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Scarring of Florida's Seagrasses:
Assessment and Management Options

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Cover Photograph

Northwest of Windley Key in the Florida Keys.
Photograph by Curtis R. Kruer, 1993.

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Scarring of Florida's Seagrasses: Assessment and Management Options

Executive Summary

Seagrasses are submerged, grass-like plants that inhabit the shallow coastal waters of Florida. Seagrasses are a vital component of Florida's coastal ecology and economy; they provide nutrition and shelter to animals important to marine fisheries, provide critical habitat for many other animals (e.g., wading birds, manatees, and sea turtles), and improve water quality.

Marine-habitat degradation in Florida is continuing at an alarming rate as the coastal residential population and the number of seasonal visitors increase. Habitat degradation has many sources (e.g., pollution, dredge and fill), but an increasingly common cause of habitat degradation is the scarring of seagrasses. In this report, scarring can refer to either the activity of scarring or to a group of scars in a seagrass bed. Seagrass beds can be scarred by many activities, but scars are most commonly made when a boat's propeller tears and cuts up roots, stems, and leaves of seagrasses, producing a long, narrow furrow devoid of seagrasses. Boats operating in shallow waters are severely scarring, and sometimes completely denuding, seagrass beds throughout the state.

The Florida Department of Environmental Protection recognized the need to reduce scarring of seagrasses by boats and committed resources to address this issue. As one component of this effort, the Florida Marine Research Institute (FMRI) investigated the distribution of scarred seagrass beds in the shallow marine waters of Florida's coastal counties. Aerial photography was used to locate seagrass scarring. Aerial surveys were then conducted in 1992–1993 to confirm the location of scarred seagrasses. We did not attempt to distinguish among the different specific causes of seagrass scarring. During aerial surveys, observations of scarred seagrasses were recorded on National Oceanic and Atmospheric Administration nautical charts and U.S. Geological Survey quadrangle maps.

Scarring intensity was categorized as *light, moderate,* or *severe.* Areas with substantial scarring recognizable on 1:24,000-scale photography were delineated on the maps with polygons, which were assigned a scarring intensity. Polygons categorized as *light* contained less than 5 percent scarring, those categorized as *moderate* contained 5–20 percent scarring, and those categorized as *severe* contained more than 20 percent scarring. The information acquired in this survey was incorporated into the FMRI's Marine Resources Geographic Information System (MRGIS), which produces maps and tabular products so that geographically based data can be effectively disseminated to resource managers, appropriate regional and county governments, and other interests (e.g., conservation groups and private citizens).

Scarred seagrasses were observed in all areas of the state, mostly in shallow coastal waters less than six feet deep. More than 173,000 acres of the state's 2.7 million acres of seagrasses were scarred—most of it lightly. This is a conservative estimate of scarring because we mapped groups of scars, not isolated, individual propeller scars. The total seagrass acreage in Florida (2.7 million acres) includes areas in the Florida Keys that have sparse seagrass and hardbottom with dense-seagrass patches. Excluding these areas, seagrasses totaled approximately 1.9 million acres. Also, these totals do not include sparse, deep *Halophila* beds that are offshore in the Big Bend region.

The greatest acreage of *moderate* and *severe* (M/S) scarring occurred in areas having denser human populations and more registered boats. The Florida Keys (Monroe and Dade counties), Tampa Bay (Hillsborough, Manatee, and Pinellas counties), Charlotte Harbor (Lee County), and the north Indian River Lagoon (Brevard and Volusia counties) had the greatest M/S scarring. Monroe County, which includes most of the Florida Keys, had the greatest acreage of M/S scarring of all counties in the survey. The Panhandle and Big Bend regions had little M/S-scarred acreage, but in the western Panhandle embayments, M/S scarring was prevalent in the few acres of seagrasses there. If an area has little seagrass acreage, then any scarring may have a critical effect on habitat functions.

All boating user-groups are responsible for scarring seagrasses. Although we did not attempt to identify each user-group's role in scarring, we believe general statements about the situations that lead to scarring are valid. The most severe single instances of scarring are caused by large commercial vessels, but most seagrass disruption results from widespread scarring by smaller boats. Our discussions with boaters, as well as our own personal experiences, suggest that scarring of seagrasses could result when one or more of the following situations occur:

- when boaters misjudge water depth and accidentally scar seagrass beds;
- when boaters who lack navigational charts or the skill to use them stray from poorly marked channels and accidentally scar seagrass beds;
- when boaters intentionally leave marked channels to take shortcuts through shallow seagrass beds, knowing that seagrass beds may be scarred;
- when boaters carelessly navigate in shallow seagrass beds because they believe scars heal quickly;
- when inexperienced boaters engage in recreational and commercial fishing over shallow seagrass flats, thinking that their boat's designed draft is not deep enough to scar seagrasses or that the design will prevent damage to their boat;
- when boaters overload their vessels, causing deeper drafts than the boaters realize;
- when boaters anchor over shallow seagrass beds, where their boats swing at anchor and scar seagrasses;
- when boaters intentionally prop-dredge to create a channel; and
- when inexperienced boaters, ignorant of what seagrasses are and the benefits they provide, accept as the behavioral norm local boating customs that disregard the environment.

