The Nature Conservancy

Identification of Priority Sites for Conservation in the Northern Gulf of Mexico: An Ecoregional Plan

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Executive Summary

The aim of this work was to identify sites within the northern Gulf of Mexico ecoregion that if protected would fully represent the biological diversity of the nearshore waters of this region. The northern Gulf of Mexico is a rich and productive subtropical environment that supports extensive wetland and seagrass habitats. The ecoregion extends from Anclote Keys, FL to the Laguna Madre de Tamaulipas, Mexico and is divided into three broad subregions. The western subregion extends south from Galveston Bay, TX, the central subregion is from Galveston Bay to Mobile Bay, AL, and the eastern subregion encompasses the northwest Florida coast. The northern Gulf of Mexico ecoregion borders three terrestrial ecoregions. The results of the northern Gulf of Mexico plan will be incorporated with these terrestrial ecoregional plans to clearly connect terrestrial, freshwater, and marine conservation throughout the coastal environments of the northern Gulf of Mexico.

The drainage basin for the northern Gulf of Mexico extends from the Appalachians to the Rockies. It contains nearly 60% of the land area of the continental United States, including some of the most fertile lands in the world. The northern Gulf is an obvious region of focus for the Conservancy's coastal and marine work, because it encompasses many shallow estuaries that have characteristics determined more by terrestrial and riverine inputs than most sets of marine systems. The Conservancy has extensive experience in abating land-based threats and is growing its capacity to address threats in freshwater and marine environments.

The best way to identify and to conserve the diversity of the Gulf is to focus on habitats and the ecological processes that affect their viability. Some of the primary habitat targets in the northern Gulf of Mexico were seagrasses, oyster reefs, sponge & soft coral, salt marshes, tidal freshwater marsh, tidal flats, and submerged freshwater grasses. Individual species were included as conservation targets if (i) they were imperiled and conservation of their habitats would be insufficient for their conservation or (ii) they were declining faster than their habitats. Examples of species targets include dwarf seahorse, fringed pipefish, Gulf sturgeon, diamondback terrapin, and Florida manatee. A Geographic Information Systems (GIS) database was developed from all the readily available information on the distribution of these targets.

As a preliminary goal, it was decided that the network of priority sites should contain at least 20% of the current distribution of each habitat and imperiled species target in each subregion. It was also decided that potential sites should generally encompass entire bays and estuaries as landscape-scale sites. These estuarine landscapes are assemblages of many species and communities with dynamics tied to variability in salinity (and associated physical-chemical conditions) created by the interaction of freshwater drainage and tidal influx.

Two primary tools were used to choose a set of high priority sites for conservation: (i) a reserve selection algorithm, Sites v1.0, and (ii) expert interviews and an expert's workshop. The final portfolio of sites integrated information on the known distribution of targets with information provided by many local experts (Fig. 1). As part of the assembly process, high priority sites (= action sites) were also identified. These high priority sites encompassed the best examples of the conservation targets in the northern Gulf of Mexico.

A preliminary analysis was done at the priority sites to assess the likely stresses to the conservation targets (see Fig. 2 for a summary). It is likely that the importance of some of the stresses and their sources will be revised upon closer examination during the more detailed process of site conservation planning. The information provided in an ecoregional plan is only intended to provide a starting point for in depth analyses of stresses, sources, and the strategies that the Conservancy and others can use to abate these stresses.

The coastal habitats of the northern Gulf of Mexico are rich and productive because they receive inputs from terrestrial, freshwater, and marine sources. This connectivity means that these nearshore habitats are impacted by stresses from all these environments and demands that conservation cross traditional boundaries. This connectivity also offers opportunities for conservation. The scale of this connectivity is most evident in an analysis of sources of stress to the zone of hypoxia ("dead zone"), which covers thousands of square kilometers off the coast of Louisiana. The biggest source of this stress is runoff of nitrogen from lands in the upper Midwest. Strategies implemented in terrestrial, aquatic, or marine environments can impact biodiversity across boundaries and can help to leverage conservation throughout the southeastern and central USA.

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Introduction to Ecoregional Planning

In its 50-year history, The Nature Conservancy (TNC) has continually adapted and expanded its conservation strategies and methods. Within the past 10 years, TNC has adopted a framework for conservation that places emphasis on the conservation of all communities and ecosystems (not just the rare ones), emphasizes conservation at multiple levels of biological organization, and recognizes the value of comprehensive biodiversity planning on ecoregional rather than geopolitical lines. To aid in this analysis, ecoregions have been identified as reasonably cohesive ecological units for conservation and management planning (e.g., Bailey, 1998). Dinerstein et al. (1995) provide a practical definition for ecoregions as “relatively large areas of land and water that contain geographically distinct assemblages of natural communities. These communities (1) share a large majority of their species, dynamics, and environmental conditions, and (2) function together effectively as a conservation unit at global and continental scales.”

The first step in ecoregional-scale conservation is the development of a plan for each ecoregion that identifies the sites that must be conserved, managed, or restored to represent the entire diversity of the ecoregion in viable populations, communities, and ecosystems.   The basic steps in ecoregional planning include; (1) identification of conservation targets, i.e., species and habitats, (2) collection of data on their ecology and distribution, (3) determination of conservation goals for the amount of targets that must be protected, and (4) identification of a set of sites that meets these goals for all targets. A map of these sites, along with pertinent information on the conservation targets contained within these sites, is the principal product of ecoregional plans. A general primer on this planning is provided in The Nature Conservancy’s Designing a Geography of Hope (Groves et al. 2000).

Introduction to the Northern Gulf of Mexico Ecoregion

Biogeography and Ecology

The northern Gulf of Mexico ecoregion extends from Anclote Keys, FL to the southern extent of the Laguna Madre de Tamaulipas, Mexico (Fig. 1), a region which is also identified as the Louisianian Province. It is a rich and productive subtropical environment that supports extensive wetland and seagrass habitats (Iverson and Bittaker 1986, Zieman and Zieman 1989, Duke and Kruczynski, 1992). Much of the nearshore waters of the Gulf are divided into bays and estuaries behind barrier islands, which form a ring of sites around the northern Gulf of Mexico.

The northern Gulf of Mexico is divided into three broad subregions (Fig. 3). The central Gulf of Mexico from Galveston Bay, TX to Mobile Bay, AL, is characterized by extremely high levels of riverine input. Fresh water and sediments from the Mississippi River and to a lesser extent fresh water entering through Mobile Bay determine the characteristics of nearshore waters in this subregion. These coastal waters are generally variable in salinity, and water clarity is low because of the sediment load. Bottom sediments tend to be fine clays and muds. These conditions are ideal for the growth of marshes and oyster reefs.

The eastern Gulf of Mexico encompasses the entire northwest Florida coast. This area is characterized by moderate riverine input (except in Apalachicola Bay); coastal waters tend to be clearer and sediments are sandier than in the central Gulf of Mexico. Conditions thus are ideal for the growth of seagrasses. The Big Bend region of Florida (the northeastern corner of the Gulf) has extensive seagrass beds, some extending into relatively deep water (12 m+). Owing in part to low sediment input, the limestone hardbottom is often exposed in the Big Bend. These hardbottom sites allow for the attachment of large sponges and soft corals. These habitats are largely unstudied by scientists and few people even know that they exist.

The western subregion of the northern Gulf of Mexico extends south from Galveston Bay. This area is also characterized by low freshwater input, sandy sediments, and clear waters; ideal conditions for the growth of seagrasses. In general, freshwater input decreases southward, and in the southern portions of this subregion evaporation is greater than freshwater input. These conditions in combination with shallow waters limit exchange with the Gulf and create the hypersaline bays of the Laguna Madre of Texas and Mexico. Taken together, the embayments of the Laguna Madre comprise the largest hypersaline lagoon in the world. Salinities are generally much higher, 35-70 parts per thousand (ppt), than typical marine waters (34-35 ppt).

The drainage basin for the northern Gulf of Mexico extends from the Appalachian to the Rocky Mountains. The drainage basin for the Mississippi River alone covers much of this area (Figure 4). The total drainage basin for the northern Gulf of Mexico contains nearly 60% of the land area of the continental United States, including some of the most fertile lands in the world (Lovejoy 1992). This productive drainage makes the Gulf one of the primary producers of finfish and shellfish in the United States. At the same time, because much of this land is in agricultural use (Figure 4), fertilizers, herbicides, and pesticides eventually threaten the productivity of the Gulf. The drainage basin also contains the heavily industrialized “Rust Belt” from which many pollutants enter into the Gulf (Lovejoy 1992).

The northern Gulf of Mexico is a productive environment. For example, in 1997 the estimated commercial value of the finfish and shellfish harvest was $823 million (NOAA 1997a). The Gulf of Mexico was ranked as the number one region for seafood harvest in both poundage and monetary value. Much of the productivity of this region is believed to have its origins in the productivity of the nearshore marshes and seagrasses (Duke and Kruczynski 1992), because these habitats serve as nurseries for juveniles, and/or simply because they are a large source of carbon and nutrients (e.g., Deegan 1993).

In general, estuarine, seagrass, and marsh environments, which are abundant in the northern Gulf of Mexico, are extremely valuable to humans. In a recent paper, these environments were estimated to be ten times more valuable to humans than any terrestrial habitat for ecosystem services like recreation and nutrient cycling (Costanza et al. 1997).

Geographic Focus of the Northern Gulf Plan and Relationship to Adjacent Ecoregions

The northern Gulf of Mexico encompasses many shallow estuaries that have characteristics determined more by terrestrial and riverine inputs than most sets of marine systems. Thus, many of the sources of stress and strategies to address these stresses will be based in terrestrial environments. TNC has extensive experience in abating land-based threats and is growing its capacity to address threats in freshwater and marine environments. Conservation efforts in the northern Gulf of Mexico will rely and build on this experience, while advancing TNC's capacity to identify targets, threats, and threat-abatement strategies in the marine environment. With this in mind, this plan focuses mainly on the nearshore environments of the Gulf, but it is recognized that the conservation of nearshore diversity can have important effects, both direct and indirect, on species offshore (e.g., many nearshore habitats are thought to provide nursery grounds for species that eventually migrate offshore).

The northern Gulf of Mexico (NGoM) borders three terrestrial ecoregions in which TNC is also working on ecoregional plans. An original impetus for this plan was that Nature Conservancy teams in the adjacent terrestrial ecoregions wanted to identify marine targets and priority coastal sites, but they were constrained by time, resources, and experience. The results of the northern Gulf of Mexico plan will be incorporated with these plans. The coastal boundaries of two of the terrestrial ecoregions, the East Gulf Coastal Plain (EGCP) and the Gulf Coast Prairies and Marshes (GCPM), are completely coincident with the northern Gulf of Mexico ecoregion. The Florida Peninsula ecoregion overlaps a part of the northern Gulf of Mexico. To link the NGoM plan to the three terrestrial plans, we will compare high priority sites in each plan. Where high priority terrestrial, aquatic, and estuarine sites are adjacent, an overall site will be created to focus on the stresses and conservation strategies that impact the biodiversity across boundaries. These expanded sites will be functional land and seascape-scale sites (see Poiani et al. 2000).

To address stresses to conservation targets, it is often necessary to act on strategies outside of the boundaries of the selected priority sites. Thus even where terrestrial and marine sites do not overlap, there may be a need to work in both environments to address the targets of concern. For example, it is likely that important rookeries of threatened birds will occur around estuaries that, on the basis of their marine diversity and productivity, were not chosen as priority estuaries in this plan. Appropriate conservation work for these bird targets could involve conservation or restoration of important areas within the estuary (e.g., salt marsh feeding areas).

Conservation Targets and Sources of Data

Targets of Conservation

For marine environments, as for terrestrial environments, it is best to examine community and system targets first and at the finest scale possible. By convention, marine communities and ecosystems are referred to as habitats. They are named according to the features that provide the underlying structural basis for the communities and systems (just as in terrestrial environments). Examples of marine habitats include salt marshes, seagrasses, mangroves, coral reefs, tidal flats, and oyster reefs. Not all marine habitats are defined by vegetation; animals form the structural basis for many marine communities (e.g., coral and oyster reefs). The principal biotic substrates (e.g., seagrasses) often define the habitat, but abiotic features (e.g., salinity and wave exposure) can modify the definition. The Conservancy has a well defined classification for terrestrial communities (Anderson et al. 1998, Grossman et al. 1998) that provides distinctions among communities at a much finer resolution than classifications developed in marine environments, i.e., marine communities have generally not been divided as finely as terrestrial communities. By Conservancy definitions, most marine habitats would be comprised of many communities in an ecosystem (i.e., habitat = ecosystem). This usage is consistent with that of most marine ecologists. For example, the same salt marsh can be referred to by ecosystem ecologists as the salt marsh ecosystem and by population and community ecologists as the salt marsh habitat; the distinction is largely in whether one is concerned primarily with carbon and nutrients or the species in which they are packaged.

The best way to identify and conserve the diversity of the Gulf is to focus on these habitats and on the ecological processes that affect their viability. This approach presumes that the protection of a representation of all the nearshore habitats in the Gulf will also protect a representation of the diversity of species in these coastal waters (many of which have unknown biogeographic distributions). Individual species were included as conservation targets if (i) they were imperiled and conservation of their habitats would be insufficient for their conservation or (ii) they were declining faster than their habitats.

The list of targets for the northern Gulf of Mexico is in Table 1. Maps of the distribution of most of the targets are found in Figures 5-8 and summary statistics are in Appendix II (a & b). Descriptions of these targets are in Appendix III a & b. All primary targets had to be fully represented at each stage in the development of the plan. After sites were determined on the basis of the primary targets, they were then checked to ensure that secondary targets were represented within these sites.

Throughout the target identification and data collection process, scientists were asked to evaluate the target list and quality of data (~25-30 scientists interviewed). In these interviews, the scientists also were asked to evaluate assumptions about sites, systems, stresses, and important ecological processes.

At present the best national classification for marine habitats is the one developed by the National Wetlands Inventory (NWI) (Cowardin et al. 1979). Some better regional classifications have been developed, e.g., in Mississippi (TNC) and Washington state (e.g., Dethier 1992). Most spatial information on habitats, however, is organized according to the NWI classification, and this classification was generally used in the northern Gulf of Mexico. Several groups, e.g., National Oceanic and Atmospheric Administration (NOAA), Ecological Society of America (ESA), and TNC, are working together to develop a better classification for marine habitats. Subdivisions were made in marsh and seagrass habitats. Marshes are commonly segregated based on salinity, but spatial information for these subdivisions was only available in Louisiana. Seagrasses were separated into low and high relief habitats, because marine animals respond strongly to the structural complexity of habitats (e.g., Beck 1995, 1997). There were few direct data on the distributions of these seagrass species (except in the Laguna Madre, TX).

There are relatively few habitat and species targets compared to many terrestrial ecoregions. There are few habitats identified because:

(i) Subtropical marine habitats are often very large in extent compared to terrestrial communities or marine habitats in temperate regions. Seagrasses and marshes occupy substantial portions of the coast of the northern Gulf of Mexico; they are large, often contiguous, habitats by any standard.
(ii) The classification of marine habitats is not as well developed as that for terrestrial communities. It is possible that further research will show that repeating assemblages of plants and animals are found consistently within subdivisions of the habitats described above and that more subdivisions should be made in the classification.

Only a few imperiled species are identified, because:

(i) It is likely that there really are relatively few rare species in this ecoregion.
(ii) It is likely that there is a lot of missing data, which might indicate that more species are rare or imperiled.
(iii) Most definitions of rarity (e.g., population size) are derived from work in terrestrial environments, which may not be appropriate in marine environments. For example, successful reproduction of marine species may require much larger populations than are required for terrestrial species. Most marine species reproduce by free spawning, releasing sperm and eggs into the water column. To be successful, this strategy requires that many individuals are releasing gametes into the water column at about the same time and/or that the adults are in close proximity.

