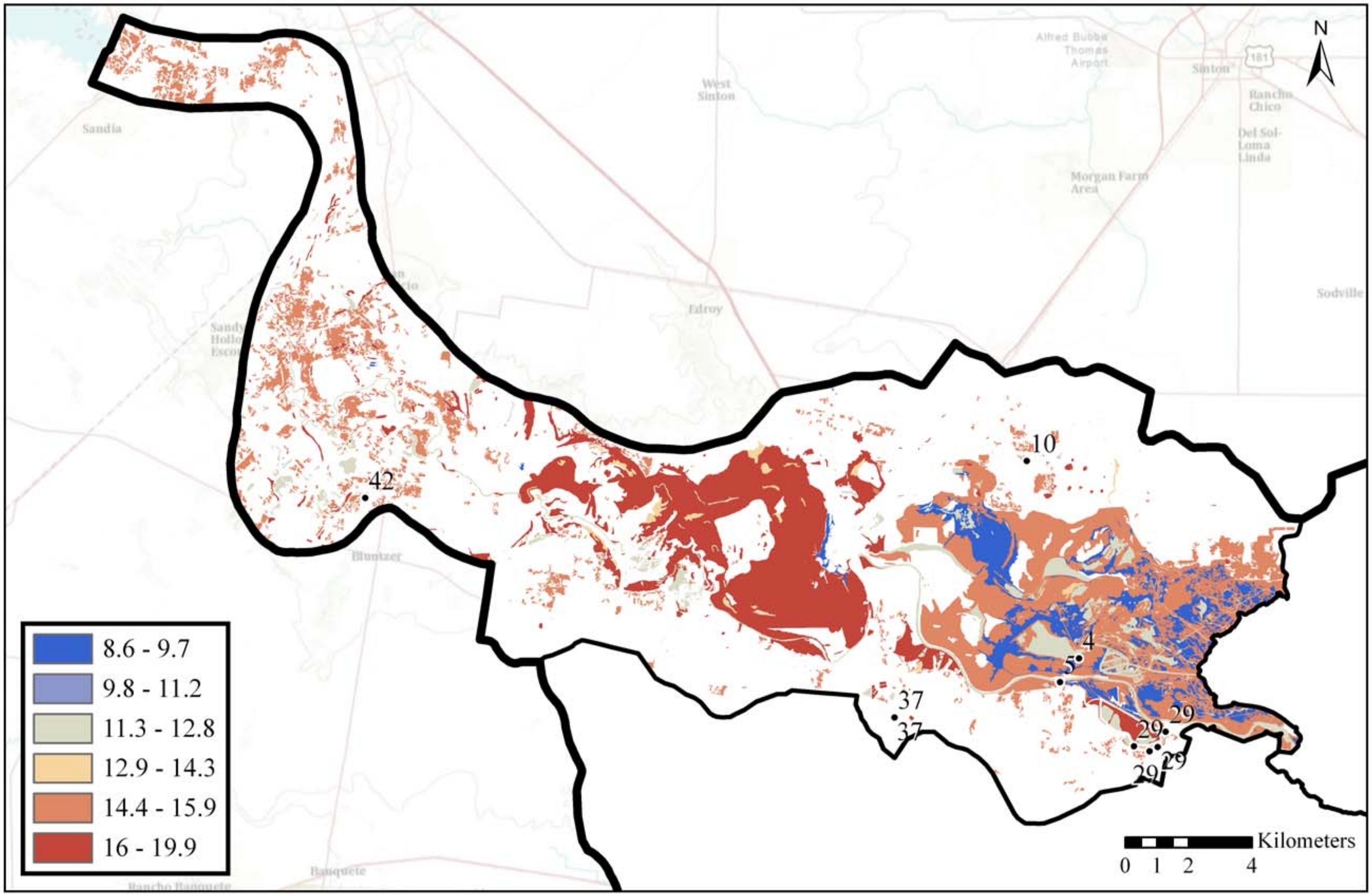

Figure 25. Nueces River and Delta sub-region heat map including permitted wastewater outfall sites.

Ten (10) permitted wastewater discharge points exist within this sub-region (Figure 25). Average number of ecosystem services provided was determined for a buffer zone surrounding permitted wastewater outfalls (Table 28). The area directly surrounding the outfall of permit entity #4 was determined to provide the highest average number of ecosystem services. The area directly surrounding the outfalls of permit entity #37 was determined to provide no ecosystem services (Figure 25).

Future Activities

Future activities for inclusion in the EBMP were suggested by stakeholders at the first workshop (Palmer et al. 2009). Activities related to potential projects within the Nueces River and Delta sub-region include: educational facilities, erosion control, improved freshwater inflows, water reuse, riparian habitat enhancements, and sediment management. Other future activities include: river clean-ups, land runoff monitoring, river water quality monitoring and kayak access.

Table 28. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Nueces River and Delta sub-region.

Permit Entity #	Mean	Min	Max	Range
4	13.68	0.00	16.53	16.53
5	8.20	0.00	15.81	15.81
29	5.55	0.00	16.53	16.53
29	4.27	0.00	16.53	16.53
29	2.47	0.00	16.53	16.53
29	1.73	0.00	16.53	16.53
42	0.97	0.00	13.70	13.70
10	0.07	0.00	16.53	16.53
37	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00

Nueces Bay Sub-region

The Nueces Bay sub-region includes Nueces Bay and a large area of land, mostly agricultural, north of the bay. The area north of the Port of Corpus Christi is also included within this sub-region. The Nueces Bay Causeway separates the Nueces and Corpus Christi Bay sub-regions. The Nueces River discharges to Nueces Bay at the southwestern boundary of the sub-region.

Four maps were created for the Nueces Bay sub-region: habitats within the sub-region (Figure 26), a heat map of habitats within the sub-region (Figure 27), a heat map with locations of permitted wastewater outfalls (Figure 28), and critical habitat for the federally endangered piping plover (Figure 29).

Habitat Assessment

Habitats within the Nueces Bay sub-region include: Marine/Open Water, Seagrass Bed, Salt marsh Wetland, Oyster Reef, Freshwater Wetland, Flat, Rookery Island, Tree Canopy/Live Oak Motte and Scrub-Shrub Wetland (Figure 26).

Areas along the northern shoreline of Nueces Bay contain estuarine emergent wetlands and seagrasses (Smith et al. 1997). Flats and oyster reefs also occur along the shores of Nueces Bay (Tremblay et al. 2008).

Priority Areas and Justification of Priorities

Several of the priority issues within the Nueces Bay sub-region (Table E2) can be addressed by protecting land that water flows over before it gets to the Nueces Bay, including the Nueces River Delta.

Gains and Losses of Habitats

The Nueces Bay sub-region is characterized by the loss of tidal flat and marsh habitat. The area and shoreline north of the Nueces River and the Tule Lake Channel has been highly modified by humans (Tremblay et al. 2008). Losses of tidal flat habitat in the area north of Tule Lake Channel have been attributed to infilling (Tremblay et al. 2008). Marsh loss, attributed to erosion and relative sea-level rise, has occurred at Indian Point and along the shoreline of Nueces Bay (Tremblay et al. 2008).

Stakeholder Areas of Interest and Concern

Current assets and existing concerns within the Nueces Bay sub-region, including four specific locations, were addressed by stakeholders at the first workshop (Table 29 and Table 30). Habitats specifically mentioned include: seagrass bed, oyster reef and rookery islands.

There are four permitted wastewater outfalls within the Nueces Bay sub-region (Figure 28). Average number of ecosystem services provided was determined for a buffer zone surrounding permitted wastewater outfalls (Table 31). The area directly surrounding the outfall of permit entity #36 was determined to provide the highest average number of ecosystem services. The area directly surrounding the outfall of permit entity #17 was determined to provide the lowest average number of ecosystem services (Figure 28).

Table 29. Current assets and existing concerns within the Nueces Bay sub-region.

Reason for Inclusion	**Information provided by Stakeholders**	**Further Description**
Current assets	Sunset Lake Park	Wetlands Bird habitat
Current assets	Pending CBBEP Marsh Restoration	
Existing concern	Oyster Reefs	Largest extent of oyster reefs in the area Limited Resource
Existing concern	Gum Hollow Watershed	Often neglected Freshwater inflow
Existing concern	Wildlife Corridor	Protects drainage
Existing concern	Seagrass	Redhead ducks
Existing concern	Agriculture runoff	
Existing concern	Open shoreline	
Existing concern	Rookery islands	
Existing concern	Shoreline erosion	

Table 30. Specific locations in the Nueces Bay sub-region mentioned by stakeholders.

Reason for Inclusion	**Information provided by Stakeholders**
Specific Location	Area north of north Nueces Bay causeway
Specific Location	Gum Hollow
Specific Location	North side of bay
Specific Location	Port of Corpus Christi

Table 31. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Nueces Bay sub-region.

Permit Entity #	**Mean**	**Min**	**Max**	**Range**
36	9.97	0.00	16.53	16.53
15	7.65	0.00	15.81	15.81
13	6.60	0.00	15.81	15.81
17	0.74	0.00	16.53	16.53

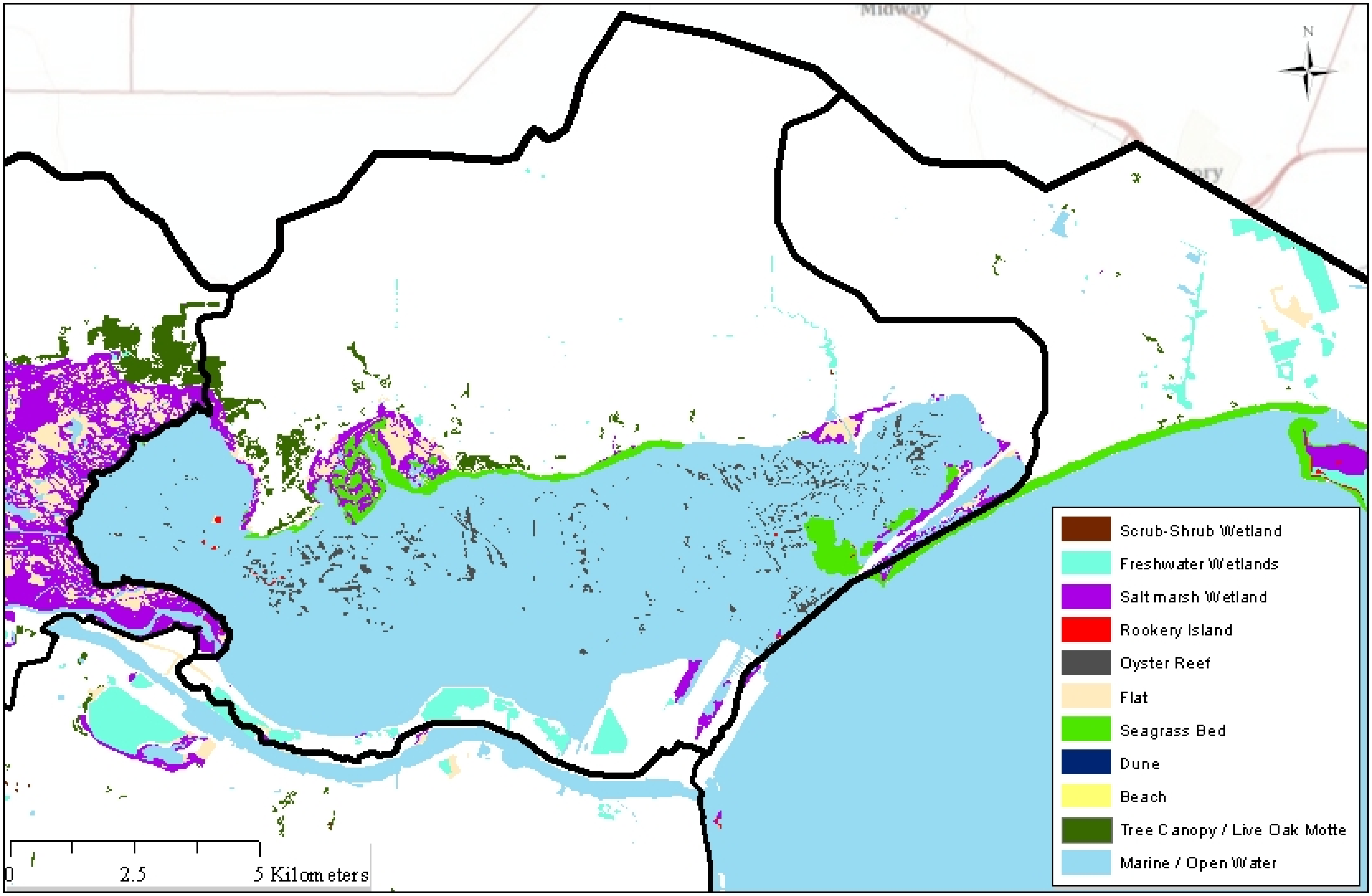

Figure 26. Nueces Bay sub-region habitat map.

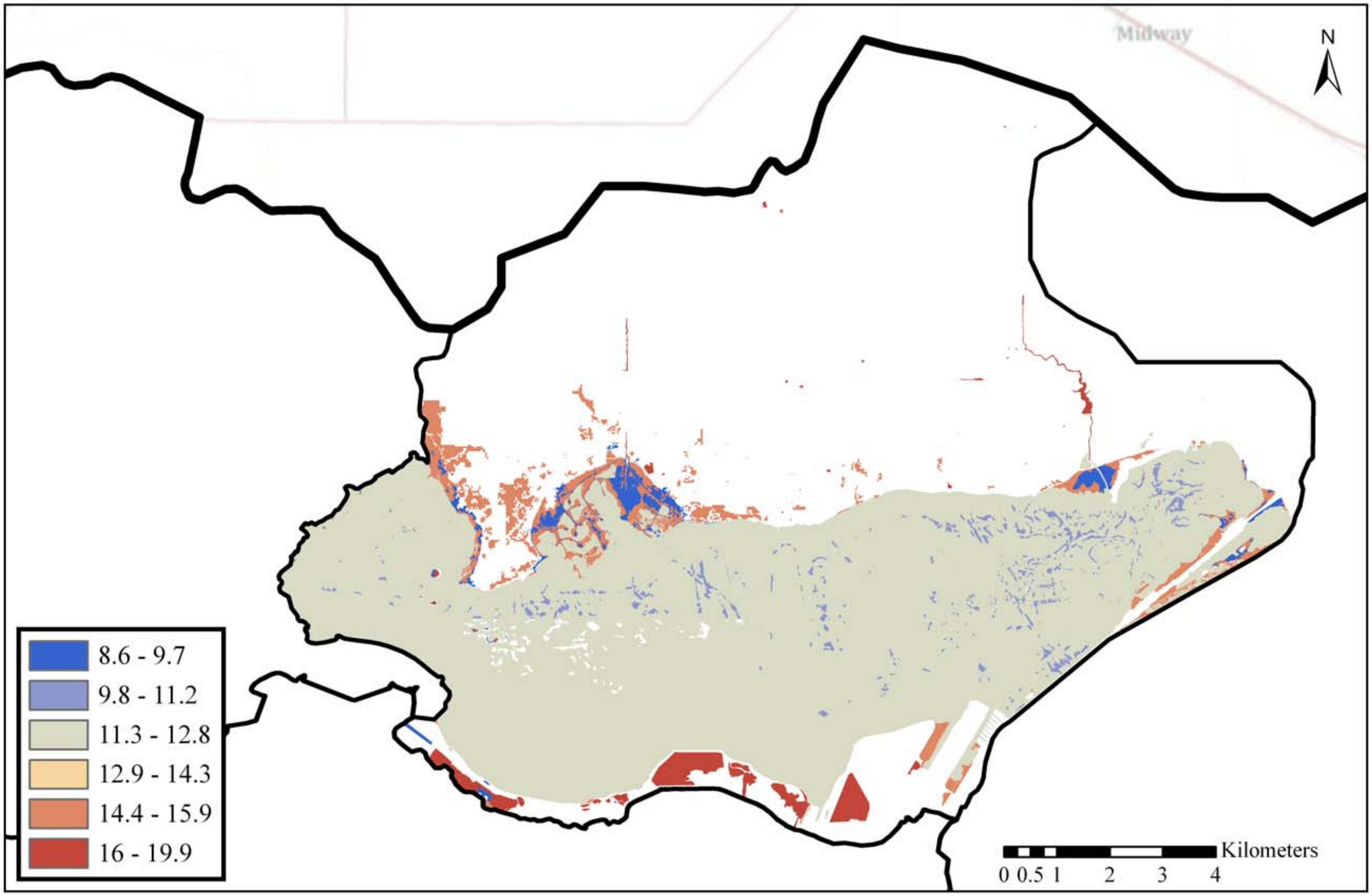

Figure 27. Nueces Bay sub-region heat map representing average number of ecosystem services provided by habitats.

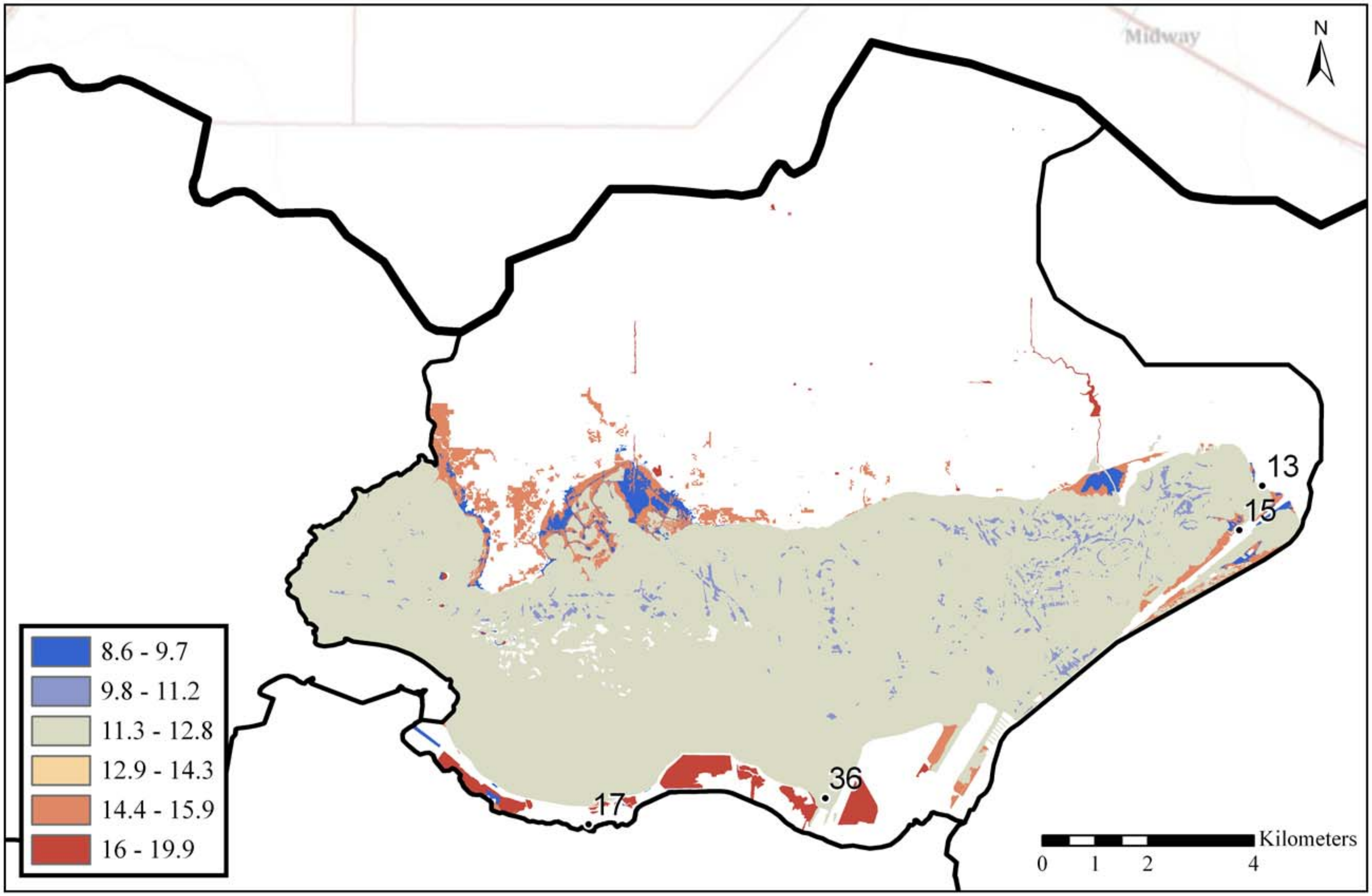

Figure 28. Nueces Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites.

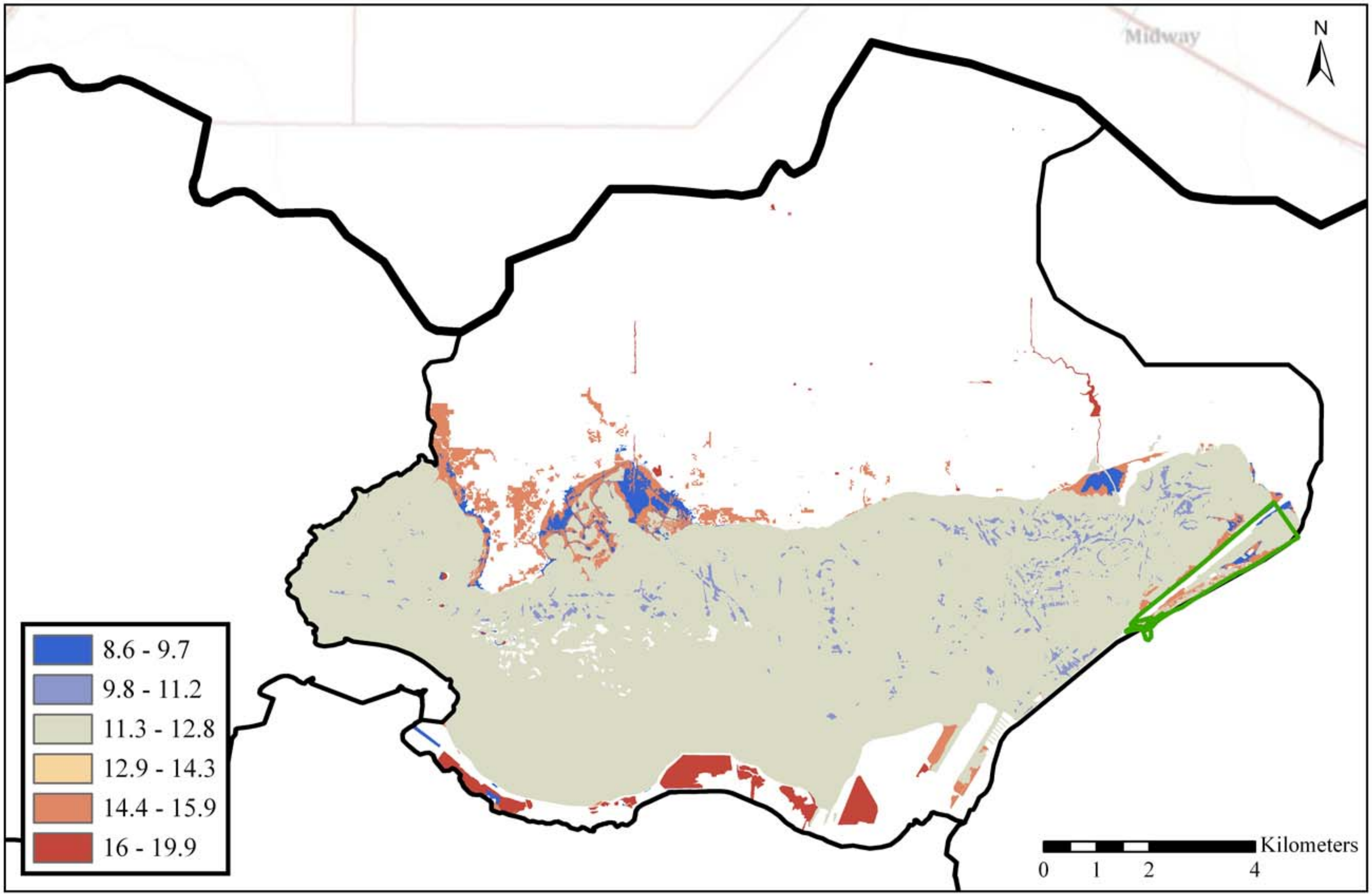

Figure 29. Nueces Bay sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover

Ecosystem Services

Stakeholder valuations of ecosystem services determined at the second workshop were used to create a heat map for the Nueces Bay sub-region. The heat map created for the Nueces Bay sub-region reflects high numbers of ecosystem services in areas such as Gum Hollow Creek and the northern and southern Nueces Bay shoreline (Figure 27).

The area near the Nueces Bay Causeway is also represented as having high ecosystem service value on the heat map (Figure 27). Also, according to USFWS data, some of this area provides critical habitat for the federally endangered piping plover (Figure 29).

Another area to consider for potential restoration/conservation projects is the area north of the Tule Lake Channel. This area is in close proximity to the Port of Corpus Christi, contains land that provides a high number of ecosystem services to stakeholders and contains two permitted wastewater outfalls (Figure 28).

Future Activities

Future activities for inclusion in the EBMP were suggested by stakeholders at the first workshop. Activities suggested by stakeholders related to potential projects within the Nueces Bay sub-region include: erosion control, creation and raising of rookery islands with dredge material, bird habitat enhancement and/or acquisition and planned marsh creation.

Corpus Christi Bay Sub-region

Access to the Port of Corpus Christi, the nation's 6th largest port, is attained through the Corpus Christi Ship Channel that extends across Corpus Christi Bay. The Corpus Christi Ship Channel is dredged at depths exceeding 15 meters. Corpus Christi Bay is the deepest bay within the EBMP area.

Shoreline retreat is an active geologic process occurring on the Eastern margins of Corpus Christi Bay (Smith et al. 1997).

Five (5) maps were created for the Corpus Christi Bay sub-region: the habitats within the sub-region (Figure 30), a heat map of habitats within the sub-region (Figure 31), specific locations identified by stakeholders (Figure 32), locations of outfalls and permitted discharges (Figure 33), and a close up view of discharge points in the northern part of the sub-region (Figure 34).

<u>Habitat Assessment</u>

There are nine habitat types within the Corpus Christi Bay sub-region: Scrub-Shrub Wetland, Seagrass Bed, Oyster Reef, Freshwater Wetland, Salt marsh Wetland, Flat, Rookery Island, Tree Canopy/Live Oak Motte and Marine/Open Water (Figure 30).

Some areas of the northern shoreline of Corpus Christi Bay are occupied by estuarine emergent wetlands (Smith et al. 1997). Seagrass habitat can be found along the northern shoreline of the Bay. Additionally, flats and oyster reefs occur along the shores of Corpus Christi Bay (Tremblay et al. 2008).

<u>Priority Areas and Justification of Priorities</u>

Priority issues with the Corpus Christi Bay sub-region include hypoxia and bacteria (Table E2). Research related to hypoxia and bacteria, encompassed in the broader category of water quality, should be supported, while at the same time continuing to protect land that ensures water quality.

<u>Gains and Losses of Habitats</u>

Tidal flat habitat loss characterizes the Corpus Christi Bay sub-region. Loss of tidal flat habitat is occurring along the Tule Lake Channel and at Indian Point.

Estuarine flat loss and to a lesser degree, marsh habitat loss, has occurred at Indian Point since the 1950's (Tremblay et al. 2008). This loss is attributed to relative sea-level rise and erosion (Tremblay et al. 2008). There was a loss of estuarine flat habitat to open water habitat during this period (Tremblay et al. 2008). Tidal flats are extensive on the spoil islands in Corpus Christi Bay.

According to TPWD's Seagrass Conservation Plan for Texas, seagrass bed distribution in the Corpus Christi Bay system is stable (Pulich et al. 1999 and Table 1). The Seagrass Conservation Plan is currently under revision.

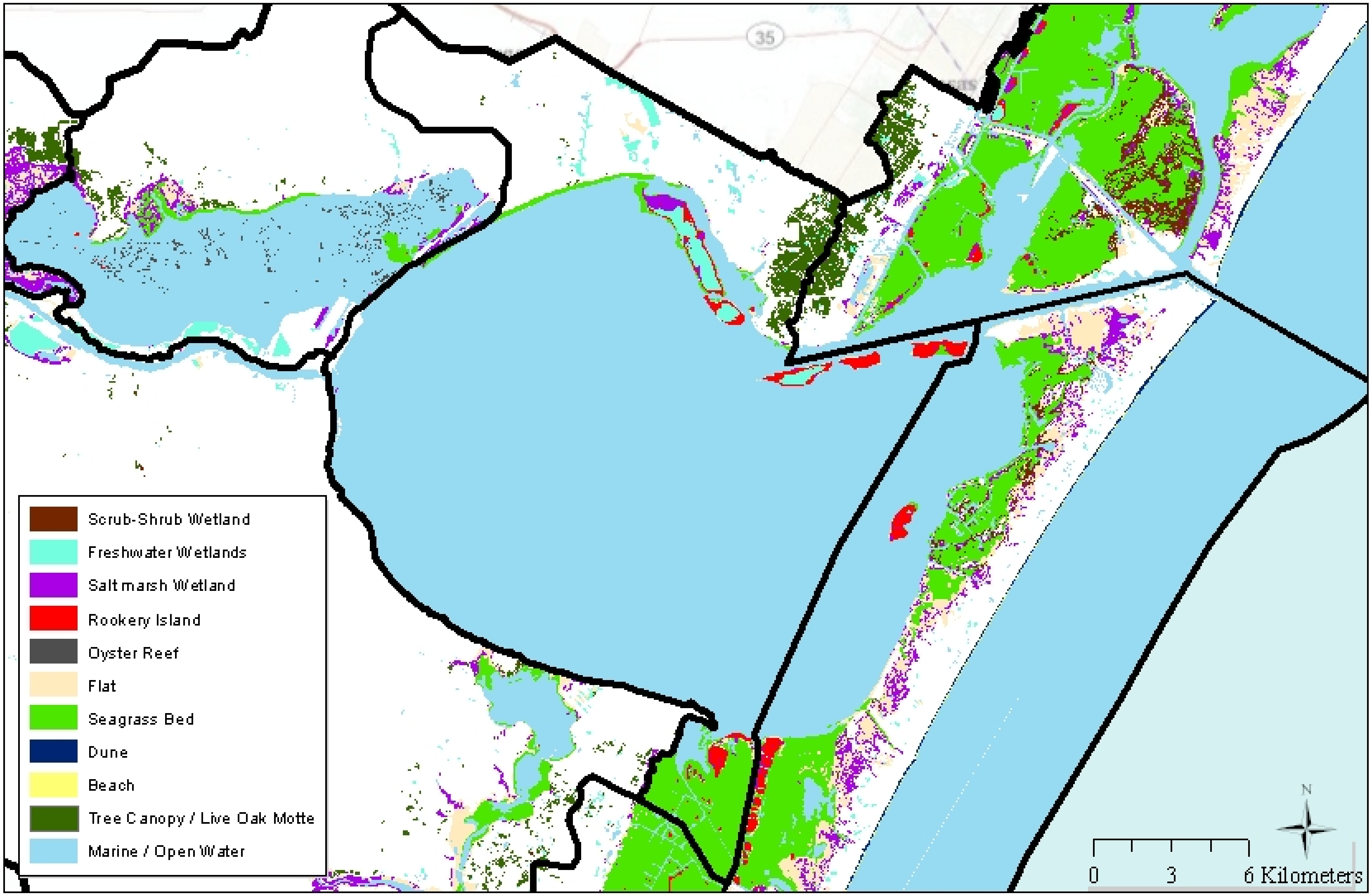

Figure 30. Corpus Christi Bay sub-region habitat map.