Management programs that address scarring of seagrasses should be based on an approach that involves (1) education, (2) channel marking, (3) increased enforcement, and (4) limited-motoring zones. Aerial monitoring and photography of the managed area are essential in evaluating the effectiveness of a program. Management programs that use this multifaceted approach have been instituted by a few local governments and at several state parks. Initial results of the programs indicate that in some areas seagrass scarring has been reduced but that in other areas emphasis may need to be increased on one or more of the components of the four-point approach. A statewide management plan is needed to address the most egregious scarring over large areas that may be difficult to regulate at the local-government level.

Scarring of Florida's Seagrasses: Assessment and Management Options

Introduction

Seagrasses are completely submerged, grass-like plants that occur mostly in shallow marine and estuarine waters. Seagrasses form small, patchy beds if their seedlings have recently colonized bare sediments or if sediment movement or other disturbances disrupt typical growth patterns. Where disturbances are minimal and conditions promote rapid growth, large continuous beds—known as meadows—may develop when patchy seagrass beds coalesce. Seagrass meadows may require many decades to form. In shallower waters of good quality, seagrass meadows may be lush and have a high leaf density, but in deeper waters, they may be sparse, or species composition may shift to a less robust species.

The predominant seagrass species in Florida (Figure 1) are turtle-grass (*Thalassia testudinum* Banks ex Koenig), shoal-grass (*Halodule wrightii Aschers*.), and manatee-grass (*Syringodium filiforme* Kutz.). Other, less common, seagrasses—star-grass (*Halophila engelmannii* Aschers.), paddle-grass (*Halophila decipiens* Ost.), Johnson's seagrass (*Halophila johnsonii* Eisem.), and widgeon-grass (*Ruppia maritima* L.)—may be locally abundant. Near river mouths subject to salinity fluctuations, other submerged aquatic plant species (e.g., *Zannichellia* sp. and *Najas* spp.) may occupy an ecologic role similar to that of the true marine seagrasses. Nevertheless, these species are rarely considered part of the seagrass flora of Florida.

Turtle-grass is the largest of Florida's seagrass species, and Johnson's seagrass is the most diminutive. Johnson's seagrass was only recently recognized and named as a distinct species (Eiseman and McMillan 1980). Unlike the other species, which are widespread in Florida, Johnson's seagrass is limited to scattered locations in the lagoonal river systems of Florida's Atlantic coast. Because of its fragile nature, restricted distribution, and vulnerable status in the lagoonal systems (from development), Johnson's seagrass has been nominated for federal listing as a threatened species under the Endangered Species Act of 1973.

The wide distribution and robust nature of turtle-grass belie its susceptibility to stress. Turtle-grass's tolerances, in respect to some environmental factors, are less developed than are those of some of the other seagrass species. Shoal-grass and widgeon-grass, for instance, are much more tolerant of periodic exposure during extremely low tides and consequently can flourish in shallower water than turtle-grass can. Manatee-grass has wiry leaves—round in cross section—that are more tolerant of strong currents. Like turtle-grass, manatee-grass is less tolerant of exposure and is often found mixed with turtle-grass at depths that are rarely exposed at extremely low tides. Species of *Halophila* are generally more tolerant of lower light conditions and usually form sparse beds in deeper waters, especially in the Gulf of Mexico offshore of Florida's Big Bend region.

The numerous plants and animals that live and grow among seagrasses form a complex, fragile community. Marine and estuarine animals—especially larval and juvenile fish—benefit from seagrasses, which provide critical shelter and sustenance. Seagrasses form some of the most productive communities in the world (Zieman and Zieman 1989) and are aesthetically and economically valuable to humans. Seagrasses are a principal contributor to the marine food web and ultimately provide humankind with much of its seafood (Thayer et al. 1975). In addition, seagrasses improve water quality by stabilizing mobile sediments and by incorporating some pollutants into plant biomass and into the stabilized sediments.

As Florida's population increases, particularly in coastal counties, threats to seagrass communities increase (Livingston 1987). Seagrass losses in Florida have been documented to range from 30 percent in the Indian River Lagoon (Haddad and Harris 1985) to 81 percent in Tampa Bay (Lewis et al. 1985). The cumulative effects of anthropogenic threats (e.g., water pollution, docks, dredging and filling) are being addressed by various federal, state, and local resource management programs. One threat that is becoming more acute—as people increasingly use boats andother watercraft for recreation and work—is scarring of seagrasses. In