Table 1- Target List for Northern Gulf of Mexico Ecoregion	
a. Habitats (with sub categories)	**Some Characteristic Species**
Primary habitat targets	
Seagrass	
High Relief (10-70 cm tall)	*Thalassia testudinum, Syringodium filiforme, Halodule wrightii*
Low Relief (< 10 cm tall)	*Halophila* spp.
Tidal Freshwater Grasses	*Vallisneria americana, Potamogeton* spp., *Ruppia maritima*
Oyster reefs	*Crassostrea virginica*
Salt marsh	*Spartina* spp., *Juncus roemerianus, Distichlis spicata*
Polyhaline Saltmarsh	*Spartina alterniflora, Juncus roemerianus, Distichlis spicata*
Mesohaline Saltmarsh	*S. alterniflora, D. spicata, S. patens, Scirpus americanus*
Oligohaline Saltmarsh	*Paspalum vaginatum, S. patens, Eleocharis* spp., *Sagittaria lancifolia*
Sponge & soft corals	Loggerhead sponges, vase sponges, sea fans, small hard corals
Tidal Flats	Algae, polychaetes, bivalves
Tidal Fresh Marsh	*Scirpus* spp., *Typha* spp., *Cladium* spp.
Intertidal Scrub/Forest	*Avicennia germinans, Iva* spp., *Baccharis* spp.
Secondary habitat targets	
Muddy-bottom Habitats	Polychaetes, amphipods, isopods
Coquina Beach Rock	*Donax* spp.
Beaches & Bars	Shorebirds, mole crabs, amphipods and isopods
Serpulid Worm Reefs	Family Serpulidae
b. Imperiled Species	
Fringed pipefish	*Anarchopterus criniger*
Gulf Sturgeon	*Acipenser oxyrinchus desotoi*
Diamondback Terrapin	*Malaclemys terrapin* (subspp.—*macrospilota, pileata, littoralis)*
Dwarf seahorse	*Hippocampus zosterae*
Opossum pipefish	*Microphis brachyurus lineatus*
Texas pipefish	*Syngnathus affinis*
Florida manatee	*Trichechus manatus latirostris*
Kemp's ridley turtle	*Lepidochelys kempii*

Conservation Targets not Selected

Many potential targets were not selected because (i) they were covered in the terrestrial ecoregional plans or (ii) they were marine species that had very little association with the coastal bays and estuaries within the ecoregion. For example, many bird species rely on the productivity of estuarine and marine environments for feeding. It was expected that the habitat targets would cover many of the most important resources for these birds, and bird species were well covered in the adjacent terrestrial plans. Many species of dolphins and turtles occasionally forage nearshore, but often do not rely on or are limited by nearshore coastal resources and stresses. Threats to populations of these species would occur principally far offshore. These species are likely to be beyond the capabilities of TNC to offer any direct assistance to their conservation. As TNC gains capacity and capability in the marine environment, these offshore targets should be revisited.

Sources of Data and Data Gaps

For terrestrial ecoregional plans, TNC relies heavily on data supplied by the Natural Heritage Programs and Conservation Data Centers (now collectively known as the Association for Biodiversity Information, ABI). These programs had some, but not extensive, data on the conservation targets of the northern Gulf of Mexico. There was, however, a substantial amount of spatial information on the habitat targets available through state databases (particularly FL and TX) and region-wide through the NWI and the National Wetlands Research Center (NWRC) (Appendix IV). Information on imperiled species came principally through a database developed at the University of Southern Mississippi (Poss et al. 1998). TNC, EPA GoMP, USGS NWRC and others are working jointly to make these data available on CD as an Arcview project.

There was little information on the distribution of freshwater grasses throughout the northern Gulf of Mexico and on oyster reefs in Louisiana. The lack of information on oysters is unfortunate, because their commercial value in Louisiana is approximately four times that in any other Gulf state. It is reasonable to assume that the distribution of oysters is more extensive in Louisiana than in the other Gulf States.

Portfolio Assembly: Choosing Priority Sites

Two primary tools were used to help in the assembly of a set or portfolio of priority sites for conservation: (i) a reserve selection algorithm and (ii) expert interviews and an expert's workshop. The point of the mathematical analysis was to provide a "strawman" set of priority sites that could be used to stimulate discussion; the analysis did not necessarily constrain the sites that had to be chosen. Before running the prioritization program, two decisions had to be made: (i) what are the conservation goals for habitats and species? and (ii) what is a site? These two questions are discussed first and then the tools for portfolio assembly are explained.

Setting Conservation Goals

A conservation goal is the amount of the target (species or habitats) that must be preserved to protect viable populations and communities that represent the full range of diversity within an ecoregion. Unfortunately, the rationale for setting specific goals (e.g., number of individuals in a population, number of populations, or areal extent of habitats) for marine habitats and species is not well developed (a similar problem exists in terrestrial and freshwater environments). It is therefore difficult to know, for example, how many individuals must be included in viable populations or how large a viable habitat must be. Several studies on marine reserves suggest that reserves may need to cover at least 20% of coastal waters to be effective as a tool in fisheries management to buffer against uncertainty, conserve heavily fished species, and provide some connectivity among reserves (NOAA Plan Development Team 1990, NRC 1999, Roberts and Hawkins in press). Another recent study suggests that most of the target species within Jervis Bay, Australia would be accounted for only when 40% of the bay was contained within protected areas and that habitats were the best surrogates to use for site selection (Ward et al. 1999). More research is needed to help determine appropriate values for conservation goals in marine and terrestrial environments.

As a preliminary goal, it was decided that any network of priority sites should contain at least 20% of the current distribution of each habitat and species. This is relatively straightforward for habitats--if the western Gulf contains 100,000 acres of seagrass and 200,000 acres of salt marsh, then the selected priority sites in this subregion must contain at least 20,000 acres of seagrass and 40,000 acres of salt marsh. For species, it was assumed for purposes of the mathematical analysis that the number of collection records in a bay (Appendix II) was related to the size of the population in that bay. Generally there were few such data on species and it often was not possible to identify separate populations of particular species.

Ideally, any conservation goal would be assessed against historical distributions not current distributions of the species and habitat targets. There are two problems with using historical distributions: (i) there are limited reliable historical data and (ii) regardless of the availability of data even if there were more historical data, it is unclear how far back we should look to balance anthropogenic vs natural changes in distributions (i.e., as we look farther back in time, anthropogenic influences will likely decrease, but there will be increasingly greater natural changes in distributions). There are few historical data on the distribution of most targets to help evaluate the status of their present range, but it appears that most of the habitats of the Gulf of Mexico have declined greatly over the past three decades (Duke and Kruczynski 1992).

A 20% goal also is only a benchmark; it is certain that future research will show that appropriate goals will vary substantially from 20% for particular species and habitats. The 20% conservation goal also only sets a minimum goal, and the set of priority sites could (and did) often include more than 20% of the targets.

Bays and Estuaries as Land and Seascape-Scale Sites

In terrestrial environments, it can be difficult to decide a priori on the boundaries of a site, because there are few natural boundaries. The marine environment in general, and the nearshore waters of the Gulf in particular, provided a more obvious solution to this problem. Much of the nearshore waters of the Gulf are divided into bays and estuaries and these form natural sites.

These bays and estuaries are land and seascape-scale sites; they are assemblages of many species, communities, and ecosystems, the dynamics of which are all tied to changes in salinity (and other associated physical-chemical conditions) created by the interaction of freshwater drainage and tidal influx and its effects on associated ecological processes. Bays and estuaries are open and dynamic, but they also have some internal integrity because many important ecological processes occur within the relatively well defined borders of the bay and its watershed.

The identification of bays and estuaries as sites made it easier to set priorities among them. More importantly, it ensured that the integrity of these estuarine landscapes was not compromised by attempts to conserve pieces of the site without attempting to understand the processes that tied the landscape together. A focus on estuarine landscapes does not preclude conservation action at particular places within a bay or on particular habitats, but it ensures a greater understanding of how these efforts should be informed by and benefit from an understanding of the site as a whole.

The boundaries of the bays were adapted from NOAA's coastal watershed analyses (Fig. 3). Only a few minor changes were made to these boundaries based on local knowledge about the integrity of certain bays and estuaries.

Developing a Portfolio of Priority Sites with Mathematical Algorithms and Expert Consultations

A strawman portfolio of high priority sites was developed with the assistance of the program, Sites (v1.0) (Andelman et al., in press). The basic input to the program was (i) information on the distribution and abundance of target habitats and species across bays (see Appendix II a & b) and (ii) a set of conservation goals (see above). The program attempted to find the minimum number of sites (bays and estuaries) that would meet the set goals for all targets. The results of these algorithms (Appendix V) provided a strawman analysis to spur discussions with scientists and managers around the northern Gulf of Mexico.

Priorities were set separately for each of the three geographic subregions within the northern Gulf of Mexico (Fig. 3, Appendix V). Priority sites were selected within each subregion to ensure (i) that potential variation in genes, species, and communities throughout the northern Gulf of Mexico was encompassed and (ii) that priority sites were spread throughout the ecoregion to protect against local environmental stochasticity and catastrophes.

Two different prioritization algorithms ("simulated annealing" and "greedy") were used (Possingham et al. 1999, Andelman et al. in press) to find the minimum number of sites that met the conservation goals. These algorithms differed in how sites were added or removed from the working set of priority sites in the search for the optimal solution.

The results of the analysis were similar for both algorithms. Some of the analyses had multiple solutions—i.e., there were several sets of high priority sites (Appendix V). Multiple solutions are a real characteristic of these algorithms—there is not always one optimal solution.

Experts were asked to evaluate the assumptions, data, and results of the analysis in personal interviews and a workshop. Overall the mathematical analysis provided a good heuristic framework and most of the results were ecologically sensible. There were, however, cases when the results of the program (both for sites included and excluded) did not accurately reflect a full understanding of the distribution of diversity and its threats in the northern Gulf of Mexico.

More priority sites were selected by experts than by the algorithm to reflect variability in communities within habitat types across the subregion. For example, it was widely acknowledged that the assemblages of plants and animals within seagrass habitats of Apalachee Bay and St. Joseph Bay, FL were different from one another and neither bay alone could represent all the species associated with seagrass habitats of the eastern subregion of the Gulf of Mexico. These additions are less indicative of a shortcoming of the program per se and more indicative of limitations in the marine habitat classification scheme, which is too coarse.

The final set of priority and high priority sites (high priority = action sites) were assembled after combining the results of the mathematical analyses with the comments of the scientists and managers (Fig. 1). The site boundary lines (Figures 1 & 2) are expected to be revised during site conservation planning; the present boundary lines serve only as a guide. The priority sites are generally whole bays and estuaries. The high priority sites contain the most important occurrences of the conservation targets in the northern Gulf of Mexico.

The conservation goals were met for almost all targets (Appendix VI). For most habitats it was reasonable to calculate the actual percentage of the habitats contained within the priority sites (owing to the lack of good population abundance estimates, these percentages were not calculated for the species). In general, the total percentage of the habitats contained within the priority sites often greatly exceeded the 20% goal for current distributions of the habitats. There are several reasons why the goals were exceeded; (i) since the set of bays and estuaries had to meet conservation goals for all targets, the priority sites had to include a greater amount than 20% for some targets, (ii) as noted above, the habitat classification was too broad and a greater amount of the habitats had to be included in order to account for variability in communities within the habitats, and (iii) most experts were concerned that a 20% goal based on current distributions was insufficient given the amount of the habitat lost in the Gulf of Mexico.

Initial Assessment of Priority Sites: Summaries of Targets and Stresses

<u>Targets and Stresses: General Introduction</u>

The distribution of the targets is indicated in Appendix II and there is specific information about each target in Appendix III. Many of these targets have declined substantially in abundance; some of the most impacted habitats include seagrasses, tidal fresh marshes, salt marshes, and freshwater grasses (Duke and Kruczynski 1992). Indeed it has been noted that estuaries may represent the most anthropogenically-degraded habitats on earth (Edgar et al. 2000). Louisiana has seen the greatest loss of coastal habitats; in this century there has been a net conversion of 4,000 square kilometers of wetland to open water (Gosselink et al. 1999). A peak loss rate of about 108 square kilometers of wetland habitat per year occurred during the 1958–1974 period, but continues presently (1990 estimate) at about 66 square kilometers per year (Gosselink et al. 1999). Oyster reefs have also declined in the Gulf, but more importantly water quality concerns threaten this fishery and may be a harbinger of the declining quality of Gulf estuarine waters. In 1995, more than half of all the areas in the Gulf that had harvestable quantities of shellfish (primarily oysters) had restrictions on fishing. The primary reason for restrictions was degraded water quality.

The estuaries and shallow coastal habitats of the northern Gulf of Mexico ecoregion are rich and productive because they receive inputs from terrestrial, freshwater, and marine sources. They are also impacted by stresses from all these environments. A stress is a factor that impairs or degrades the size, condition, or landscape context of a conservation target and therefore reduces its viability (Groves et al. 2000). The primary stresses to these targets, as well as the many animals that use them, include nutrification, pollution, altered hydrologic regime, and direct and indirect target destruction. These stresses arise from many sources including incompatible crop production practices (agriculture and aquaculture), incompatible coastal development, industrial discharge, and waterway dredging, among many others. The following is a list of some common stresses and examples of their sources.

Nutrification: Nutrification, an oversupply of nutrients (particularly nitrogen and phosphorous), can arise from many sources although in most sites around the northern Gulf of Mexico it arises principally from agriculture with secondary inputs from municipal sources and aquaculture. Nutrification can have pervasive ecological effects on shallow coastal and estuarine systems. These effects include reduced water clarity, loss of aquatic habitat, algal blooms (toxic and non-toxic), and a decrease in dissolved oxygen (=hypoxia). Nutrification generally favors the growth of single-celled and small algae at the expense of macrophytes (like seagrass and marsh species), and when waters become hypoxic few animals that require oxygen can survive.

Altered water chemistry (particularly salinity): Many nearshore species are euryhaline, i.e., tolerant of a wide range of salinities. Nonetheless, long term changes in the mean and variability of salinity still affect the distribution and abundance of these species. This is clearly evident in the dynamic change in oyster and salt marsh distributions as salt water encroaches inland on this coast.

Altered freshwater hydrologic regime: Alterations in freshwater flow (generally from freshwater diversions) change the basic characteristics of estuaries by altering the dynamic exchange between fresh and salt water. Change in the volume and timing of freshwater inflow affects many important ecological processes, which control the abundance of many target species and habitats. Sources of this stress include dams, levees, channelization, and excessive surface and groundwater withdrawal.

Altered salt water flow regime: Changes in the flow of salt water principally affect tidal and wave energy and sediment transport. In many places, shorelines are being armored by seawalls and similar structures, which reflect wave energy and lead to erosion of adjacent soft sediment habitats (e.g., marshes). Jetties and groins affect the long shore transport of sediments, which changes the movements of barrier islands and causes sediment accretion in some areas and sediment loss in others.

Altered sediment regime: A major problem in several areas on the coast of the northern Gulf of Mexico is river modifications, particularly damming and channelization, which have substantially reduced the supply of sediments needed for the development of coastal marshes. Much of the coast of Louisiana is subsiding as older riverine sediments are compacted. This subsidence would normally be balanced by the accretion of new river-derived sediments, but the delivery of sediments out of the Mississippi River has been cut by 80% from historical levels (Gosselink et al. 1999).

Light attenuation: The distribution of submerged macrophytes (seagrasses and freshwater grasses) is closely tied to light availability. If light levels are reduced, the blade density of grass beds declines (i.e., thinning) and eventually the entire grass bed can be lost. Blooms of algae associated with brown tides are an important source of this stress. The source of these brown tides is an open question, but it is well known that they thrive when there are excess nutrients. Incompatible coastal development can increase water turbidity through direct runoff across hardened surfaces and indirect runoff from municipal wastewater. Trawling and heavy boat traffic in shallow water can suspend bottom sediments, which also reduces light availability. On a smaller scale, docks can attenuate the light that reaches the grasses underneath and around them.