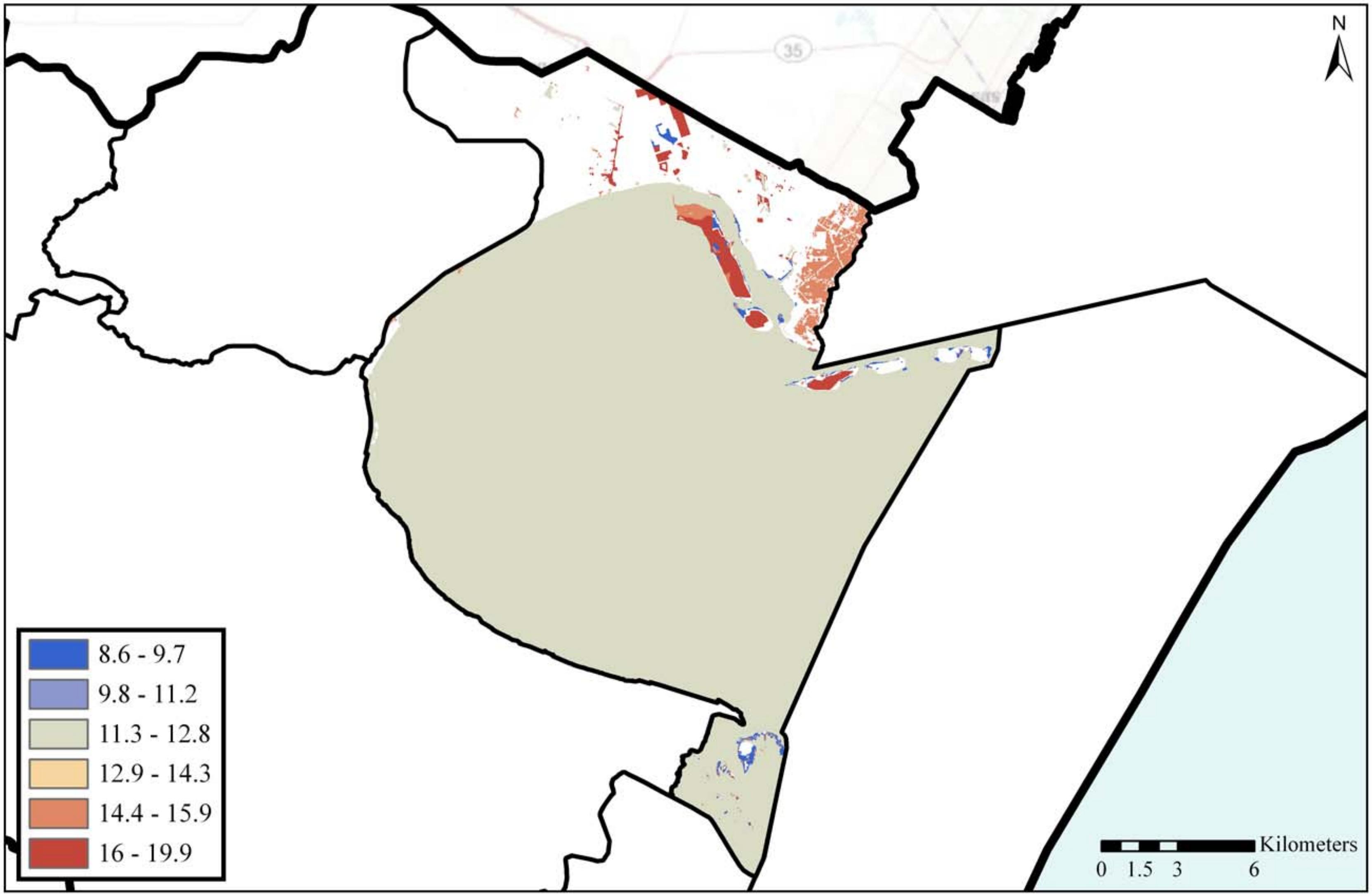

Figure 31. Corpus Christi Bay sub-region heat map representing average number of ecosystem services provided by habitats.

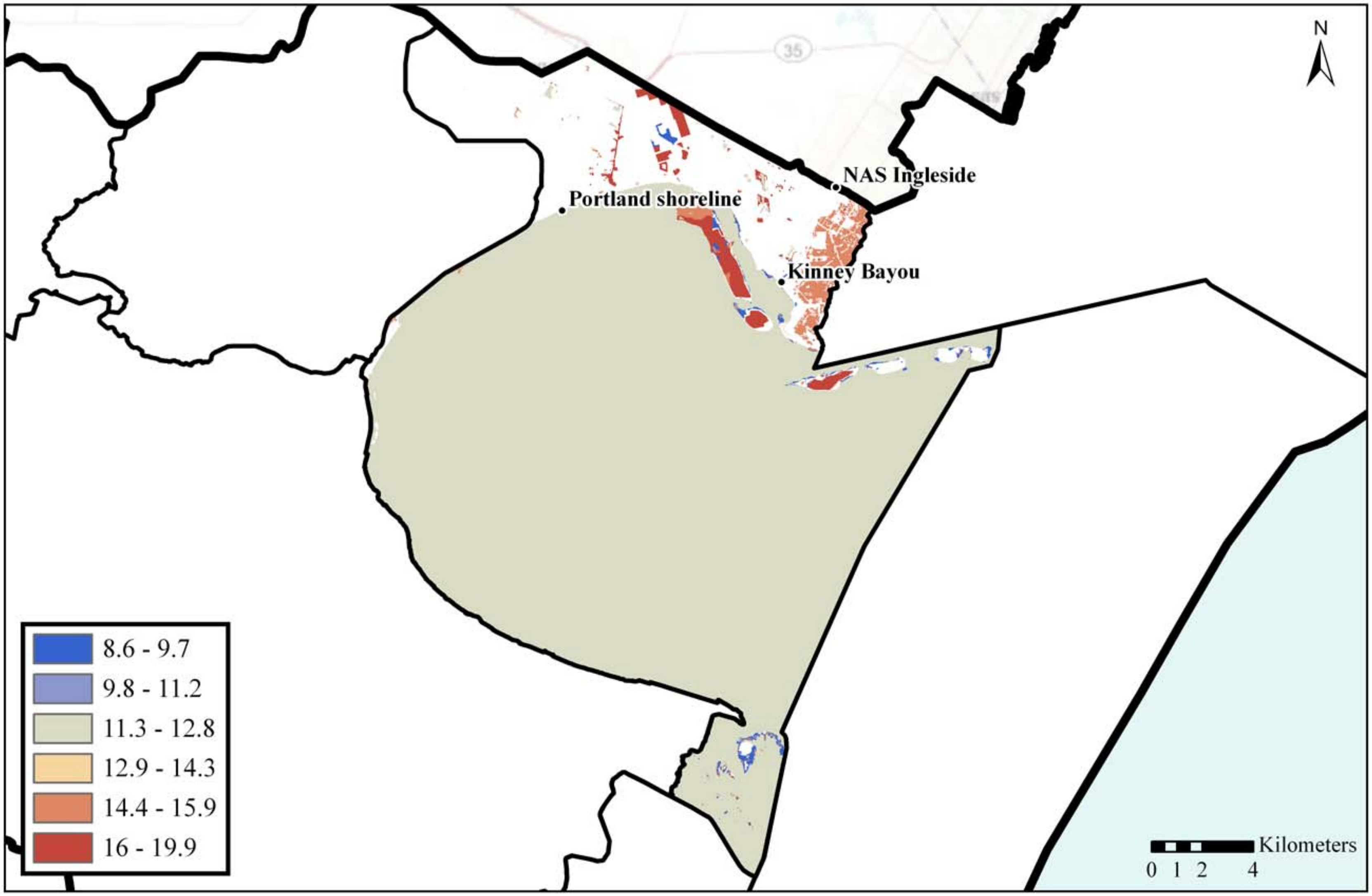

Figure 32. Corpus Christi Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with specific locations mentioned by stakeholders at the first workshop.

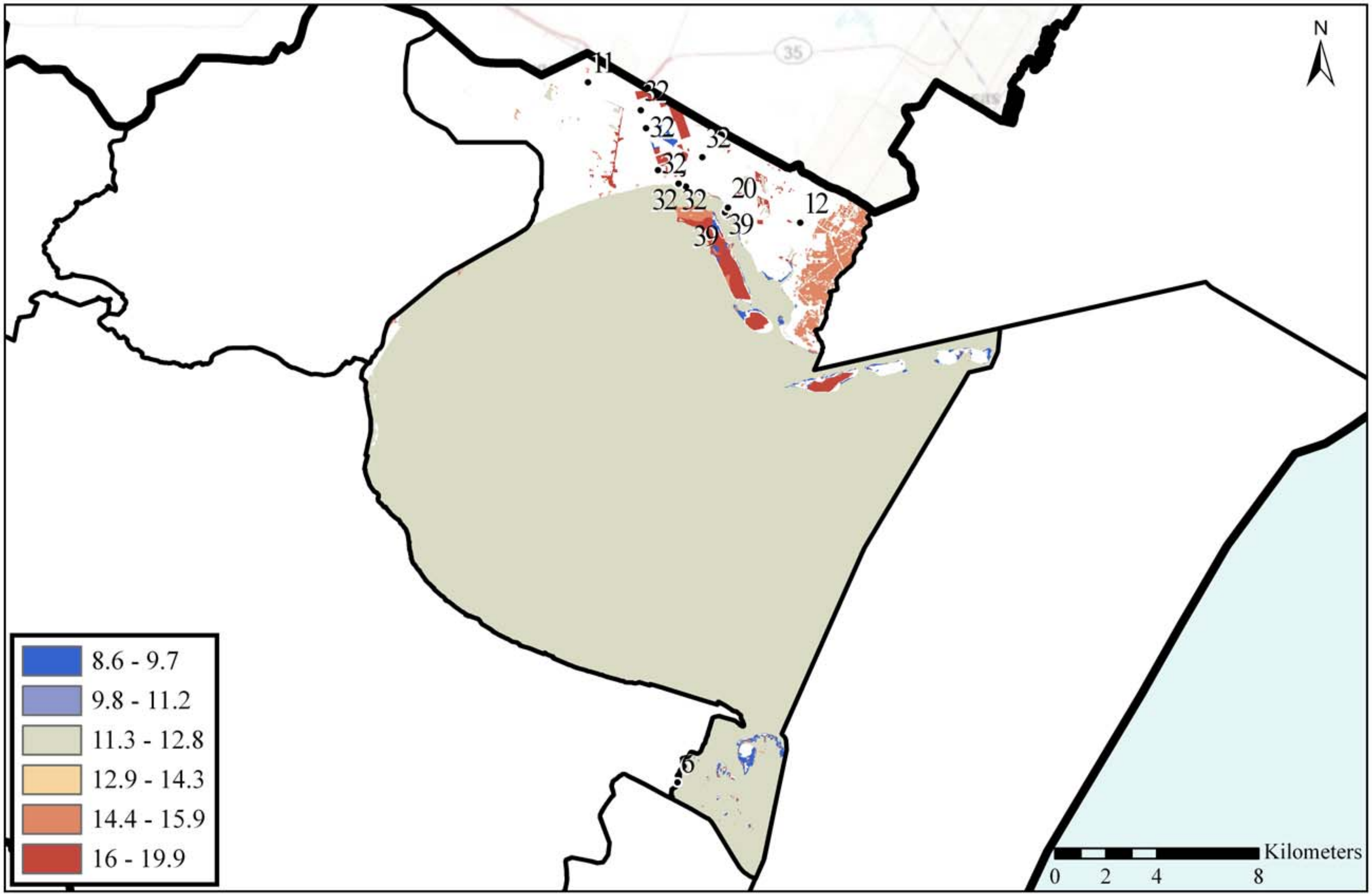

Figure 33. Corpus Christi Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites.

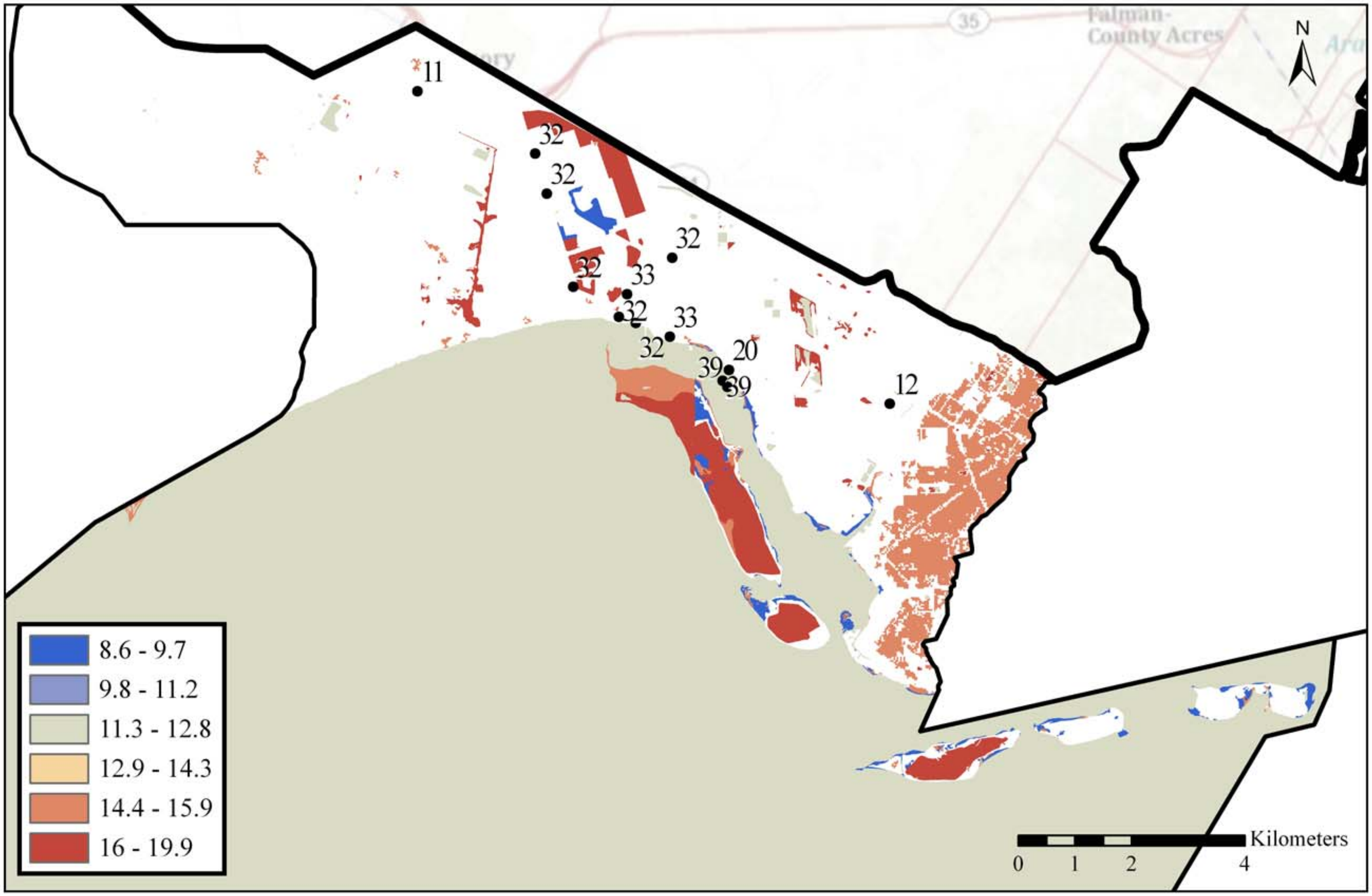

Figure 34. Northern portion of Corpus Christi Bay sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites.

Stakeholder Areas of Interest and Concern

Stakeholder valuation of ecosystem services was used to create a heat map for the Corpus Christi Bay sub-region (Figure 31).

Current assets and existing concerns were addressed by stakeholders at the first workshop. No habitats were specifically mentioned for the Corpus Christi Bay sub-region (Table 32), but three specific locations were mentioned (Figure 32 and Table 33). The locations mentioned were Kinney Bayou, NAS Ingleside, Portland shoreline and the spoil islands along the ship channel (Figure 32).

Many permitted wastewater discharge points exist within this sub-region (Figure 33). Most of these discharges exist in the northern section of the Corpus Christi Bay sub-region (Figure 34).

Table 32. Current assets and existing concerns within the Corpus Christi Bay sub-region.

Sub-region	Reason For Inclusion	Information Provided by Stakeholders
Corpus Christi Bay	Current assets	Fish thermal refuge
Corpus Christi Bay	Existing concern	Artificial reef/shell pads
Corpus Christi Bay	Existing concern	Beds – fishing
Corpus Christi Bay	Existing concern	Dredge concern/manage material
Corpus Christi Bay	Existing concern	Erosion going to chip into hackberry rookeries
Corpus Christi Bay	Existing concern	Fishing pressure
Corpus Christi Bay	Existing concern	Hypoxic Zone
Corpus Christi Bay	Existing concern	Industry
Corpus Christi Bay	Existing concern	Major rookery
Corpus Christi Bay	Existing concern	Open Bay bottom
Corpus Christi Bay	Existing concern	Public Bay / Beach Access
Corpus Christi Bay	Existing concern	Relevant sailing area
Corpus Christi Bay	Existing concern	Ship channel
Corpus Christi Bay	Existing concern	Shoreline erosion
Corpus Christi Bay	Existing concern	Trawling practice
Corpus Christi Bay	Existing concern	Wind turbine construction

Table 33. Specific locations within the Corpus Christi Bay sub-region mentioned by stakeholders.

Reason for Inclusion	Information provided by Stakeholders
Specific Location	Kinney Bayou
Specific Location	NAS Ingleside
Specific Location	Portland Shoreline
Specific Location	Spoil islands along ship channel

Ecosystem Services

The northern portion of the Corpus Christi Bay sub-region contains habitat with the highest number of ecosystem services (Figure 31).

The averages number of ecosystem services provided within a buffer zone surrounding stakeholder mentioned sites (Palmer et al. 2009) was determined (Table 34). The area directly surrounding Kinney Bayou was determined to provide the most ecosystem services, while the area directly surrounding NAS Ingleside was determined to provide the lowest number of ecosystem services (Figure 31).

Table 34. Average number of ecosystem services provided by buffer zones surrounding sites mentioned by stakeholders at the first workshop.

Site Name	**Mean**	**Min**	**Max**	**Range**
Kinney Bayou	6.14	0.00	20.91	20.91
Portland shoreline	6.09	0.00	11.68	11.68
NAS Ingleside	0.22	0.00	11.68	11.68

The average number of ecosystem services provided was also determined for a buffer zone surrounding permitted wastewater outfalls (Table 35). The area directly surrounding outfalls of permit entity # 39 was determined to provide the highest average number of ecosystem services. The area directly surrounding three of the outfalls of permit entity #32 was determined to provide no ecosystem services (Figure 33 and Figure 34).

Table 35. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Corpus Christi sub-region.

Permit Entity #	**Mean**	**Min**	**Max**	**Range**
39	11.68	11.62	15.81	4.19
39	10.50	0.00	15.81	15.81
6	9.65	0.00	15.81	15.81
20	6.14	0.00	15.81	15.81
32	5.17	0.00	11.68	11.68
33	4.17	0.00	11.68	11.68
32	3.96	0.00	16.53	16.53
32	2.70	0.00	16.53	16.53
33	2.58	0.00	16.53	16.53
12	0.12	0.00	13.70	13.70
11	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00

Future Activities

Future activities related to potential projects within the Corpus Christi Bay sub-region include: beneficial use of dredge material, sediment management, studying and raising awareness of the hypoxic zone, erosion control and acquisition and easement.

Mustang and North Padre Islands Sub-region

The Mustang and North Padre Island (MANPI) sub-region includes Mustang and North Padre islands. Padre Island is the world's longest barrier island. Both Mustang and north Padre Island are highly influenced by eolian processes. The shoreline is retreating on the bayward side of Mustang Island, along Corpus Christi Bay (Smith et al. 1997).

There are less washover channels and fewer connections to the estuarine system on north Padre Island than Mustang Island (White et al. 2006). On Mustang Island, there are several permanent inlets to the estuarine system from the Gulf of Mexico: Packery Channel, Aransas Pass and Fish Pass. Aransas Pass and Packery Channel (formerly Corpus Christi Pass) are both natural tidal inlets that have been altered by man through the construction of jetties and via dredging. Fish Pass (Corpus Christi Water Exchange Pass) is not a natural inlet, and was dredged in 1972 (Smith et al. 1997). There are also ephemeral washover channels across the barrier islands that are only active after storm events.

There are many large areas of public lands within the MANPI sub-region, including: The Mollie Beattie Coastal Habitat Community, Shamrock Island Nature Preserve and Management Complex, Mustang Island State Park. The southern boundary of the MANPI sub-region borders the Padre Island National Seashore.

The Mollie Beattie Coastal Habitat Community is located on the southern portion of Mustang Island off of highway 361 and borders Mustang Island State Park. This area protects important intertidal habitat for many species of birds, including the federally endangered piping plover.

The Shamrock Island Nature Preserve is an island that was formed when it was separated from Mustang Island following Hurricane Celia in 1970. Shamrock Island serves as an important bird rookery. Relative sea-level rise is attributed to the erosion of Shamrock Island (White et al. 2006). Geotubes have been constructed around Shamrock Island to try to reduce the amount of erosion occurring on the island. Marsh restoration projects using dredge material have also been conducted to restore marsh habitat important for nesting birds.

Mustang Island State Park was established in 1974 on Mustang Island and is bisected by highway 361. The park is over 4,000 acres in area and encompasses 5 miles of beach and dune habitats. Mustang Island State Park currently provides critical habitat for the federally endangered piping plover.

Padre Island National Seashore was established in 1962 and protects approximately 134,000 acres of land, including the longest undeveloped stretch of barrier island in the world. There are many habitats within the park boundary, including beach, dune, wetland and flat habitat. The park provides habitat for 13 threatened and endangered bird species in addition to other sensitive species, such as the endangered Kemp's Ridley sea turtle.

Five maps were created to for the MANPI sub-region: the habitats with the sub-region (Figure 35), a heat map of habitats within the sub-region (Figure 36), locations mentioned by stakeholders (Figure 37), locations of outfalls and permitted discharges (Figure 38), and a map of critical habitat of the federally endangered piping plover (Figure 39).

Habitat Assessment

There are ten habitat types in the MANPI sub-region: Beach, Dune, Freshwater Wetland, Marine/Open Water, Salt marsh Wetland, Scrub-shrub Wetland, Seagrass Bed, Flat, Tree Canopy/Live Oak Motte and Rookery Island (Figure 35).

Priority Areas and Justification of Priorities

Priority issues with the MANPI sub-region include dune protection and public access to beaches (Table E2). Many future activities and locations of interests related to these priority issues were suggested by stakeholders. .

Gains and Losses of Habitats

An assessment of changes in wetland distribution between the late 1950's and 1979, was conducted by White et al. (1983). During this time period, it was noted that seagrass habitat was spreading over flats and that vegetation was spreading over sand flats and dunes (Smith et al. 1997). Loss of tidal flat habitat and beach habitat characterize Mustang and North Padre Islands. Since 1979, there has been a loss of palustrine marsh habitat on the Mustang Island. The loss of palustrine habitat is partially attributed to development. Mangroves are found in increasing numbers within this sub-region (Tremblay et al. 2008). Changes in habitat distribution, by specific location, is described below in more detail.

Mustang Island. Between the 1950's and 2002 - 2004, change in habitat at Mustang Island is characterized by extensive loss of tidal flats and increase in estuarine marsh and seagrass habitat (White et al. 2006). Area mapped as tidal flats in the 1950's was mapped as seagrass, open water and marsh (and mangrove) habitat in 2002 - 2004 (White et al. 2006). This transition of habitats is partially explained by relative sea-level rise, as the inundation of tidal flats drives the transition to more water dominated/tolerant habitats (White et al. 2006). Interpretation of loss of tidal flats on Mustang Island is also attributed to misclassification of tidal flats as seagrass habitat and uplands in the 1979 habitat assessment process (White et al. 2006).

According to White et al. (1983) estuarine emergent wetlands expanded along the bayward side of Mustang Island between the late 1950's and 1979. Area of estuarine marsh on Mustang Island was reevaluated by White et al. (2006) and showed continued expansion. Increase in the amount of estuarine marsh on Mustang Island is attributed to relative sea-level rise. An increase in low estuarine marsh compared to high estuarine marsh is also an indicator of relative sea level rise (White et al. 2006). Additionally, increase of estuarine marsh is attributed to the discharge of the Port Aransas Wastewater Treatment Plant located on the northern end of Mustang Island (White et al. 2006). Black mangrove is also abundant on Mustang Island (White et al. 2006).

The shallow areas along the bayward side of Mustang Island are characterized by seagrass habitat (White et al. 2006). Seagrasses extend from these shallow areas along the edge of Mustang Island to the deeper waters of Corpus Christi Bay (Smith et al. 1997).

White et al. (1983) noted that between the late 1950's and 1979, palustrine emergent marshes were increasing on central Mustang Island. Since 1979, loss of palustrine habitat on Mustang Island is partially attributed to development (White et al. 2006).

Beach habitat loss has been documented on Mustang Island and is attributed to shoreline erosion on the fore-beach, expansion of vegetation on the back-beach, and differences in interpretation methods throughout the study period (White et al. 2006).

North Padre Island. Between the 1950's and 2002 - 2004, change in habitat at north Padre Island is characterized by loss of tidal flats and expansion of seagrass habitat (White et al. 2006). The development of the Padre Isles residential housing area, on the north part of the island, is attributed to some of the loss of flat habitat and also to the expansion of seagrass habitat (White et al. 2006). Seagrass habitat expanded into newly-created channels (White et al. 2006).

There was an increase in palustrine wetlands on north Padre Island between the 1950's and 2002 - 2004, despite the loss of palustrine wetland habitat to the development of the Padre Isles Country Club Golf course (White et al. 2006). North Padre Island supports palustrine wetlands in topographically low areas (White et al. 2006). Palustrine wetland habitat was lost to migrating dunes between the 1950's and 1979, but new vegetation was able to reestablish itself between 1979 and 2002 - 2004 (White et al. 2006). Increase in palustrine wetlands is partially attributed to an increase in moisture on the island (White et al. 2006).

Beach habitat has declined at North Padre Island since the 1950's (White et al. 2006). The northern section of the island's coastline is described as historically eroding and so beach loss is potentially attributed to shoreline erosion (White et al. 2006). The shoreline on the south of the island is described as stable or accreting (White et al. 2006).

Stakeholder Areas of Interest and Concern

Current assets and existing concerns were addressed by stakeholders at the first workshop (Table 36). Habitats within the MANPI sub-region specifically mentioned by stakeholders include: flats, seagrass beds, tree canopy/live oak motte, dunes, freshwater wetlands, and prairies and marshes (Table 36).

Specific locations were also mentioned by stakeholders at the first workshop. The sites within the MANPI sub-region for which latitude and longitude points were obtained were channelized housing, the Port Aransas jetties, and Shamrock Island (Table 37). Latitude and longitude points were also determined for the Padre Island National Seashore, which is not in the MANPI sub-region, but creates the southern border of the sub-region.