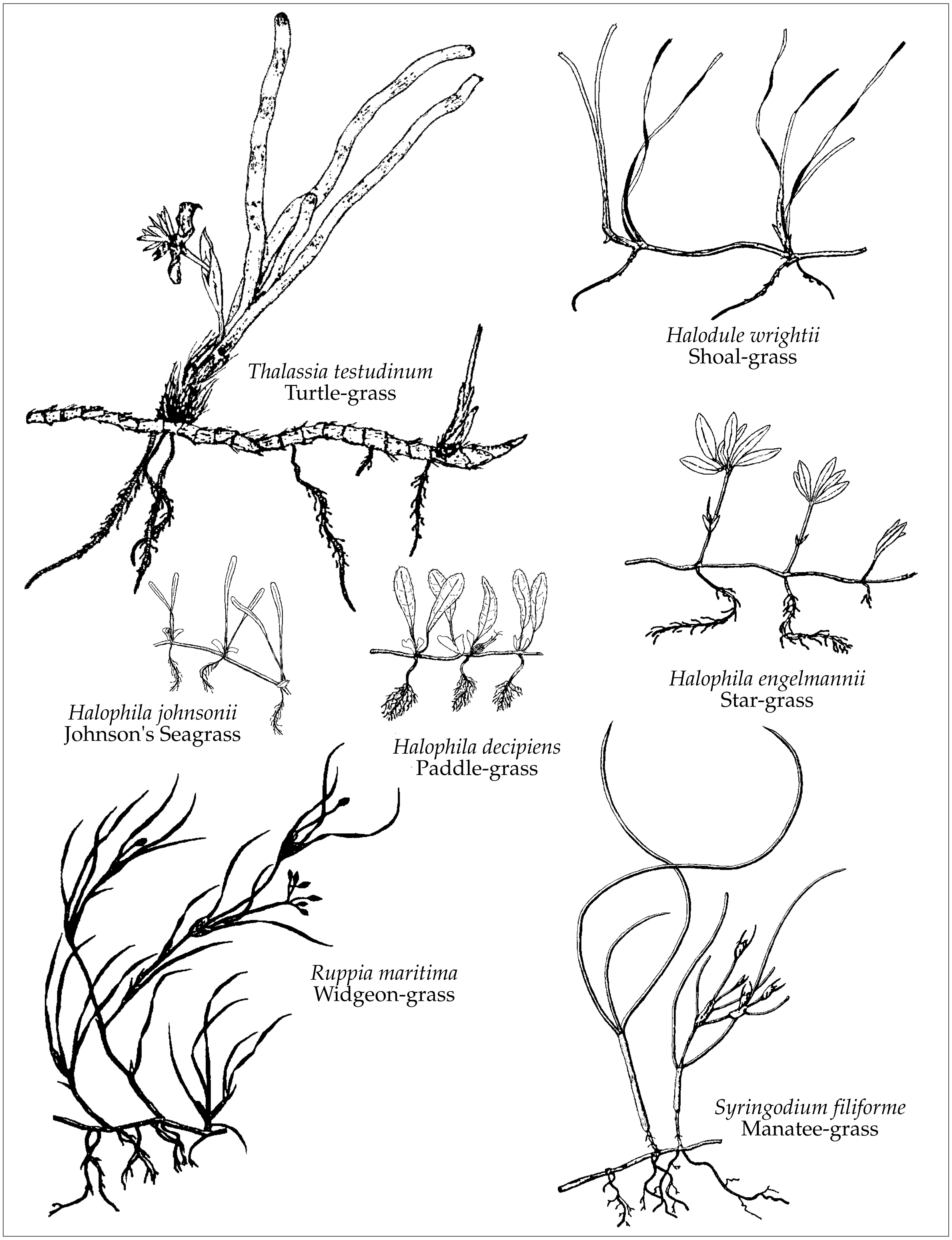

Figure 1. *Seagrass species occurring in the shallow coastal waters of Florida (based on drawings by Mark D. Moffler).*

this report, *scarring* can refer to either the activity of scarring or to a group of scars in a seagrass bed. Boat propellers scar seagrasses more often than do other sources.

Most scarring of seagrasses is caused by small-boat propellers; however, larger craft, which are usually confined to deeper waters, may have much larger individual effects when they run aground, especially near shipping channels and ports. Propeller scarring of seagrasses was commented on in the scientific literature as early as the late 1950s (Woodburn et al. 1957, Phillips 1960). Concern has occasionally been voiced since then (e.g., U.S. Dept. of the Interior 1973, Chmura and Ross 1978). Eleuterius (1987) noted that scarring in Louisiana seagrasses was common and in deeper water was caused by shrimp boats, which also ripped up the margins of the beds with their trawls. Shrimper-related scarring and seagrass damage were also recognized by Woodburn et al. (1957).

Usually, propeller scarring of seagrasses occurs when boaters motor through water that is shallower than the drafts of their boats. The propellers tear and cut up seagrass leaves, roots, stems, and sediments, creating unvegetated, light-colored, narrow furrows called *prop scars*. In some areas, watercraft have extensively scarred seagrass beds, which has alarmed environmentally concerned citizens (Wilderness Society et al. 1990). In the Florida Keys, for example, as waterfront and recreational development has increased since the 1970s, so has the number, size, and power of vessels in this region—resulting in widespread, and in some cases severe, scarring of shallow seagrass communities. Nearly all shallow seagrass beds in Florida show some degree of scarring. Portions of seagrass beds throughout the state have been completely denuded by repeated scarring (Figure 2).