Direct target destruction: There are many sources that contribute to the direct destruction of targets including: incompatible coastal development, dredging, inappropriate recreational use, invasive species, and overfishing.

Incompatible coastal development (e.g., poorly designed homes, ports, docks, seawalls, golf courses, and marinas) has major direct impacts on habitats and species. This development also contributes to indirect target destruction by being a source of some of the other stresses identified in this section (e.g., altered flow regime, sedimentation, light availability, or nutrient source). Dredging also can destroy targets directly and indirectly.

Inappropriate recreational use can also be a problem. Propellers of recreational boats are responsible for extensive scarring of seagrass, which affects nearly every shallow seagrass habitat in the northern Gulf of Mexico (e.g., Sargent et al. 1995, TPWD 1998). In places with few seagrasses left, like Mississippi Sound, even scarring from anchors can be a significant problem. All terrain vehicles (ATVs) can destabilize dunes (particularly when driven on top of dunes) and degrade wind tidal flats.

Invasive species can also directly destroy targets through competition for substrate, competition for food, or herbivory. Currently, there are relatively few invasive species that cause major problems in the northern Gulf of Mexico as compared to most regions (although the number of problem species is likely to grow). Submerged freshwater grass habitats are subject to substantial invasions from introduced macrophytes like Eurasian milfoil, *Myriophyllum spicatum*, which commonly outcompete native species for space. Nutria, which were accidentally released in the 1930s and became unprofitable to trap for fur in the 1980s, graze on marsh plants and disrupt the substrate.

Overfishing can significantly alter population abundance and habitats. Trawl fishing (particularly for shrimp) can affect targets directly when they are taken as bycatch (e.g., turtles) and it can significantly impact habitats directly when the trawl scrapes them. The loss of some species, like shellfish, can, in turn, have system level effects on water clarity.

Inflow of toxins, contaminants, and pollutants: Overall the level of these stresses from point sources has decreased, but inputs from non-point sources (e.g., septic systems and stormwater runoff) are on the rise.

Sea level rise: Sea level is projected to rise around 20 cm in the next 50 years (LA Coastal Wetlands Conservation and Restoration Task Force 1998). The influx of salt water is most likely to affect species and communities that require brackish to fresh water and these communities are already at risk from many other stresses. In many places, however, the rates of coastal subsidence are several times greater than the rate of sea level rise; that is, the problem of land sinking is greater than the problem of sea rising.

Principal Targets and Stresses at Priority Sites

The following is a preliminary description of some of the most important targets at the priority sites with a brief indication of possible stresses and sources of stresses. **It is likely that the importance and magnitude of some of the stresses and their sources will be revised upon closer examination during site conservation planning.** This information is only intended to provide a starting point for future in-depth analyses of stresses, sources, and the strategies that the Conservancy and others can use to abate these stresses.

1. Laguna Madre de Tamaulipas

Principal targets: Seagrasses, tidal flats, Kemp's ridley turtle, intertidal shrub/forest (mangrove)
Principal stresses: direct target destruction **(**overfishing)

2. Lower Laguna Madre

Principal targets: Seagrasses, tidal flats, Kemp's ridley turtle, dwarf seahorse
Principal stresses: Nutrification, pollution, direct target destruction (dredging, incompatible development)

3. Upper Laguna Madre

Principal targets: Seagrasses, tidal flats, Kemp's ridley turtle
Principal stresses: Nutrification, light attenuation

The Laguna Madre of Texas and Tamaulipas is the only set of coastal, hypersaline lagoons on the North American continent and one of only five worldwide. Extending along 277 miles of shoreline in South Texas and northeastern Mexico, the lagoons are separated by 47 miles of Rio Grande Delta. Each lagoon is about 115 miles in length and each is further divided into subunits: the upper and lower Laguna Madre in Texas, separated by the Land-Cut tidal flats, and the northern and southern Laguna Madre de Tamaulipas, separated by the El Carrizal tidal flats.   The historically recorded extreme salinities of over 100-ppt have been greatly moderated in recent decades due to channel dredging and the cutting of passes. There has been more dredging in the lagoons in Texas than in the Laguna Madre de Tamaulipas, which has salinities closer to historical levels.

The lagoons are protected on the east by barrier islands and peninsulas, and bound on the mainland side by vast cattle ranches, farmlands, and the brush country of the Tamaulipan Biotic Province (Tunnell and Judd in press). South Padre Island is a nesting area for Kemp's ridley turtles. In Texas, almost 80% of all seagrass beds in the state are found in Laguna Madre and the historically, highly productive commercial fisheries have now given way to some of the best recreational fishing for red drum, black drum, and spotted sea trout in North America.

The Laguna Madre also has the most extensive wind-tidal flats and clay dunes in North America. Wind-tidal flats occupy 354 miles of shoreline in the Texas Laguna Madre and 196 miles in Tamaulipas. A unique strain of oysters, adapted to the high salinity conditions of Laguna Madre, are found in South Bay, the southernmost portion of the lower Laguna Madre in Texas (Tunnell and Judd in press).

The highest priority of these three sites should be the seagrass and tidal flat communities of the Lower Laguna Madre. At present, Mexican partners are collecting and analyzing spatial information on the distribution of submerged habitats in the Laguna Madre de Tamaulipas, and this effort is expected to identify a smaller area of high priority sites within this Laguna.

The principal sources of stress on the Mexican side of the Laguna Madre are from overfishing. On the Texas side, stresses arise from nutrification and pollution, which come principally out of the Arroyo Colorado from agricultural, municipal, and shrimp aquacultural outflows. Direct and indirect target destruction on the Texas side arises from the dredging of the Intercoastal Waterway and from the use of ATVs on dunes and tidal flats.

4. Corpus Christi Bay; high priority site-- Redfish Bay

Principal targets: Seagrass, oyster reef, Kemp's ridley turtle
Principal stresses: Direct target destruction (prop scarring), altered freshwater hydrologic regime, inflow of contaminants and pollutants

Corpus Christi Bay borders a growing city, the gateway to the nation's sixth largest port, which has substantial influence on the bay. A particular problem for this area is water diversions from rivers and streams for residential, industrial, and agricultural uses, because this area receives little precipitation. The lack of fresh water contributes to losses of oysters and white shrimp in the estuary (Coastal Bends Bay Plan, 1998). One of the biggest problems within Redfish Bay is prop scarring from recreational boaters. There also are significant concerns with development of hardened shorelines, docks, and marinas and with debris and contaminants from urban runoff.

The Coastal Bends Bay Plan (1998) from the Corpus Christi National Estuary Program provides many useful insights and strategies for better conservation and management. The first step in site conservation planning should be to assess the strategies identified in this plan.

5. San Antonio Bay

Principal targets: salt marsh, oyster reef, seagrass
Principal stresses: Altered freshwater hydrologic regime (diversions), direct target destruction (incompatible development), nutrification

San Antonio Bay, on the central Texas coast, lies in a subtropical region receiving 91-99 cm average annual rainfall. The Guadalupe and San Antonio are the main rivers flowing into this bay. The balance of evaporation and rainfall is approximately equal along the mid-coast of Texas. Bays farther south receive less rainfall and have greater evaporation rates, whereas in estuaries to the north of Matagorda Bay, rainfall is greater and evaporation less. The average depth of the bay is 1.4 m. Oyster reefs, numerous in the shallow areas, significantly affect currents and water circulation.

Matagorda Island borders the south shore of the bay, which isolates the bay from effects of the Gulf. The influence of freshwater (rainfall or inflow) is retained in the bay until circulation changes favor the intrusion of saline waters from adjacent estuaries such as Matagorda Bay. Matagorda Island is entirely under federal protection. The south shore of San Antonio Bay and the mainland are fringed by salt marsh, an important habitat (food source) for the endangered whooping crane that winters at the adjacent Aransas Wildlife Refuge.

Stresses to this bay include direct and indirect target destruction associated with incompatible development and altered hydrologic regimes from freshwater diversions. Decreased rainfall to the area in 1999/2000 threatens the abundance of blue crabs in the salt marsh, one of the whooping crane's favorite foods. Most of the land surrounding the bay is used for grazing or farming, and nutrient runoff from agriculture can be a problem.

6. Northeast Matagorda Bay

Principal targets: seagrass, salt marsh, tidal fresh marsh, freshwater grasses
Principal stresses: altered freshwater hydrologic regime

Matagorda Bay is the second largest estuary on the Texas Gulf coast. The abundant production of finfish and shellfish make this environmentally sensitive area important not only as an ecological resource, but also as a source of economically significant commercial and sports fisheries. Many factors contribute to this high natural productivity, but the most significant is an ample source of freshwater. Freshwater inflows are vital to the continued health of the natural ecosystems in and around Matagorda Bay.

Secondary and tertiary bays deliver freshwater from two important rivers: the Colorado (flowing into East Matagorda Bay and the eastern portions of West Matagorda Bay), and the Lavaca (flows into the Lavaca River delta and Lavaca Bay). Other smaller tributaries include Turtle Creek, the Carancahua River, and Cox Creek, which flow respectively into Turtle Bay, Carancahua Bay, and Keller Bay (all secondary bays). These secondary bays serve as nursery habitat for many species, such as brown and white shrimp, blue crab, eastern oyster, spotted seatrout, flounder, and red drum.

The bay side of Matagorda Peninsula contains seagrass habitat that is also used by many species, including the ones mentioned above. This shoreline, running the entire southern border of Matagorda Bay, is covered by *Ruppia maritima* and *Halodule wrightii*.

Stresses to this bay include a decrease in freshwater inflow due to the construction of dams along rivers, industrial-use diversion, and industrial discharge. While incompatible development is a concern, many areas receive some protection through the Perry R. Bass Fisheries Research Station, Mad Island Marsh Preserve, and privately owned hunting and grazing property. While runoff from agricultural herbicide/pesticide use has been a concern, no research has indicated that it is serious.

Sites 7-11: A general introduction to the Louisiana coast

The Louisiana coastal marshes (sites 7-11) are some of the most dynamic and threatened habitats on the US coast. These marshes have been and continue to be lost at an alarming rate. This marsh loss has occurred largely in this century and peaked in the 1950 and 1960s. Marsh loss has slowed but it is still staggering. Part of this loss is from natural subsidence of coastal lands. Much of this subsidence would normally have been balanced by an influx of sediments from the Mississippi River. The annual sediment load of the Mississippi that reaches the Gulf of Mexico has been cut in half just since the 1950's, because of dams on tributaries and extensive channel works (Gosselink et al. 1999). In addition, there has been extensive dredging, draining, and diking throughout the coast, which contributes to the loss of coastal marshes (Turner 1997).

The LA Coast 2050 plans provide specific objectives for conservation and management (LA Coastal Wetlands Conservation and Restoration Task Force 1998). It was not possible to examine these strategies individually and in depth in this plan. In general, the strategies appear to be well defended and consistent with the goals outlined in this plan.

Some common strategies suggested in the LA Coast 2050 plan include:

- better use of dredged material spoil to help build marshes;
- stabilization of shorelines to slow erosion and loss of barrier islands and lake shorelines;
- better use of pump outfalls for wetlands benefits, which generally entails directing freshwater outflow through wetlands instead of straight into channels;
- control of nutria herbivory;
- planting of vegetation to help restore marshes.

7. Grand & White Lake

Principal targets: Mesohaline salt marsh, oligohaline salt marsh
Principal stresses: Altered water chemistry; altered sedimentation regime, altered freshwater hydrologic regime

Grand and White Lake occur within the Chenier Plain of western Louisiana; an area that supports extensive marshland interspersed with large inland lakes formed in river valleys that were drowned after the last glaciation (Gosselink et al. 1999). The most rapid wetland losses in this area occur in the low-salinity interior marshes, possibly because land subsidence and saltwater intrusion stress the marsh vegetation beyond its ability to survive (Gosselink et al. 1999). The flow of water, particularly fresh water, is highly regulated throughout much of the Chenier Plain through locks and navigational channels. The loss of the coastal shoreline in and around the Rockefeller Refuge and the loss of shoreline and coalescence of the Lakes affect the interior low-salinity marshes. The LA Coast 2050 plan suggests that these shorelines should be stabilized to help prevent further marsh loss.

8. Atchafalaya Bay

Principal targets: Tidal fresh marsh
Principal stresses: Altered freshwater hydrologic regime, altered sedimentation regime

The Atchafalaya Delta is the largest actively accreting delta in this subregion, which is extremely important in a region where so much coastal lands are being lost. Overall, the Atchafalaya Bay systems are in comparatively good shape and are reasonably well protected. The flow into this bay is highly regulated, but significant concern is given to wildlife and habitats. Flow, however, could still be better regulated to enhance marsh development (LA Coastal Wetlands Conservation and Restoration Task Force 1998).

9. Barataria Bay (particularly Little Lake to Bayou La Fourche and Grand Isle)

Principal targets: Salt marsh (all types), freshwater grasses, tidal fresh marsh
Principal stresses: Altered sedimentation regime, altered hydrologic regime (freshwater), pollution, direct target destruction (herbivory by introduced nutria)

The Barataria Basin has extensive marshes that contain the highest diversity of animals of any water body in Louisiana (Duke and Kruczynski 1992). Many of the problems in this area originated decades ago when the Mississippi River was leveed and marsh lands were drained, which resulted in coastal erosion and barrier island retreat. The freshwater habitats were particularly affected by the damming of Bayou La Fourche (Condrey et al. 1995). A lesser but important problem is the impacts of nutria herbivory.

At present, not too many estuarine and marine species have been adversely affected by this marsh loss. The explanation for this apparent anomaly appears to be that as marshes are fragmented, the amount of marsh edge habitat increases. This edge habitat is particularly important, because many estuarine species cannot easily penetrate dense and productive marshes. Marsh edges have the highest densities of animals and are the transfer point for productivity between marshes and the rest of the estuary (Condrey et al. 1995). As marsh loss continues, however, the amount of marsh edge will eventually decline and there may be a breaking point after which conservation and even restoration may have little effect.

10. Chandeleur Islands

Principal targets: Seagrass, fringed pipefish
Principal stresses: Sea-level rise, subsidence, erosion of barrier islands (largely natural), direct target destruction (scarring of seagrasses from props and nets)

The seagrass beds behind the Chandeleur Islands are unique and one of the least anthropogenically impacted grass beds in the northern Gulf of Mexico. The water is quite clear, because these islands are far offshore. These grass beds have been increasingly impacted by major storm events that have caused substantial erosion of the barrier islands and deposition of sediments onto the grass beds. The seagrasses can survive and grow through periodic burials by sediments, but cannot survive persistent burial. It seems likely that there will be further erosion of the barrier islands and without this protection the grass beds will disappear as well. In addition to the impacts of natural erosion, there are anthropogenic impacts, which arise mostly from prop scarring and groundings by recreational boaters and occasional impacts from trawl nets.

11. Lake Pontchartrain and northern Lake Borgne

Principal targets: Gulf sturgeon, freshwater grasses
Principal stresses: Direct target destruction (incompatible development, invasive species), nutrification, pollution, and light attenuation (from agricultural and municipal runoff)

Historically, freshwater vegetation was abundant on all shores of Lake Pontchartrain. Between the 1950's and 1985, the distribution of vegetation declined by over 90% (Montz 1975, Duffy and Baltz 1998). This decline is largely attributed to reductions in water clarity from agricultural and municipal runoff. Presently, submerged aquatic vegetation is only found in the northeastern corner of Lake Pontchartrain, and this area is coming under increasing development pressure. The remaining areas in northern Lake Pontchartrain and northern Lake Borgne with submerged vegetation appear to be important feeding grounds for the Gulf sturgeon.