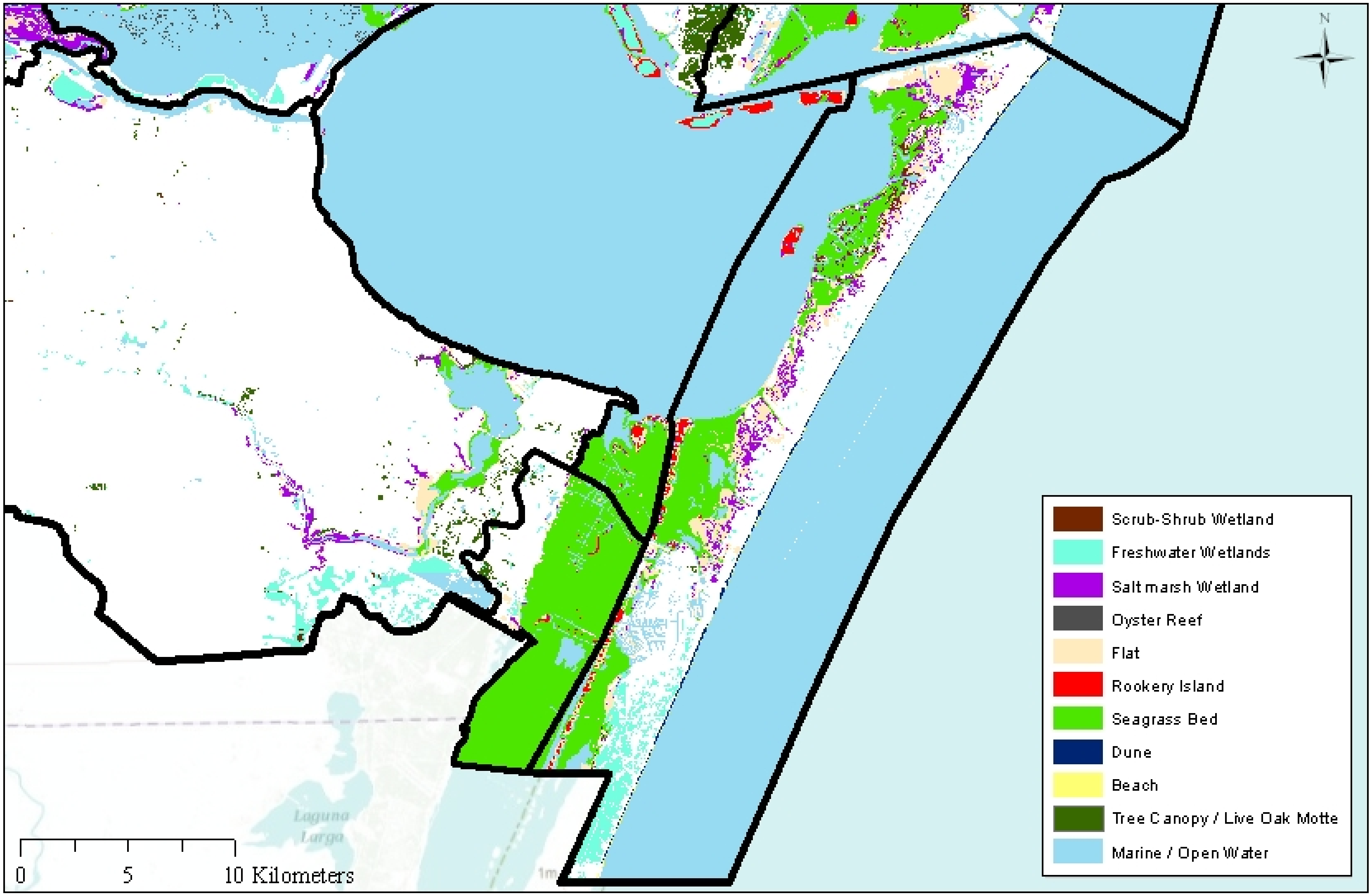

Figure 35. Mustang and North Padre Island sub-region habitat map.

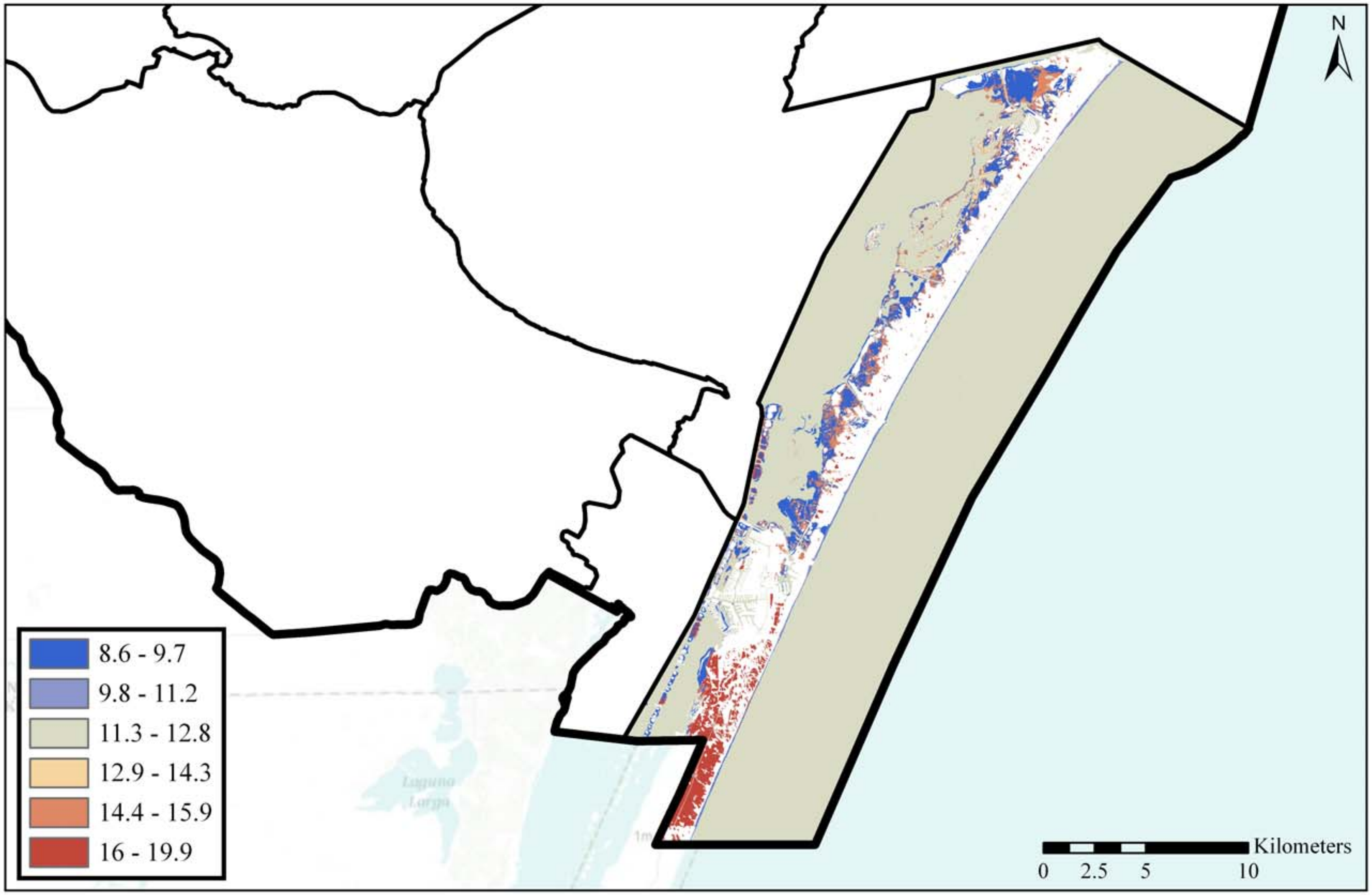

Figure 36. Mustang and North Padre Islands sub-region heat map representing average number of ecosystem services provided by habitats.

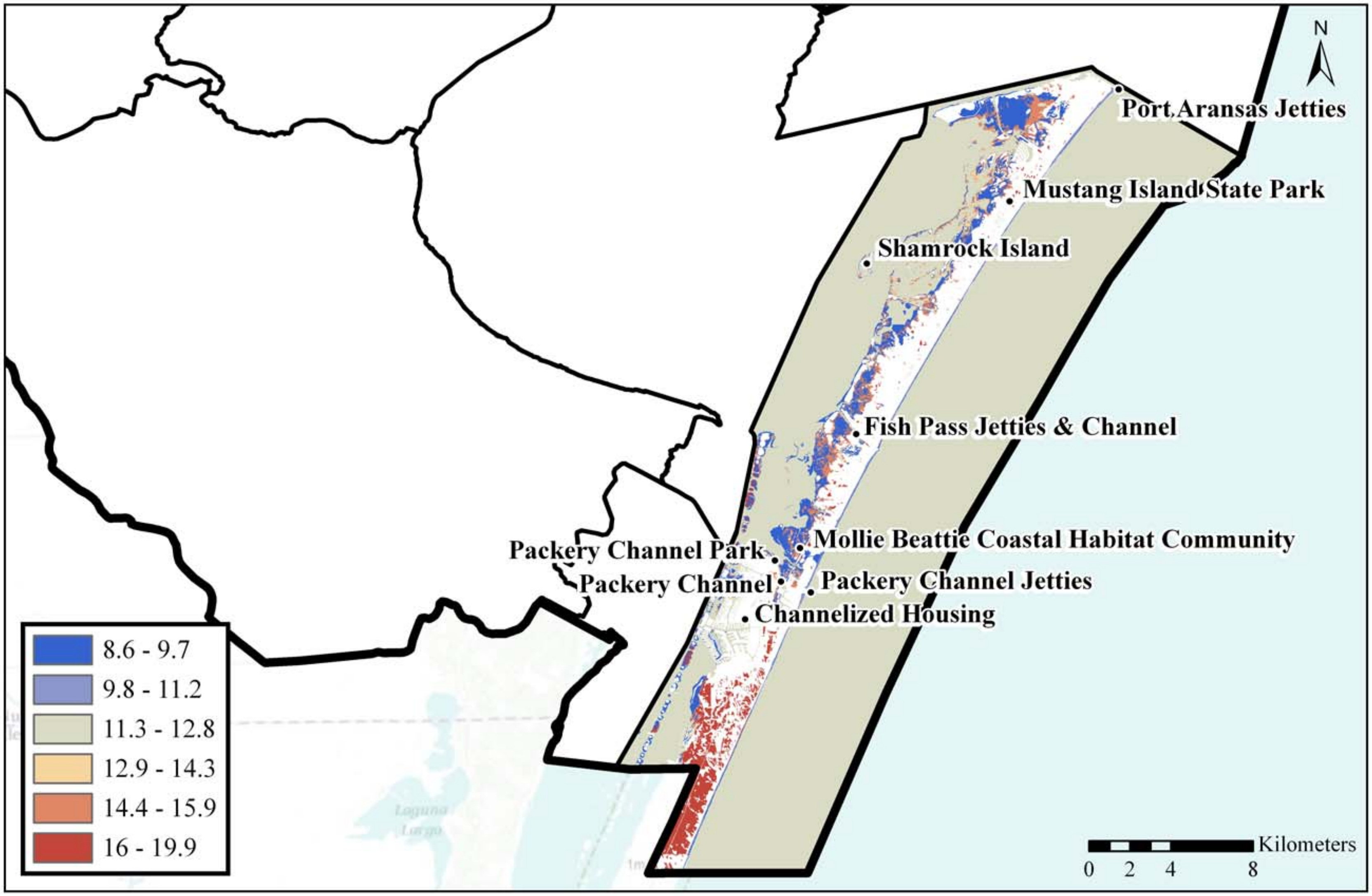

Figure 37. Mustang and North Padre Islands sub-region heatmap (representing average number of ecosystem services provided by habitats) with specific locations mentioned by stakeholders at the first workshop.

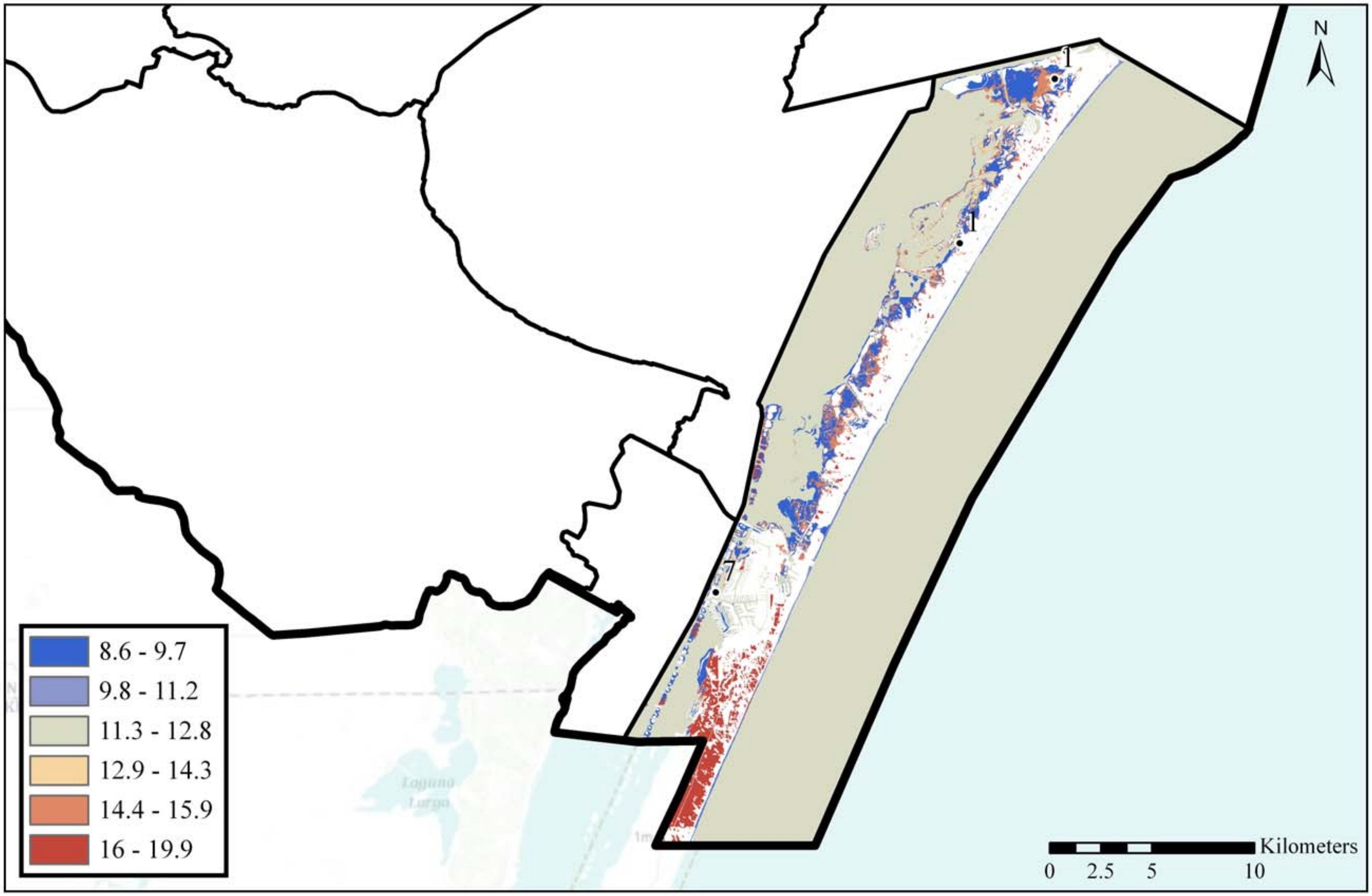

Figure 38. Mustang and North Padre Islands sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites.

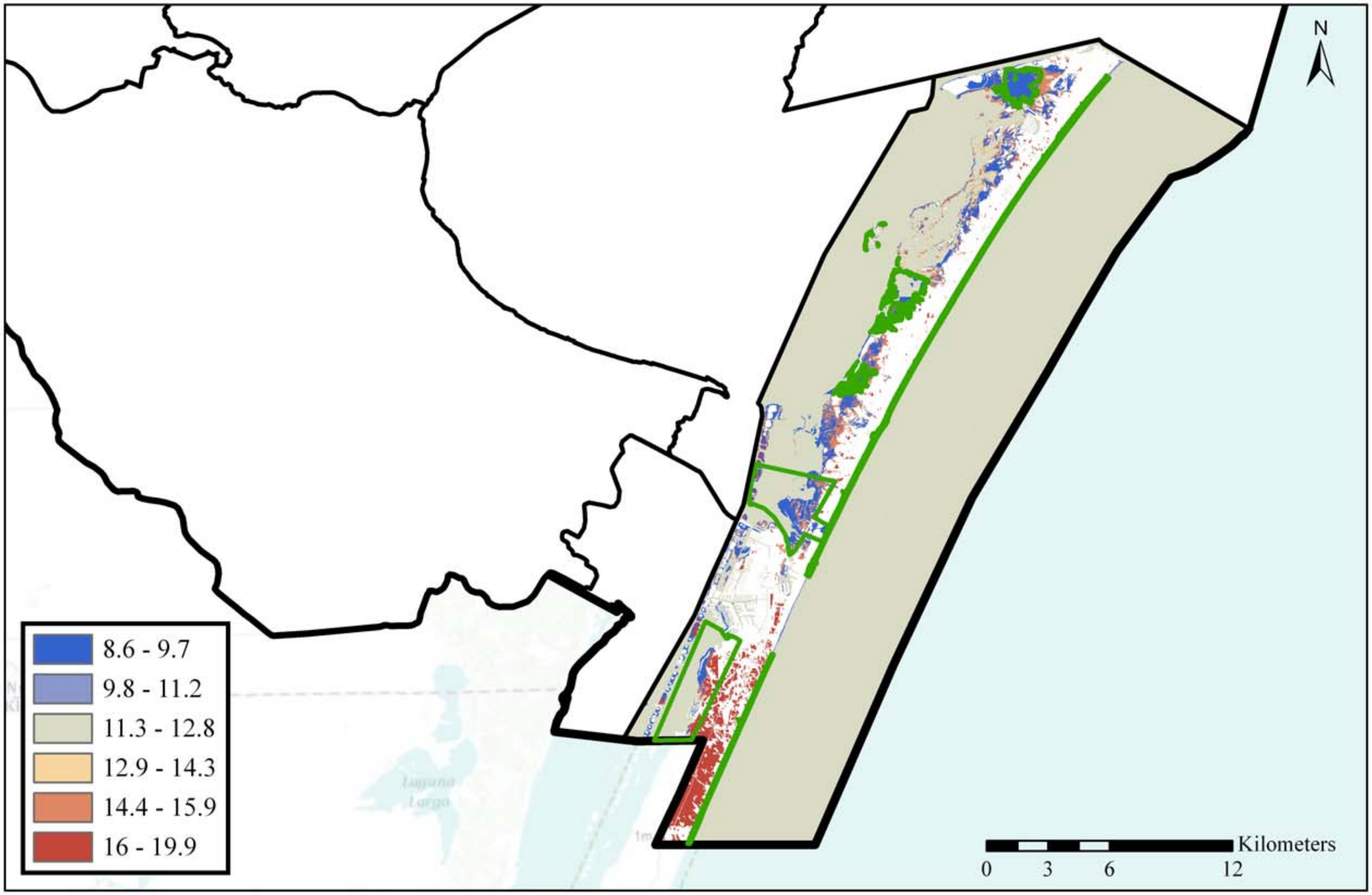

Figure 39. Mustang and North Padre Islands sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover.

Table 36. Current assets and existing concerns in Mustang and North Padre Islands sub-region.

Reason for Inclusion	**Information provided by Stakeholders**	**Further Description**
Current assets	Mollie Beattie Coastal Habitat Community	
Current assets	Mustang Island State Park	
Current assets	Packery Channel Park	
Existing concern	Tidal flats	Bird habitats Potential loss to sea level rise
Existing concern	Seagrass	Need to protect
Existing concern	Oak Mottes	Only oak forest on Mustang Island
Existing concern	Fishpass Channel	Sea turtles
Existing concern	Packery Channel	Sea turtles
Existing concern	Willows	Some habitat behind PINS
Existing concern	Aesthetic	
Existing concern	Archeology	
Existing concern	Birds	
Existing concern	Boat access	
Existing concern	Dunes	Including Dune swales;
Existing concern	Fish	
Existing concern	Fore dunes	Storm surge protection
Existing concern	Freshwater Wetlands	
Existing concern	Need new setbacks in view of sea level rise	
Existing concern	Padre Island Uplands	No regulatory protection exists to protect natural upland habitats
Existing concern	Prairies and Marshes	
Existing concern	Sea turtles	

Table 37. Specific locations within the Mustang and North Padre Islands sub-region mentioned by stakeholders.

Reason for Inclusion	**Information provided by Stakeholders**
Specific location	Backside of Mustang Island : Marsh
Specific location	Barrier island uplands: Prairies
Specific location	Beach
Specific location	Channelized housing
Specific location	Padre Island National Seashore
Specific location	Port Aransas
Specific location	Port Aransas jetties
Specific location	Scrub-shrub habitat
Specific location	Shamrock Island
Specific location	Temporary tidal inlets / Washover channels

The Mustang and North Padre Islands sub-region contains lots of critical habitat for the federally endangered piping plover (Figure 39). Also, according to USFWS data, the Mustang and North Padre Islands sub-region contains more habitat area for the federally endangered piping plover than any other sub-region. Some of these critical habitat areas are adjacent to housing developments.

Ecosystem Services

Stakeholder valuation of ecosystem services provided by habitats, determined at the second workshop, was used to create a heat map for the EBMP area. A heat map was created for the Corpus Christi Bay sub-region for ease of viewing (Figure 36).

Averages of number of ecosystem services in a buffer zone surrounding stakeholder mentioned sites (Palmer et al. 2009) were determined (Table 38). The Packery Channel Jetties site was determined to provide the highest number of ecosystem services. The channelized residential housing community site was determined to provide the lowest number of ecosystem services of sites assessed (Figure 36).

Table 38. Ecosystem service values for buffer regions surrounding areas mentioned by stakeholders at the first workshop.

Site	**Mean**	**Min**	**Max**	**Range**
Packery Channel Jetties	11.14	0.00	22.32	22.32
Mollie Beattie Coastal Habitat Community	9.97	0.00	15.81	15.81
Shamrock Island	7.99	0.00	15.81	15.81
Packery Channel Park	6.15	0.00	15.81	15.81
Packery Channel	5.11	0.00	15.81	15.81
Fishpass Channel	4.61	0.00	15.81	15.81
Mustang Island State Park	1.53	0.00	16.53	16.53
Channelized Housing	0.54	0.00	11.68	11.68

A total of five permitted wastewater discharge points exist within this sub-region (Figure 38). Average number of ecosystem services provided was determined for a buffer zone surrounding permitted wastewater outfalls (Table 39). The area directly surrounding the outfalls of permit entity # 1 was determined to provide the highest average number of ecosystem services. The area directly surrounding the outfall of permit entity # 7 was determined to provide the lowest average number of ecosystem services (Figure 38).

Table 39. Ecosystem service values for buffer regions surrounding permitted wastewater outfalls in the Mustang and North Padre Islands sub-region.

Permit entity #	Mean	Min	Max	Range
1	9.57	0.00	15.81	15.81
1	7.02	0.00	15.81	15.81
7	3.90	0.00	23.30	23.30

Future Activities

Future activities for inclusion in the EBMP were suggested by stakeholders at the first workshop. Activities related to potential projects within the MANPI sub-region include: stop hazard stabilization, mitigation of future flood loss due to hurricanes/storm surge, preservation of scrub-scrub and upland habitat, protection/stabilization of dunes, allow natural retreat of marsh land and mud flats due to sea level rise and need for new setbacks in view of sea level rise.

Further suggestions for future activities related to potential projects include: stopping the excavation of canals/channels through bayside habitats, creation of rolling easements, erosion control, effective wastewater reuse, sargassum and freshwater pond management, and creation of parks as possible enhancement areas.

Oso Bay and Creek Sub-region

The Oso Bay and Creek sub-region includes the Oso Bay and Creek and all of the urban area of Corpus Christi, including the area that borders the southern portion of Corpus Christi Bay. The urban area between Oso Creek and Corpus Christi Bay is characterized by rapid urban development (Tremblay et al. 2008). The Tule Lake Channel (aka the Corpus Christi Ship Channel), the Corpus Christi Botanical Gardens, and the Barney Davis Power Plant are all found within the Oso Bay and Creek sub-region. The northern and western parts of Encinal Peninsula are also in the Oso Bay and Creek sub-region.

Six maps were created for the Oso Bay and Creek sub-region: the habitats with the sub-region (Figure 40), a heat map of habitats within the sub-region (Figure 41), locations of sites specifically mentioned by stakeholders (Figure 42), locations of outfalls and permitted discharges within the entire sub-region (Figure 43), locations of outfalls and permitted discharges in the Port area (Figure 44), and locations of critical habitat for the federally endangered piping plover (Figure 45).

Habitat Assessment

Habitats within the Oso Bay and Creek sub-region include: Scrub-shrub Wetland, Marine/Open Water, Freshwater Wetland, Flat, Seagrass Bed, Salt marsh Wetland, Tree Canopy/Live Oak Motte and Rookery Island (Figure 40).

Priority Areas and Justification of Priorities

By protecting land, especially the land adjacent to the Oso Bay and Creek, priority issues within the Oso Bay and Creek sub-region will be addressed. Priority issues include protecting tidal flats and the riparian zone and the improvement of water quality (Table E2).

Gains and Losses of Habitats

Tidal flat habitat loss characterizes the EBMP area and the Oso Bay and Creek sub-region. Some losses can be attributed to the spread of marsh habitat due to higher nutrient loads from wastewater effluent, golf course runoff, and sea level rise (Tremblay et al. 2008). Habitat gains and losses are described below in more detail for specific areas within the Oso Bay and Creek sub-region.

Oso Bay. Between the 1950's and 2004, flat habitat loss occurred along the edges of Oso Bay, but it is noted that in 2004 tidal flats were still extensive at the bayhead of Oso Bay (Tremblay et al. 2008). Estuarine emergent wetlands occur along the edges of Oso Bay (Smith et al. 1997). Seagrass habitat in Oso Bay has increased since the 1950's (Tremblay et al. 2008). This increase in seagrass habitat is attributed to permitted point source discharges into the Bay, i.e. effluent released from municipal and industrial facilities and "cooling ponds and drainage channels" (Tremblay et al. 2008). Seagrass habitat also spread on both sides of Ward Island, at the mouth of Oso Bay (Tremblay et al. 2008).

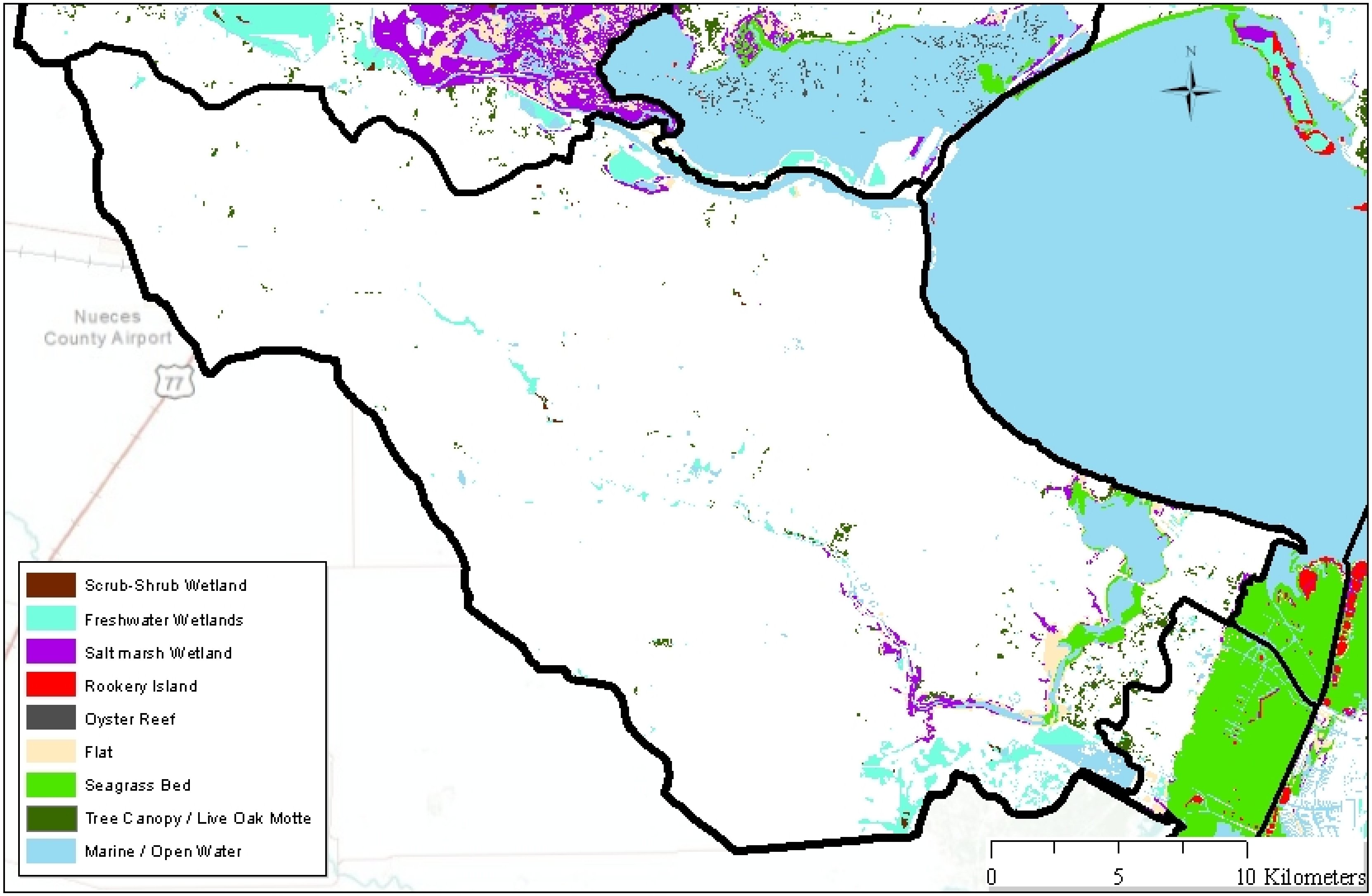

Figure 40. Oso Bay and Creek sub-region habitat map.