The degree of scarring depends, among other things, on the interaction between water depth and the size, kind, and speed of the boat. Vessels with more than one motor can have a much greater single-event effect on seagrasses than do single-motored (and usually smaller) vessels. Several parallel tracks through a seagrass bed are a strong indicator that a multiple-motored vessel has probably passed that way. At lower tides, seagrass beds are more susceptible to scarring, even from a boat that would not scar them at higher tides. At high tide, a boat may navigate safely over seagrasses without scarring them, but at medium to low tide on the return trip, the same boat may scar them. A smaller boat operating at a slow speed or powering up may scar seagrass beds that would not be scarred after the boat reaches a plane.

A boater's attitude is another factor that may influence the degree of scarring. Sometimes boaters are aware of but unconcerned about seagrasses and therefore do not avoid scarring them; A conscientious boater who trims his motor may only scar seagrasses slightly when he inadvertently enters a bed. A more extreme form of scarring occurs when a boater intentionally uses the boat's propeller as a dredge to remove seagrasses and sediments to produce a channel so that the boater can have easier access to other areas. This is called *prop-dredging*, and in some areas, it has permanently prohibited seagrass recovery, especially if sediments were dredged to bare rock. Currently, prop-dredging is illegal (see U.S.A. and FDER v. M.C.C. of Florida and Michael's Construction Company, Case No. 81-2373-CIV-EBD, Southern District of Florida) but is difficult to enforce. Although everyday boating activities—which may repeatedly scar seagrasses over extensive areas—are more difficult to control because they are less overt, they may ultimately do greater harm to overall seagrass productivity than prop-dredging alone does.

Substantial scarring of shallow seagrass beds, which are critical feeding and sheltering areas for wading birds, juvenile finfish, and shellfish, results in a cumulative reduction of productive habitat. Extensive scarring may expose the beds to further disruption from storms and other natural erosional forces, thereby increasing the rate of cumulative loss. This can result in the resuspension of sediments in the water column, which may further contribute to habitat loss by inhibiting the growth of seagrasses. Location and species composition of seagrass beds are probably principal determinants of the kind of animal habitat lost to scarring; however, comprehensive data do not exist concerning animal distributions in most seagrass areas of Florida.

Figure 2. *Aerial view of seagrass-bed scarring at Lignumvitae Key in the Florida Keys.*

Seagrass Recovery

Seagrass scarring has received limited study since the 1970s (e.g., Godcharles 1971, Zieman 1976), and only recently, as scarring has increased, has research become more focused on scar recovery (e.g., Matthews et al. 1991, Durako et al. 1992). Research on many aspects of seagrass biology and ecology has contributed greatly to our ability to protect marine resources. This research has shown that each of Florida's seagrass species has structural and physiological differences that affect their growth characteristics, stress tolerances, and ecologic contributions. As with other elements of seagrass ecology, scar recovery differs for each of the seagrass species.

Seagrass species differ in their growth forms, particularly in the relationship between their rhizomes (underground stems) and leaves (Duarte et al. 1994). Some seagrass species' rhizomes are weakly differentiated for vertical growth, and these plants may be more vulnerable to burial by mobile sediments. Other species (especially turtle-grass) have more strongly developed vertical rhizomes (i.e., short-shoots) and so can withstand some sedimentation (Figure 3). Because of this differentiation, branching and lateral growth are usually slower in species with the latter morphology, and scar recovery is also likely to be slower. Zieman (1976) attributed slow recovery of scars in turtle-grass beds to unsuitable sediment quality, damaged rhizomes, and the naturally slow growth of rhizome tips. He suggested that shoal-grass recovers more quickly than turtle-grass does because shoal-grass has a shallower rhizome system and grows well from seed. Also, shoal-grass probably recovers faster because its rhizomes have a greater density of short-shoots and nodes—from which lateral branching occurs—than does turtle-grass (Durako et al. 1992).