In 1978, an exotic species, Eurasian milfoil *Myriophyllum spicatum,* was first reported in Lake Pontchartrain. It has since become established as the dominant submerged vegetation and has been displacing native species, particularly widgeon grass *Ruppia maritima* (Duffy and Baltz 1998).

12. East Mississippi Sound and Mississippi Gulf Islands

Principal targets: Dwarf seahorse, opossum pipefish, seagrass, salt marsh
Principal stresses: Altered freshwater hydrologic regime, direct target destruction (scarring of seagrasses from anchors, nets, and props), nutrification

Seagrass has declined in abundance and diversity throughout Mississippi Sound. Since 1967, almost half the acreage of seagrass has been lost. In 1967, four seagrass species (*T. testudinum, H. wrightii*, *H. engelmannii*, *S. filiforme*) and *R. maritima* were present in the Sound. The only seagrass species currently found in the Sound is *H. wrightii*. *R. maritima* is also present in patches (Moncreiff et al. 1998). Seagrasses are presently found behind some of the barrier islands (they used to be behind all the islands) and in the Grand Bay area. The principal reasons for loss include increased turbidity from incompatible development and nutrient runoff. There is also a problem of excessive freshwater inflow from the Bonnet Carré spillway, which is opened during Mississippi River floods to reduce their impacts on New Orleans.

Most of the seagrasses behind the islands are deep enough that they are not impacted by prop scarring, but these shallow, nearshore, protected areas behind the islands are common anchoring sites. The scars from these anchors are an increasing problem in these areas where little seagrass is left.

13. Mobile Bay (Mobile-Tensaw Delta)

Principal targets: Freshwater grasses, tidal fresh marsh, oyster reefs
Principal stresses: Altered hydrologic regime, altered sedimentation regime, nutrification, altered flow regimes, direct target destruction (incompatible silviculture, invasives)

The Mobile-Tensaw Delta contains the greatest abundance of freshwater grasses in the northern Gulf of Mexico and there is a great diversity of grass species in this area. Freshwater grasses are likely to have declined by more than 50% from the 1940s-1979 (Duke and Kruczynski 1992), but there appear to be recoveries in the past 20 years, especially in areas south of the causeway. Current sources of stress to the fresh water grasses are natural (e.g., hurricanes) and anthropogenic. The anthropogenic sources that currently affect these grasses are shoreline development, shrimp net scarring, and scarring by recreational boats and other vehicles. Invasive vegetation has had great adverse effects on these grasses, but these impacts may have peaked (and may possibly be declining). Elevated nutrient levels may also contribute to the growth of algae, which reduce light levels and overgrow the grasses. The causeway at the end of the Delta has altered flow and sedimentation regimes.

14. Bayous of Escambia Bay

Principal targets: Tidal fresh marsh, Gulf sturgeon
Principal stresses: Direct target destruction (incompatible development), pollution, nutrification, altered sedimentation regime

The Escambia River delta supports extensive beds of *Vallisneria*, which extend into the upper reaches of Escambia Bay. These beds are critical in the life histories of a number of species, including Gulf sturgeon, redfish, and speckled trout. Chemical plants have been a major problem, but their impact has been reduced. Development is fragmenting coastal habitats and causing pollution, nutrification, and siltation.

15. Santa Rosa Sound

Principal targets: Seagrass
Principal stresses: Direct and indirect target destruction (incompatible development)

A significant amount of the Santa Rosa Sound area is undeveloped barrier islands that are protected under the auspices of the Eglin Air Force Base. There are extensive seagrass beds in the sound. Green Turtles nest on the Eglin Air Force Base beaches. Panhandle beaches are also important for beach mice, snowy plovers and piping plovers. Development is increasing on the north side of the Sound and on either end of the barrier island. Turbidity in the Sound may be increasing and appears to be related to the inflows of treated wastewaters that are picking up tannic acids.

16. St. Joseph Bay

Principal targets: Seagrass
Principal stresses: Nutrification (septic tanks), direct target destruction (incompatible development, prop scarring), pollution

St. Joseph Bay and Apalachicola Bay sit shoulder to shoulder, but provide a great contrast in condition because all the fresh water of the region goes to Apalachicola Bay. St. Joseph Bay has a very small watershed and it is the only bay in the eastern Gulf of Mexico that is not influenced by freshwater inflow. It thus has high and consistent salinity. It is also nearly enclosed and protected from heavy wave energy by Cape San Blas. It is rare to have these conditions of high salinity and clear water immediately nearshore in a shallow, low-energy environment in the northern Gulf of Mexico. Under these conditions, a high diversity of plants and animals can thrive. The productivity of invertebrates (e.g., amphipods, mussels, crabs, and worms) within St. Joseph Bay is the highest ever recorded in seagrass beds (Valentine and Heck 1993). There are a number of animals that appear to occur at greater densities in St. Joseph Bay than in most other places in the northern Gulf of Mexico including stone crabs, scallops, horse conchs (the largest gastropod in North America), lightning whelks, and pen shells. Scallops once thrived in the eastern Gulf of Mexico, but now they are only found in abundance in two places, St. Joseph Bay and the Steinhatchee area.

St. Joseph Bay is small, contained, and accessible; these conditions make it easily threatened. The major stresses are leaking of dioxins, leaching of nutrients from septic systems on Cape San Blas, prop scarring of seagrass beds from small boats, and incompatible development. The industrial canal, which used to principally service the pulp mill, is probably still a source of dioxins and heavy metals. The soils on Cape San Blas are very porous and material leached from the septic systems of vacation homes and rentals probably moves into the bay quickly. Prop scarring by motorboats creates an additional stress on the seagrass habitat in this bay. A recent analysis showed that more than 50% of the seagrass habitat in St. Joseph Bay had been at least lightly scarred (Sargent et al. 1995). As recreational use increases (particularly from inexperienced boaters), the level of scarring will increase.

17. Apalachicola Bay

Principal targets: Oyster reef, tidal fresh marsh, manatee

Principal stresses: Altered freshwater hydrologic regime (dams, diversions), direct target destruction (incompatible development), nutrification, pollution

Apalachicola Bay is fed by the Chattahoochee, Flint and Apalachicola rivers and their tributaries, which drain an area of nearly 20,000 square miles reaching from the southern Blue Ridge mountains to the Gulf of Mexico. The Apalachicola-Chattahoochee-Flint watershed is one of the largest watersheds feeding into the eastern Gulf of Mexico. It is estimated that the discharge from the Apalachicola River accounts for 35 percent of the total freshwater contribution from the west coast of Florida to the Gulf of Mexico. The magnitude of flow from the river and the natural productivity of the bay make it of great significance to the entire Gulf of Mexico. Apalachicola Bay is the largest National Estuarine Research Reserve in the conterminous United States and has been designated a Florida Aquatic Preserve, an Outstanding Florida Water and an International Biosphere Preservation Area.

Apalachicola Bay is one of the most biologically productive estuaries in the country. The productivity of the bay is related to its geography. The Apalachicola River enters the bay at right angles to the tidal currents, which move from east to west, and creates a dynamic mixing of fresh and salt water. The relatively shallow basin, with an average depth of 2-3m, and the barrier island chain form a natural container for nutrients that are either washed into the bay from the river and overland runoff or are present in the bottom of the bay.

Ninety percent of Florida's oysters, over 10% of the total U.S. harvest, are taken from Apalachicola Bay. Although best known for its oysters, Apalachicola Bay also supports other commercial fisheries. It is a regional center for penaeid shrimp, blue crabs and other commercially and recreationally valuable species including striped bass, grouper, drum, flounder, whiting, menhaden, and spotted seatrout.

Because Apalachicola Bay retains much of its natural resource values it plays an important role in the Gulf of Mexico. East Bay is a primary nursery area for many Gulf of Mexico species. Blue crabs are known to come from as far as 300 miles away to spawn at the entrance of the bay so their young can mature in East Bay.

The health of the Apalachicola Bay depends on freshwater inflows that have not been altered in their magnitude or timing. Changes in river flows occur primarily from the operations of the five federal dams on the Chattahoochee River and water withdrawals for municipal and industrial water supply for metro-Atlanta and agricultural irrigation in southwest Georgia. Water quality alterations can also have a significant impact with local sources being improperly treated wastewater (septic tanks and city sewer systems), stormwater runoff and silviculture practices.

18. Northeastern Apalachee Bay (Ochlocknee Bay to Econfina River)

Principal targets: Sponge and coral, seagrass, manatee, Kemp's ridley turtle, Fringed pipefish

Principal stresses: Nutrification, pollution (urban discharge), altered freshwater hydrologic regimes (diversions and withdrawals)

There is a substantial degree of habitat variation and species diversity throughout the Apalachee Bay region (sites 18 and 20 and the areas between these sites). Apalachee Bay is the only bay in this ecoregion that contains significant hardbottom sponge and coral habitats. These hardbottom habitats are interspersed in a mosaic with all four of the seagrass genera. *Halophila* spp. in this region extend far offshore in waters up to 12+ m deep. Spring-fed rivers and submarine freshwater upwellings are important features throughout Apalachee Bay. Extensive salt marsh systems fringe the coastline in this region, and they provide important connectivity between estuarine, marine and terrestrial communities. Many places throughout Apalachee Bay would be ideal for a marine protected area. Much of the uplands are intact and in public ownership, the marine biota is in near pristine condition, human population density is low, and there are few economic detractions and many positive economic incentives for the protection of the natural resources.

In the northeastern section of Apalachee Bay, Kemp's ridley turtles feed in Dickenson Bay. Manatees seasonally use northeastern Apalachee Bay and the Ocklochnee, Wakulla and St. Marks Rivers. The northern portion of Apalachee Bay also contains pockets of oyster habitat off of river mouths such as the Ocklochnee, St. Marks, Aucilla and Econfina rivers. During dry years, bay scallop populations dramatically increase in seagrass meadows within this region and are comparable to those regularly found in St. Joseph Bay and off Steinhatchee. Nearshore habitats support important commercial blue and stone crab fisheries and recreational fisheries for red drum and spotted seatrout. Much of the coastal zone is in public land ownership, but growth in the Tallahassee region is leading to greater pollution in the northern part of the bay and greater freshwater diversions away from it.

19. Suwannee Sound

Principal targets: Gulf sturgeon, manatee, oyster reef

Principal stresses: nutrification, altered freshwater hydrologic regime (proposed flow diversion)

This site includes just the area of estuarine influence (i.e., the area of mixed salinity). Suwannee Sound has significant oyster habitat and is an important feeding and breeding ground for what is probably the largest remaining population of the Gulf sturgeon. Manatees are also found in this area.

This area faces problems with nutrification from agricultural runoff seeping into the groundwater and then into the river and sound. Nitrite concentrations have increased greatly in recent years. A proposed interbasin transfer from the Suwannee River to Tampa could have substantial detrimental effects on the river and sound.

20. Southern Apalachee Bay (Cedar Key to Chassohowitzka Bay)

Principal targets: Sponge and soft coral, seagrass, manatee, Kemp's ridley turtle, Dwarf seahorse, Fringed pipefish, intertidal shrub/forest

Principal stresses: Direct target destruction (incompatible development, prop scarring), altered freshwater hydrologic regime (groundwater withdrawals), nutrification

This section of Apalachee Bay, just like the northern section (see above), has a great diversity of habitats including substantial hardbottom sponge and coral habitats. The Cedar Key area has significant oyster habitat and is a principal summer feeding ground for Kemp's ridley turtles. Crystal River and Homosassa River are the northern-most natural warm water refuges for wintering manatees.

An abundance of offshore freshwater upwellings means that excess nutrients can migrate quickly from land into these waters. Phosphorus appears to be limiting in the bay, and if there were an increase of phosphates there could be an explosion of nutrification impacts. Groundwater withdrawals for agricultural and municipal use and from springs for bottled water will decrease freshwater flow in this area as the human population increases. Lowered magnitudes of flow have already been documented in some springs (e.g., Homosassa Springs). There is a large threat to this area as urban pressure heads north of Tampa along the soon-to-be built Suncoast Highway.

<u>Zone of Hypoxia (Site 21)</u>

The focus of this plan is on the bays and estuaries of the northern Gulf of Mexico, but there is an important area near the shores of Louisiana and northeast Texas that is increasingly threatened by a lack of oxygen in the waters. Few animals can survive these conditions of low oxygen and the area of hypoxia (< 2 mg/L O_2) has been called a "dead zone". This zone of hypoxia has generally been growing in size over at least the past two decades and is the largest zone of hypoxia in the entire western Atlantic and the third largest in the world. The mid-summer areal extent of hypoxic bottom waters in 1985-1992 averaged 8,000 to 9,000 km^2 but increased to 16,000 to 18,000 km^2 in 1993-1997. The estimated extent was 12,500 km^2 in mid-summer of 1998 (Rabalais et al. 1999). In the summer of 1999, the zone of hypoxia was approximately 20,000 km^2. Recent reports indicate that the size of the zone decreased in the summer of 2000 to 4,400 km^2.

This hypoxia is principally a result of excess nutrients that flow out of the Mississippi and Atchafalaya River basins. The amount and impact of the nutrient influx have been enhanced by channelization of the rivers, loss of natural wetlands along the banks, and the increased stratification of the Gulf coastal waters. Nitrogen is the principal limiting nutrient in most coastal waters. Nitrate concentrations in the Mississippi River and some tributaries have increased 2-5 fold in the last century. "The principal source areas for the nitrogen that discharges to the Gulf are watersheds draining intense agricultural regions in southern Minnesota, Iowa, Illinois, Indiana, and Ohio" (Fig. 9). "These regions contribute several times more nitrogen per unit area than do areas outside this region. Streams draining two States, Iowa and Illinois, contribute as much as 35% of the total nitrogen flux of the Mississippi River during years of average rainfall, and much more during years with high rainfall" (Goolsby et al. 1999). The decrease in the size of the zone of hypoxia in the summer of 2000 has been largely attributed to the low amount of rainfall in the basin, which has resulted in less nutrients washing off the lands.

Mechanisms must be put in place to ameliorate this excessive inflow of nutrients to the Gulf. In a cost-benefit analysis, Doering et al. (1999) found that "a strategy that combined a 5-million acre wetland restoration with a 20% fertilizer reduction is the most cost-effective strategy we examined for meeting a 20% nitrogen loss reduction goal" (i.e., keeping nitrogen on the land as opposed to in the rivers). "We find that this program reduces nitrogen loss by about 20% with few if any secondary effects that are beyond our historical experience of sectoral adjustment in agriculture." Doering et al. (1999) suggest that riparian buffers were not very cost effective at reducing nutrient inputs in the Mississippi/Atchafalaya River basin.

At present most plans for management and restoration of the zone of hypoxia call for reductions in nutrient inputs. These reductions, however, should not be the measurable endpoints of a successful conservation, restoration, and management program. The ultimate measurable endpoint should be the return of the natural plant and animal communities to the freshwater and marine environments of the Mississippi and Atchafalaya drainage basin and the coast of Louisiana.

Implementation Plan and Next Steps

<u>Combining High Priority Terrestrial, Aquatic and Marine Sites</u>

The first step in coastal conservation is to look for sites that are jointly listed as high priorities in terrestrial and marine plans. In most cases, the boundaries for these adjacent sites should be modified to include all components of diversity within the larger land and seascape. The bays and estuaries of the northern Gulf of Mexico are integrally linked by important processes to the surrounding terrestrial and aquatic environments. Conservation in a part of these landscape-scale sites will benefit biodiversity across environments, and this connectivity must be recognized and used in the development of conservation strategies. Ultimately our understanding of this connectivity will improve the chances for successful conservation of biodiversity throughout the southeastern and central USA.