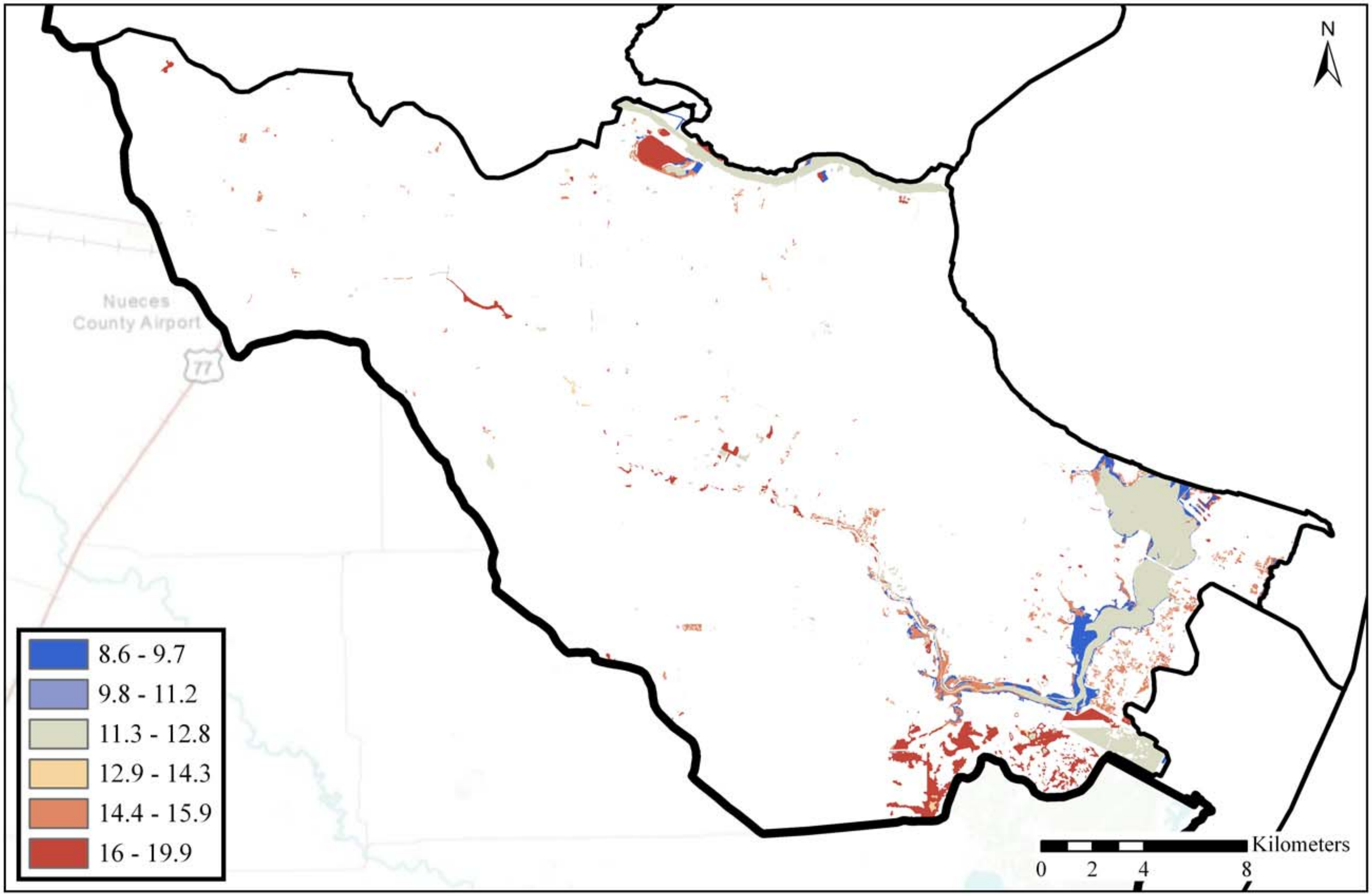

Figure 41. Oso Bay and Creek sub-region heat map representing average number of ecosystem services provided by habitats.

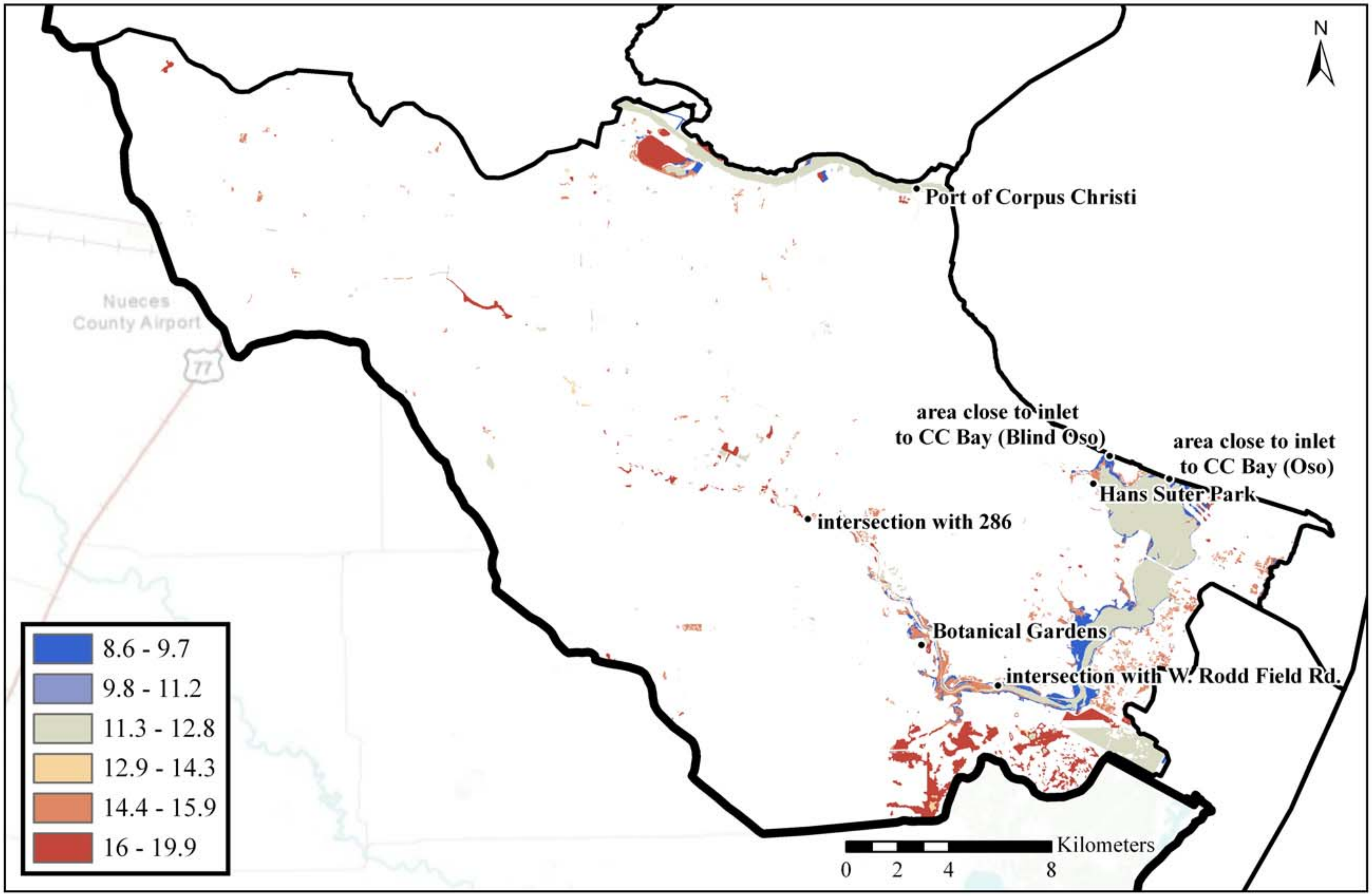

Figure 42. Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) with specific locations mentioned by stakeholders at the first workshop.

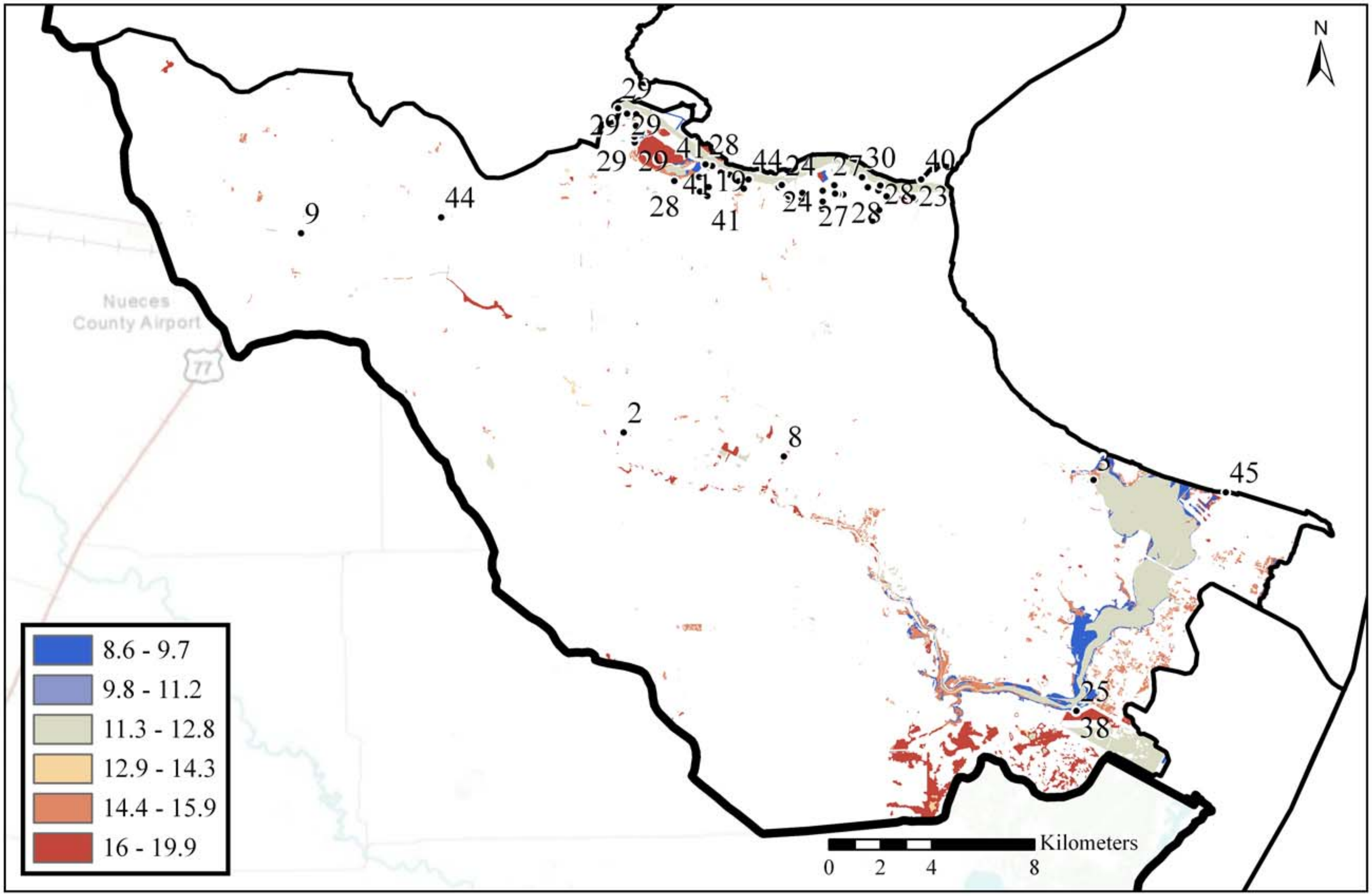

Figure 43. Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites.

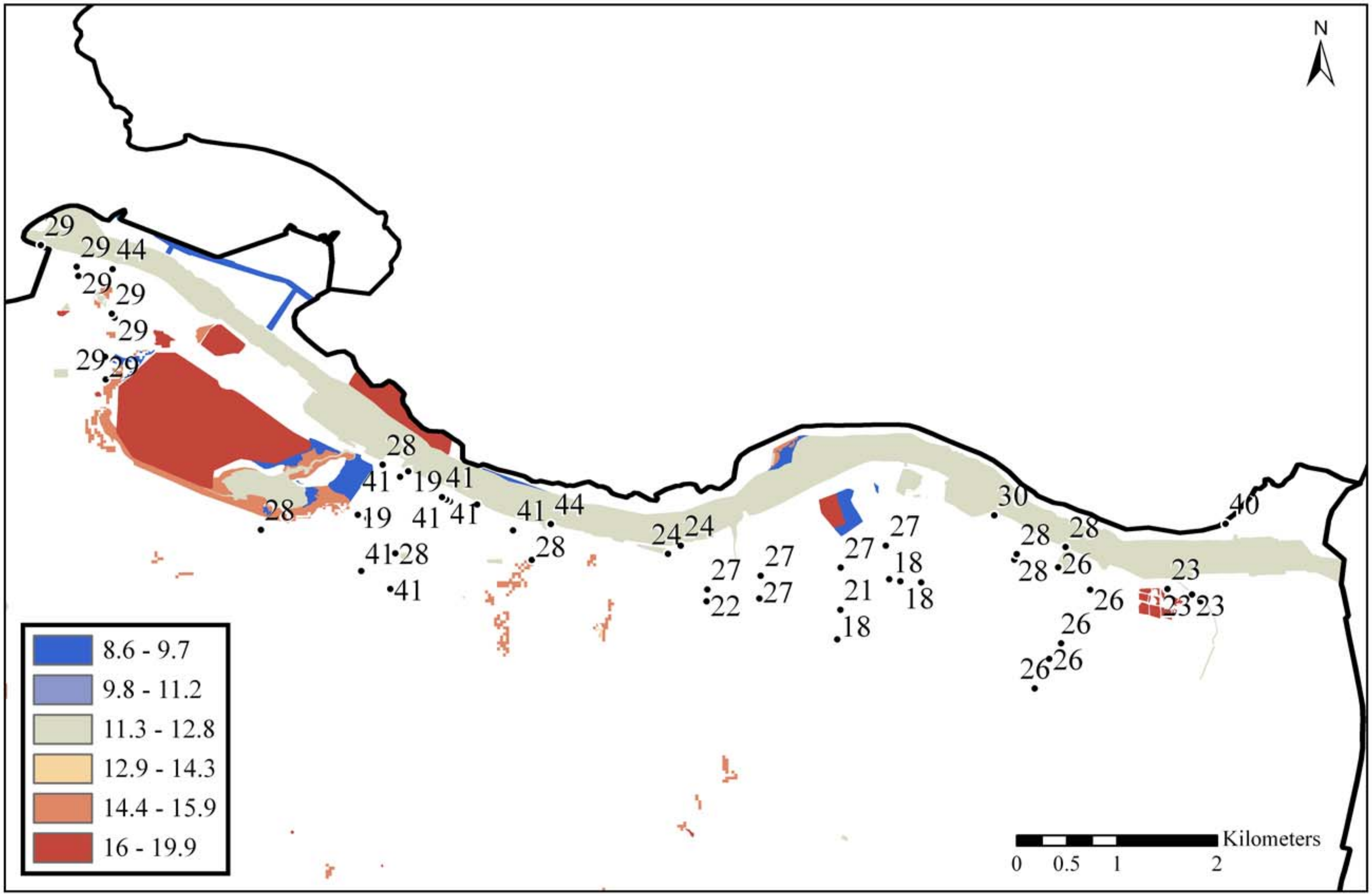

Figure 44. Northern portion of Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) with permitted wastewater outfall sites.

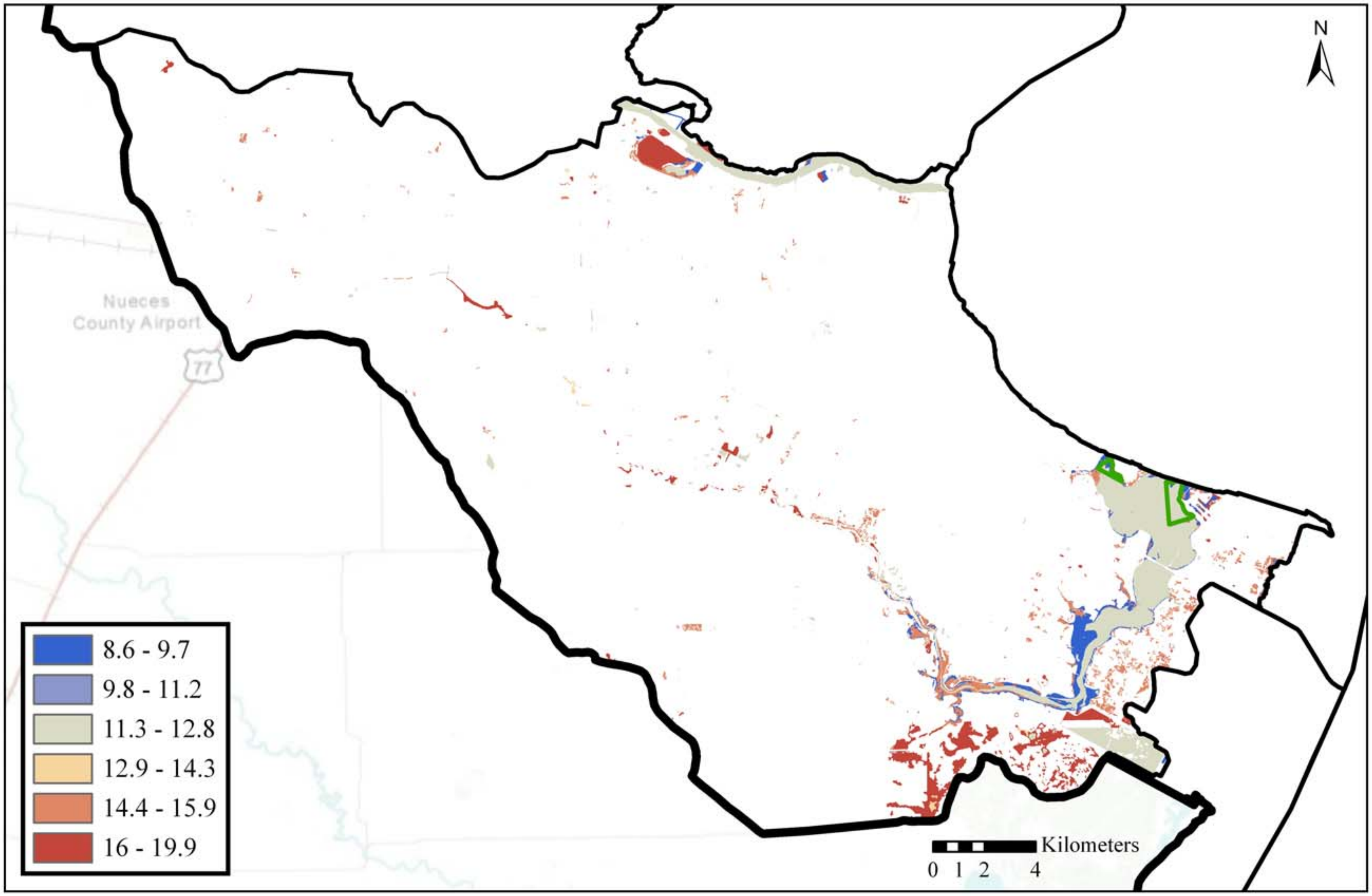

Figure 45. Oso Bay and Creek sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover.

Oso Creek. Between the 1950's and 2004, freshwater inflow into Oso Creek and Bay allowed for the expansion of emergent vegetation and thus the expansion of marsh habitat (Tremblay et al. 2008). Seagrass habitat has also expanded in Oso Creek since the 1950's while flat habitat loss has occurred on the channels of Oso Creek during the same period (Tremblay et al. 2008).

Industrial Area near Port of Corpus Christi. Large areas of tidal flat habitat were lost in the Port of Corpus Christi area between the 1950's and 2004 due to the filling of areas next to the Tule Lake Channel (Tremblay et al. 2008).

Stakeholder Areas of Interest and Concern

Current assets and existing concerns were addressed by stakeholders at the first workshop (Table 40). Habitats specifically mentioned include: riparian, mangroves, and tidal flats.

Ten (10) specific locations within the Oso Bay and Creek sub-region were mentioned by stakeholders at the first workshop as priority areas (Table 41).

Table 40. Current assets and existing concerns within the Oso Bay and Creek sub-region.

Reason For Inclusion	**Information Provided By Stakeholders**	**Further Description**
Current assets	Agriculture	Crop land Victoria clay soils Maintains drainage Erosion control
Current assets	City parks / land	
Current assets	Botanical Gardens	
Existing concern	Riparian habitat	Restoration
Existing concern	Urban development	Habitat acquisition necessary because of urban expansion
Existing concern	Agriculture	
Existing concern	Birds	
Existing concern	Colonias storm runoff and septic drainage flowing into the Oso	
Existing concern	Drainages / buffers	
Existing concern	Enhance filtration and prevent construction	
Existing concern	Eutrophication	
Existing concern	Fresh water flows and sewage	
Existing concern	Mangroves	
Existing concern	Nursery grounds	
Existing concern	Soil / water conservation	
Existing concern	Tidal flats	
Existing concern	Waste water plants	

Table 41. Specific location in the Oso Bay and Creek sub-region mentioned by stakeholders and the first workshop.

Reason for Inclusion	Information provided by Stakeholders
Specific location	Along Ennis Joslin
Specific location	Areas close to inlets to CC Bay
Specific location	Oso Creek intersection w/ west Rodd Field Rd
Specific location	Botanical Gardens
Specific location	Flour Bluff
Specific location	Hans Suter Park
Specific location	Oso Creek intersection with 286
Specific location	Mud flats
Specific location	Port of CC
Specific location	Shoreline Dr

Ecosystem Services

Stakeholder valuation of ecosystem services provided by habitats, determined at the second workshop, was used to create a heat map for the Oso Bay and Creek sub-region (Figure 41). The lands near Tule Lake, along Oso Creek and on the southeastern border of the sub-region represent areas that provide a high number of ecosystem services (Figure 41 and Figure 42).

Average number of ecosystem services, in a buffer zone surrounding stakeholder mentioned sites, (Palmer et al. 2009) was determined (Table 42). The inlets from Oso Bay to Corpus Christi Bay and the site at the intersection of Oso Creek and West Rodd Field Road were determined to provide the highest average number of ecosystem services within the Oso Bay and Creek sub-region. The site where Oso Creek intersects with Hwy 286 was determined to provide the lowest average number of ecosystem services (Figure 42).

Many permitted wastewater discharge points exist within this sub-region (Figure 43). Most of these points exist near the Port of Corpus Christi (Figure 44). Average number of ecosystem services was also determined for a buffer zone surrounding permitted wastewater outfalls (

Table 43). The area directly surrounding the outfall of permit entity # 38 had the highest average number of ecosystem services (Figure 43). The area directly surrounding 12 outfalls of various permit entities within this sub-region had less than one ecosystem service (Table 43).

The inlets from Oso Bay to Corpus Christi Bay were highlighted by stakeholders as areas of concern. Upon completion of the heat map, it was determined that these inlets provided the most ecosystem services when compared to other areas within the sub-region (Figure 41). The inlets are also critical habitat for the federally endangered piping plover. Thus, these inlets should strongly be considered for potential restoration/conservation projects.

Table 42. Ecosystem service values for buffer regions surrounding areas mentioned by stakeholders at the first workshop. Mean, minimum, maximum and range are included.

Site	**Mean**	**Min**	**Max**	**Range**
area close to inlet to CC Bay (Blind Oso)	10.28	0.00	15.81	15.81
intersection with west Rodd Field Rd.	9.48	0.00	20.91	20.91
area close to inlet to CC Bay (Oso)	9.41	0.00	15.81	15.81
Port of Corpus Christi	7.94	0.00	11.68	11.68
Hans Suter Park	3.82	0.00	15.81	15.81
(Corpus Christi) Botanical Gardens	2.75	0.00	16.53	16.53
intersection with 286	1.58	0.00	16.53	16.53

Table 43. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Oso Bay and Creek sub-region.

Permit entity #	Mean	Min	Max	Range
38	15.80	0.00	16.53	16.53
23	11.68	11.68	11.68	0.00
28	10.43	0.00	11.68	11.68
25	9.35	0.00	23.30	23.30
44	8.22	0.00	11.68	11.68
41	7.70	0.00	11.68	11.68
3	7.50	0.00	15.81	15.81
30	7.24	0.00	11.68	11.68
28	6.98	0.00	15.81	15.81
23	6.39	0.00	16.53	16.53
44	6.24	0.00	11.68	11.68
24	5.51	0.00	11.68	11.68
45	5.47	0.00	16.53	16.53
29	4.85	0.00	16.53	16.53
41	4.81	0.00	11.68	11.68
19	4.68	0.00	11.68	11.68
41	3.91	0.00	11.68	11.68
41	3.71	0.00	11.68	11.68
29	3.51	0.00	11.68	11.68
28	3.22	0.00	15.81	15.81
41	3.06	0.00	11.68	11.68
29	2.85	0.00	11.68	11.68
40	2.25	0.00	11.68	11.68
24	2.12	0.00	11.68	11.68
26	1.91	0.00	11.68	11.68
19	1.80	0.00	15.81	15.81
23	1.61	0.00	11.68	11.68
29	1.20	0.00	9.23	9.23
29	0.42	0.00	11.68	11.68
28	0.30	0.00	11.68	11.68
26	0.30	0.00	11.68	11.68
28	0.21	0.00	11.68	11.68
23	0.20	0.00	11.68	11.68
2	0.14	0.00	16.53	16.53
44	0.10	0.00	11.68	11.68
29	0.09	0.00	11.68	11.68
27	0.07	0.00	11.68	11.68
8	0.05	0.00	11.68	11.68
29	0.03	0.00	11.68	11.68
28	0.01	0.00	11.68	11.68

Future Activities

Future activities for inclusion in the EBMP were suggested by stakeholders at the first workshop.

Oso Creek Watershed. Activities related to potential projects in the Oso Creek Watershed include: habitat restoration, education initiatives, water quality initiatives, and creation of recreation friendly initiatives. Habitat restoration projects suggested include: habitat acquisition due to expansion of urban development and riparian habitat restoration. Education initiatives suggested include: education of landowners on incentive programs and education with agriculture owners and the public. Creation of recreational-friendly initiatives include: creation of regional park(s), creation of hike and bike trail(s), and the installation of a kayak access point at highway 286 and Oso Creek. Water quality initiatives include: conversion of septic systems to sewer systems, management of agricultural runoff, soil and water conservation and the enhancement of filtration and prevention of construction. Creation of drainages and buffers was also mentioned by stakeholders at the first workshop.

Oso Bay. Activities related to potential projects in the Oso Bay area include: land acquisition along Ennis Joslin and Oso Bay, protection of mudflat habitat by limiting ATV access and the creation of a planned city park with a retention pond.

Corpus Christi Urban Area. Activities related to potential projects in the Corpus Christi urban area include: increasing green space and parks and the enhancement of existing parks such as Hans Suter Wildlife Refuge and the Greenbelt. Other potential projects suggested include: educational endeavors, the creation of a soft shoreline, and storm drain retrofit for debris and contaminants.

Redfish and South Aransas Bay Sub-region

The Redfish and South Aransas Bay sub-region includes Redfish Bay, the lower extent of Aransas Bay, the lower portion of San Jose Island, Harbor Island, Mud Island, and a small portion of Live Oak Ridge and Peninsula. Much of this sub-region is encompassed by the Redfish Bay Scientific Study area, established in May 2006. Five species of seagrasses found in Texas are also found within this area and are protected by law. Redfish Bay supports extensive areas of relatively pristine seagrass habitat (Pulich et al. 1999). Many other habitats, including oyster reefs and salt marsh wetlands are found in this area as well.

Five (5) maps were created for the Redfish and South Aransas Bays sub-region: the habitats within the sub-region (Figure 46), a heat map of habitats within the sub-region (Figure 47), locations of specific sites mentioned by stakeholders (Figure 48), locations of outfalls and permitted discharges (Figure 49), and locations of critical habitat for the federally endangered piping plover (Figure 50).

Habitat Assessment

Habitats found in the Redfish Bay and South Aransas Bay sub-region are Marine/Open Water, Seagrass Bed, Salt marsh Wetland, Flat, Scrub-shrub Wetland, Freshwater Wetland, Rookery Island, Dune, Beach, Tree Canopy/Live Oak Motte and Oyster Reef (Figure 46).

Priority Areas and Justification of Priorities

Priority issues within the Redfish and South Aransas Bay sub-region include protection of habitats and erosion control (Table E2). Habitats to be considered for protection include palustrine marsh, tidal flats, live oak mottes, coastal prairie and rookery islands. Erosion control is also a priority issue according to stakeholders.

Gains and Losses of Habitats

Habitat gains and losses are described for specific locations in detail below.

Redfish Bay. Between the 1950's and 2004, there were extensive losses of tidal flats and increases in estuarine marsh in Redfish Bay (Tremblay et al. 2008). Former tidal flat habitat was converted to open water and subsequently to estuarine low marsh. The transition of tidal flat habitat to estuarine marsh habitat is characteristic of wetland areas on the Texas coast primarily due to relative sea-level rise (Tremblay et al. 2008). Most of this habitat change occurred on the islands that separate Aransas and Corpus Christi Bays, such as Harbor Island and the spoil islands along the Gulf Intracoastal Waterway. Industrial development, dredging, and channelization along the Gulf Intracoastal Waterway are also attributed to the loss of tidal flat habitat in Redfish Bay (Tremblay et al. 2008). Seagrass habitat is extensive in Redfish Bay and has remained relatively constant since the 1950's (Tremblay et al. 2008). Mangroves have a broad distribution in Redfish Bay (Tremblay et al. 2008).

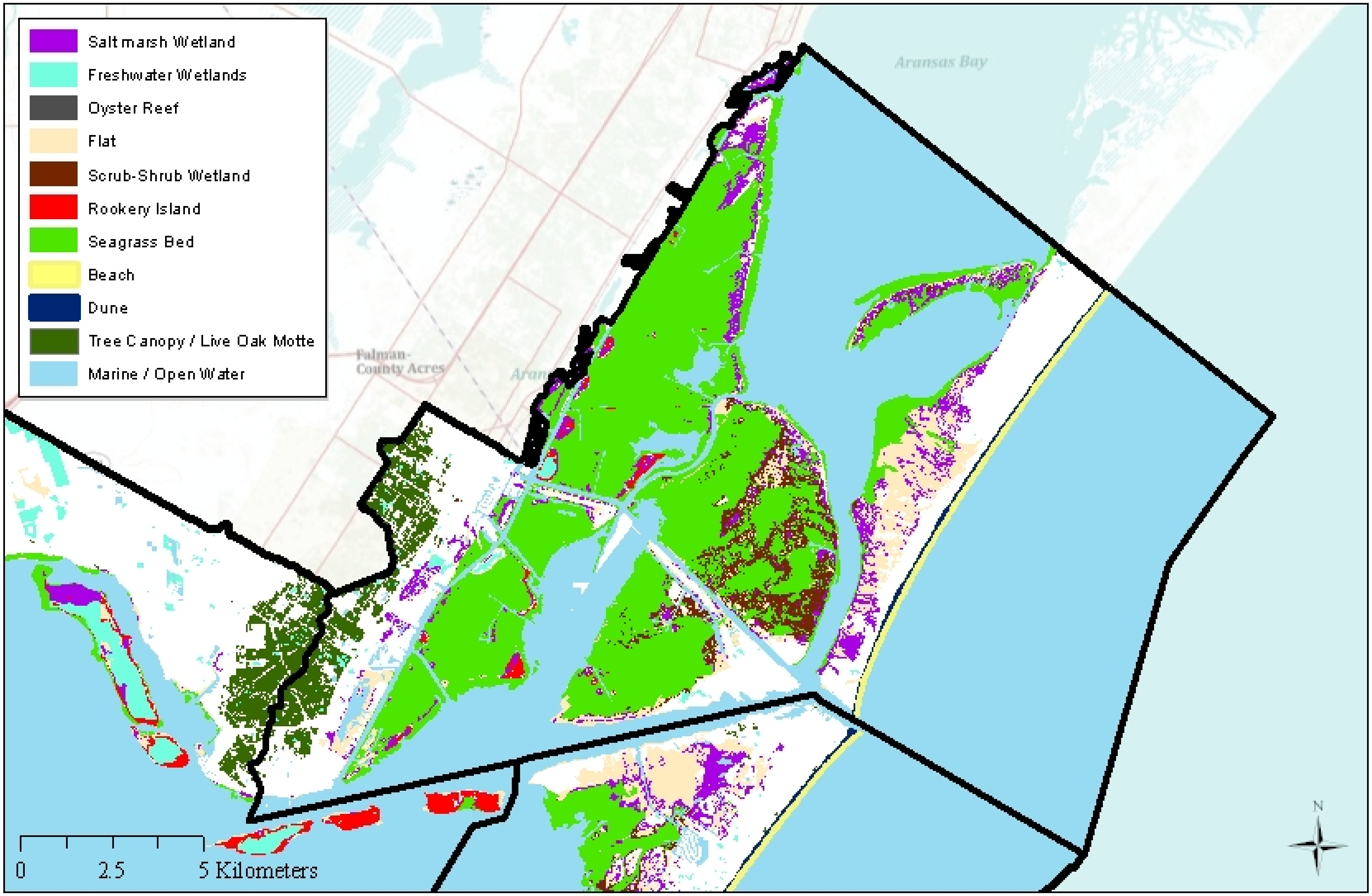

Figure 46. Redfish and South Aransas Bays sub-region habitat map.