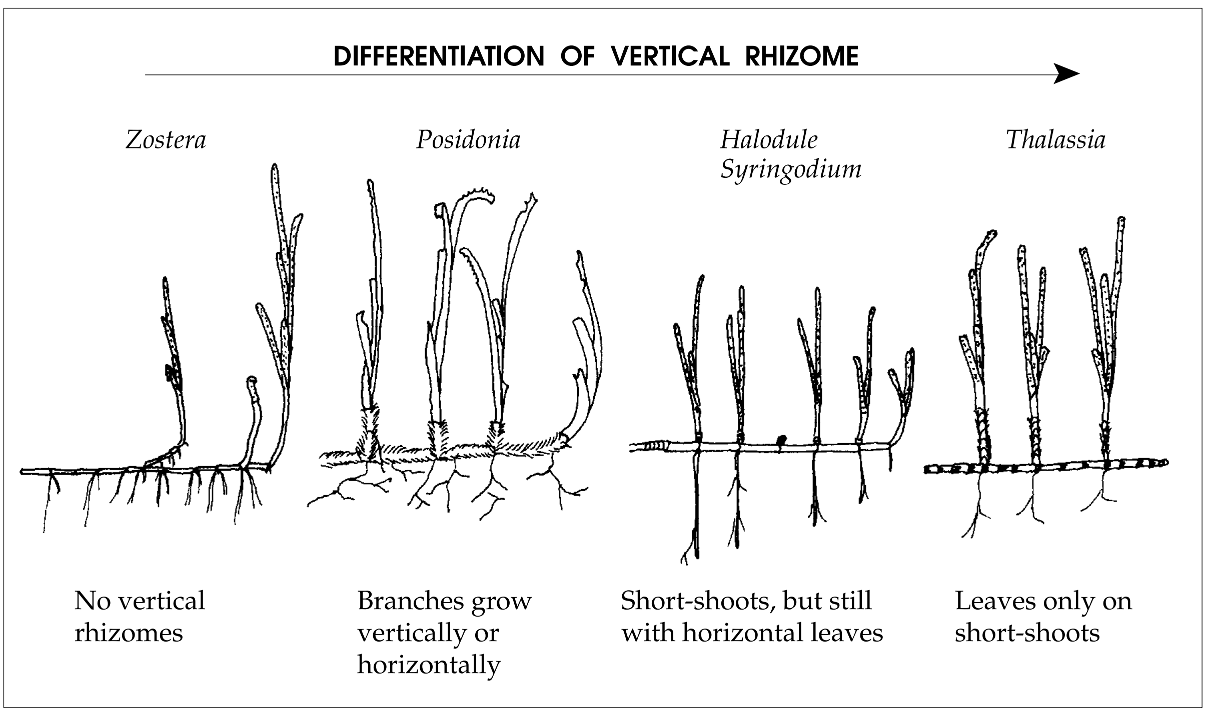

Figure 3. *Gradient of horizontal and vertical rhizome differentiation in different seagrass genera, from those with no differentiation to those that only have leaves on the vertical rhizomes (after Duarte et al. 1994). Species within genera may differ in form. Gradient does not imply a phylogenetic relationship.*

Studies in which trenches were cut 6 to 18 inches deep into seagrass beds indicated that seagrasses may recover slowly from scarring (Jones 1968 cited in Zieman 1976, Godcharles 1971). The trenches readily refilled with sediment, but seagrass regrowth was minimal even after two years. Zieman (1976) found that turtle-grass may require at least two years to begin to recolonize scars; even after five years, some scars were still visible. In a more recent study, Durako et al. (1992) used a linear-regression model to predict that individual scars 0.25 m wide cut into the centers of shoal-grass beds require 0.9–1.8 years to recover to a normal density (2000–4000 short-shoots/m^2) but that turtle-grass takes approximately 3.6–6.4 years to achieve normal density (400–700 short-shoots/m^2). At the sparser edges of shoal-grass beds, however, recovery times (2.3–4.6 years) approached those of turtle-grass, probably because of lower nodal densities at the margins of shoal-grass beds. Some researchers have indicated that *complete* seagrass-scar recovery may take as long as ten years, depending on the size of the denuded area (Lewis and Estevez 1988). For seagrass to recover in the shortest period, scarred areas must remain free of additional scarring, and other environmental conditions must be favorable for plant survival and growth. Even so, the recovery period for scarred seagrass beds (especially for turtle-grass) averages at least three to five years and is probably much longer in areas of poor water quality and where scarring is severe and repetitive. Some scarred seagrass beds may never recover.

The rate of seagrass recovery from scarring depends on many factors. Some of the variables that may affect recovery from scarring are sediment composition, water quality, current velocity, wave and wind energy, drift algae, scar depth, seagrass species, water depth, and latitude. Sediment properties and water quality are overriding determinants of recovery from scarring. Seagrasses absorb nutrients from the sediments in which they are rooted and also derive nutrition from the water column. Durako et al. (1992) suggested that south Florida sediments, which are usually carbonaceous marl muds, could affect seagrass regrowth differently than do the predominantly quartz-sand sediments of Tampa Bay. Over short distances, sediment quality may vary significantly; sediments in scars can differ in quality even from adjacent, undisturbed seagrass sediments. In the Florida Keys, for example, soil particle sizes were coarser in scars, and sediments had a lower pH and EH (Zieman 1976). In Tampa Bay, by contrast, particle-size distributions did not differ between scars and adjacent seagrass sediments (Dawes et al. 1994). Therefore, sediment type and other local conditions may affect whether scar sediments differentiate from adjacent unscarred seagrass sediments.

Water quality (e.g., salinity and clarity) affects plant physicochemical attributes such as osmotic balance and photosynthetic rates and, therefore, it can affect the amount of energy available for seagrass growth. Some seagrass species tolerate much lower salinities than others do. Turtle-grass, for example, does not survive for long in salinities below 20–25 parts per thousand (Lewis et al. 1985, Dawes 1987). Although Eleuterius (1987) observed that widgeon-grass could withstand totally fresh water, he found that of the truly marine seagrasses, shoal-grass was the most tolerant of low salinities and star-grass was the least tolerant. Turtle-grass and manatee-grass were intermediate in their responses to lower salinity. In areas where frequent and large freshwater pulses are common (e.g., near the mouths of rivers), recovery rates will be faster in seagrass species that tolerate lower salinities (i.e., shoal-grass and widgeon-grass).