<u>Some Research and Monitoring Recommendations</u>

Presently in the Gulf of Mexico, seagrasses, salt marshes, and the zone of hypoxia are major areas of research and monitoring. These efforts are well placed and address important habitats and significant problems in the northern Gulf of Mexico. There, however, are a few habitats and problems that could also benefit from additional scientific attention. There are several understudied habitats including the (1) sponge and soft coral habitats of Apalachee Bay, (2) oyster reefs, and (3) tidal freshwater grasses. There are also a few problems that need attention to target management and conservation efforts including (4) the determination of conservation goals, (5) the classification of habitats, and (6) the identification of nursery habitats. The research and monitoring needs for these habitats and problems are described below.

(1) Sponge and soft coral habitats of Apalachee Bay—These habitats are the most understudied areas in the nearshore waters of the Gulf of Mexico. Preliminary work indicates that the extent of these habitats is substantial and they may well be the most species rich of any habitat in the northern Gulf of Mexico but little else is known about these habitats. There are very little data on their distribution, abundance, species richness, temporal variability, or major stresses. The nearshore habitats of Apalachee Bay are difficult to reach, and this area is one of the least populated sections of the Gulf coast. It is likely that these habitats have not been substantially degraded and they may even be near pristine in condition. There are only some minor impacts at present, but this area will face increasing pressure from development, which may lead to greater problems of marsh habitat loss, freshwater withdrawals, and excess nutrient input. This last stress could prove the most detrimental as increased algal blooms could kill the loggerhead sponges and foul and degrade the soft corals. It would be unfortunate if these habitats were badly degraded by algal blooms, as occurred in the Florida Keys. It would be best to understand the factors that affect these habitats before major problems develop. Sections of Apalachee Bay would make ideal marine protected areas or parks.

(2) Oyster reefs— Oysters provide an important food source and habitat structure for many species. They are likely to be essential fish habitat for some species. Unfortunately, there has been little work done to examine community structure around oyster reefs. This is in part because they are difficult to sample. Nonetheless, they are important habitats and a better understanding of their ecology would improve management and restoration. In Louisiana in particular, there is very little information on the distribution of this ecologically and economically important species.

(3) Tidal freshwater grass—This is the second least studied habitat in the northern Gulf of Mexico. It is also one of the most threatened habitats. This habitat appears to fall between the cracks of freshwater and marine management and ecology. Some recent isotopic evidence suggests that these habitats may make important contributions to estuarine food webs, and prey from these habitats is found in the guts of many transient marine fishes. In general, invasive species are not yet a major problem in the Gulf of Mexico, except in the tidal freshwater grass habitat. In some places more than 50% of this habitat has been taken over by invasive freshwater vegetation, e.g., Eurasian milfoil, *Myriophyllum spicatum*.

(4) Conservation goals. One of the greatest challenges in conservation and management is the setting of clear conservation goals. This is problem in all environments (terrestrial, freshwater and marine). Ideally, it would be useful to know minimum goals that must be met for successful conservation and management of species, communities, habitats, and ecosystems (e.g., what is the minimum viable population?). Unfortunately, there is a good understanding of these goals for just a handful of species.

(5) Habitat classification scheme. As indicated above, there are well developed classification schemes for terrestrial communities, but only coarse level classifications for most marine habitats and communities. A classification scheme is useful because it helps to identify consistent and recurring assemblages of plants and animals. An understanding of the distribution of these assemblages and the ecological processes that shape them is vital to the conservation and management of biodiversity.

(6) Identification, conservation and management of nursery habitats. At present, it is common for conservation and management organizations to consider all seagrass and wetland habitats as nurseries. These broad declarations may be useful for generating public interest, but they hinder the actual work that needs to be accomplished by these groups, because the statements lack focus. Seagrasses and wetlands have been the focus of most work on nurseries, and in many cases this emphasis has been justifiable, but it is likely that

previously ignored habitats (e.g., oyster reefs) also serve as nurseries and should be better conserved and managed. A clearer understanding of the particular species that require nursery habitats, and the factors that make some sites within habitats more valuable as nurseries will allow better expenditures of limited money, time, and effort. Not all oyster reefs or wetlands are created equal. If it were known, for example, that for some species the best seagrass nurseries were large beds near sources of larval influx and in close proximity to adult habitats, then efforts in habitat conservation and management could be more judiciously invested in those types of sites. Some of this information is or should be available, but it has not been applied specifically to the identification of the habitats and, more importantly, the sites within habitats that serve as nurseries. We need a better understanding of nursery habitats to help non-governmental organizations to better place their conservation efforts to protect the diversity of species and natural resources, and to help state and federal agencies and fishery management councils to make better regulatory decisions for fisheries management, habitat conservation, restoration and mitigation.

<u>TNC's Role in the Conservation of Estuarine and Marine Biodiversity</u>

The Nature Conservancy has been and should continue to be a good partner in the conservation of nearshore diversity. The Nature Conservancy commonly uses a number of strategies to help conserve biodiversity including:

- Land acquisition and conservation easements (e.g., to diminish impacts of development)
- Compatible economic development
- Community-based conservation
- Compatible resource management
- Development of effective partnerships
- Public policy (e.g., marine parks, Essential Fish Habitat, Land and Water Conservation Fund)

All of these strategies can be effective in the conservation of estuarine and marine biodiversity. Land acquisition, the Nature Conservancy's trademark strategy, is extremely effective in the conservation of marine biodiversity. In many places the biggest stresses to salt marsh, seagrass, tidal flat, and oyster reefs are associated with incompatible development along the coastlines and nutrification and pollution from within the watershed. TNC has vast experience in addressing and abating these stresses.

To expand on the strategies above, the Conservancy can help to conserve and protect marine diversity with some of the following more specific strategies:

- Acquire strategic tracts of land in the upstream delta areas, barrier islands and shoreline.
- Acquire submerged land leases (e.g., on oyster reefs) and work with fishermen to develop better management of these resources and give a voice to shellfishermen for their concerns about water quality.
- Work with local government and land owners to install/upgrade sewage treatment.
- Develop partnerships with agricultural interests to encourage best management practices to reduce nutrient and chemical loading.
- Establish a cooperative venture with oil and gas interests to encourage best management practices to reduce shallow water habitat loss.
- Partner with the seafood industry to build support for research to investigate the role of seagrasses and marshes as nursery grounds for key commercial species and to monitor target habitats.
- Expand our work with EPA, NOAA, COE, and others to target federal resources toward research and protection of essential habitats in the northern Gulf of Mexico.
- Help to expand the Land and Water Conservation Fund (and related funds/legislation) and direct these resources to coastal conservation.
- Help to establish marine protected areas.

As in terrestrial conservation, TNC can be successful in the conservation of coastal waters by ensuring that coastal development is compatible with natural resource protection, by working with communities and by bringing partners together to deal with critical compatible-use issues. TNC misses enormous opportunities to leverage all its conservation work by ignoring a niche that it already fills in coastal and marine conservation. Most people who live near the coast care about their coastal waters and their concern can be leveraged into action. Oystermen and other shellfishermen should be natural allies in the quest for sensible land and water use, because almost any activity on land that degrades water quality in the rivers, bays, and estuaries will affect their livelihood before most other resource users.

TNC is already working directly on estuarine and marine conservation at several sites around the northern Gulf of Mexico, including Apalachicola Bay, FL; Laguna Madre, TX, MX; and Grand Bay, AL, MS. In many other places, TNC is working on estuarine and marine conservation without calling it as such. For example, it has worked to protect coastal marshes in every state in the Gulf without realizing that the primary beneficiaries of this work are the marine biota—marshes drive the diversity and productivity of much of our coasts. The opportunities that lie ahead are (i) to recognize that TNC is already engaged in marine conservation in nearly all of its coastal projects, (ii) to reap the benefits from this work (community outreach, development, and knowledge of functionality and connectivity of systems) and (iii) to continue to adapt TNC's approaches and practices to coastal projects. The Conservancy's wealth of experience from its land-based work allows it to make a critical contribution to conservation in nearshore marine and estuarine environments.

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Appendices

<u>Appendix I. The Nature Conservancy Core Team Members</u>

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Appendix IIa. Distribution of Imperiled Species in the Gulf[1]

Bay	Diamondback Terrapin	Dwarf Seahorse	Manatee	Fringed Pipefish	Gulf Sturgeon	Kemp's Ridley	Opossum Pipefish	Texas Pipefish
Lower Laguna Madre		7				5	1	
Upper Laguna Madre						7		
Corpus Christi Bay	1	4				3		2
Aransas Bay	5	1						
San Antonio Bay	4							
Matagorda Bay	3					2		
Galveston Bay	4							
Grand & White Lake	6							
Terrebonne/Timbalier Bays		1						
Barataria Bay	1							
Chandeleur Sound	2	1		5				
Lake Borgne	1				5			
Lake Pontchartrain	1							
West Mississippi Sound				2			9	
East Mississippi Sound	6	2		1	2			
Mobile Bay	1				4			
Perdido Bay		1		1		1		
Pensacola Bay		1		1	3	7		
Choctawhatchee Bay			1		8	1		
St. Andrew Bay			3	2		23		
St. Joseph Bay						10		
Apalachicola Bay			3		7	18		
St. George Sound		2		1		7		
Apalachee Bay (north)		4	1	6	1	3		
Suwannee Sound			19		15			
Apalachee Bay (south)		7	170	11		1		

[1]The values represent the number of independent collection records (e.g., in museum records or through state Natural Heritage programs). Independent records may represent multiple individuals collected at the same time, but these are are only counted as one record.

Appendix IIb. Distribution of Habitats (hectares) in the Gulf

Bay	Estuary[1]	Seagrass	Tidal Fresh Grass (Rooted Vascular)	Oyster	Saltmarsh	Salt Marsh Polyhaline	Salt Marsh Mesohaline	Salt Marsh Oligohaline
Laguna Madre de Tamaulipas	637758[2]	33801[2]	0[B]	1[3]	19184[3]	1[A]	0[A]	0[A]
Lower Laguna Madre	1450016	46613	0[B]	1[B]	6012	1[A]	0[A]	0[A]
Baffin Bay	177228	4842	0[B]	0[7]	185	1[A]	0[A]	0[A]
Upper Laguna Madre	276503	23834 [3]	0[B]	0[7]	1454	1[A]	0[A]	0[A]
Corpus Christi Bay	181210	5014	126	48	4384	1[A]	1[A]	1[A]
Aransas Bay	688715	6285	0	158	13398	1[A]	1[A]	1[A]
San Antonio Bay	408663	4312	160	1243	13035	1[A]	1[A]	1[A]
Matagorda Bay	1519408	427	233	17010[6]	24934	1[A]	1[A]	1[A]
Brazos River	824626	0	701	0[A]	13453	1[A]	1[A]	1[A]
Galveston Bay	1159648	142	429	11343	33675	1[A]	1[A]	1[A]
Sabine Lake	1246658	0[B]	430	9[10]	58996	1994	23561	14570
Calcasieu Lake	271885	0[B]	523	99[10]	62755	2360	31135	29132
Grand & White Lake	612530	0[B]	837	0[A]	83912	9469	43088	31354
Atchafalaya Bay/Vermillion Bay	1721410	0[B]	75	9999[10]	90861	7757	60738	22366
Terrebonne/Timbalier Bays	522374	0[B]	544	9999[10]	117994	65453	36496	16044
Barataria Bay	565163	0[B]	1[A]	9999[10]	102554	40272	39243	23040
Chandeleur Sound	644365	6502	0[A]	9999[10]	122959	48844	71610	1341
Lake Borgne	553080	0[B]	3	99[10]	23912	5233	10580	3079
Lake Pontchartrain	1473774	0[B]	1[A]	9[10]	18680	0	11480	7200
West Mississippi Sound	558286	191	1[A]	9999[8]	11780	2861	120	0
East Mississippi Sound	535258	555	1[A]	999[8]	14889	1[A]	1[A]	1[A]
Mobile Bay	481620	0[B]	5555	521	6655	1[A]	1[A]	1[A]
Perdido Bay	304911	124	1	0[A]	791	1[A]	791	1[A]
Pensacola Bay	612996	1655	143[p]	99[9]	2953	1[A]	678	1[A]
Choctawhatchee Bay	601201	1725	1	99[9]	1173	1[A]	1169	1[A]
St. Andrew Bay	297693	3979	1	99[9]	3753	1[A]	3745	1[A]
St. Joseph Bay	29937	3914	0[A]	0	517	1[A]	517	1[A]
Apalachicola Bay	418224	1765	1100	5033	2379	1[A]	2368	1[A]
St. George Sound	94916	4084	0[A]	2	212	1[A]	126	1[A]
Apalachee Bay (north)	1368658	67265	1[B]	262	18851	1[A]	9639	77
Suwannee Sound	897669	21952	1[B]	145	13388	1[A]	0	1[A]
Apalachee Bay (south)	1399485	162254	1[B]	50	26129	1[A]	0	1[A]

Appendix IIb continued

Salt Marsh Unk. Salinity	Intertidal Shrub/forest	Sponge/Coral (hard bottom)[D]	Tidal Flat	Beaches & Bars	Tidal Fresh Marsh	Serpulid worm reef	Bay
0	87253[3,C]	0	50887[2]	1	0[B]	0	Laguna Madre de Tamaulipas
6012	126	0	82062[2]	1	0[A]	0	Lower Laguna Madre
185	0	0	183	1	3	1601[2]	Baffin Bay
1454	7	0	11409[2]	1	10	0	Upper Laguna Madre
4384	48	0	0[A]	2713	9	0	Corpus Christi Bay
13398	38	0	0[A]	4435	68	0	Aransas Bay
13035	46	0	0[A]	2554	109	0	San Antonio Bay
24934	30	0	0[A]	3928	1214	0	Matagorda Bay
13453	40	0	0[A]	621	64	0	Brazos River
33675	100	0	0[A]	1862	2278	0	Galveston Bay
18871	171	0	0[A]	448	3038	0	Sabine Lake
127	275	0	0[A]	940	4168	0	Calcasieu Lake
0	162	0	0[A]	376	60	0	Grand & White Lake
0	535	0	0[A]	946	69443	0	Atchafalaya Bay/Vermillion Bay
0	2404	0	0[A]	1728	30670	0	Terrebonne/Timbalier Bays
0	700	0	0[A]	514	8338	0	Barataria Bay
1164	280	0	0[A]	3148	418	0	Chandeleur Sound
5019	19	0	0[A]	130	2663	0	Lake Borgne
0	90	0	0[A]	78	3263	0	Lake Pontchartrain
8798	260	0	0[A]	705	145	0	West Mississippi Sound
14889	77	0	0[A]	231	155	0	East Mississippi Sound
6655	620	0	0[A]	1160	157	0	Mobile Bay
0	394	0	434	89	104	0	Perdido Bay
2275	238	0	1830	7	1	0	Pensacola Bay
3	167	0	1840	0[A]	0[A]	0	Choctawhatchee Bay
9	19	0	246	0[A]	0[A]	0	St. Andrew Bay
0	9	0	355	0[A]	0[A]	0	St. Joseph Bay
11	48	0	391	0[A]	5400	0	Apalachicola Bay
86	50	0	63	0[A]	341	0	St. George Sound
9135	1196	338461 [5]	2159	599	103	0	Apalachee Bay (north)
13388	649		1[A]	1037	114	0	Suwannee Sound
26129	4841		1[A]	2993	1646	0	Apalachee Bay (south)

Appendix IIb continued

Sources:

Areas, except as noted, are taken directly from TNC Coastal Waters Program northern Gulf of Mexico GIS (multiple data sources)

Seagrass-- NWRC, Texas Parks and Wildlife (TPWD)
Oyster--NWRC, NWI, Florida Marine Research Institute (FMRI), Northwest Florida Water Management District (NWFWMD)
Freshwater Rooted Vascular-- NWI, NWRC
Saltmarsh, Tidal Fresh Marsh, Intertidal Shrub Forest, Tidal Flats, Beaches and Bars-- NWRC, NWI, NWFWMD

(1) The estuarine area includes the terrestrial areas of the coastal watershed as defined by NOAA (e.g., NOAA 1997b). The area for Laguna Madre de Tamaulipas includes only the area of open water; it does not include portions of the watershed.
(2) Tunnell and Judd (in press)
(3) Quammen and Onuf (1993) 24654 hectares- Onuf (in press) 820 hectares.
(4) From Tatum et al. (1995)
(5) From Continental Shelf Associates (1985)
(6) Ward et al. (1980)
(7) Based on Patillo et al. (1997)
(8) Order of magnitude estimates based on fisheries intake between AL and MS (NMFS), known area of oyster in AL (2), known areas of production in AL and MS (Berrigan et al. 1991)
(9) Order of magnitude estimates based on fisheries intake (NMFS), oyster acreages in FL (2), known areas of production in FL (Berrigan et al. 1991)
(10) Order of magnitude estimates based on fisheries intake (NMFS) and known areas of production in FL (Berrigan et al. 1991)

Notes:

(A) Spatial data shows habitat not present.1= habitat presumed present; 0 = habitat presumed absent; (blank)= presence/absence unknown
(B) No spatial data available. 1= habitat presumed present; 0 = habitat presumed absent; (blank)= presence/absence unknown
(C) Classified as upland halophyte
(D) Sponges and corals exist as a habitat only in the Florida Big Bend region of the northern Gulf of Mexico. Sponges and corals exist in many other gulf bays/estuaries, but not as habitats
(p) Partial data available.