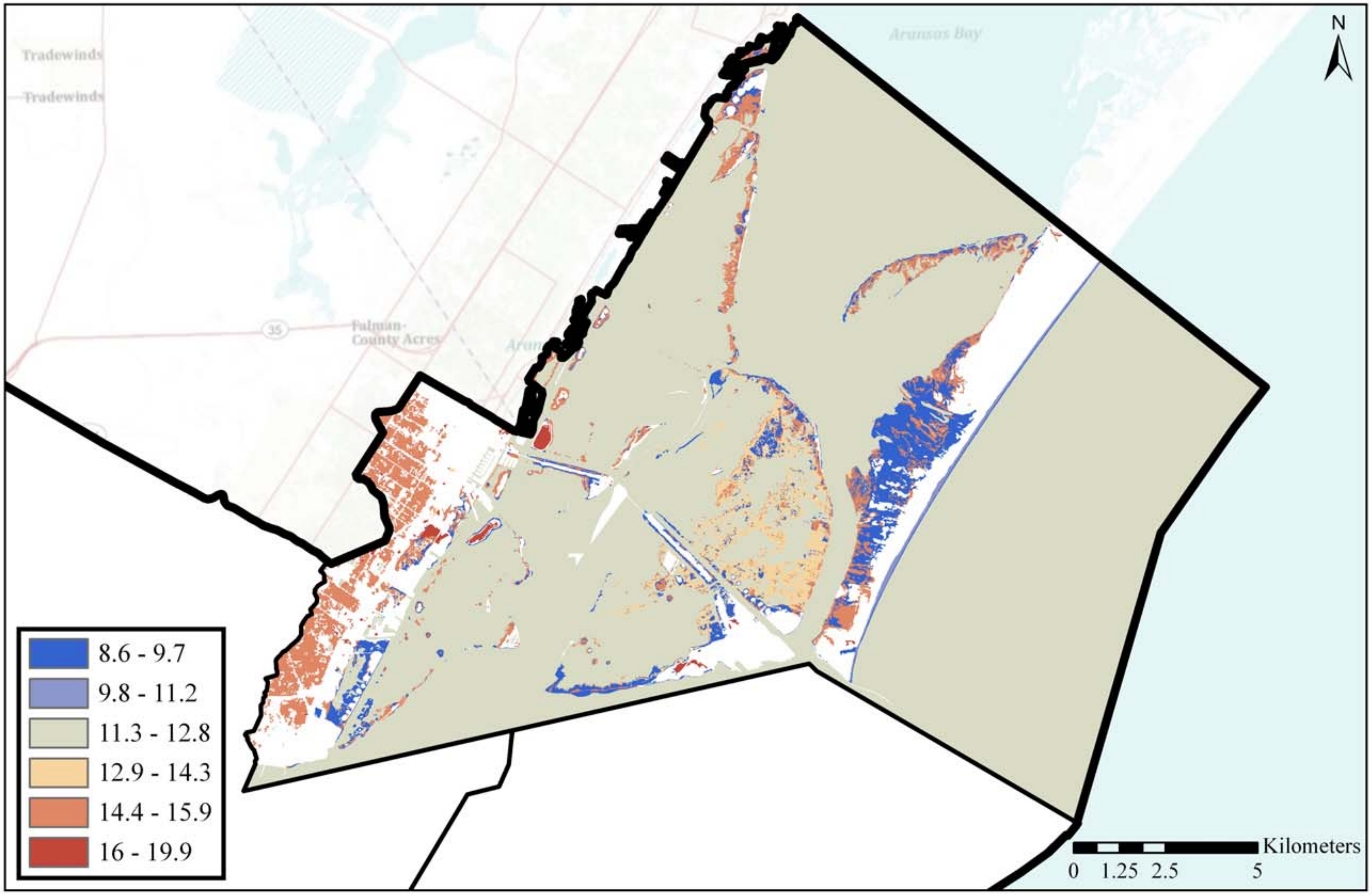

Figure 47. Redfish and South Aransas Bays sub-region heat map representing average number of ecosystem services provided by habitats.

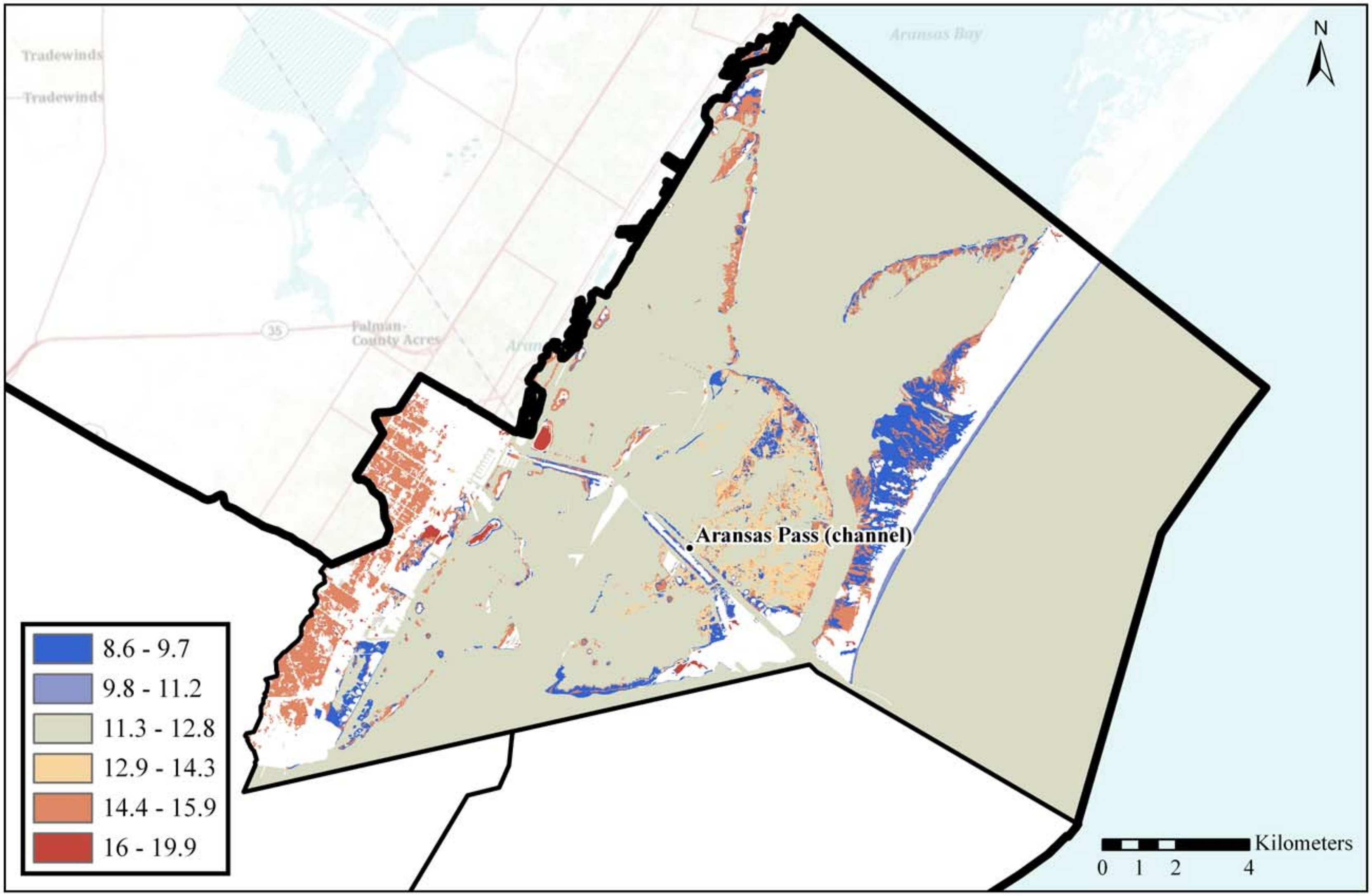

Figure 48. Redfish and South Aransas Bays sub-region heatmap (representing average number of ecosystem services provided by habitats) with specific location mentioned by stakeholders at the first workshop.

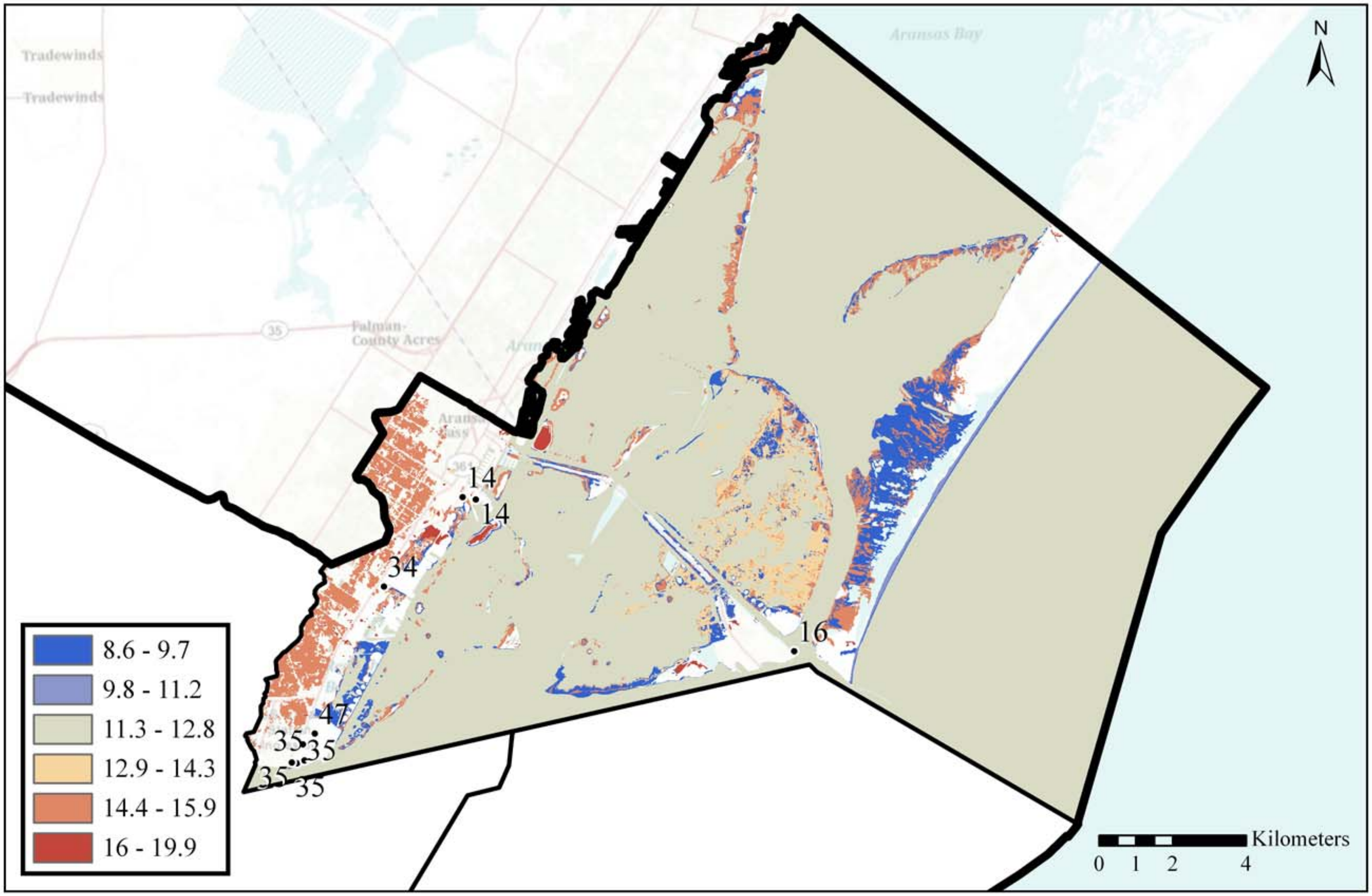

Figure 49. Redfish and South Aransas Bays sub-region (representing average number of ecosystem services provided by habitats) heat map with permitted wastewater outfall sites.

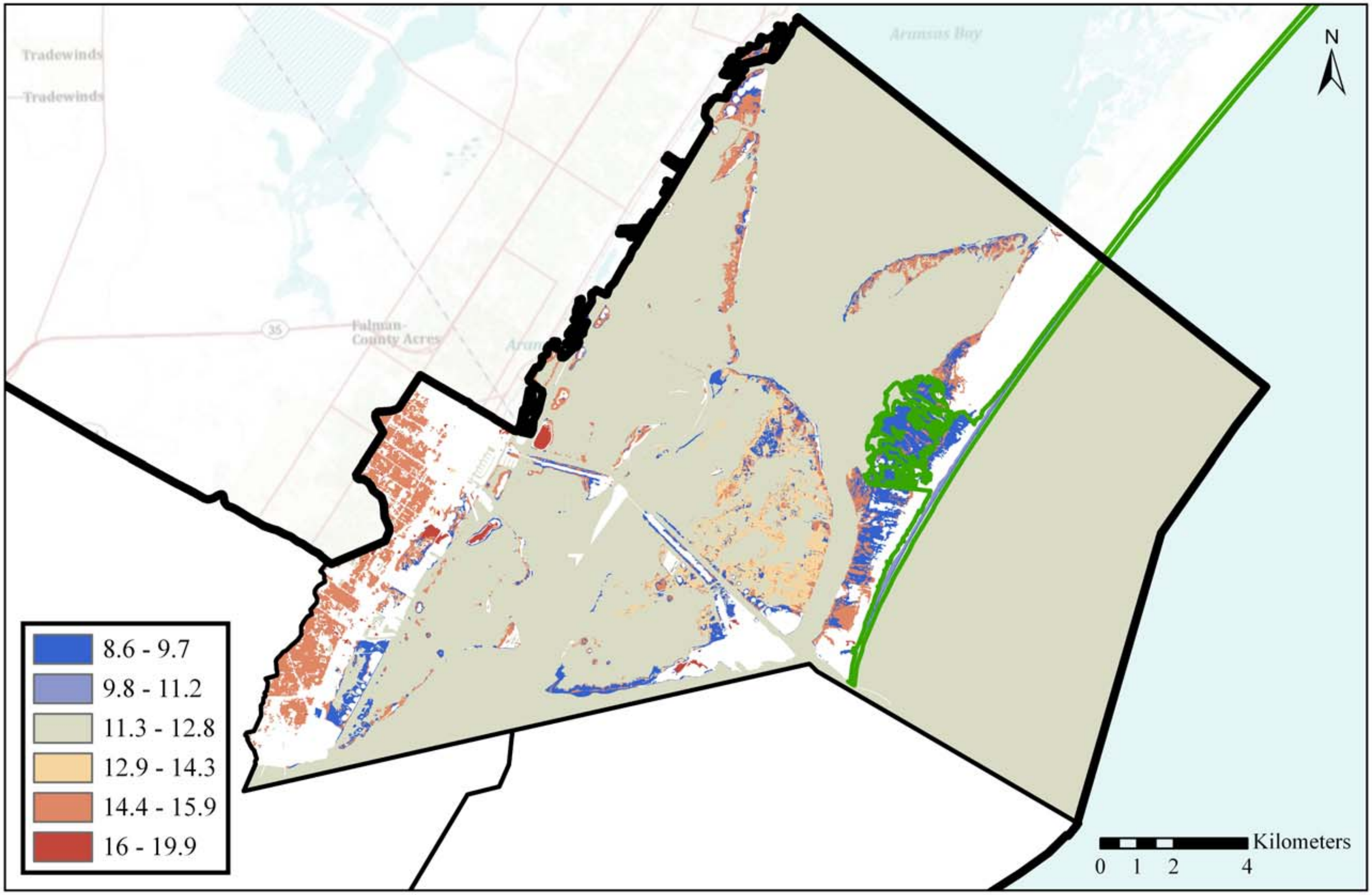

Figure 50. Redfish and South Aransas Bays sub-region heat map (representing average number of ecosystem services provided by habitats) including critical habitat (in green) of the federally endangered piping plover.

Harbor Island. Harbor Island is landward of San Jose and Mustang Islands at the Aransas Pass inlet (White et al. 2006). The Aransas Channel divides the island into two sections (White et al. 2006). The Aransas Channel was created by dredging and construction of jetties to create the Corpus Christi Ship Channel. Marsh vegetation and upland species are supported by dredged material from the ship channel that has been deposited along the edges of Harbor Island that line the Corpus Christi ship channel (White et al. 2006). Harbor Island is characterized by abundant mangrove habitat (White et al. 2006). Black mangroves are extensive on Harbor Island, despite setbacks due to freezes in the 1980's (White et al. 2006). The black mangrove habitat appears to be increasing because of recent warmer sea surface temperatures (Montagna et al. 2010). The shallow areas along the bayward side of Harbor Island are characterized by seagrass habitat (White et al. 2006).

San Jose Island. San Jose Island is an accretionary barrier island (White et al. 2006). Estuarine marshes and tidal flats are extensive on San Jose Island (White et al. 2006). Between the 1950's and 2002 - 2004, San Jose Island experienced an increase in estuarine marsh habitat (White et al. 2006). Estuarine marsh expanded into areas previously categorized as low flats and uplands (White et al. 2006). The change in habitat distribution is attributed to relative sea-level rise (White et al. 2006). Despite the expansion of estuarine marsh habitat into areas previously categorized as tidal flat habitat, the tidal flat area remained stable between 1979 and 2002 - 2004 (White et al. 2006).

Another trend driven by relative sea-level rise was the expansion of seagrasses into tidal flat and open water habitat (White et al. 2006). This trend is not unique to San Jose Island, as it is consistent with documented trends in other parts of the Coastal Bend of Texas (White et al. 2006). Specific areas where this trend is observable is on the back side of San Jose Island near North Pass and on Mud Island (White et al. 2006). The shallow areas along the bayward side of San Jose Island are characterized by seagrass habitat (White et al. 2006).

Palustrine marsh habitat can be found in swales on San Jose Island, but compose a relatively small component of the salt marsh wetland habitat on the island (White et al. 2006). Land management practices, specifically cut and/or burn methods of grass removal, are attributed to negative impacts on the palustrine marsh habitat (White et al. 2006).

Beach habitat decreased between the 1950's and 2002 - 2004 (White et al. 2006). Shoreline erosion is historically linked to San Jose Island (White et al. 2006). There are two main areas of critical habitat for the federally endangered piping plover in the Redfish and South Aransas Bays sub-region. One area is along the beach/dune habitats near the Gulf of Mexico and the other area is on the bayward side of San Jose Island (Figure 50).

Live Oak Ridge and Peninsula. Loss of tidal flat habitat occurred between the 1950's and 2004 on the eastern side of Live Oak Ridge near Redfish Bay (Tremblay et al. 2008). This loss of tidal flat habitat is attributed to both residential and industrial development and relative sea-level rise (Tremblay et al. 2008). During the same period and at the same location, there was an increase in estuarine marsh habitat (Tremblay et al. 2008). Palustrine marsh habitat in this area decreased (Tremblay et al. 2008). This decrease is attributed to conversion to upland habitat due to filling (Tremblay et al. 2008). Loss of wetlands occurred at Aransas Pass due to "local community development" (Tremblay et al. 2008).

Mud Island. Mud Island is a small island, approximately 3 miles in length, in Aransas Bay and is separated from San Jose Island by Blind Pass (White et al. 2006). Seagrass habitat is extensive along the length of Mud Island (White et al. 2006).

Stakeholders Areas of Interest and Concern

Existing concerns, current assets and future activities were established by stakeholders at the first workshop (Figure 48). These topics, discussed in more detail below, should be used to guide decision-making concerning potential restoration projects.

Current assets and existing concerns were addressed by stakeholders at the first workshop (Table 44). Habitats specifically mentioned within the Redfish and South Aransas Bay sub-region include: mangroves, marsh, oyster reefs, tree canopy/live oak motte, and seagrass beds. Several specific locations within the Redfish and South Aransas Bays sub-region were mentioned by stakeholders at the first workshop (Table 45).

Table 44. Current assets and existing concerns within the Redfish and South Aransas Bay sub-region.

Reason For Inclusion	**Information Provided By Stakeholders**	**Further Description**
Current assets	Mangroves	Largest black mangrove extent in the area
Current assets	Aesthetic	
Current assets	Birds	
Current assets	Crabbing	
Current assets	Dolphin nursery	
Current assets	Fish	
Current assets	Huge nursery for marine in winter	
Current assets	Marsh area	
Current assets	Oysters	
Current assets	Recreation	
Existing concern	Wetlands	High density of wetlands
Existing concern	Live Oak Mottes / Coastal Prairie Habitat	Largest oak forest area Not protected Limited resource
Existing concern	Fresh water ponds	Not protected Limited resource
Existing concern	Recreational Boating	Seagrass propeller scars
Existing concern	Circulation	
Existing concern	Erosion control	
Existing concern	Flushing of system	
Existing concern	Industry	
Existing concern	Inlet	
Existing concern	Lightening of Natural Gas	
Existing concern	Rigs	
Existing concern	Spawning	
Existing concern	Transportation	

Table 45. Specific locations within the Redfish and South Aransas Bay sub-region mentioned by stakeholders.

Reason For Inclusion	**Information Provided By Stakeholders**
Specific location	Aransas Pass (channel)
Specific location	Intracoastal easement
Specific location	just north of ship channel

Ecosystem Services

Stakeholder valuation of ecosystem services, determined at the second workshop, was used to create a heat map for the Redfish and South Aransas Bays sub-region (Figure 47).

Average number of ecosystem services was determined in a buffer zone surrounding the one stakeholder mentioned site (Palmer et al. 2009) within the sub-region (Table 46).

Table 46. Ecosystem service values for buffer regions surrounding area mentioned by stakeholders at the first workshop.

Site	Mean	Min	Max	Range
Aransas Pass (channel)	13.41	0.00	29.51	29.51

Nine (9) permitted wastewater discharge points exist within the Redfish and Aransas Bay sub-region (Figure 49). Average number of ecosystem services was determined for a buffer zone surrounding permitted wastewater outfalls (Table 46). The area directly surrounding the outfall of permit entity # 16 had the highest average number of ecosystem services. The area directly surrounding the outfall of permit entity #47 had no ecosystem services (Figure 49).

Table 47. Average number of ecosystem services provided within buffer regions directly surrounding permitted wastewater outfalls in the Oso Bay and Creek sub-region.

Permit entity #	Mean	Min	Max	Range
16	8.20	0.00	11.68	11.68
14	7.14	0.00	27.49	27.49
14	6.11	0.00	27.49	27.49
35	5.28	0.00	15.81	15.81
35	4.53	0.00	11.68	11.68
34	3.66	0.00	15.81	15.81
35	2.43	0.00	15.81	15.81
35	0.01	0.00	16.53	16.53
47	0.00	0.00	0.00	0.00

Future Activities

Future activities for inclusion in the Management Plan were suggested by stakeholders at the first workshop. Activities related to potential projects within the Redfish and South Aransas Bay sub-region include: habitat protection and restoration for seagrass, marsh and oyster reefs, erosion control and stabilization of sediments, establishment of easements (including intracoastal easements and land acquisition), and beneficial use of dredge material.

Upper Laguna Madre Sub-region

The Upper Laguna Madre sub-region borders three other sub-regions: Oso Bay and Creek to the west and northwest, Corpus Christi Bay to the north and Mustang and North Padre Islands to the east. This Upper Laguna Madre sub-regions' northern boundary is defined by the JFK Causeway. The southeastern portion of Encinal Peninsula, which includes the Redhead Pond Wildlife Management area, is within the boundaries of the Upper Laguna Madre sub-region.

Three (3) maps were created for the Upper Laguna Madre sub-region: the habitats within the sub-region (Figure 51), a heat map of habitats within the sub-region (Figure 52), and locations of specific sites mentioned by stakeholders (Figure 53).

Habitat Assessment

Habitats found in the Upper Laguna Madre sub-region are Seagrass Bed, Marine/Open Water, Flat, Freshwater Wetland, Rookery Island, Tree Canopy/Live Oak Motte and Salt marsh Wetland (Figure 51).

Priority Areas and Justification of Priorities

Priority issues within the Upper Laguna Madre sub-region include management of seagrass beds and creation/protection of rookery islands (Table E2).

Gains and Losses of Habitats

Average salinity levels in the Laguna Madre are above 30 psu (Tremblay et al. 2008). Seagrass habitat is abundant in the Laguna Madre (Tremblay et al. 2008). Estuarine emergent marshes can also be found in this sub-region (Smith et al. 1997).

Stakeholder Areas of Interest and Concern

Current assets and existing concerns were addressed by stakeholders at the first workshop (Table 48). Habitats specifically mentioned within the Upper Laguna Madre sub-region include: oyster reefs wind tidal flats, tree canopy/live oak motte, seagrass beds and rookery islands. Oyster reef habitat in Laguna Madre is very limited due to the high salinities and lack of freshwater inflow. The only specific location mentioned for the Upper Laguna Madre sub-region is the western urban shore (Figure 53).

Ecosystem Services

Stakeholder valuation of ecosystem services by habitats, determined at the second workshop, was used to create a heat map for the Upper Laguna Madre sub-region (Figure 52). Average ecosystem service values in a buffer zone surrounding the single stakeholder mentioned site (Palmer et al. 2009) within the sub-region (Figure 53). This site provides an average number of 7 ecosystem services (Table 49).

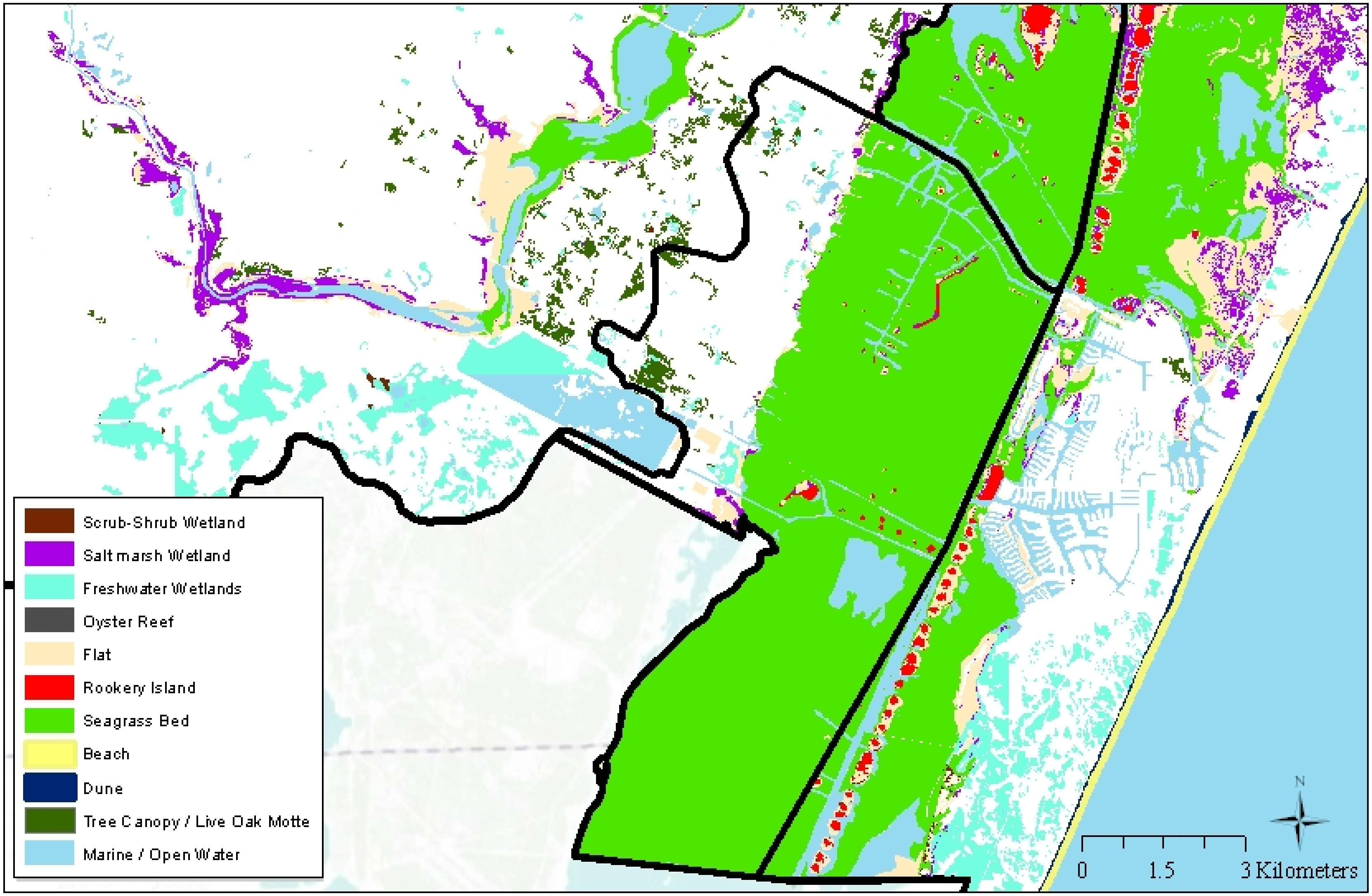

Figure 51. Upper Laguna Madre sub-region habitat map.