Shading experiments and surveys of seagrass extents in turbid waters have shown that light reduction lowers shoot density and reduces survivability (Hall et al. 1991, Onuf 1991). Sediments that are composed mainly of finer particle sizes are more subject to resuspension (Gucinski 1982) and could pose a threat to photosynthetic processes in seagrasses. Sediment resuspension and water clarity are affected by current velocity, wave and wind energy, and nutrient fluxes, among other things. In particular, drift algae may respond vigorously to higher nutrient levels and depress scarring-recovery rates by physically inhibiting seagrass growth (e.g., Holmquist 1992) and photosynthesis and by accumulating in scars.

Water depth influences photosynthetic rates and seagrass growth, especially in nutrient-rich waters. Seagrasses in deeper water receive lower amounts of solar radiation and a different quality of light, both of which could affect energy-allocation patterns. Energy-allocation patterns of seagrasses can also be affected by latitude. Latitude, coupled with other local environmental variables, affects seagrass growth because of differing water-temperature, solar-incidence, and day-length regimes. The warmer water, longer day-lengths, and more intense solar radiation occurring at lower latitudes probably enhance seagrass growth rates and fruit production in deeper or more turbid water. Therefore, potential recovery and recolonization rates may be faster for seagrasses in the Florida Keys than in the Florida Panhandle. However, local physicochemical conditions, such as sediment characters, may override latitudinal effects.

Scar depth probably affects regrowth rate as well. Deeper scars may not fill with sediment, or may become enlarged, if they occur in areas of strong currents (Zieman 1976, Eleuterius 1987). Scars in shallow-water seagrass beds that are exposed to long wind fetches may be scoured by strong winds and waves, especially during extremely low tides. Boat wakes can also scour scarred areas. Kenworthy et al. (1988) concluded that boat-wake waves substantially elevate bottom-shear stress along shallow seagrass beds and seriously jeopardize seagrass health.

Study Objectives

Slow recovery from scarring, coupled with increased scarring rates, elevates the rate of cumulative loss of seagrasses and their habitat values. Concerns about the effects of seagrass scarring and recovery on marine productivity compelled the Florida Marine Research Institute (FMRI) to survey the extent and intensity of scarring in the shallow coastal waters of Florida. Information from this general study is intended to assist government agencies with developing specific management programs in regard to boat-generated scarring of seagrasses.

A general survey of the extent and intensity of scarring is the necessary first step in developing appropriate and cost-effective management protocols. This report identifies and quantifies the extent of scarred seagrass beds throughout most of Florida. We collected and analyzed the data using a combination of aerial photography, aerial surveys, and Geographic Information System (GIS) technology. For the first time, the statewide extent of seagrasses is described, and the magnitude of scarring is estimated and documented so that Florida's seagrass resources can be more effectively protected. Based on the data and anecdotal observations generated in this study, we identify and discuss behavioral activities and navigational circumstances that exacerbate seagrass scarring. Further investigations and surveys using developing technologies will refine our knowledge of seagrass distributions and the effects of human activities on the resource's productivity.

Methods

The main goal of this project was to survey Florida's shallow marine and estuarine waters for scarring of seagrasses. For most of Florida, we used an approach combining analysis of high-resolution aerial photographs with ground-truthing during aerial surveys. In the Florida Keys, the aerial surveys were conducted first, and aerial photography was used as collateral data.

The study area extended from the Alabama-Florida border at Perdido Bay (Escambia County), east and south along the Gulf coast to the Florida Keys, and then north along the lagoonal river systems of the Atlantic Coast to just south of New Smyrna Beach (Volusia County) in Mosquito Lagoon. A total of 31 of the state's 35 coastal counties are included in this survey (Figure 4). The four counties north of Volusia County on the Atlantic coast of Florida were not included because areas suitable for seagrass growth are not present. Only the southern part of Volusia County below U.S. Highway A1A at Port Orange was included in this survey.

Even though seagrass scars can result from many sources (e.g., ship groundings, live-aboard houseboats, and even four-wheel-drive vehicles), boat propellers are the most widespread cause of scarring. In this study, we did not distinguish among the various scarring sources. Individual prop-scar widths are narrow and average approximately 12 inches; scar lengths vary considerably, from miles to only yards long and can be difficult to see in aerial photographs. In a previous study of scar recovery, Durako et al. (1992) suggested that the smallest-scale (least detailed) aerial photography useful for recognizing scars in seagrass beds is 1:24,000 (1 inch = 2,000 ft). A greater number of scars can be identified using larger-scale photography (e.g., 1:2,400). At a single site in Tampa Bay, Durako et al. (1992) were able to distinguish 700 individual scars in 1:2,400-scale photography, 104

Figure 4. Study area for assessment of seagrass scarring.

scars at 1:12,000, and only 5 scars with 1:24,000. Nevertheless, they suggested that most of the heavily scarred areas could be identified at the 1:24,000 scale and that the trade-off in the time saved using 1:24,000 photography justified its use.