1=presumed present; 0= presumed absent; (blank) = unknown

Appendix III. Brief Descriptions of Habitat and Species Targets

A. Primary Habitat targets

1. Seagrasses. Seagrasses provide a vital link in the maintenance of species diversity and secondary production throughout the Gulf of Mexico. Seagrasses are critically important because they provide food and refuge for many species, help to remove suspended sediments from the water column, add oxygen to the water and sediments, and may serve as nursery areas for juveniles of many species that migrate to the open Gulf as adults.

Seagrasses in the northern Gulf of Mexico were subdivided into two major groups based on their height and structural complexity: 1) *Halophila* spp. and 2) *Thalassia testudinum, Halodule wrightii* and *Syringodium filiforme*. The latter species grow to 1m in height and are more structurally complex than the former species, which grow to ~ 10 cm. It is possible that the larger seagrasses could be further subdivided by species if future work indicates that the communities contained within these grasses differ significantly. Seagrasses are sensitive to any factor that changes light availability, particularly nutrient enrichment, eutrophication, and sedimentation. Scarring from recreational boat propellers and trawl nets also impacts them.

2. Tidal Freshwater Grasses. When the salinity of estuarine waters is consistently 10 ppt or less, seagrasses cannot survive and where light levels are sufficient, beds of tidal freshwater grasses are common. *Ruppia maritima* and *Vallisneria americana* are the most abundant species in this habitat, but it is possible to find 12-15 or more species of submerged aquatic vegetation in some areas. Despite their abundance and importance, these habitats have been understudied in part because they can be difficult to access and because they are more ephemeral than seagrass habitats. These habitats are at substantial risk from nutrification, incompatible development, and altered hydrology. These habitats have also been greatly impacted by invasive species, particularly Eurasian milfoil, *Myriophyllum spicatum*. In some places, these invasive species comprise more than 50% of the vegetation.

3. Oyster reefs. Oysters are a critical species in the northern Gulf of Mexico. Oysters provide food and refuge for many animals. In addition, they are vital regulators of water quality and clarity because they filter substantial quantities of water. The northern Gulf of Mexico provides more than half of the oysters harvested in the nation (NOAA 1997a).

Oysters can serve as good indicators of human impacts on estuarine environments, because their biology is well known and the factors that strongly impact their distribution and abundance can be clearly identified. Oysters respond most strongly to factors that change salinity. Oysters also provide a handy measure of water quality, because they filter large quantities of water and bioaccumulate contaminants and pollutants.

4. Marshes. Coastal salt, brackish, and tidal fresh marshes are extremely important to the productivity of coastal waters throughout the US and elsewhere. They are particularly abundant in the northern Gulf of Mexico and may support much of the fisheries production in this region. They also stabilize shorelines and provide structure to shelter many small fishes and invertebrates. The marshes in this region were separated by salinity into polyhaline saltmarsh, mesohaline saltmarsh, oligohaline saltmarsh, and tidal fresh marsh.

5. Sponge & soft corals. In areas where hard surfaces are exposed, sponges and soft corals can attach to the bottom forming a structurally diverse and species-rich habitat. Large loggerhead sponges and sea fans are common in this habitat. This habitat is abundant in the nearshore waters of Apalachee Bay. In this area the underlying limestone (ancient reef) substrate is commonly exposed and these habitats are often intermixed with seagrasses in this region.

Little is known about the distribution or dynamics of these habitats because they occur in fairly remote areas and are logistically difficult to study. This habitat may, however, contain a great diversity of species, maybe even more than any other habitat in the northern Gulf of Mexico. These areas merit much further study.

6. Tidal Flats. Tidal flats are sandy and muddy habitats that are periodically exposed by tides and winds. These habitats have little emergent structures, but the algae and burrowing infauna on these flats can be diverse and abundant. The periodic exposure of these flats makes them an important point for the transfer of marine resources to terrestrial species. Birds, for example, can commonly be found foraging on these flats. This habitat is most abundant in the lagoons of the Laguna Madre, where strong winds help to expose large tidal flats just behind the barrier islands.

These habitats are threatened in large part, because they occur in shallow waters often right on coastal margins. Erosion of coastal habitats (e.g. dunes), coastal development, and channel dredging all affect these habitats in many bays and estuaries. Heavy metals, often from recreational boats, can accumulate in the fine sediments on these flats and may be transferred into marine and terrestrial food webs.

7. Intertidal Scrub/Forest. The intertidal scrub/forest is a NWI category that includes a mix of species and multiple community types. In saltier environments, this category includes mangroves and marsh elders. Mangroves are near the end of their range within this ecoregion, and mangrove trees are generally interspersed with salt marsh species. There are few if any true mangrove forests. The NWI makes finer divisions within this category, but they did not appear to be mapped reliably. In the future it would be best at least to separate the communities by salinity.

B. Species Targets

There are some species for which preserving habitat is not enough in the northern Gulf of Mexico. The biology and ecology is well known for some of these species (e.g., manatees), but much less so for other species (e.g., pipefishes and seahorses).

1. Fringed pipefish, *Anarchopterus criniger*. Fringed pipefish have been found in the Bahamas, North Carolina, southeastern Florida and northeastern Gulf of Mexico. They are reported to occur almost exclusively in seagrass beds in water less than 5 m in depth with salinities ranging from 19.2-52 ppt (Poss 1998). They also can be associated with the alga *Sargassum* (McEachran and Fechhelm 1998).

Fringed pipefish are extremely rare in the Gulf of Mexico. They are more likely to be found in the northeastern and eastern Gulf than the northern Gulf and have been observed in seagrass beds behind the Chandeleur Islands (Hoese and Moore 1998). They are not known west of the Mississippi River (Hoese and Moore 1998) and may be extirpated from the Mississippi Sound (Poss 1998).

2. Opossum pipefish, *Microphis brachyurus lineatus*. Opossum pipefish range from New Jersey to Brazil (Poss 1998). Adults usually are collected inshore in shallow water (0.2-3 m) across a wide range of salinities (0.03-35 ppt). They occur in a variety of habitats and can be found in *Sargassum* in the Bahamas and west Florida and *Spartina* marshes in Mississippi (Hoese and Moore 1998). They breed in marine and freshwater habitats. Reproduction of the Florida population appears to occur entirely in freshwater. Gilbert (1992) report maturation and breeding in freshwater habitats with dense emergent vegetation, most notably species of *Panicum* and *Polygonum*. Young subsequently move into offshore waters where they remain for indeterminate periods of time (Poss 1998). Juveniles can be found in pelagic rafts of *Sargassum* as well as in estuarine waters.

Adults appear to breed only in fresh (possibly brackish) water, so these microhabitats are critical to the reproductive success of the species. In Biloxi Bay, they may breed nearshore, in fresh or brackish waters, but specimens have not been taken recently. Their distribution in coastal rivers is patchy and limited by the occurrence and abundance of clumps of emergent vegetation (e.g., *Polygonum* and *Panicum* spp.). They are threatened by river modifications and loss of vegetation as well as nutrification and pollution of coastal habitats. Buffer areas should be established to prevent loss and degradation of habitat. They are also threatened in part by seasonal applications of herbicides to bank vegetation where they live and breed (Poss 1998).

2. Texas Pipefish, *Syngnathus affinis*. Texas pipefish, which occur in relatively shallow inshore waters, are very rare. Twenty one of 26 known specimens were taken in 1976 in Corpus Christi Bay at Fish Pass, but it has not been reported since. There are older records from Prien Lake in 1932 and Grande Island, LA, in 1953 (Poss 1998). If *S. affinis* is still extant, it should be listed as federally endangered or threatened. Stresses may include reduction in water clarity and physical damage to seagrass beds. This species may also have been affected by anoxic conditions in Grande Isle and Prien Lake (Poss 1998). *S. affinis* produces a limited number of eggs, which are probably not widely dispersed.

3. Dwarf seahorse, *Hippocampus zosterae*. Dwarf seahorse are found in Bermuda, the Bahamas, northeast Florida, and the entire Gulf of Mexico (Hoese and Moore 1998). In the Gulf, specimens have been collected from Campeche, Mexico to the tip of peninsular Florida and eastward to south of Vero Beach. Early reports suggested that *H. zosterae* was common in Corpus Christi Bay. Currently there are few records from eastern Texas and western Louisiana, but this could be due to low sampling (Poss 1998).

H. zosterae appear to be limited to high salinity seagrass flats and inshore drifting vegetation (Hoese and Moore 1998). At Cedar Key, FL, they were found in vegetation in spring, summer, and fall. In the winter, when seagrasses were exposed during low tides, *H. zosterae* tended to concentrate in deeper water and in tide pools where vegetation was most abundant (Strawn 1958). Several specimens were picked up during routine sampling in October 1999 near Shamrock Island, Corpus Christi Bay (pers. comm., C. Porter, TNC).

H. zosterae appears to be threatened in part by the loss of seagrass habitats and some direct collections. Mississippi Sound populations have declined in conjunction with loss of seagrass beds (Poss 1998).

4. Diamondback Terrapin, *Malaclemys terrapin (subspp.—macrospilota, pileata, littoralis)*
The diamondback terrapin is found in coastal salt marshes, estuaries and tidal creeks (Ernst et al. 1994). *M. terrapin* is a highly aquatic species seen out of water for an extended period of time only when nesting. *M. terrapin* is active during the day and feeds on small marine invertebrates, particularly mollusks. It appears to spend the night buried in muds. Terrapins form large breeding aggregations of as many as 75-250 individuals in the spring. Females lay their eggs in dry sand cavities above the high tide line from April-July. Terrapins are edible, and this characteristic contributed to their decline in the past. In the 1920's populations near metropolitan centers were heavily harvested to make terrapin stew (Ernst et al. 1994). *Malaclemys terrapin macrospilota*, the ornate diamondback terrapin ranges from Florida Bay to the Florida panhandle. *Malaclemys terrapin pileata*, the Mississippi diamondback terrapin, ranges from the Florida panhandle to western Louisiana. *Malaclemys terrapin littoralis*, the Texas diamondback terrapin ranges from western Louisiana to western Texas (Ernst et al. 1994).

5. Gulf Sturgeon, *Acipenser oxyrinchus desotoi*. Historically this species ranged from the Rio Grande, TX to Florida Bay, but it is primarily a northern Gulf endemic. It is an anadromous species that spends most of the year in rivers, but migrates out into the Gulf to feed in the winter. Estuarine seagrass beds with mud and sand appear to be important wintering habitats where most feeding occurs (Mason and Clugston 1993). It appears that for the 8-9 months that they are in rivers, the sturgeon feed little if at all.

Gulf sturgeon appear to exhibit a high degree of river fidelity. There appear to be as many as five different stocks of gulf sturgeon: (1) Lake Pontchartrain/Pearl River, (2) Pascagoula River, (3) Escambia and Yellow Rivers, (4) Choctawhatchee River, and (5) Apalachicola, Ochlocknee, and Suwannee Rivers.

6. Florida manatee, *Trichechus manatus latirostris.* The Florida manatee is found throughout Florida's rivers, estuaries, and bays, and a few range as far west as Louisiana and as far north as Virginia. Manatees were once found principally in south Florida, where water temperatures rarely dropped below the critical level for manatees (~55^{o} F). Over the past 30 years, however, the construction of power plants and other industrial facilities that have warm-water discharges has enabled manatees to survive the winter as far north as Jacksonville. About 24 warm-water sources—six of them natural springs—now host winter aggregations of manatees. Natural warm-water refuges include springs forming the Homosassa and Crystal rivers in southern Apalachee Bay. Manatees are herbivores and they typically eat marine and freshwater plants.

The population of manatees was estimated at 2,600 individuals in 1996. Generally, most mortality of manatees is caused by direct interactions with boats, and manatees are now principally identified by propeller scars on their backs. They can become tangled in crab traps and fishing gear or crushed in floodgates. Manatee mortality has been documented since 1974, and each year the number of manatee deaths has exceeded 10 percent of the estimated total population. The population, however, does appear to be growing slightly. Manatees are protected under the Endangered Species Act, Marine Mammal Protection Act, and the Florida Manatee Sanctuary Act.

7. Kemp's ridley turtle, *Lepidochelys kempii* (Garman). The Kemp's ridley is critically endangered and some estimates suggest that it may be the twelfth most critically endangered vertebrate in the world (Landry and Costa 1999). The Kemp's ridley is a small turtle; adults weigh between 77 and 93 pounds and have a carapace length of 22 to 28 inches. Its diet consists primarily of invertebrates, mostly crabs, but it also includes shrimp, snails, sea urchins, sea stars, medusae, fish, and occasionally, marine plants. Landry and Costa (1999) suggest that a substantial portion of the population feeds on blue crabs in the muddy waters near passes on the upper Texas and western Louisiana coasts.

Adults are restricted to the Gulf of Mexico, but immatures have been observed along the Atlantic coast as far north as Massachusetts. The majority of the population nests on approximately 14.9 miles of beach between Barra del Tordo and Ostional in the state of Tamaulipas, Mexico. Nesting occurs from April to June. The breeding population was estimated to have been about 40,000 individuals in 1947, but no more than 500 females arrived to nest at Rancho Nuevo in 1988. The total population is estimated at 1,500 to 3,000. The major threat is drowning when inadvertently caught in shrimp nets (USFWS 1991).

The Kemp's ridley is protected under the Endangered Species Act. The Mexican government prohibits harvesting and is working to increase the population through more intensive law enforcement, the fencing of nest areas to diminish natural predation, and artificial incubation to assure maximum survival of hatchlings. In 1978 some eggs from nests at Rancho Nuevo were moved to Padre Island, TX and turtles were released after hatching in an attempt to establish a second nesting colony. The imprinted hatchlings are now returning to Padre Island.

Kemp's ridley was included as a target in the northern Gulf of Mexico ecoregion, because it is the most endemic of the sea turtles to the Gulf of Mexico and is critically endangered. In addition, beaches in the northern Gulf of Mexico ecoregion and particularly those just outside of the ecoregion are the most important nesting grounds for this species.