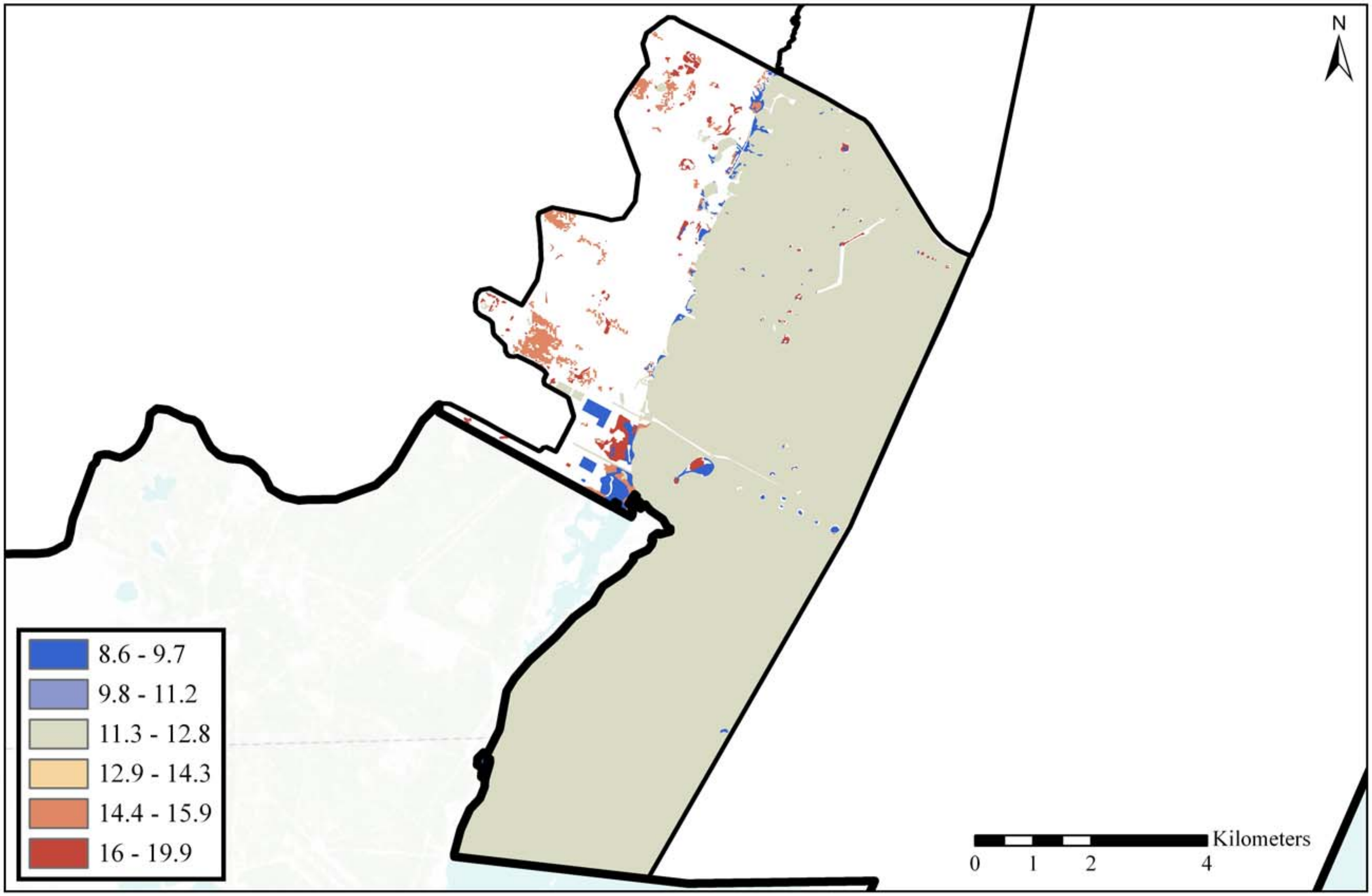

Figure 52. Upper Laguna Madre sub-region heat map representing average number of ecosystem services provided by habitats.

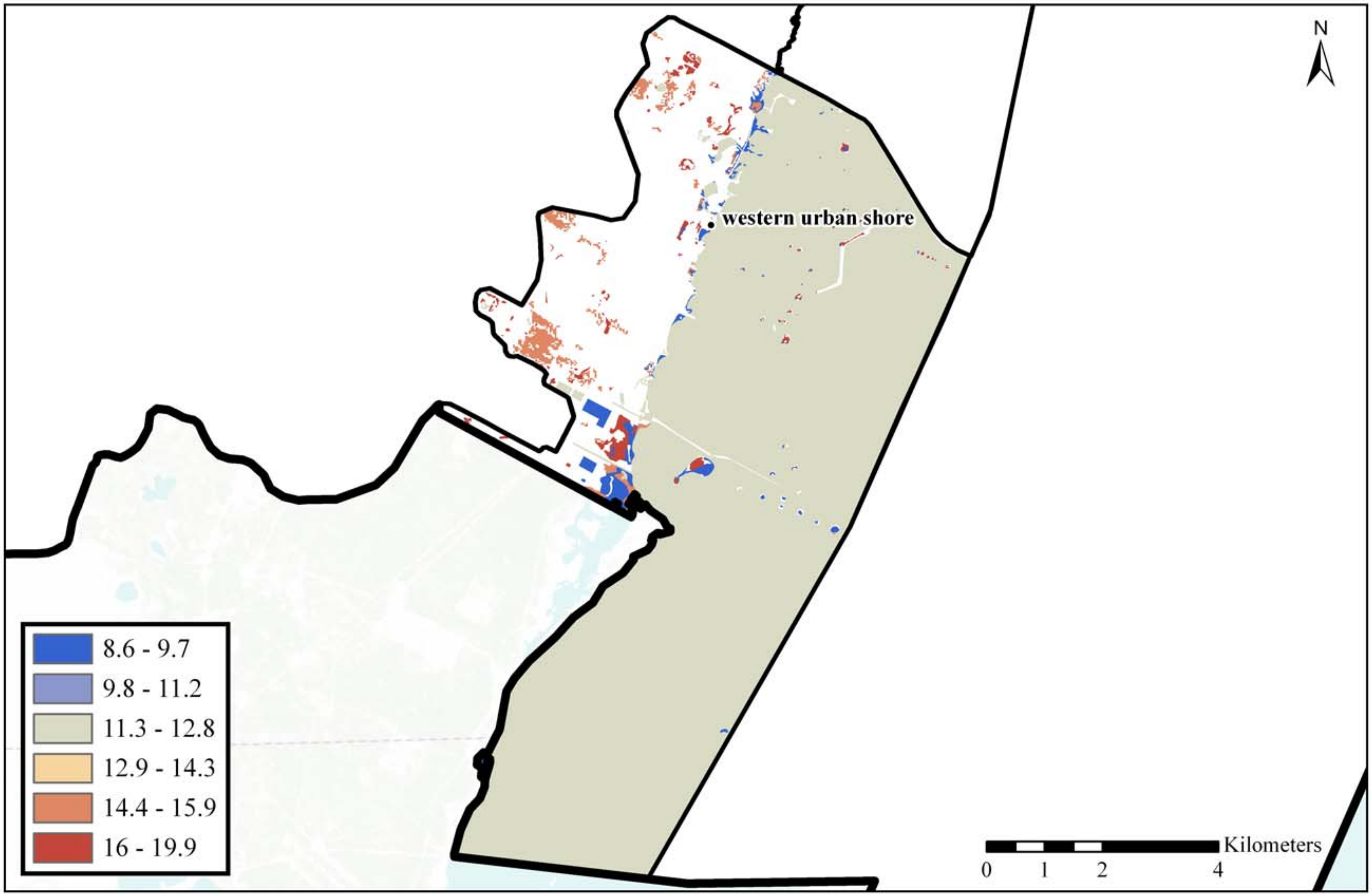

Figure 53. Upper Laguna Madre sub-region heatmap (representing average number of ecosystem services provided by habitats) with specific location mentioned by stakeholders at the first workshop.

Table 48. Current assets and existing concerns within the Upper Laguna Madre sub-region.

Reason For Inclusion	Information Provided By Stakeholders	Further Description
Current assets	Parks	Parks as possible enhancement areas
Current assets	Oysters	To 10 miles offshore; There are more oysters than shown
Current assets	Laguna Madre Field Station	
Existing concern	Blue Hole (channel)	Fish habitat
Existing concern	Tidal flats	Water circulation restoration Tidal flats by Padre Island
Existing concern	Erosion control	
Existing concern	Oak Mottes	
Existing concern	Removal of old obstructions	
Existing concern	Rookery islands	
Existing concern	Seagrass	
Existing concern	Sewage retrofit	
Existing concern	Water quality management	

Table 49. Ecosystem service values for buffer regions surrounding area mentioned by stakeholders at the first workshop.

Site	Mean	Min	Max	Range
Western urban shore	6.94	0.00	16.53	16.53

Future Activities

Future activities for inclusion in the EBMP were suggested by stakeholders at the first workshop. Activities related to potential projects within the Upper Laguna Madre sub-region include: beneficial use of dredge material, using existing parks/field stations (Mollie Beattie Coastal Habitat Community and Laguna Madre Field Station) as enhancement areas, increasing kayak access and educational outreach.

General projects and/or concerns

An area of concern identified by stakeholders and described in the Initial Meetings Summary Report (Brenner et al. 2009a) was the impact to natural habitats from anthropogenic structures and activities, e.g. development, agriculture, wastewater treatment plants, navigation channels, and dredged material placement areas. Stakeholders identified four types of manmade structures of concern including parks, agriculture, permitted point sources, and rookery islands. The purpose of this section of the report, therefore, is to compile and summarize available information related to the four types of manmade structures and associated activities and the impacts to natural habitats from the manmade structures.

Parks

Parks data was acquired from the City of Corpus Christi and only includes state, county and city parks within the City of Corpus Christi (Peggy Sumner pers. com.). Parks comprise approximately 26.4 km^2 (2,639 ha) within the City and they are managed by three levels of government including state, county and city governments (Figure 54). The two (2)state parks are managed by the Texas Parks and Wildlife (TPWD), the three (3) county parks are managed by Nueces County, and the two hundred and two (202)city parks are managed by the City of Corpus Christi (Table 50).

Park lands are managed by different levels of government with different management goals. The State Parks Division within the TPWD is "…responsible for protecting, interpreting and managing cultural and natural resources of statewide significance and providing outdoor recreation opportunities and opportunities to learn about Texas history and natural science" (http://www.tpwd.state.tx.us/business/about/divisions/state_parks/). Nueces County has Park Board Commissioners responsible for the operation of the County Park System. The Board is comprised of seven commissioners each serving a two year term and appointed by the County Judge. The City of Corpus Christi Parks and Recreation Department's goal is to "…provide an environment to enrich everyone's lives and encourage positive lifestyle choices" (www.cctexas.com/pr/). The City's programs are designed to emphasize health and fitness, quality of life, accessibility and affordability.

City parks are considered "urban" ecosystems. These urban ecosystems are documented as providing cultural ecosystem services such as education and recreation in addition to ecosystem services related to the mitigation of noise, heat and air pollution (Ernstson et al. 2008). The ecosystem services provided by these urban ecosystems are degraded when parks are isolated or fragmented (Ernstson et al. 2008). Management of these urban ecosystems can affect the ecosystem services provided (Ernstson et al. 2008). For example, city parks can be designed in a way that enhances and adds to ecosystem services, not only for users of the park, but also for residents who live in the area. Living infrastructure, such as functional landscapes, rainwater harvesting, outfall treatment, bioswale conveyances and stormwater ponds and wetlands are all options that try to mimic natural systems and provide and enhance ecosystem services.

Impacts:

- Loss of natural habitat
- Habitat partitioning and fragmentation
- Increased debris from park users
- Increased runoff from parking lots and buildings

Ways to address impacts:

- Demonstration projects
- Educational resources

Volunteer restoration projects (students, civic groups, etc.):

- Outdoor laboratory concept for education/outreach
- Adequate solid waste disposal
- Rain gardens
- Biofilters and swales to filter runoff
- Organic recycling program/composting

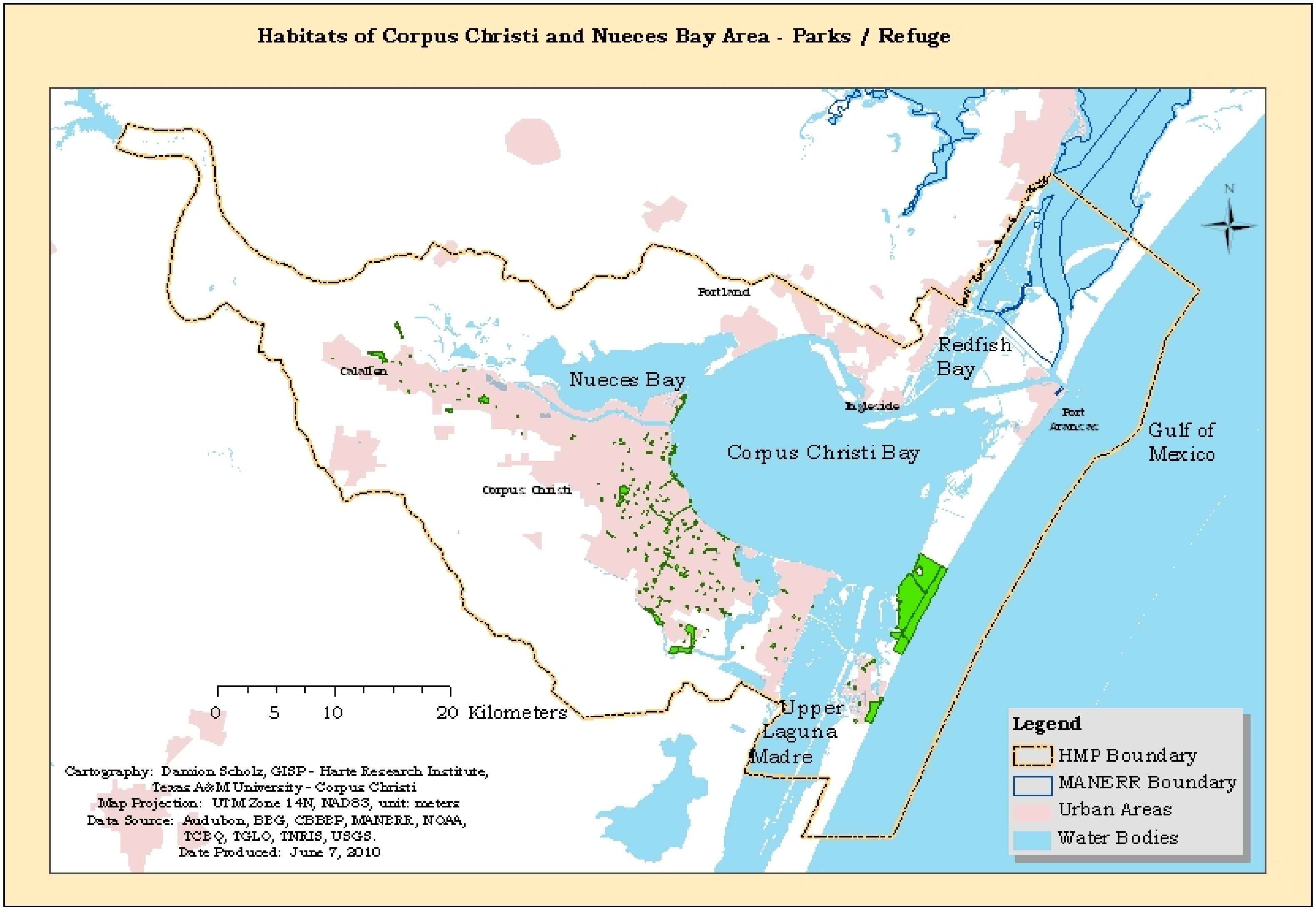

Figure 54. Parks and refuges in the EBMP area.

Table 50. Parks within the City of Corpus Christi, Texas.

Park Name	Type	Location
Mustang Island	State	Hwy. 361 & S. Padre Island Dr.
Padre Island Beach	State	Marquesa Dr. & Whitecap Blvd.
Padre Balli	County	Park Road 5 & S. Padre Island Dr.
Packery Channel	County	S. Padre Island Dr. & Marina Dr.
Hazel Bazemore	County	Spring Creek Dr.
Fountain	Municipal	Fountain St. & Moody Dr.
Inwood	Municipal	Mansheim Blvd. & Vestal St.
Garrett Memorial	Municipal	Vitemb St. & Sherman St.
West Haven	Municipal	Cliff Moss Dr. & Rockford Dr.
Molina Veterans	Municipal	Bloomington St. & Teresa St.
Don And Sandy Billish Memorial	Municipal	Gypsy St. & Fortuna Bay Dr.
Aquarius	Municipal	Aquarius St. & Schooner Dr.
Commodore	Municipal	Commodores Dr. & Swordfish St.
Kent Ulberg	Municipal	Jackfish Ave.
Caribbean	Municipal	Mediterranean Dr. & Otranto Dr.
Wranosky	Municipal	Graham Rd.
Parker	Municipal	Woldron Rd. & Graham Rd.
Dimitt	Municipal	Jester St. & Laguna Madre
Turtle Cove	Municipal	Love Bird St. & Oriole St.
South Seas	Municipal	Panay Dr. & Sulu Dr.
Golden Oaks	Municipal	Red Oak Dr.
Waldron	Municipal	St. Francis St. & St. Benedict Crt.
Retta	Municipal	Furgale Dr. & Vialoux Dr.
Castle	Municipal	Alhambra Dr. & Versailles Dr.
Los Encinos	Municipal	Greenwood Dr. & La Joya St.
Friar Fernandez	Municipal	Frio St.
Temple	Municipal	Burnet St. & Niagra St.
San Diego	Municipal	Niagra St. & Presa St.
Parklane	Municipal	Arlene Dr. & Mt. Vernon Dr.
Lincoln	Municipal	Marie St. & Lamont St.
Maple Hills	Municipal	Deer Run Dr. & Up River Rd.
Labonte	Municipal	Nueces River & U. S. Hwy. 77
Dr. Hector P. Garcia	Municipal	Greenwood Dr. & Gollihar Rd.
Sherwood	Municipal	Sherwood Dr. & Redwood St.
Collier	Municipal	Redwood St. & Teak St.
South Pope	Municipal	Ft. Worth St. & Driftwood Pl.
Mistletoe	Municipal	Mistletoe Dr. & Chestnut St.
Mt. Vernon	Municipal	Holmes Dr. & Mcardle Rd.
Lions	Municipal	Holmes Dr. & Mcardle Rd.
Southside Kickball Complex	Municipal	Mcardle Rd. & Edith St.
Doddridge	Municipal	Ocean Dr. & Doddridge St.
Brawner Parkway	Municipal	Brawner Pkwy. & S. Staples St.
Carmel	Municipal	S. Staples St. & Carmel Pkwy.
Flynn-Shea	Municipal	Flynn Pkwy. & Holly Rd.
Overland	Municipal	Frontier Dr. & Winrock Dr.
West Guth	Municipal	Up River Rd. & Ih 37
Patterson	Municipal	N. Harrington Dr.
Willow	Municipal	Willowood Creek Dr.
Country Estates	Municipal	Emory Dr.
Violet	Municipal	Windsor St. & Viloet Rd.
Woodland	Municipal	Wandering Creek Dr. & Chispa Creek Dr.

Senior Officer Prieto	Municipal	Woodland Creek Dr.
Brookhill	Municipal	Brookhill Dr. & Shelton Blvd.
Castle River	Municipal	Castle Valley Dr.
Northwest	Municipal	Spaulding Dr.
Forest	Municipal	Calallen Dr. & Smith Dr.
Cenizo	Municipal	Rolling Ridge Trl.
San Carlos	Municipal	Figueroa St. & Sharpsburg Rd.
John Jones	Municipal	Shaw St. & Harriett St.
Moody	Municipal	Castenon St.
Edgewood	Municipal	Alexander St. & Brentwood Dr.
Caswell	Municipal	Naples St. & Alexander St.
Cuiper	Municipal	Cuiper St. & Verner Dr.
Sam Houston	Municipal	Brentwood Dr.
Belaire	Municipal	Bentwood Dr. & Orlando Dr.
Vanderbilt	Municipal	Vanderbilt Dr. & Ellis Dr.
Broadmoor	Municipal	Churchill Dr. & Arlington Dr.
Parkview	Municipal	Parkview Dr. & Wickersham Dr.
Crestmont	Municipal	Cresthill & Carroll Ln.
Camargo	Municipal	Camargo Dr.
Kingston	Municipal	Kingston Dr.
Almanza	Municipal	Buggywhip Dr. & Lariat Ln.
Sacky	Municipal	Sacky Dr. & Richter St.
Evelyn Price	Municipal	Gollihar Rd. & Sequoia St.
Botsford	Municipal	Hamlet Dr. & Mcardle Rd.
Pebble	Municipal	Crestpebble Dr. & Hillcrest Dr.
Southside	Municipal	Sunnybrook Rd. & Odem Dr.
Bill Witt	Municipal	Rodd Field Rd. & Yorktown Blvd.
Southfork	Municipal	Oso Pkwy. & Twin Creek Dr.
Sgt. J. D. Bock	Municipal	Vancouver Dr. & Canadian Dr.
Brockhampton	Municipal	Brockhampton St. & Dunbarton Oak St.
Brighton	Municipal	Brockhampton St. & Stone Henge St.
Brandywine	Municipal	Mansfield Dr. & Summer Ridge Dr.
Airline	Municipal	Airline Rd. & Hollister Dr.
Windsong	Municipal	Meadowbreeze Pkwy. & Cotton Club Dr.
Durant	Municipal	Durant St.
Cimarron	Municipal	La Salle Dr. & Rock Crest Dr.
Wooldridge	Municipal	Cricket Hollow Dr. & Cinnamon Oaks Dr.
Peary	Municipal	Paul Jones Ave. & Barnhart Dr.
Victoria	Municipal	Oso Pkwy. & Quebec Dr.
Holly	Municipal	Meadowvista Pkwy.
Rancho Vista	Municipal	Rancho Vista Blvd. & Vaquero Dr.
St. Denis	Municipal	St. Denis St. & Annemasse St.
Greystone	Municipal	Sydney St. & Greystone Dr.
Vineyards	Municipal	Vineyard Dr. & Napa Dr.
Bear Creek	Municipal	Wolverine Dr.
Capt. Falcon	Municipal	Oso Pkwy & Moritz Lake Dr.
Lipes	Municipal	Lethaby Dr.
Creekway	Municipal	Prairie Dr.
Crossgate	Municipal	Crossvalley Dr. & Rivergate Dr.
Sugar	Municipal	Candy Ridge Rd.
Cedar Ridge	Municipal	Ridge View Dr. & Brentridge Dr.
Breckenridge 2	Municipal	Sun Valley Dr. & Cedar Pass Dr.
Middlecoff	Municipal	Long Meadow Dr.

Wales	Municipal	Wapentate Dr. & Grand Junction Dr.
Snead	Municipal	Snead Dr. & Hogan Dr.
Acushnet	Municipal	Acushnet Dr.
St. Andrews	Municipal	Royalton Dr. & St. Andrews Dr.
Ridgewood	Municipal	Malden Dr. & Crestwick Dr.
Congress	Municipal	Capitol Dr. & Congressional Dr.
Penn Place	Municipal	Aaron Dr. & Sun Valley Dr.
Stony Brook	Municipal	Stony Brook Dr. & Cedar Brook Dr.
Schanen Estates	Municipal	Kerry Dr. & O'toole Dr.
Winrock	Municipal	Cedar Pass Dr. & Winrock Ln.
Oso Creek	Municipal	Oso Pkwy.
Country Club	Municipal	Congressional Dr. & Brisbane Dr.
Reflections Linear	Municipal	Oso Pkwy.
Prescott	Municipal	Shely St. & Crosstown Expwy.
Candlewood	Municipal	Birchwood Dr. & Lemonwood Dr.
Glen Arbor	Municipal	Tanglewood Dr. & Braeswood Dr.
Koolside	Municipal	Dorothy Dr. & Bobalo Dr.
Lee Manor	Municipal	Palmetto St. & Troy Dr.
Poenisch	Municipal	Ocean Dr. & Claremore St.
Windsor	Municipal	Sheridan Dr. & Harry St.
Claremont	Municipal	Caddo St. & Tim Ln.
Brookdale	Municipal	Ashland Dr. & Gaines St.
Dan Whitworth	Municipal	Airline Rd. & St. Pius Dr.
Cullen	Municipal	Airline Rd. & Gollihar Rd.
Han & Pat Suter	Municipal	Ennis Joslin Rd. & Nile Dr.
Palmetto	Municipal	Ocean Dr. & Palmetto St.
Lakeview	Municipal	Holly Rd. & Rodd Field Rd.
Oso Place	Municipal	Prince Dr. & Burr Dr.
Sands	Municipal	Silver Sands Dr. & Dawn Breeze Dr.
Lexington	Municipal	Rhine Dr. & Thames Dr.
Nature	Municipal	Greely Dr. & Poenisch Dr.
Ennis Joslin 2	Municipal	Ennis Joslin Rd. & S. Alameda St.
Ennis Joslin 1	Municipal	Ennis Joslin Rd. & S. Alameda St.
Swantner	Municipal	Ocean Dr. & S. Shores Dr.
South Bay	Municipal	Sealane Dr. & Seashore Dr.
Lamar	Municipal	Sante Fe St. & Barracuda Pl.
North Pope	Municipal	Catalina Pl. & Ft. Worth St.
Carroll Lane	Municipal	Carrol Ln. & Poplar St.,
Casa Linda	Municipal	Norton St. & Casa Grande Dr.
Ropes	Municipal	Ocean Dr. & Sinclair St.
Gardendale	Municipal	Holly Rd. & Betty Jean Dr.
Stonegate	Municipal	Oxford Dr. & Bonner Dr.
Malibu	Municipal	Kingston Dr. & Fresno Dr.
Wilmot	Municipal	19th St. & Howard St.
Jackson Woods	Municipal	Fair Oaks Dr. & Up River Rd.
First Colony	Municipal	Lone Oak Dr. & Prairie Ridge Dr.
Spohn	Municipal	Mesquite St. & Lipan St.
Mccaughan	Municipal	S. Shoreline Blvd. & Park Ave.
South Bluff	Municipal	Park Ave. & S. Tancahua St.
T. C. Ayers	Municipal	Coke St. & Winnebago St.
Lovenskold	Municipal	Brownlee Blvd. & Ih 37
Cabra	Municipal	Parker Alley & Broadway St.
Artesian	Municipal	N. Chaparral St. & Twigg St.

Heritage	Municipal	N. Chaparral St.
Blucher	Municipal	N. Carrizo St. & Blucher St.
T. C. Ayers	Municipal	Coke St. & Martin Luther King Dr.
La Retama	Municipal	Peoples St. & N. Mesquite St.
Sherrill	Municipal	S. Shoreline Blvd. & Cooper's Alley
Old City Hall	Municipal	Shoreline Blvd. & Kinney St.
Mcgee Beach	Municipal	Shoreline Blvd. & Park Ave.
Breakwater	Municipal	Breakwater Ave. & N. Shoreline Blvd.
Douden	Municipal	Cobo De Bara Cir. & Port Royal Crt.
Surfside	Municipal	Surfside Blvd. & Stewart Pl.
C. C. Beach	Municipal	C. C. Beach Off Timon Blvd.
Kiwanis	Municipal	Timon Blvd. & Tourist Ave.
Lawndale	Municipal	Daytona Dr. & Blevins St.
Lindale	Municipal	Swantner Dr. & Mccall St.
Ocean View	Municipal	7th St.
H. E. B.	Municipal	Fig St. At Shely St.
Louisiana Parkway	Municipal	Louisiana Ave. & Ocean Dr.
Cole	Municipal	Ocean Dr.
Easley	Municipal	Annapolis Dr. & Devon Dr.
Longview	Municipal	Longview East St. & Longview West St.
Kosar	Municipal	S. Staples St. & Kosar St.
Dalhia Terrace South	Municipal	Clodah Dr. & Eunice Dr.
Village On The Green	Municipal	Green Tree Dr. & Green Willow Dr.
Dalhia Terrace North	Municipal	Clodah Dr. & Eunice Dr.
Chiquito	Municipal	Pine St. & Pueblo St.
Youth Sports Complex	Municipal	Greenwood Rd. & Horne Rd.
Lawson	Municipal	Elgin St. & Soledad St.
Dr. H.C. Dilworth	Municipal	Elgin St. & Dunbar St.
Airport	Municipal	Beechcraft Ave. & Post Ave.
Austin	Municipal	Hidalgo St. & Guatemozin St.
Joe Garza	Municipal	Highland Ave. & Osage St.
Parkview	Municipal	
Oak	Municipal	Mueller St. & Live Oak St.
Dr. H. J. Williams	Municipal	Kennedy Ave. & Minton St.
Woodlawn	Municipal	Westside St.& Erwin Ave.
Tom Graham	Municipal	Up River Rd. & Oak Park Ave.
Glen Royal	Municipal	Liberty Dr. & Victory Dr.
Mobile	Municipal	Benys Rd. & Skyline Dr.
Ben Garza	Municipal	Coke St. & Howard St.
Westgate	Municipal	Longview West St. & Granada St.
Westchester	Municipal	Westchester Dr. & Avondale Dr.
Academy Heights	Municipal	Comal St.
Mcnorton	Municipal	Mcnorton Rd. & Caroline Rd.
Tuloso	Municipal	Timberline Dr. & Tuloso Rd.
Hudson	Municipal	Main Dr. & Erne St.
Solar Estates	Municipal	Rainmist Ln.
Soccer Field	Municipal	Haven Dr. & Warrior Rd.
Lawrence St. T-Head	Municipal	Lawrence St. & N. Shoreline Blvd.
Peoples St. T-Head	Municipal	Peoples St. & N. Shoreline Blvd.
Coopers Alley L-Head	Municipal	Coopers Alley & N. Shoreline Blvd.

Agriculture

Spatial data from the United States Geological Survey (USGS), Multi-Resolution Land Characteristics Consortium (MRLC 2001) with a 30x30 m pixel resolution was used to derive the extent of agriculture lands in the EBMP area (Figure 55). There are approximately 561 km^2 (56,056 ha) of agriculture lands in the EBMP area, approximately 23% of the total EBMP area. The dominant crops cultivated in Nueces County within the Coastal Bend area include sorghum and cotton, with corn, wheat, and sunflowers coming in third, fourth and fifth respectively (Table 51) (pers. com. J.R. Stapper, Nueces County Extension Agent).