Even though aerial photography can provide sufficient detail to allow recognition of prop scars, high-detail photography is often limited to certain areas. Pertinent photography not contained in the FMRI library was obtained from the appropriate water-management districts. The largest-scale aerial photography available was 1:13,200 color-infrared (CIR) transparencies made for the Florida Keys Land Cover Mapping Project (funded by the U.S. Environmental Protection Agency's Advanced Identification of Wetlands Program) in December 1991. The smallest-scale photography used to delineate scarring in our study consisted of 1:40,000 CIR transparencies provided by the South Florida Water Management District (SFWMD). These photographs covered Hobe Sound, southeast Florida, Biscayne Bay, the upper Florida Keys and Florida Bay, and the southwest region of Florida from Florida Bay to Charlotte Harbor. The Southwest Florida Water Management District (SWFWMD) supplied 1:24,000 CIR photographs from Yankeetown south to Charlotte Harbor. The St. Johns River Water Management District (SJRWMD) furnished 1:24,000 CIR photographs for Mosquito Lagoon and Indian River Lagoon. The only aerial photographs available for the Panhandle and Big Bend regions were approximately ten years old and therefore were too dated for delineating seagrass scarring for this study. The oldest photographs used for scarring delineation were taken in November 1990. Although these photographs did not represent conditions at the time of the survey, historical scarring patterns were documented from them, and areas requiring closer examination were identified.

Some problems are inherent in using photography of different scales. In particular, comparing maps of different scales should be done with caution. Large-scale photography (e.g., 1:2,400) can give more accurate representations of seagrass distributions and scarring than smaller-scale (e.g., 1:40,000) photography can. Just the width of a line drawn on a small-scale photograph may contain many hundreds or thousands of acres of seagrass, depending on the line's length and the scale of the photography. One problem in implementing this study was that large-scale photography—or even photography of the same scale for different areas of the state—did not exist. Also, offshore county lines were based upon 1:100,000 TIGER cultural data, and subtle differences in county-line boundaries could alter conclusions if the data are used too strictly in detailed comparisons. Therefore, we urge caution when making comparisons of the differences between regions and between counties.

Scarring Recognition

Scarring was recognized as distinct areas of light-colored lines and patches—visible in photographs and from the air—that contrasted with the darker colors of seagrass beds. Scarred areas in the 9 inch x 9 inch CIR aerial photographs were delineated using binocular macroscopes and stereoscopes, and the delineations were transferred to registered acetate overlays. Where scars merged, a bounding polygon was drawn around the entire scarred area (Figure 5). Polygons were only drawn around groups of scars, not around single, isolated prop scars. We did not map areas less than one acre due to the small-scale maps used. Because of the mapping procedure and differing map scales used, we may have inadvertently included small portions of bare substrate, channels, and open water in some polygons. For example, in areas that contained intricate shorelines with numerous islands—such as the Ten Thousand Islands and the Chassahowitzka and Crystal rivers—delineating small polygons was impossible at the available map scales; as a consequence, some unscarred areas were incorporated within the polygons.

The intensity of scarring in each polygon was categorized based upon the Comparison Chart for Visual Estimation of Percentage Composition (after Terry and Chilingar 1955). Polygons designated as light enclosed areas where less than 5 percent of the seagrasses were scarred, moderate polygons contained areas with from 5 percent to 20 percent scarring, and severe polygons delineated areas with more than 20 percent scarring. For example, a 20-acre polygon that was classified as being moderately scarred would contain between 1 and 4 acres of actual scars. Diagrammatic representations of the three categories of estimated scarring intensity are shown in Figure 6. In some areas, different intensities of scarring were adjacent and could not be easily differentiated. These areas were delineated as a single polygon and were assigned

Figure 5. *Example of polygon delineation.*

a value for the overall scarring intensity. An oblique aerial photo in Figure 7 illustrates this situation.

Information about seagrass scarring in Florida Bay was furnished by Skip Snow of the Everglades National Park (ENP). Within Florida Bay, scarring occurs principally on seagrass banks, which are exposed at low tide. To confirm the locations of scarred seagrasses, a brief aerial survey was conducted by FMRI staff over a portion of Florida Bay.

Polygons drawn on the registered overlays on the aerial photographs were transferred to National Oceanic and Atmospheric Administration (NOAA) nautical charts using a zoom transfer scope (ZTS). The ZTS superimposes an image onto a base map of a different scale, providing for accurate transfer of the hand-drawn polygons from the photograph overlays onto the NOAA base maps. In most cases, 1:40,000-scale NOAA charts were used as base maps. The lack of larger-scale charts for the region from Anclote Key (Pasco County) to Alligator Harbor (Franklin County) forced us to use 1:80,000-scale charts. When possible, we used inset maps of various scales (1:5,000–1:20,000) to supplement small-scale chart information. In a portion of the Florida Keys, 1:24,000-scale U. S. Geological Survey (USGS) quadrangle maps were used as base maps because the largest-scale NOAA charts were only available at a scale of 1:80,000 (Table 1).

Scar Mapping

After marking the maps and charts with polygons, we conducted aerial surveys to verify scarring and refine the delineations of scarring intensity. Most aerial surveys were conducted between May 1992 and May 1993. The Florida Keys surveys were conducted between October 1992 and March 1993. Aerial surveys were important in assuring accurate representations of the extent and intensity of scarring because even in the better photographs, not all scars were visible. During the aerial surveys, boats were frequently observed scarring shallow seagrass beds. Some of these events were photographed, and the photographs were deposited in the FMRI library.