Appendix IV: Some Sources of Data

Agency/Program	Data Type	Source
National Wetland Inventory	Seagrass, Wetland Vegetation, Oyster	www.nwi.fws.gov
National Wetland Research Center	Seagrass, Wetland Vegetation, Oyster	www.nwrc.usgs.gov/sdms
NOAA Special Projects Office	Salinity, Shoreline, State Boundary,	spo.nos.noaa.gov
NOAA	Water Quality (Category 1A)	CD-ROM
EPA EMAP Project (1991-94)	Biodiversity (Benthic, Fish, Invertebrate)	www.epa.gov/emap/
Texas General Land Office	Biodiversity (trawl data), Parks Seagrass, Oyster, Upland Vegetation Type, Marina, Hard Reef, Channels, Coastal Preserves, Audubon Sanctuaries, Rookery, National Parks	www.glo.state.tx.us/nri/ www.glo.state.tx.us/wetnet/
NOAA National Shellfish Register	Water Quality for Shellfish Growing Water Bay, Estuary, and Other Water Bodies	CD-ROM
Florida Marine Research Institute	Seagrass, Mollusc, Seagrass Bed Scars	FMRI ftp site
ESRI Data and Maps	Parks, State & County bndy, City Names	CD-ROM
The Nature Conservancy	Eco-regions, Parks, Preserves, Natural bndy (Watershed, Estuaries, etc.)	TNC SE Regional Science Center TX Conservation Data Center
Florida Dept. of Envirn. Protection	Manatee Distribution and Abundance	CD-ROM
Northwest FL Water Management District	Apalachicola Bay Habitat (Oyster, Seagrass, Saltmarsh), Tidal soils, Panhandle and Big Bend Seagrass, Saltmarsh, Wetland	CD-ROM
LA Dept. of Natural Resources	LA Coastal Wetlands Vegetation Types	LA DNR

Appendix V: Results of Sites v1.0: mathematical algorithm to determine strawman priority sites

Western Gulf-- Laguna Madre de Tamaulipas to Brazos River

Algorithm=	Simulated Annealing
Results=	Laguna Madre de Tamaulipas
	Lower Laguna Madre
	Baffin Bay
	Upper Laguna Madre
	Corpus Christi Bay
	Matagorda Bay

Central Gulf-- Galveston Bay to Mobile Bay

Algorithm=	Simulated Annealing	
Results=	Mobile Bay	
	West Mississippi Sound	
	Chandeleur Sound	
	& one of either	*with one of either*
	Atchafalaya/Vermillion Bay	Grand &White Lake
	Terrebonne/Timbalier Bays	Galveston Bay

Eastern Gulf-- Perdido Bay to Anclote Keys

Algorithm=	Simulated Annealing		
Results=	Apalachee Bay (south)	Apalachee Bay (south)	Apalachee Bay (south)
	Apalachicola Bay	Apalachicola Bay	Apalachicola Bay
	Choctawhatchee Bay	Apalachee Bay (north)	Pensacola Bay

Appendix VI- Goals Met for Targets in Each Subregion[1].									
a. Habitats (with sub categories)	**20% goal met for target**			**% of known distribution**					
				High priority sites			**Priority sites**		
	West	**Central**	**East**	**West**	**Central**	**East**	**West**	**Central**	**East**
Primary habitat targets									
Seagrass	Y	Y	Y	42%	0%	35%	98%	98%	49%
High Relief (10-70 cm tall)	Y	Y	Y	U	U	U	U	U	U
Low Relief (< 10 cm tall)	Y[2]	U	Y[2]	U	U	U	U	U	U
Tidal Freshwater Grasses	Y	Y	Y	<1%	66%	88%	41%	67%	98%
Oyster reefs	Y	Y[2]	Y	U	U	91%	>20%	>20%	96%
Salt marsh	Y	Y	Y	3%	16%	35%	67%	30%	66%
Polyhaline Saltmarsh	U	Y	U	U	19%	U	U	26%	U
Mesohaline Saltmarsh	U	Y	Y	U	14%	U	U	26%	U
Oligohaline Saltmarsh	U	Y	U	U	19%	U	U	40%	U
Sponge & soft corals	n/a	n/a	Y[2]	n/a	n/a	>20%	n/a	n/a	>20%
Tidal Flats	Y	Y	Y	19%	U	10%	81%	U	54%
Tidal Fresh Marsh	Y[2]	Y	Y	1%	9%	89%	64%	53%	91%
Intertidal Scrub/Forest	Y	Y	Y	U	20%	58%	>20%	31%	69%
Secondary habitat targets									
Muddy-bottom Habitats	Y[2]	Y[2]	Y[2]	U	U	U	U	U	U
Coquina Beach Rock	Y	n/a	n/a	U	U	U	U	U	U
Beaches & Bars	Y	Y	Y	8%	10%	19%	60%	33%	26%
Intertidal/subtidal beaches & bars	Y	Y	Y	U	U	U	U	U	U
Serpulid Worm Reefs	Y	n/a	n/a	U	n/a	n/a	64%	n/a	n/a
b. Imperiled Species									
Fringed pipefish	n/a	Y	Y						
Gulf Sturgeon	n/a	Y	Y						
Diamondback Terrapin	Y	Y	U						
Dwarf seahorse	Y	Y	Y						
Opossum pipefish	Y	Y	n/a						
Texas pipefish	Y	n/a	n/a						
Florida manatee	n/a	n/a	Y						
Kemp's ridley Turtle	Y	U	Y						

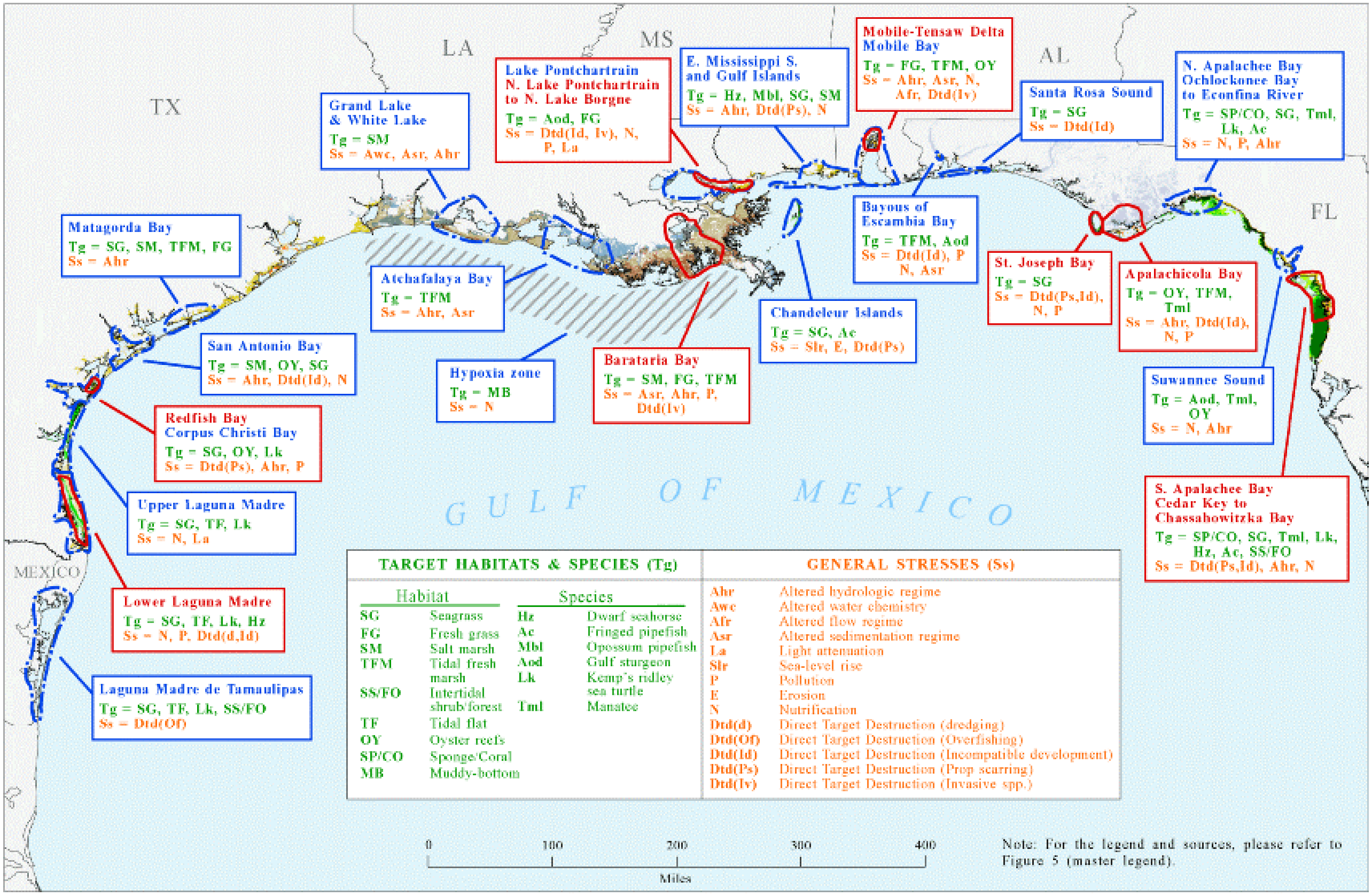
[1] Y= Yes, N= No, U= Unknown, n/a = not applicable

[2] Goal presumed to be met. Little spatial data available.

Priority Sites of the Northern Gulf of Mexico Ecoregion

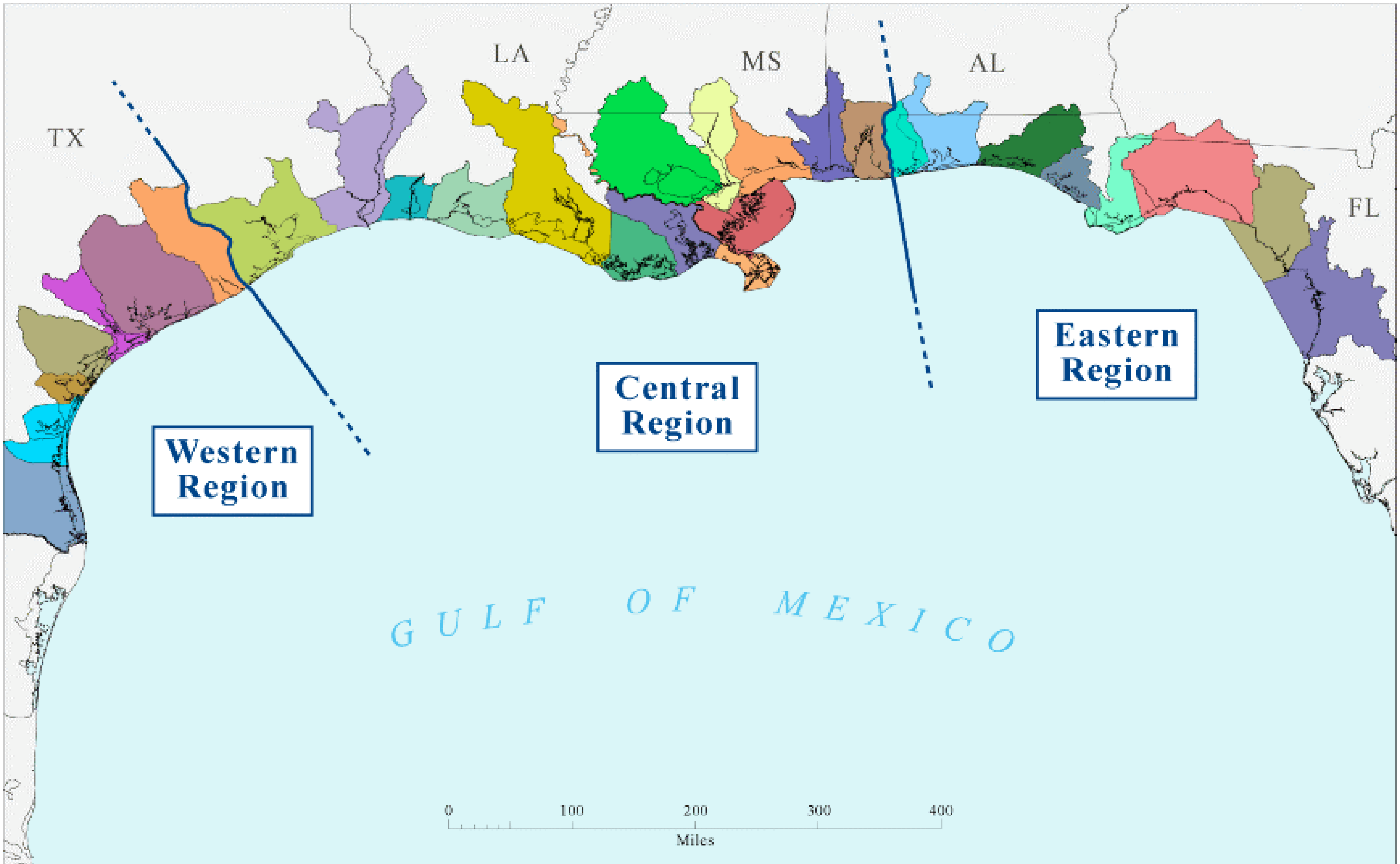
Principal Targets and Stresses at Priority Sites

The Nature Conservancy
Coastal Waters Program

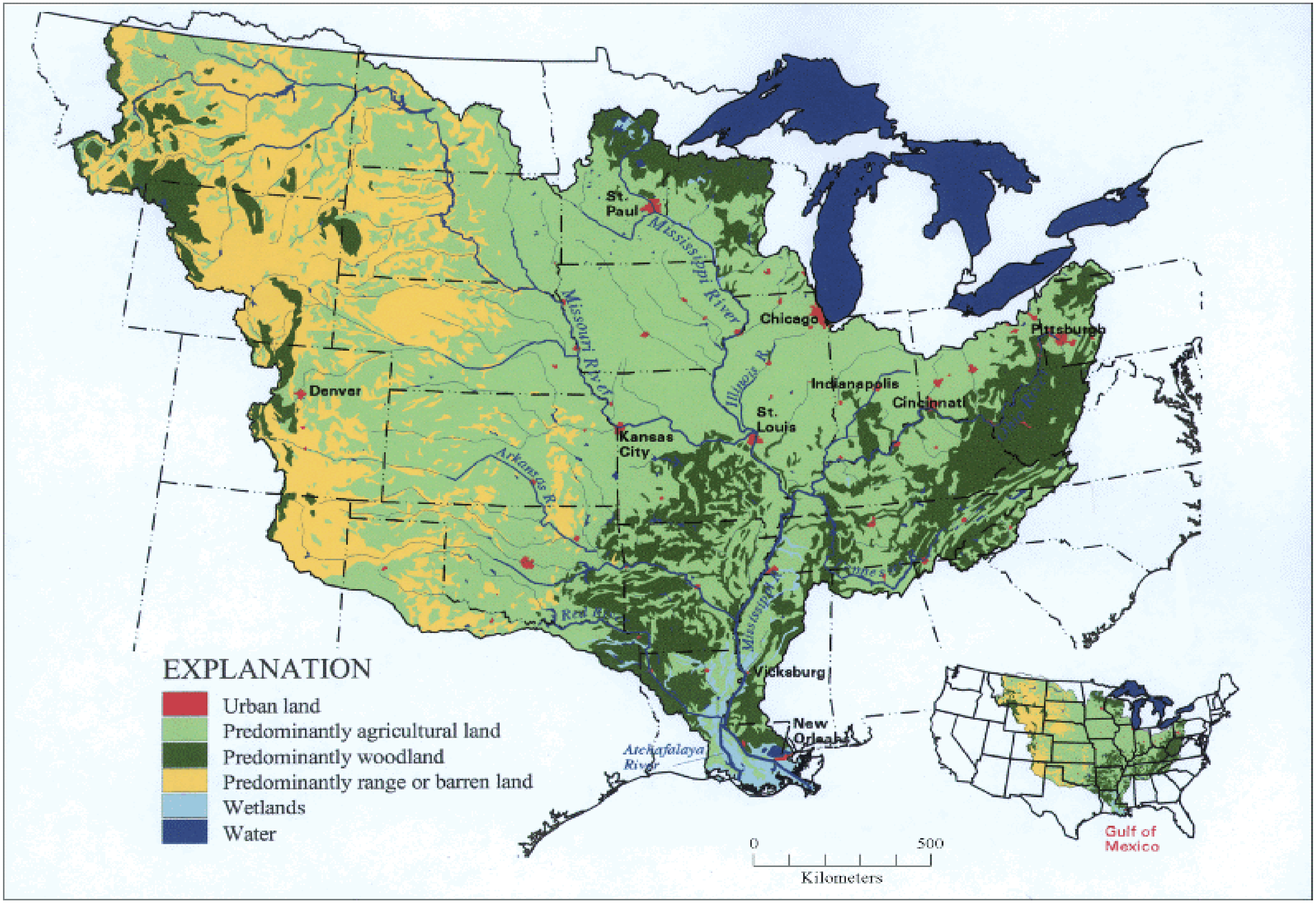


Bays and Estuaries of the Northern Gulf of Mexico
(Based on NOAA Coastal Watersheds)