Historically, agricultural lands were converted by humans from other habitat types. The conversion from native ecosystems to cultivated farmland has led to a loss in biodiversity (Swinton et al. 2007). Between the mid-1950's and early 1990s Texas lost about 98,000 acres of palustrine or inland, nontidal wetlands to agriculture (Moulton et al. 1997). Urbanization increased during this same period, "…mostly at the expense of agriculture and other upland land uses" (Moulton et al. 1997). Between 1996 and 2006 agriculture experienced a loss of 1.33 km^2 within the EBMP area. Agricultural lands are being converted to developed lands as the footprint of the cities increase.

Agriculture has been referred to as a "managed ecosystem" providing both ecosystem services and disservices (Swinton et al. 2007). The most obvious and important ecosystem service provided by agricultural lands is the provision of food, fuel and fiber (Swinton et al. 2007). Other ecosystem services provided by agricultural lands include a wide range of regulating services including the regulation of water and climate and cultural services such as aesthetics and cultural heritage of rural lifestyle (Swinton et al. 2007). Ecosystem disservices are also provided by agricultural lands. Nutrient loading from agricultural lands is known to decrease the biodiversity and alter plant communities of wetlands. These changes decrease habitat quality for native species (Tomer et al. 2009).

The management of ecosystem services involves tradeoffs. Tradeoffs occur between ecosystem services and between current and future benefits of an ecosystem service (Carpenter et al. 2006). Tradeoffs of ecosystem services are difficult to analyze, but understanding these tradeoffs can help to inform sustainable decision-making (Carpenter et al. 2006). Economic discounting is one way to assess tradeoffs between current and future ecosystem services (Carpenter et al. 2006).

When considering management options that seek to protect biodiversity and at the same time, enhance economic development, understanding factors that affect the outcome is crucial (Tallis et al. 2008). The conversion of native ecosystems to agricultural lands reduces some ecosystem services and enhances others (Carpenter et al. 2006). For example, the use of fertilizer on agricultural lands has helped to increase food security, while simultaneously degrading water quality. Restoration of agricultural lands back to native ecosystems can restore some ecosystem services. Further, simply maintaining agricultural lands from conversion to urbanized areas may protect ecosystem services as well (Swinton et al. 2007).

Based on input from local stakeholders, concerns exist within the EBMP area regarding impacts from agriculture such as the use of pesticides, fertilizers and sediment erosion (Palmer et al. 2009). Management options exist to address these stakeholder concerns and include year round plant cover and conservation tillage (Swinton et al. 2007). These management options enhance the ecosystem services of groundwater recharge in addition to carbon sequestration (Swinton et al. 2007). Additionally, native communities and wetlands can be restored within agricultural lands, and in buffer zones near waterways, to further enhance the ecosystem services mentioned above in addition to providing habitat for pollinators and natural predators of crop pests (Swinton et al. 2007). An example of farming that incorporates native communities into agricultural practices is "wildlife-friendly farming" (Fischer et al. 2008).

Table 51. Agricultural statistics for 2010 in Nueces County from the AgriLife Extension Service (pers. com. J.R. Stapper, Nueces County Extension Agent).

Commodity	**Planted (ac)**
Grain Sorghum	185,425
Cotton	105,485
Corn	9,867
Wheat	8,463
Sunflowers	1,593
TOTAL	310,833

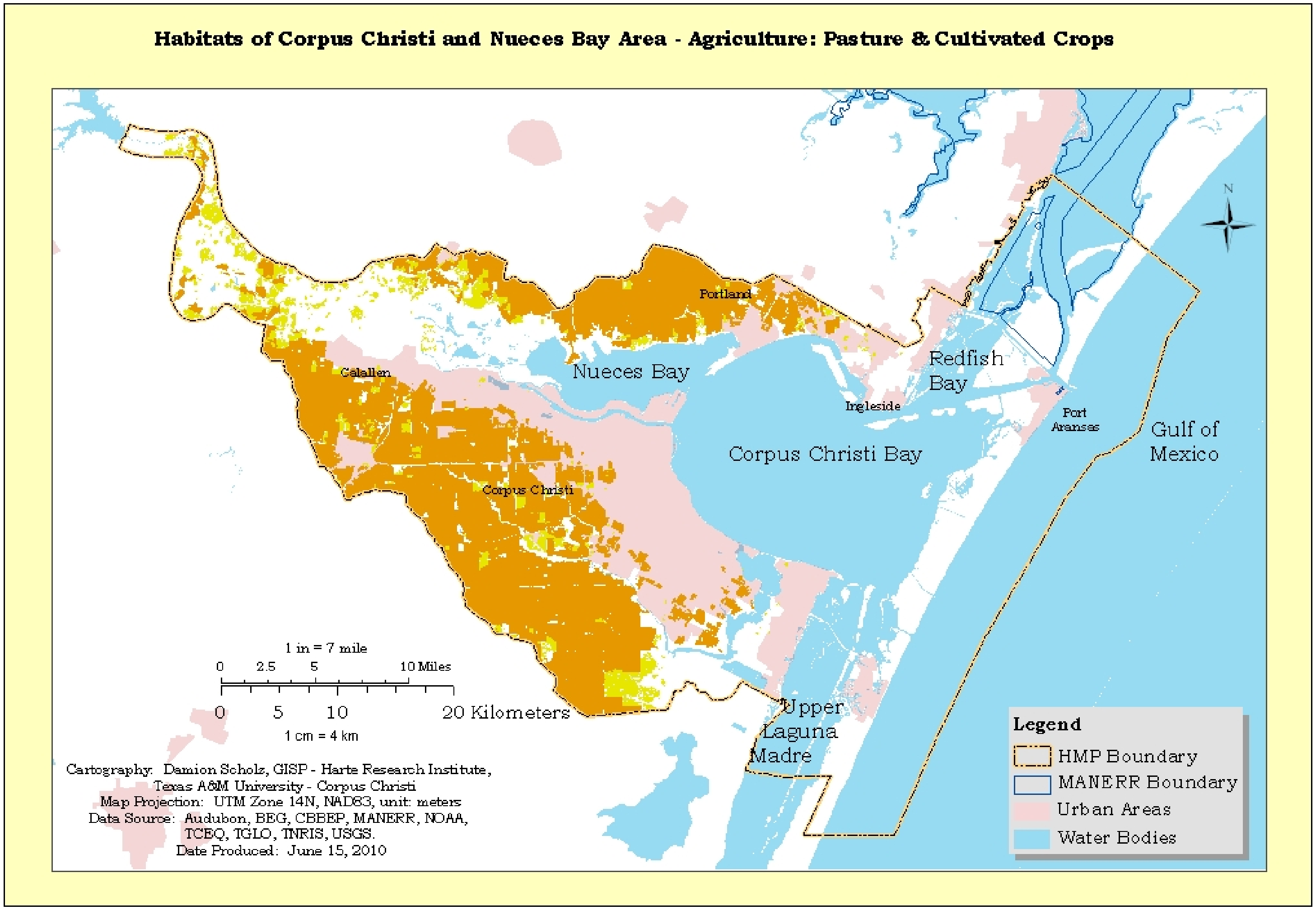

Figure 55. Agriculture in the EBMP area.

Permitted Point Sources

The state agency responsible for regulating air, water, and waste is the Texas Commission on Environmental Quality (TCEQ). One of the many roles of the TCEQ is to issue wastewater permits for point or 'end of pipe' and non-point or 'diffuse' sources of pollution. The purpose of this section of the report is to identify the number and type of permitted outfalls within the EBMP area and discuss impacts to habitats from the outfalls.

The TCEQ maintains a Geographic Information Systems (GIS) data layer of georeferenced locations of the permitted wastewater outfalls issued in the state (http://www.tceq.state.tx.us/gis/sites.html). The TCEQ GIS data was downloaded and used to determine the number and type of permitted wastewater outfalls that exist within the EBMP boundary. The EBMP boundary layer was used as a mask to extract the permitted wastewater outfalls within the Plan area. The Central Registry Query at the TCEQ website (http://www12.tceq.state.tx.us/crpub/index.cfm?fuseaction=cust.CustSearch) was also used to aid with acquiring permit information for each permitted entity. Results were categorized as industrial point sources or domestic wastewater treatment facilities (Figure 56). A total of thirty-one (31) permitted industrial point sources and sixteen (16) domestic wastewater treatment facilities were identified (Table 52). The industrial point sources include waste process water from the industrial facilities and in most cases storm water that drains from the facility's footprint. We attempted to differentiate between point and non-point sources, however many permits included provisions for both sources in the same permit; therefore it was not possible to distinguish between the two source types. The domestic wastewater treatment facilities are required to disinfect the effluent using chlorination or ultra-violet light before the effluent is discharged. Facilities with a permit to discharge more than 1.0 MGD and use chlorination as a disinfectant must also dechlorinate to reduce negative effects on stream organisms.

The permitted entities were further categorized based on the amount of effluent they are allowed to discharge into the environment. A major discharger includes those entities allowed to discharge more than 1.0 MGD and a minor discharger includes those entities allowed to discharge less than 1.0 MGD. In total, there were forty-seven (47) permitted outfalls in the HPM area, twenty-five (25) were major dischargers while 17 were minor. Five (5) permitted entities had no established maximum daily average limit but instead had an intermittent and flow variable condition. The largest dischargers were the Nueces Bay and Barney Davis Power Stations with 500 and 540 MGD respectively. Excluding the City of Odem discharge, the total maximum permitted daily average discharge from the domestic wastewater facilities within the EBMP area is 57.5328 MGD.

Impacts from outfalls may include:

- Transfer of zinc laden water from the CCIH to Nueces Bay resulting in zinc contaminated oyster tissue (TMDL for zinc in Nueces Bay)
- Transfer of hypersaline water from the Upper Laguna Madre to Oso Bay

- Entrainment of living resources at intakes
- Scouring of bay sediments at outfall locations
- Contaminated surface waters and sediments, e.g. Petroleum products, pesticides, herbicides, fertilizers, car wash detergents, etc.
- Bacterial contamination
- Nutrient enrichment
- Increased discharges over time due to increased demands from human population growth
- Increased loadings of biochemical oxygen demanding substances
- Domestic refuse e.g. Solid waste
- Freshwater inflow diversions

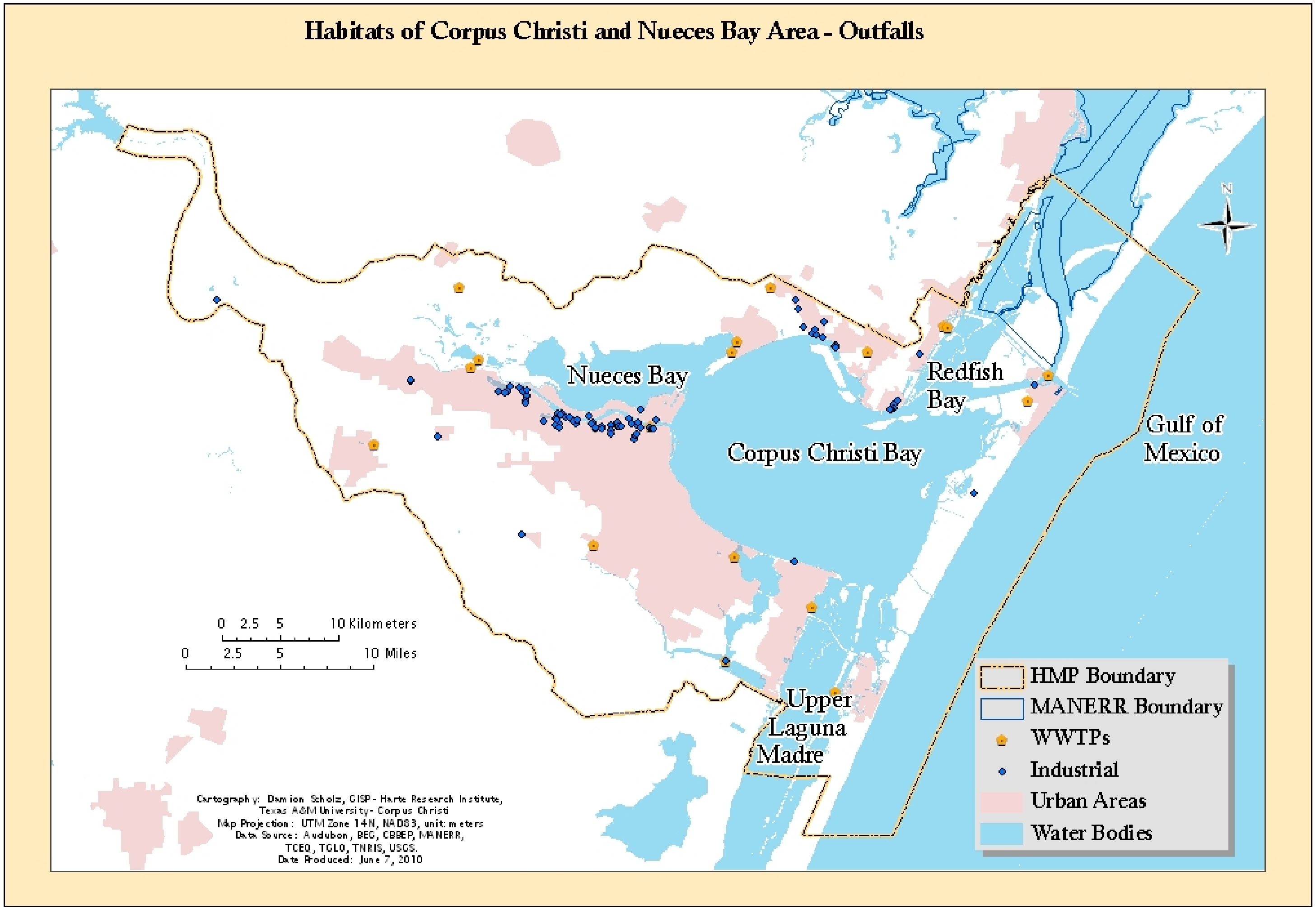

Figure 56. Permitted outfalls in the EBMP area.

Table 52. Discharge permits in the EBMP for the Corpus Christi Bay area. Major category means the permit allows discharge > 1 million gallons per day; Minor category means the permit allows discharge < 1 MGD; NA means information not available.

Permitted Entity	**TCEQ Permit Number**	**Category (MGD)**
Domestic Wastewater Treatment Facilities		
1. Nueces County WCID 4 – North Mustang Island	WQ0010846-001	Major (1.88)
2. Corpus Christi Peoples Baptist Church	WQ0011134-001	Minor (0.02)
3. City of Corpus Christi, Oso	WQ0010401-004	Major (16.2)
4. City of Corpus Christi, New Broadway	WQ0010401-006	Major (10)
5. City of Corpus Christi, Allison	WQ0010401-006	Major (7)
6. City of Corpus Christi, Laguna Madre	WQ0010401-008	Major (3)
7. City of Corpus Christi, Whitecap	WQ0010401-009	Major (2.5)
8. City of Corpus Christi, Greenwood	WQ0010401-003	Major (8.0)
9. City of Robstown	WQ0010261-001	Major (3.00
10. City of Odem	WQ0010237-001	Minor (NA)
11. City of Gregory	WQ0010092-001	Minor (0.32)
12. City of Ingleside	WQ0010422-001	Major (1.5)
13. City of Portland	WQ0010478-001	Major (2.5)
14. City of Aransas Pass	WQ0010521-002	Major (1.6)
15. Sublight Enterprises Inc., Portland Inn	WQ0011096-001	Minor (0.009)
16. Martin Operating Partnership LP, Harbor Island	WQ0012731-001	Minor (0.0038)
Industrial Permitted Facilities		
17. Valero Refining – Texas LP, East Plant Coke Handling Pad	WQ0002540-000	Intermittent and flow variable
18. Citgo Refining and Chemicals Company LP, Deep Sea Terminal	WQ0002614-000	Intermittent and flow variable
19. BTB Refining LLC	WQ0002720-000	Minor (0.12)
20. Occidental Chemical Corporation, Oxychem Ingleside Plant	WQ0003083-000	Major (NA)
21. Flint Hills Resources LP, West Plant	WQ0000531-000	Major (NA)
22. Markwest Javelina Company LLC, Gas Processing Facility	WQ0003137-000	Minor (0.478)
23. Citgo Refining and Chemicals Company LP, Deep Sea Terminal	WQ0003562-000	Intermittent and flow variable
24. Encycle Texas Inc.	WQ0000314-000	Major (NA)
25. Texas A&M University, Shoreline Environmental Research Facility	WQ0003646-000	Minor (0.99)
26. Flint Hills Resources LP, East Refinery	WQ0000457-000	Major (NA)
27. Valero Refining, East Plant	WQ0000465-000	Major (3.325) Intermittent and flow variable
28. Citgo Refining and Chemicals Company LP, East Plant	WQ0000467-000	Major (NA)

Permitted Entity	**TCEQ Permit Number**	**Category (MGD)**
29. Flint Hills Resources LP, Corpus Christi West Plant	WQ0000531-000	Major (NA)
30. Corpus Christi Cogeneration	WQ0004158-000	Minor (NA)
31. Texas A&M University System, Agrilife Research Mariculture Lab	WQ0004165-000	Minor (NA)
32. Reynolds Metals Company, Reynolds Metal	WQ0004606-000	Intermittent and variable
33. Sherwin Alumina LP, Sherwin Alumina Plant	WQ0004646-000	Intermittent and variable
34. Gulf Marine Fabricators LP – North	WQ0012064-001	Minor (NA)
35. Flint Hills Resources LP – Ingleside Marine Terminal Facility	WQ0001207-000	Minor (NA)
36. Nueces Bay WLE LP, Power Station	WQ0001244-000	Major (500)
37. Lon C. Hill LP, Power Station	WQ0001255-000	Major (1.098)
38. American Electric and Power, Barney Davis Power Station	WQ0001490-000	Major (540.0)
39. E.I. Dupont De Nemours and Company, Corpus Christi	WQ0001651-000	Major (NA)
40. Koch, Corpus Christi Terminal	WQ0002578-000	Minor (NA)
41. Valero Refining – Texas LP, West Plant	WQ0001909-000	Major (NA)
42. Wright Materials Inc., Nason Plant 1	WQ0002027-000	Minor (NA)
43. Magellan Terminals Holdings LP, Corpus Christi Terminal	WQ0002070-000	Minor (NA)
44. Equistar Chemicals LP, Corpus Christi Plant	WQ0002075-000	Major (1.5)
45. US Department of the Navy	WQ0002317-000	Major (1.5)
46. Texas A&M University, Agricultural Extension Service	WQ0011345-001	Minor (0.0015)
47. Gulf Marine Fabricators LP, South	WQ0003012-000	Minor (0.004)

Rookery Islands

Rookery island habitat was primarily created with sediment derived from dredging of navigation channels (Chaney and Blacklock 2003) such as the Gulf Intracoastal Waterway, Corpus Christi Ship Channel, La Quinta Channel, and other smaller channels located within the EBMP area. Sediment from dredging activities was placed in areas of the bay bordering navigation channels which created island chains. The islands created by the dredged material developed into productive habitat that support a diversity of highly valued colonial nesting waterbirds (Sims and Smith 2001).

There are currently 286 mapped rookery islands within the EBMP area (Figure 57). In 2003, Chaney and Blacklock developed the Colonial Waterbird and Rookery Island Management Plan with the goal of restoring, enhancing and protecting waterbird habitat, however, they did not determine areal extent nor did they assess status and trends of the rookery island habitat. Ongoing work to determine areal extent of rookery island habitat is being conducted by Cullen Hanks with the Nature Diversity Database and David Newstead of the CBBEP (personal communication).

Rookery islands are predominantly manmade structures that provide productive habitat for colonial nesting birds. Although initially most rookery islands served as dredged material placement areas and may have impacted natural habitats such as open bay bottom and seagrass beds, they are now considered habitats themselves experiencing impacts from anthropogenic activities. For example, rookery islands have experienced impacts from erosion and inundation due to natural and human induced phenomenon such as storms, boat traffic, vegetation changes, invasive species and sea level rise.

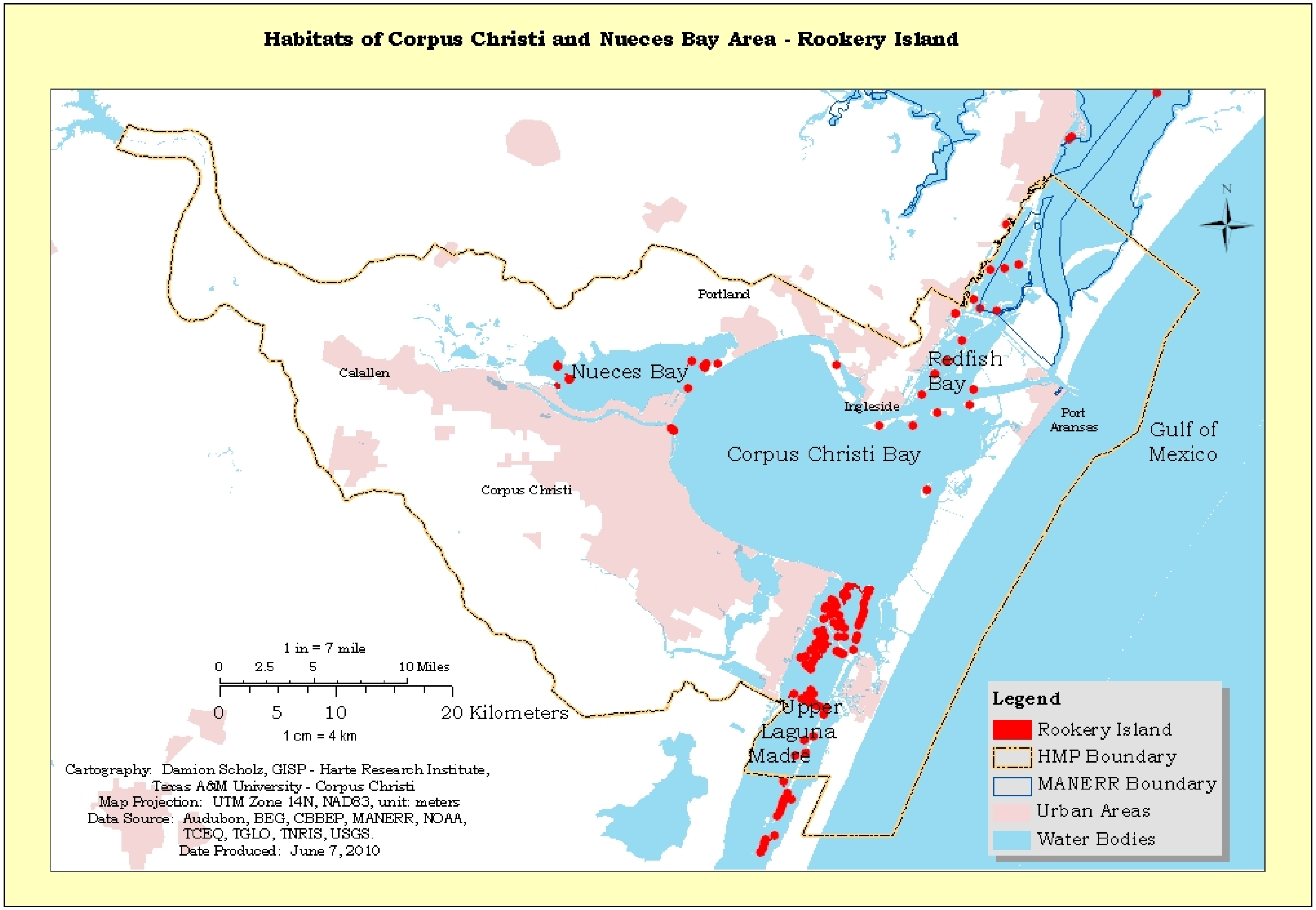

Figure 57. Rookery islands in the EBMP area.

FUTURE OUTCOMES AND NEXT STEPS

The EBMP provides information about the habitats, threats and risks, project approach and process, ecosystem service valuation of habitats, and an inventory and prioritization of projects for protection/restoration/creation in the Corpus Christi Bay area. This information has been collectively used to create a valuable tool, the 'heat maps', for the project area that identify priority areas for targeting implementation of future projects. The current section of the EBMP discusses the mechanisms or implementation tools by which these projects can be implemented and provides recommendations that resulted from development of the EBMP.

Implementation Tools

<u>Governance structure, regulatory, policy and legal constraints</u>

The primary regulatory mechanism used to protect wetland and aquatic resources is the Clean Water Act (CWA). The goal of the CWA is to restore and maintain the chemical, physical and biological integrity of our Nation's waters. In striving to achieve the CWA goal, the discharge of dredged or fill material into waters of the U.S. are prohibited unless a CWA §404 permit has been issued by the United States Army Corps of Engineers (USACE) and authorizes such activities. While the USACE has the primary responsibility for implementing the CWA §404 permitting program, other federal and state agencies in Texas such as the EPA, USFWS, NRCS, TPWD, TCEQ and NMFS also play important regulatory and advisory roles. The discharge of dredged and fill material into waters of the U.S. results in adverse impacts to natural resources, therefore to address these adverse impacts the mitigation sequence is implemented as part of the permitting process. The mitigation sequence involves three steps:

1. Avoid adverse impacts to aquatic resources by not discharging when a practicable alternative with less adverse impact is available,
2. Minimize impacts when they are not avoidable, and
3. Compensate for unavoidable adverse impacts through compensatory mitigation.

If adverse impacts are not avoidable and cannot be minimized, then compensatory mitigation becomes the alternative. The USACE is responsible for determining the appropriate form and amount of mitigation required which typically consists of restoration, establishment or creation, enhancement and preservation. There are three mechanisms by which compensatory mitigation is achieved including permittee-responsible mitigation, mitigation banking, and in-lieu fee mitigation. Permittee-responsible mitigation is undertaken by the permittee after the permit has been issued and they are ultimately responsible for implementation and success of the mitigation project. This type of mitigation may occur either at the site of the adverse impact(s) or an off-site location within the same watershed. Mitigation banking consists of a wetland area that has been restored, established, enhanced or preserved then set aside to compensate for future adverse impacts to wetlands. Permittees can then purchase off-site credits from a mitigation bank within the same watershed to meet their permit requirements. In-lieu fee mitigation occurs when a permittee provides funding to a sponsor who collects the funds from multiple permittees and pools the resources necessary to build and maintain a mitigation site. In-lieu fee mitigation occurs off-site and after the permitted impacts, like mitigation banking.

Nearly all of the habitats identified in this plan are found primarily on public lands. The General Land Office (GLO) has the responsibility for managing public lands in Texas. The primary tool used by the GLO for State control of habitats is the Texas Resource Management Code (RMC) definitions for state tracts. The RMCs were created to assist potential users of the state-owned submerged lands during the CWA §404 permitting process by the USACE and are used to represent development and use guidelines. The codes enhance protection of sensitive natural resources by providing recommendations for minimizing adverse impacts to sensitive natural resources from mineral exploration and development activities. The RMCs are based on recommendations from the USFWS, NMFS, TPWD, Texas Historical Commission, and the USACE. The management codes indicate that only some of the area within the state tract contains those resources. Before beginning work on state submerged land, lessees may be required to conduct a survey for sensitive habitats and resources by the USACE. In most cases, tract development may proceed when an applicant demonstrates that the development plan is consistent with the concerns listed in the codes. When impacts to sensitive habitats or resources are unavoidable, development may be allowed, subject to negotiation for mitigation in the permit requirements as previously described.

<u>In Lieu Fee Program</u>

One possible outcome of this Plan might be the creation of an In Lieu Fee Program that would be used to accumulate mitigation dollars for implementation of large scale ecosystem restoration projects outlined in this Plan. An in-lieu-fee program is an agreement between a regulatory agency (state, federal, or local) and a sole sponsor, generally a public agency or non-profit organization. Under an in-lieu-fee agreement, the mitigation sponsor seeks monetary funds from an individual or a number of individuals who are obligated to conduct compensatory mitigation required under a CWA §404 permit or another state or local wetland regulatory program. The sponsor may utilize the funds collected from multiple permittees to develop one or a number of sites under the power of the agreement to satisfy the permittees' required mitigation. In-lieu-fee mitigation is usually described as mitigation conducted after permitted impacts have occurred. In-lieu-fee mitigation occurs when a permittee provides money to an in-lieu-fee sponsor instead of either completing project-specific mitigation or purchasing credits from a wetland mitigation bank approved under the Banking Guidance.

Although an in-lieu fee program has been described as having "the potential to be an effective mitigation tool that benefits the environment and provides developers flexibility in meeting their mitigation requirements" there are also concerns about their effectiveness (GAO 2001). Some specific concerns stem from the limited oversight to determine the status of the mitigation required by the permits.

Potential Financing Outcomes

Collaboration and cooperation among federal, state, and local governmental and nongovernmental agencies is essential for successful plan implementation. Leveraging funding sources among various agencies with similar natural resource goals and objectives results in implementation projects with the potential to have greater positive impacts. Co-financed projects typically have a larger resource base, therefore are capable of addressing multiple issues of concern, are larger in aerial extent, can restore, enhance, and conserve more and diverse habitats, and typically undergo more scrutiny due to the multiple partners involved. Some funding sources identified by stakeholders for consideration during EBMP implementation include a variety of potential sources (Table 53).

Table 53. Funding sources identified by stakeholders during the first workshop.

Entity	**Source**
Federal	
Natural Resource Conservation Service	Conservation Reserve Program
National Science Foundation	K-12 grants
U.S. Army Corp of Engineers	§1135 Water Resources Development Act for Ecosystem Restoration
U.S. Fish and Wildlife Service	Coastal grants, Land and erosion control grants, Wildlife partners conservation grants
National Oceanic and Atmospheric Administration	All
U.S. Environmental Protection Agency	All
State	
Texas General Land Office	Coastal Management Program Coastal Impact Assistance Program
Texas Parks and Wildlife	Boat ramp grants State Wildlife grants
Texas Birding Classic	Land acquisition, restoration and enhancement grants
Texas Commission on Environmental Quality	Supplemental Environmental Project (SEP) §319 CWA funding for non point source water quality impairments
Texas Soil and Water Conservation Board	§319 CWA funding for non point source water quality impairments
City	
City of Corpus Christi	Tax Increment Financing (TIF)
Non-governmental organization	
Coastal Bend Bays & Estuaries Program	Annual work plan projects
Community Development Block Grants	Bond funds, federal housing administrative grants

Entity	Source
Industry grants	Flint Hills Resources, DOW Chemical, Valero, etc.
Texas Sea Grant	Research and education grants
Fish America Foundation	Marine and Anadromous Fish Habitat Restoration, Grants, Conservation Grants, Fisheries Research Grants
Coastal Conservation Association Texas	Fishery habitat enhancement grant
Gulf of Mexico Alliance	Education, Research, Habitat restoration
Shell Marine Development	Habitat restoration

The GLO participates in Federal programs that fund land acquisition, habitat enhancement and restoration, and management. These programs provide a potential source of funding to implement a ecosystem-based management plan. The Federal programs are housed in several different agencies such as the USACE and the National Oceanic and Atmospheric Administration (NOAA). In addition, there are several non-governmental organization (NGO) and private industries to support conservation actions.

One constraining issue identified during the first stakeholder workshop (Palmer et al. 2009) is that different organizations have different purposes, procedures, policies, and interests. In fact, even within the Federal government, different agencies may take different views on projects. Given the complex nature of the various public and private stakeholders, it is not surprising that there are barriers to implementation of valued projects.

One area where local control can have a positive effect on the governing structure is in the adoption of zoning rules, planning infrastructure, creation of parks and recreation areas, and set-back requirements. Of course this is all balanced by the property rights of private owners. Never-the-less, adoption of local rules and best-management-practices can be powerful tools to stem the loss of habitats.

Recommendations

Research and Monitoring Recommendations

Recently the Harte Research Institute Endowed Professors participated with the General Land Office in creating a planning document for the Texas Coastal Management Plan for the next five years. This document is required in part so that the State of Texas can receive funding from the National Oceanic and Atmospheric Administration's 309 funding. One discovery was that there is little to no follow-up or monitoring of Clean Water Act §404 permit mitigation requirements. This is a large information gap that could have important implications for the current ecosystem-based management plan. Thus it is recommended that there be follow-up monitoring and evaluation of mitigation projects.

While locations of Federal, State, County and State park boundaries are known, and they are included in the maps in the section of the EBMP titled "General projects and/or concerns", there is lacking a general description of amenities and facilities available in these areas. This would be useful for the general public and for habitat planning.

One concern in the planning area is future degradation in dissolved oxygen resulting from environmental stressors such as climate change, increased human population growth, increased permitted point source discharges, and increased nutrient loads, which can lead to hypoxia and dead zones. However, there is no water quality standard for ambient nutrient concentrations that are routinely monitored, especially by permitted entities, to be reported as part of the permit requirements. It is recommended that nutrient concentrations/loadings monitoring from waste water treatment plants be included in self-reporting data to TCEQ and EPA Permit Compliance System database.

Locations of storm water outfalls are not included in the TCEQ outfall GIS layer. This is a large oversight and that information would be valuable for habitat planning. It is recommended that the CBBEP continue to work with local governments to develop a map of all existing storm water outfalls. This type of information would be of great use for planning wetland protection/restoration/creation projects at storm water outfalls that can serve as biofilters for polluted runoff.

Adaptive management has been characterized as a structured, iterative process that optimizes decision making when faced with uncertainty. The goal of adaptive management is to reduce uncertainty over time with the use of system monitoring. In this way, decision making simultaneously maximizes one or more resource objectives and, either passively or actively, accrues information needed to improve future management. Adaptive management has often been characterized as "learning by doing." Therefore, we recommend the EBMP be revised every 5 to 10 years based on lessons learned from projects that have been implemented. To accomplish this, we recommend development of a tracking database for the projects identified and implemented in the EBMP.

Improvements to the Ecosystem Service Valuation Process

Stakeholder Involvement

Representation of a more diverse group of stakeholders (and thus a larger sample size) should be incorporated into future experimental designs. Stakeholders from industry and development were relatively underrepresented at the both workshops (Figure 10 and Palmer et al. 2009). Local government was also underrepresented at the second workshop. Further, the general public was not involved in the development of the EBMP.

Data Gaps

Long-term datasets of habitat coverage in the Coastal Bend are lacking. The data available for the habitats within the study area are only relevant when determining general trends in habitat changes over time. The calculation of actual change in habitat for the entire study area is only available at 30 x 30 meter pixel resolution for years 1996, 2001, and 2005 through the NOAA Coastal Change Analysis Program (C-CAP). The continued collection of this data and similar data at an even higher spatial resolution is imperative for monitoring and effective decision-making at the local level.

Further, the data used to assess the change in habitat area of open water habitats, such as oyster reefs and seagrass beds, is affected by both the tidal levels and the turbidity of the water. Efforts to better map these habitats, such as NOAA's Benthic Habitat Mapping and work conducted by the Seagrass Working Group and TPWD, are currently underway and necessary for effective monitoring and conservation of these habitat types.

Need for Ecosystem Service Education

Many stakeholders at the second workshop seemed unfamiliar with the specifics related to ecosystem services and thus relied heavily on the materials presented and provided to them. Because of this uncertainty related to defining and assessing ecosystem services, we propose that future workshops set aside time to allow stakeholders to converse and agree on definitions of ecosystem services before proceeding to the assessment of habitats.

Further, stakeholders cited specific examples of confusion regarding the definitions of ecosystem services. Some stakeholders could not determine the difference between water supply and water regulation. These two services are under the umbrella of different categories of ecosystem services. Water supply is defined as a provisioning ecosystem service and water regulation as a regulating ecosystem service. More detail could have been and should be provided regarding the differences between the categories of ecosystem services.

Additionally, a lack of knowledge led to confusion amongst stakeholders. For example, some stakeholders expressed doubt related to the genetic and medicinal resource ecosystem service. The stakeholders understood what this ecosystem service was, but were not educated enough in this area to determine whether or not a habitat provided this type of service to them. For this reason, it could be that some ecosystem services were determined as not being provided to a stakeholder, not because the service was lacking, but because the knowledge regarding the provision of that service to the stakeholder was lacking. Because of the survey design, this lack of knowledge was not captured in the survey. Thus, future studies should allow stakeholders to relay the fact that they do not know whether or not a service is provided. This would give a clear indication of a need for education related to a specific ecosystem service and/or habitat. Also, many stakeholders requested coastal examples of ecosystem services. Thus, there is a need for documentation and education related to ecosystem services provided by coastal and marine habitats.

Improvements to the Surveying Method

The importance of pretesting surveys and following-up with respondents after the surveys have been completed is imperative to the success of a study. Because the concept of stakeholder analysis of ecosystem services is a relatively new area of research, the ability to follow-up with stakeholders regarding why they assessed certain habitats as they did is imperative to understanding the perceptions related to ecosystem services.

Improvements to the End Product

The key to developing useful end products for decision-makers is the movement away from static representation of information. For example, the data layers used to create the heat maps within this report can be exported as KML files and used within Google maps. Further, there are facilities available that enable decision-makers to tackle real world problems as a group within a 3D, interactive environment. One of these facilities is the Decision Theatre at Arizona State University (http://dt.asu.edu/). This type of environment allows decision makers to input different scenarios into models in real time and thus address and tackle difficult questions in a group setting.

Further, there are many modeling tools available to better assist decision-makers. The Ecosystem-based Management (EBM) tools network (http://www.ebmtools.org/) provides information about many of these tools. Examples of such modeling tools are ARIES and InVEST. The output of these modeling tools can help decision-makers determine the effects of trade-offs and compatibilities between environmental, economic, and social benefits.

Using ecosystem service data, similar to the data collected at the workshops, models of provision and use of ecosystem services can be determined with the ARIES model (http://www.ariesonline.org/). The benefit of the ARIES model is that local knowledge and the knowledge of experts can be combined to model locally specific ecosystem services. The ability to prioritize areas of high value and flow of ecosystem services can be useful to better inform decision-making.

Additionally, the InVEST tool (http://www.naturalcapitalproject.org/InVEST.html) can help decision-makers visualize the impacts of potential decisions under different scenarios. InVEST is a production function-based approach to natural resource decision-making. The availability of data determines the types of outputs decision-makers can obtain by using the InVEST tool.

Action vs. Inaction

Society is often faced with making technical decisions and one option often chosen is that of "no action." Even science-based decision-making is not based on science alone. In decision-making, policy makers must balance science with economic, social, and political/legal considerations. It is important that decisions rest on this four-legged stool (science, economic, social, and policy) rather than science alone.

The use of science in decision-making is important because it provides an unbiased view of the best technical information available. However, all scientific information comes with uncertainty. The uncertainty derives from two main sources: mechanisms and measurements. The mechanistic uncertainty is a result of our incomplete knowledge or understanding of the processes controlling the subject of interest. Often measurement of phenomenon yields varying results that can be summarized with statistics. But the statistical uncertainty in measurements must be accounted for when recommending a range of responses. Mechanistic and measurement uncertainty is often used as an excuse for inaction. The statement is often made, "we cannot make a decision, because we are unsure." Uncertainty is no reason for inaction. Instead, adopting an adaptive management framework based on the best available science is often the best and most responsible course of action.

Adaptive management is the acknowledgement that our decisions are based on a degree of uncertainty, and the decisions may require alteration in the future. The key to adaptive management is recognizing that our decisions are essentially hypotheses that need to be tested. It is important to put in place a monitoring program that tests our assumptions and understanding of mechanisms and measures the variability of ecosystem response. After a period of time, the decisions should be reviewed using the new information. The review should be used as a basis for maintaining or altering a decision or policy.

The precautionary principle is an important tool in adaptive management. When there is insufficient information to make decisions, the least harmful choice will ensure environmental protection. With new information, the rules can be relaxed if it is discovered that the stressor in question or human activity effects are less than expected, or if the environmental assimilation capacity is discovered to be greater than originally thought. Thus employment of the precautionary principal with monitoring and adaptive management is the best tools to ensure environmental protection while still promoting economic development of human resources.

The current ecosystem-based management plan uses a scientific process to identify the ecosystem services habitats provide to human health and well-being. Data gaps exist, ecosystem service valuation studies lag far behind routine monitoring, and the public has little knowledge of what ecosystem services are or why they should care about them. However, the uncertainty related to spatial distributions and ecosystem service values is no reason to avoid taking action to preserve, enhance or restore those habitats in the face of threats. The heat map and summary of habitats by sub-region can be used to identify priority areas where protection, conservation, or enhancement projects should be carried out. There are numerous activities that have been proposed during the workshops and stakeholders are ready and willing to participate in cooperative and collaborative efforts to implement the EBMP.

CBBEP's Responsibility to the Bays and Estuaries of the Coastal Bend

The Coastal Bend Bays & Estuaries Program's (CBBEP) responsibility to the bays and estuaries includes bringing the community (scientists, governments, industries, environmental groups, and other stakeholders) together to accomplish environmental and economic sustainability. The mission of the CBBEP is the implementation of the Coastal Bend Bays Plan, which is to protect and restore the health and productivity of the bays and estuaries while supporting continued economic growth and public use of the bays. The Coastal Bend Bays Plan identifies 50 actions that will benefit the bay system and the users of the bays. The Bays Plan is intended to help manage the needs of the bay system for the people who use it for the next 20 – 50 years. The creation of this plan that identifies habitat protection, enhancement, creation, and conversion opportunities based on an assessment of regional ecological needs, social interests, and economic capabilities and securities further enhances CBBEP's role in bringing common interests together to accomplish regional ecological benefits.

REFERENCES

Accorsi, R., G. Apostolakis and E. Zio. 1999. Prioritizing stakeholder concern in environmental risk management. Journal of Risk Research 2:11-29.

Anderson, A.A. 1960. Marine resources of the Corpus Christi Area. Bureau of Business Research, Research Monograph 21: 1-49. University of Texas, Austin, TX.

Brenner, J., P. Montagna and J. Pollack. 2009a. Initial meetings summary - habitat management plan for Corpus Christi/Nueces Bay. Report submitted to the Coastal Bend Bays & Estuaries Program for project 0708. Texas A&M University – Corpus Christi, Harte Research Institute for Gulf of Mexico Studies. 17 pp.

Brenner, J., P.A. Montagna, T. Nance and T.A. Palmer. 2009b. Boundary map report - habitat management plan of Corpus Christi Bay. Report submitted to the Coastal Bend Bays & Estuaries Program for project # 07-08. Texas A&M University - Corpus Christi, Harte Research Institute for Gulf of Mexico Studies. 33 pp.

Brevik, E.C. and J.A. Homburg. 2004. A 5000 year record of carbon sequestration from a coastal lagoon and wetland complex, southern California, USA. Catena 57:221–32.

Brown, L.F., J.H. Brewton, J.H. McGowen, T.J. Evans, W.L. Fisher and C.G. Groat. 1976. Environmental geologic atlas of the Texas coastal zone: Corpus Christi area. Bureau of Economic Geology, University of Texas, Austin. 123 pp.

Buskey, E. J. 1993. Annual pattern of micro- and mesozooplankton abundance and biomass in a subtropical estuary. Journal of Plankton Research 15:907-924.

Buskey, E.J., P.A. Montagna, A.F. Amos and T.E. Whitledge. 1997. Disruption of grazer populations as a contributing factor to the initiation of the Texas brown tide algal bloom. Limnology and Oceanography 42:1215-1222.

Carpenter S., E. Bennett and G. Peterson. 2006. Scenarios for Ecosystem Services: An Overview. Ecology and Society 11:29-33.

Carr, R.S., P.A. Montagna, J.M. Biedenbach, R. Kalke, M.C. Kennicutt, R. Hooten and G. Cripe. 2000. Impact of storm water outfalls on sediment quality in Corpus Christi Bay, Texas. Environmental Toxicology and Chemistry 19:561 574.

Chaney, A. and G.W. Blacklock. 2003. Colonial Waterbird and Rookery Island Management Plan. Coastal Bend Bays & Estuaries Program, Corpus Christi, Texas. 281 pp.

Chaney, A.H., G.W. Blacklock and S.G. Bartels. 1996. Current status and historical trends of selected estuarine and coastal habitats in the Corpus Christi Bay national estuary program study area; Vol. 2. Corpus Christi, Texas, CCBNEP.

Choi Y.H. and Y. Wang. 2004. Dynamics of carbon sequestration in a coastal wetland using radiocarbon measurements. Global Biogeochemical Cycles 18: Article GB4016

Code of Federal Regulations. 1999. Presidential documents: Executive Order 13112, Invasive Species. Federal Register 64:6183-6186.

Corpus Christi Bay National Estuary Program. 1998. Coastal Bend Bays Plan (CBBP). Texas Natural Resource Conservation Commission, Austin, Texas. CBBEP-1. 80 pp.

Costanza, R., R. d'Arge, R.S. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. Nature 387:253–260.

Council on Environmental Quality (CEQ). 2009. Proposed National Objectives for Water Resources Planning. http://www.whitehouse.gov/sites/default/files/microsites/091203-ceq-revised-principles-guidelines-water-resources.pdf

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/wetlands/classwet/index.htm (Version 04DEC1998).

Daily, G.C. 2000. Management Objectives for the Protection of Ecosystem Services. Environmental Science and Policy 3:333-339.

Daily, G.C. (Ed.). 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC.

Day, J.W., C.A.S. Hall, W.M. Kemp and A. Yàñez-Arancibia (Eds.). 1989. Estuarine Ecology. John Wiley & Sons. 558 pp.

De Groot, R.S., M.A. Wilson and R.M.J. Boumans. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41:393-408.

DeYoe, H.R. and C.A. Suttle. 1994. The inability of the Texas "brown tide" alga to use nitrate and the role of nitrogen in the initiation of a persistent bloom of this organism. Journal of Phycology 30:800-806.

Early Detection and Distribution Mapping System. 2010. Status of Invasive Plants in Texas. Accessed 12/09/2010: http://eddmaps.org/tools/statereportcfm?id=us_tx.

Ernstson H., S. Sörlin and T. Elmqvist. 2008. Social movements and ecosystem services: the role of social network structure in protecting and managing urban green areas in Stockholm. Ecology and Society 13:Article 39.

Everitt, J. H., F.W. Judd, D.E. Escobar and M.R. Davis. 1996. Integration of remote sensing and spatial information technologies for mapping black mangrove on the Texas Gulf Coast. Journal of Coastal Research 12:64-69.

Farber, S., R. Costanza, D.L. Childers, J. Erickson, K. Gross, M. Grove, C.S. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren and M. Wilson. 2006. Linking ecology and economics for ecosystem management. BioScience 56:121.

Fichtner J. 1986. On deriving priority vectors from matrices of pairwise comparisons. Socio-Economic Planning Sciences 20:341-345.

Fischer, J., B. Brosi, G.C. Daily, P.R. Ehrlich, R. Golfman, J.H. Goldstein, A.D. Manning, H.A. Mooney, L. Pejchar, J. Ranganathan, and H. Tallis. 2008. Should agricultural policies encourage land sparing or wildlife friendly farming? Frontiers in Ecology and Environment 6:380-385.

Gibeaut, J.C. and T.A. Tremblay. 2003. Coastal Hazards Atlas of Texas: A Tool for Hurricane Preparedness and Coastal Management - Volume 3: Austin, Texas, Bureau of Economic Geology, The University of Texas at Austin. 29 pp.

Gibeaut, J.C., E. Baraza and B. Radosavljevic. 2010. Estuarine wetland habitat transition induced by relative sea-level rise on Mustang and North Padre Islands, Texas: Phase1. Coastal Bend Bays & Estuaries Program, Corpus Christi, Texas. Publication CBBEP – 64, Project Number – 0822. 21 pp.

Government Accountability Office (GAO). 2001. Wetlands protection: assessments needed to determine effectiveness of in-lieu-fee mitigation. GAO, Washington, DC, GAO-01-325.

Griffith, G., S. Bryce, J. Omernik and A. Rogers. 2007. Ecoregions of Texas. Report to Texas Commission on Environmental Quality, Austin. 125 pp.

Gulf Coast Bird Observatory. 2010. Packery Channel Oak Motte Sanctuary. http://www.gcbo.org/html/packery.pdf Accessed 15 August 2010.

Gunter, G. 1941. Death of fishes due to cold on the Texas coast, January 1940. Ecology 22:203-208.

Helliwell, D.R. 1969. Valuation of Wildlife Resources. Regional Studies 3:41-47.

Hicks, D.W. and J.W. Tunnell, Jr. 1993. Invasion of the south Texas coast by the edible brown mussel Perna perna (Linnaeus, 1758). The Veliger 36:92-94.

Hosseini, J. and S.N. Brenner. 1992. The stakeholder theory of the firm: a methodology to generate value matrix weights. Business Ethics Quarterly. 2: 99-119.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: Synthesis Report. IPCC, Valencia, Spain. 74 pp.

King, R.T., 1966. Wildlife and Man. The Conservationist June-July: 8-11.

Leslie, H. 2005. A synthesis of marine conservation planning approaches. Conservation Biology 19:1701-1713.

Lofgren, C.S. 1985. The economic importance and control of imported fire ants in the United States. Pages 227-256 in Economic Impact and Control of Social Insects (S.B. Vinson, ed.) Praeger Publishers, New York, N.Y.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being. Island Press, Washington, DC.

Montagna, P.A. 2009. Preliminary Habitat Management Plan for the Corpus Christi Bay Area. Report submitted to the Coastal Bend Bays & Estuaries Program for project 0708. Texas A&M University - Corpus Christi, Harte Research Institute for Gulf of Mexico Studies, 6 pp.

Montagna, P.A. and R.D. Kalke. 1995. Ecology of Mollusca in the south Texas estuaries. American Malacological Bulletin 11:163-175.Montagna, P.A., J.C. Gibeaut and J.W. Tunnell Jr. 2007. South Texas Climate 2100: Coastal Impacts. In: J. Norwine and K. John (eds.), South Texas Climate 2100: Problems and Prospects, Impacts and Implications. CREST-RESSACA. Texas A&M University-Kingsville, Kingsville, Texas. Chapter 3, pp. 57-77.

Montagna, P.A., J. Li and G.T. Street. 1996. A conceptual ecosystem model of the Corpus Christi Bay National Estuary Program Study Area. Publication CCBNEP-08, Texas Natural Resource Conservation Commission, Austin. 114 pp.

Montagna, P.A, E.M. Hill and B. Moulton. 2009a. Role of science-based and adaptive management in allocating environmental flows to the Nueces Estuary, Texas, USA. In: Brebbia, C.A. and E. Tiezzi (eds.), Ecosystems and Sustainable Development VII, WIT Press, Southampton, UK, pp. 559-570

Montagna, P.A., T. Palmer, M. Gil, E. Hill, B. Nicolau and K. Dunton. 2009b. Response of the Nueces Estuarine Marsh System to Freshwater Inflow: An Integrative Data Synthesis of Baseline Conditions for Faunal Communities. Final Report submitted to the Coastal Bend Bays & Estuaries Program for project 0821. Texas A&M University - Corpus Christi, Harte Research Institute for Gulf of Mexico Studies, 27 pp.

Montagna, P.A., J. Brenner, J. Gibeaut and S. Morehead. 2010. Coastal Impacts. In: Gerald North, G., J. Schmandt, and J. Clarkson (eds.), The Impact of Global Warming on Texas, The University of Texas Press. In press.

Moulton, D.W., T.E. Dahl and D.M. Dall. 1997. Texas Coastal Wetlands; Status and Trends, mid-1950's to early 1990s. U.S. Department of the Interior, Fish and Wildlife Service, Albuquerque, New Mexico. 32 pp.

Moulton, D.W. and D.M. Dall. 1998. Atlas of National Wetlands Inventory maps for

Nueces County, Texas. U.S. Fish and Wildlife Service and Texas Parks and Wildlife, Austin, TX, USA.

National Oceanic Data Center (NODC). 2010. Tides & Currents, Mean Sea Level Trend 8774770 Rockport, Texas. Accessed 3 Sept 2010 http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8774770

Nelson, K. and P.A. Montagna. 2009. Causes and Monitoring of Hypoxia in Corpus Christi Bay. Final Report submitted to the Coastal Bend Bays & Estuaries Program for project 0817. Texas A&M University - Corpus Christi, Harte Research Institute for Gulf of Mexico Studies, 88 pp.

Nielsen-Gammon J. 2010. The changing climate of Texas. In: Schmandt J, Clarkson J, North G.R. (Eds.), The Impact of Global Warming on Texas, 2nd edition. University of Texas Press, Austin.

Odum, H.T., P.E. Muehlberg and R. Kemp. 1959. Marine resources: Texas natural resources. Report of the Research Committee of the Houston Chamber of Commerce, Houston, TX, pp. 39-52.

Onuf, C.P. 1996. Biomass patterns in seagrass meadows of the Laguna Madre, Texas. Bulletin of Marine Science 58:404-420.

Orth, R.J., T.J.B. Carruthers, W.C. Dennison, C.M. Duarte, J.W. Fourqurean, K.L. Heck, Jr, A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, S. Olyarnik, F.T. Short, M. Waycott, and S.L. Williams. 2006. A global crisis for seagrass ecosystems. Bioscience 56:987-996.

Paine, J.G. and R.A. Morton. 1993. Historical Shoreline Changes in Copano, Aransas, and Redfish Bays, Texas Gulf Coast: Austin, Bureau of Economic Geology, The University of Texas at Austin. 66 pp.

Palmer, T., J. Brenner, T. Nance and P. Montagna. 2009. Habitat Management Plan of Corpus Christi Bay Workshop summary. Report presented to the Coastal Bend Bays and Estuaries Program (CBBEP), Project # 0710. Harte Research Institute, Corpus Christi, Texas. 126 pp.

Pulich, W., K.H. Dunton, L.R. Roberts, T. Calnan, J. Lester and L.D. McKinney. 1999. Seagrass conservation plan for Texas. Texas Parks and Wildlife, Austin.

Restore America's Estuaries (RAE) and National Oceanic and Atmospheric Administration (NOAA). 2002. A National Strategy to restore coastal and estuarine habitat. Restore America's Estuaries, Arlington, Virginia. http://www.estuaries.org/

Ritter, M.C. and P.A. Montagna. 1999. Seasonal hypoxia and models of benthic response in a Texas bay. Estuaries 22: 7-20.

Sherrod, C. L. and C. McMillan. 1981. Black mangrove, *Avicennia germinans*, in Texas - past and present distribution. Contributions in Marine Science 24:115-131.

Sims, M. and E. Smith. 2001. Integrating GIS to develop a conservation and monitoring plan for rookery islands in Laguna Madre, Texas, USA. Environmental Systems Research Institute, Users Conference Proceedings, San Diego, CA.

Smith, E.H., T.R. Calnan and S.A. Cox. 1997. Potential sites for wetland restoration, enhancement, and creation: Corpus Christi/Nueces Bay area. Texas Natural Resource Conservation Commission, Austin, Texas. CCBNEP-15. 165 pp.

Smith, E.H., D.M. McCann, O. Gomez and A. Tomar. 2004. Coastal Bend conservation project inventory. Coastal Bend Bays and Estuaries Program, Project No. 0412. 146 pp.

Stewart, R.E. 1951. Clapper rail populations of the middle Atlantic states. Transactions of the North American Wildlife Conference 16:421-430.

Stockwell, D. A. 1989. Effects of freshwater inflow on the primary production of a Texas Coastal Bay System. Nitrogen Processes Study (NIPS) (Final Report), University of Texas Marine Science Institute, Technical Report No. TR/89-010. 180 pp.

Swinton, S.M., F. Lupi, G.P. Robertson and S.K. Hamilton. 2007. Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. Ecological Economics 64:245–252.

Tallis H, P. Kareiva, M. Marvier and A. Chang. 2008. An ecosystem services framework to support both practical conservation and economic development. Proceedings of the National Academy of Sciences USA 105:9457–9464.

Texas Commission on Environmental Quality. 2010. Draft 2010 Texas 303(d) List. Texas Commission on Environmental Quality, Austin. 106 pp.

Texas General Land Office. 2003. Dune protection and improvement manual for the Texas Gulf Coast. Third Edition.

Texas Water Development Board. 2007. Water for Texas – 2007: Volume II. Document no. GP-8-1. TWDB, Austin. 392 pp.

The Nature Conservancy. 2000. Designing a geography of hope: a practitioners handbook for ecoregional conservation planning. Volume 1. Second Edition. The Nature Conservancy (TNC), Arlington, 85 pp.

Tomer, M., C. Tanner and C. Howard-Williams. 2009. Discussing Wetlands, Agriculture and Ecosystem Services. Wetland Science and Practice 26:26-29.

Tremblay, T.A., J.S. Vincent and T.R. Calnan. 2008. Status and trends of inland wetland and aquatic habitats in the Corpus Christi Area. Final report prepared for the Coastal Bend Bays and Estuaries Program, the Texas General Land Office and National Oceanic and Atmospheric Association, CBBEP Contract No. 0722, 89 pp.

Tunnell, Jr. J.W., Q.R. Dokken, E.H. Smith and K. Withers. 1996. Current status and historical trends of the estuarine living resources within the Corpus Christi Bay National Estuary Program study area, Volume 1. Corpus Christi, Texas, CCBNEP-06A.

Tunnell, J.W., Jr., J. Andrews, N.C. Barrera and F. Moretzsohn. 2010. Encyclopedia of Texas Seashells: Identification, Ecology, Distribution, and History. Texas A&M University Press, College Station, Texas. 512 pp.

Twilley, R.R., E.J. Barron, H.L. Gholz, M.A. Harwell, R.C. Miller, D.J. Reed, J.B. Rose, E.H. Siemann, R.G. Wetzel and R.J. Zimmerman. 2001. Confronting climate change in the Gulf coast region: Prospects for sustaining our ecological heritage. Union of Concerned Scientists, Washington, D.C.: Cambridge, Massachusetts, and Ecological Society of America.

USDA. 2010. Laws and Regulations: Administrative Code and Statutes. Accessed 12/09/2010: http://www.invasivespeciesinfo.gov/laws/tx.shtml.

Ward, G.H. 2009. Water resources and water supply. In : Schmandt, J., Clarkson, J., North, G.R. (Eds.), The Impact of Global Warming on Texas, 2nd edition. University of Texas Press, Austin.

White, W.A., T.R. Calnan, R.A. Morton, R.S. Kimble, T.G. Littleton, J.H. McGowen, H.S. Nance, and K.S. Schmedes. 1983. Submerged lands of Texas, Corpus Christi area: Sediments, geochemistry, benthic macroinvertebrates, and associated wetlands. University of Texas Austin, Bureau of Economic Geology, Austin. Special Publication, 154 pp.

White, W.A., T.A. Tremblay, R.L. Waldinger and T.R. Calnan. 2006. Status and trends of wetland and aquatic habitats on barrieriIslands, Coastal Bend. Final Report prepared for the Texas General Land Office and National Oceanic and Atmospheric Administration under GLO Contract No. 05-041. Austin, Texas.

Whitledge, T.E. 1989. Nutrient distribution and dynamics in the Lavaca, San Antonio and Nueces/Corpus Christi Bays in relation to freshwater inflow. Nitrogen Processes Study (NIPS) (Final Report), The University of Texas Marine Science Institute, Technical Report No. TR/89-017. 211 pp.

Wilson, S.G. and T.R. Fischetti, 2010. Coastline Population Trends in the United States: 1960 to 2008. U.S. Census Bureau. 28 pp.

Winston, M.L. 1992. The biology and management of Africanized honey bees. Annual Reviews in Entomology 37:173-193.

Withers, K. and J.W. Tunnell Jr. 1998. Identification of tidal flat alterations and determination of effects on biological productivity of these habitats within the coastal bend. Corpus Christi, Texas, CCBNEP-26.

Yoskowitz, D., C. Santos, B. Allee, C. Carollo, J. Henderson, S. Jordan and J. Ritchie. 2010. Proceedings of the Gulf of Mexico Ecosystem Services Workshop: Bay St. Louis, Mississippi, June 16-18, 2010. October. Harte Research Institute for Gulf of Mexico Studies. Texas A&M University-Corpus Christi. 16 pp.

Zedler, J. B. and S. Kercher. 2005. Wetland resources: status, trends, ecosystem services, and restorability. Annual Review of Environment and Resources 30:39–74.

Zhao, B., U. Kreuter, B. Lia, Z. Ma, J. Chena, and N. Nakagoshi. 2004. An ecosystem service value assessment of land-use change on Chongming Island, China. Land Use Policy 21:139–148.