The Nature Conservancy
Coastal Waters Program



Mississippi River Watershed



MASTER LEGEND FOR GULF OF MEXICO MAP SERIES

The Nature Conservancy
Coastal Waters Program

HABITAT

Seagrass:

Species:
Laguna Madre, Baffin Bay & Matagorda Bay, TX[8, 10, 11]

- *Halophila engelmanni* (clover grass)
- *Halodule wrightii* (shoal grass)
- *Thalassia testudinum* (turtle grass)
- *Syringodium filiforme* (manatee grass)

Density:
Corpus Christi Bay to Espiritu Santo Bay, TX[5, 10]

- Continuous (c, wc)
- Patchy (p, wp)
- Very patchy (pp)

Density:
Chandeleur Is., LA to Anclote Keys, FL[5, 6]

- Continuous (90% or more crown cover)
- Dense (75% - 85%)
- Moderate (45% - 70%)
- Sparse (15% - 40%)
- Very sparse (10% or less)

Fresh Grass:

Density:
Mobile Bay, AL[6]

- Dense (75% or more crown cover)
- Moderate (45% - 70%)
- Sparse (40% or less)

Rest of Gulf of Mexico[5, 6, 7]

- Unknown density

Salt Marsh:[5, 6, 7]

- Polyhaline
- Mesohaline
- Oligohaline
- Unknown salinity

Fresh Marsh:

- Tidal fresh marsh[5, 6, 7]

Perdido Bay to Apalachee Bay, FL[7]

- Fresh marsh

Oyster and Worm Reefs:

- Oyster reefs[1, 3, 5, 6, 7, 9, 10]

Baffin Bay, TX

- Worm reefs[9, 10]

Other Habitats:

- Intertidal shrub and forest[5, 6]
- Tidal flat[5, 6]

Laguna Madre, TX

- Tidal flat[5]

IMPERILED SPECIES

- Kemp's ridley sea turtle
  Strandings (Florida)[2, 3]
  Nesting sites (Texas, 1998)[12]
- Imperiled fish, recorded sightings[4]
  (Species noted with each sighting;
  exact locations unknown)
- Manatee[2, 3]
  Mortalities and sightings
  in synoptic survey

GENERAL

- Managed natural area[10, 11, 12]
- Zone of hypoxia[13]

Sources:
(1) Alabama Department of Conservation and Natural Resources, 1995
(2) Florida Fish and Wildlife Commission
(3) Florida Marine Research Institute
(4) Gulf Coast Research Lab, University of Southern Mississippi, Institute of Marine Sciences
(5) National Wetlands Inventory
(6) National Wetlands Research Center
(7) Northwest Florida Water Management District
(8) Onuf, C. P., *Bull. Mar. Sci. 58(2):404*
(9) Texas A&M University
(10) Texas Parks and Wildlife Department
(11) U.S. Fish and Wildlife Service
(12) U.S. Geological Survey
(13) Rabalais, et al. *Characterization of hypoxia*, 1999

Base map from NOAA

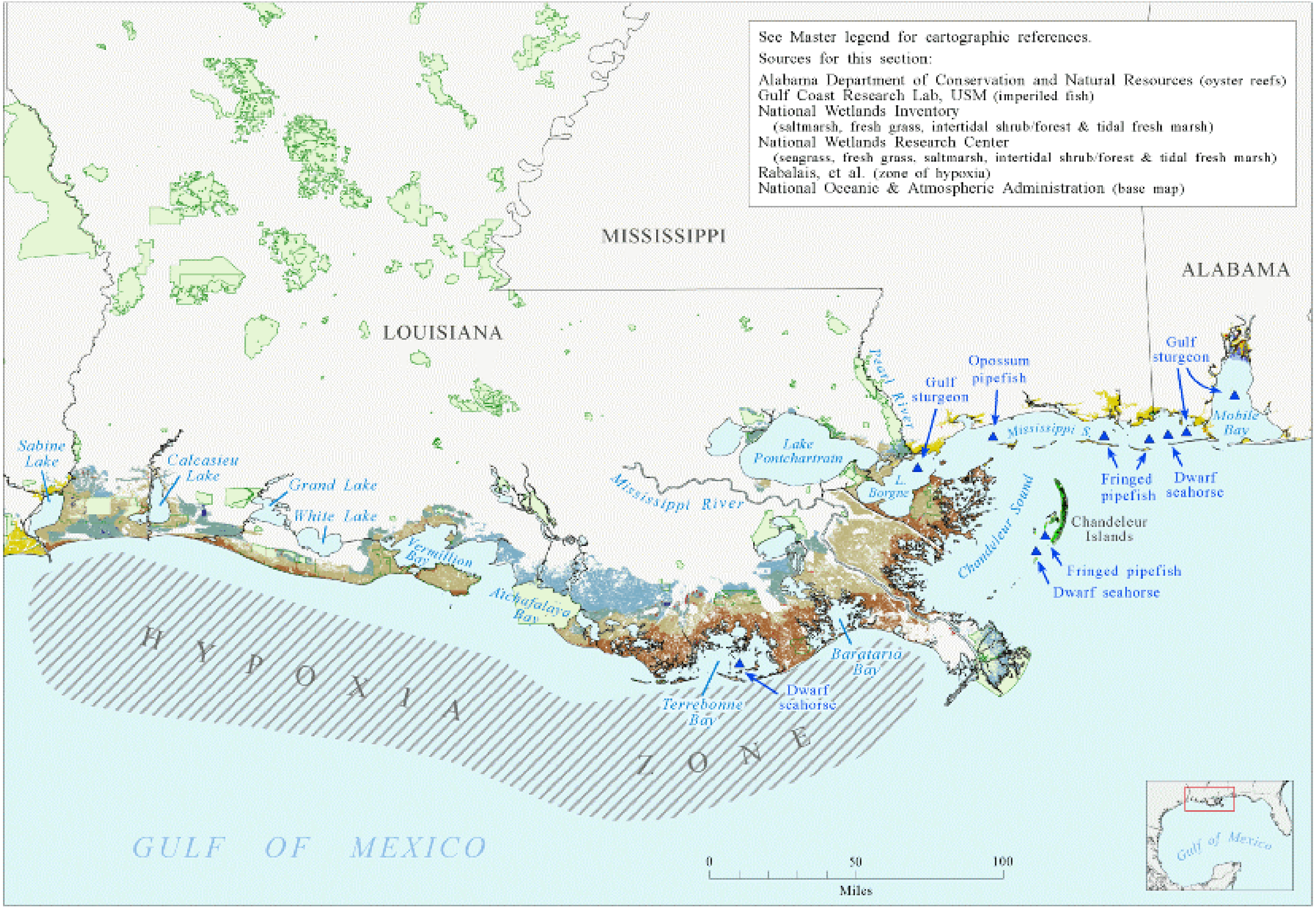
Habitats and Species, Western Region

Laguna Madre to Galveston Bay, Texas

The Nature Conservancy
Coastal Waters Program

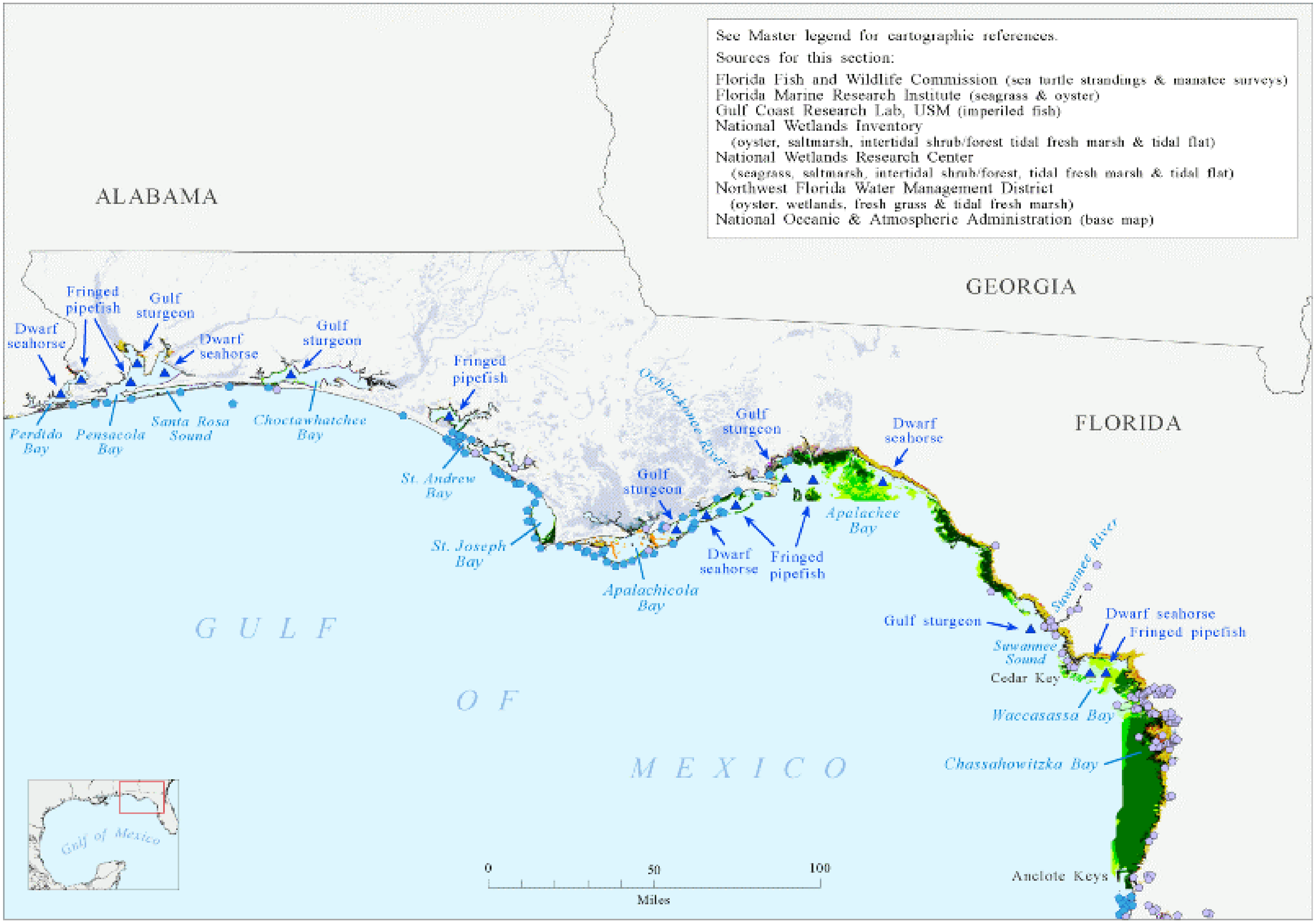
Habitats and Species, Central Region
Sabine Lake, Louisiana to Mobile Bay, Alabama

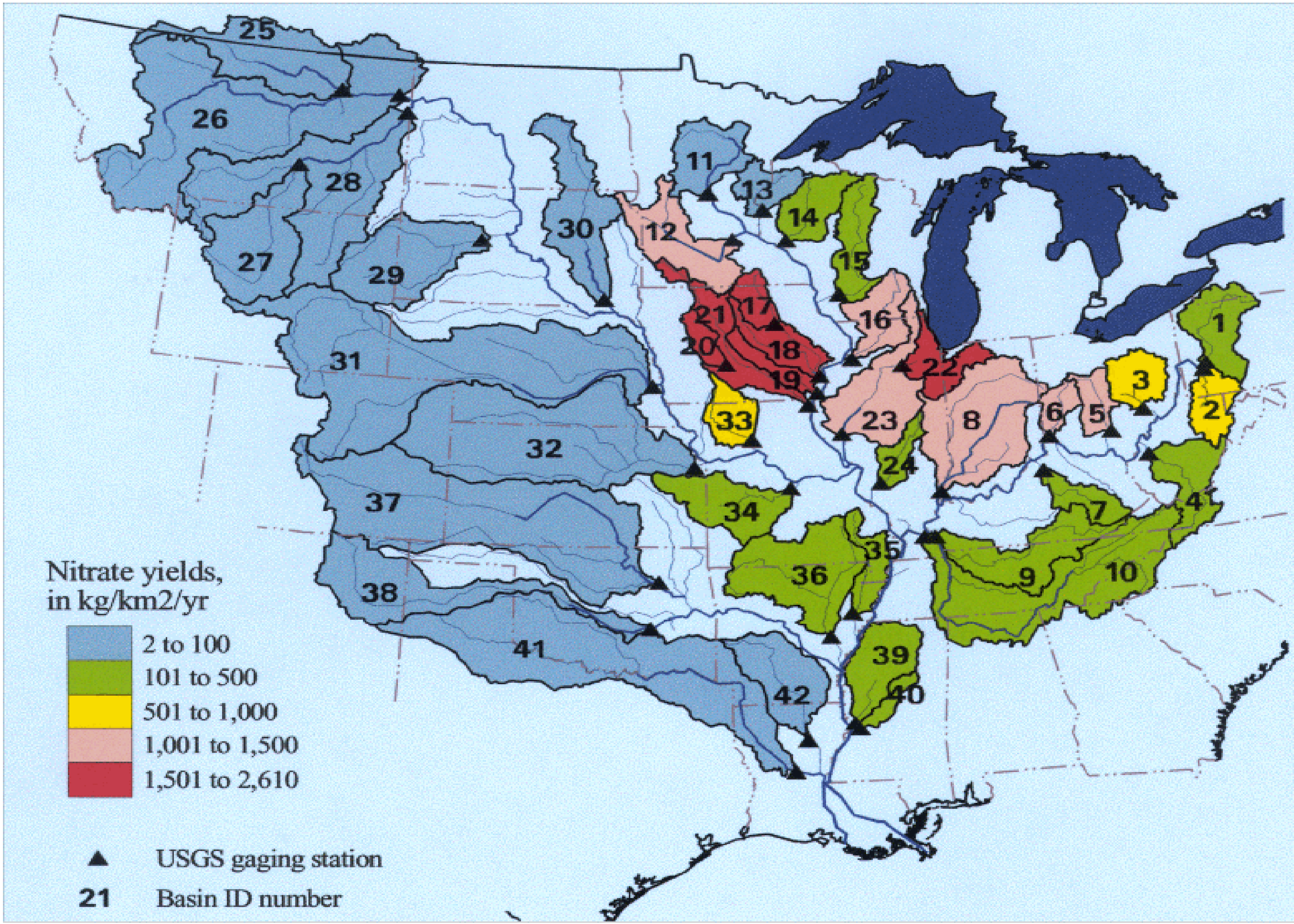
The Nature Conservancy
Coastal Waters Program



Habitats and Species, Eastern Region
Perdido Bay to Anclote Keys, Florida

The Nature Conservancy
Coastal Waters Program





Adapted from Goolsby (1999). Gulf of Mexico Hypoxia Assessment