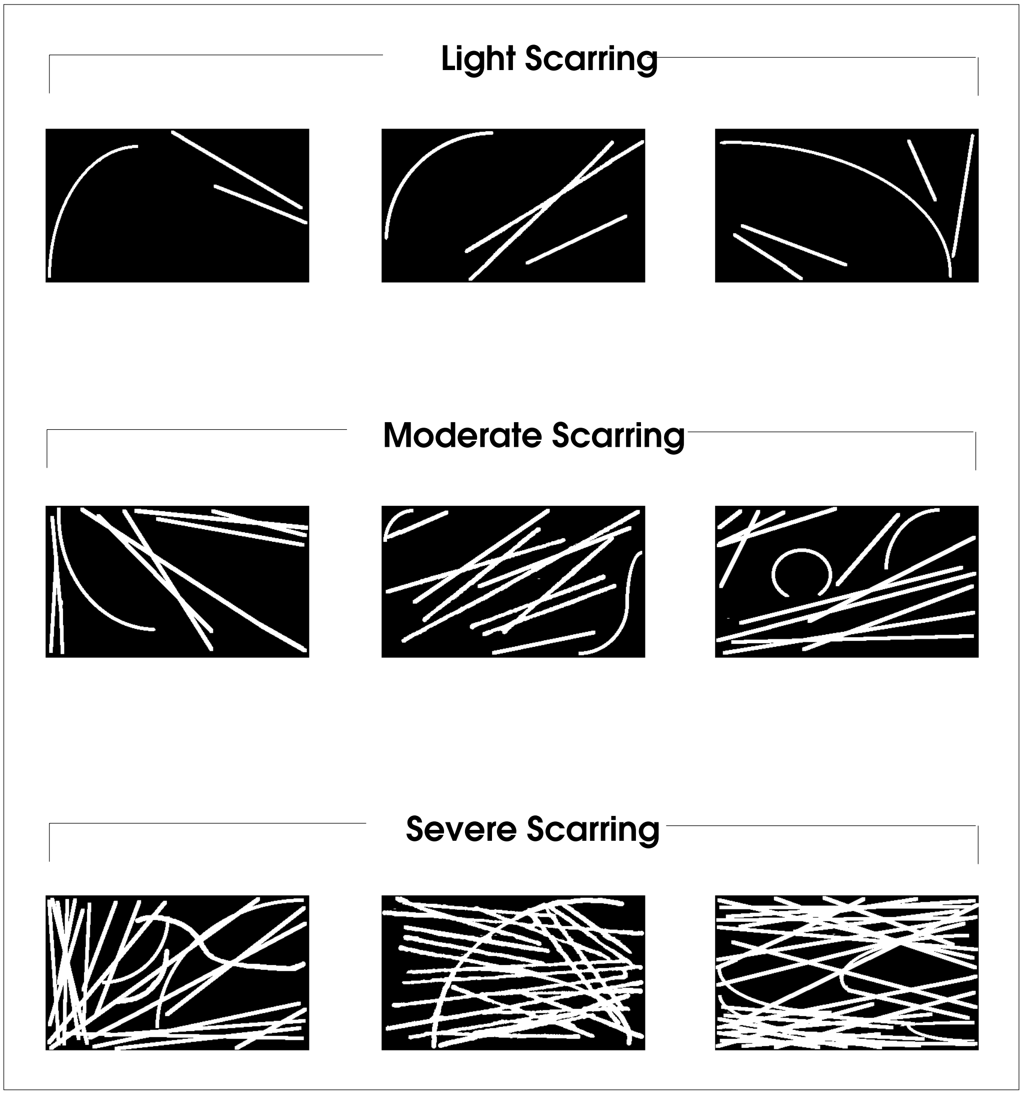

Figure 6. *Diagrammatic representation of the three categories of estimated scarring intensity. Black space within each block represents seagrasses, and white marks represent scarring. Light scarring is defined as the presence of scars in less than 5 percent of the delineated polygon, moderate scarring as the presence of scars in 5 to 20 percent of the polygon, and severe scarring as the presence of scars in more than 20 percent of the polygon.*

The Indian River Lagoon, the southeast Intracoastal Waterway, and the Florida Keys were surveyed from light, fixed-wing aircraft (Cessna 152 or 172) in regions where seagrasses were distributed along relatively straight and continuous shorelines. Regions with convoluted shorelines and numerous islands, such as Tampa Bay, Biscayne Bay, Waccasassa Bay, and parts of Florida Bay, were surveyed from a helicopter (Hughes 500). In the lower Florida Keys, where wide areas of seagrass extend from the Atlantic Ocean into Florida Bay, transects approximately 1000 feet apart were conducted perpendicular to the main axis of the Florida Keys. The Intracoastal Waterway formed the boundary between Everglades National Park and the Florida Keys in this assessment. Military bases prohibited aerial surveys of some seagrass areas.

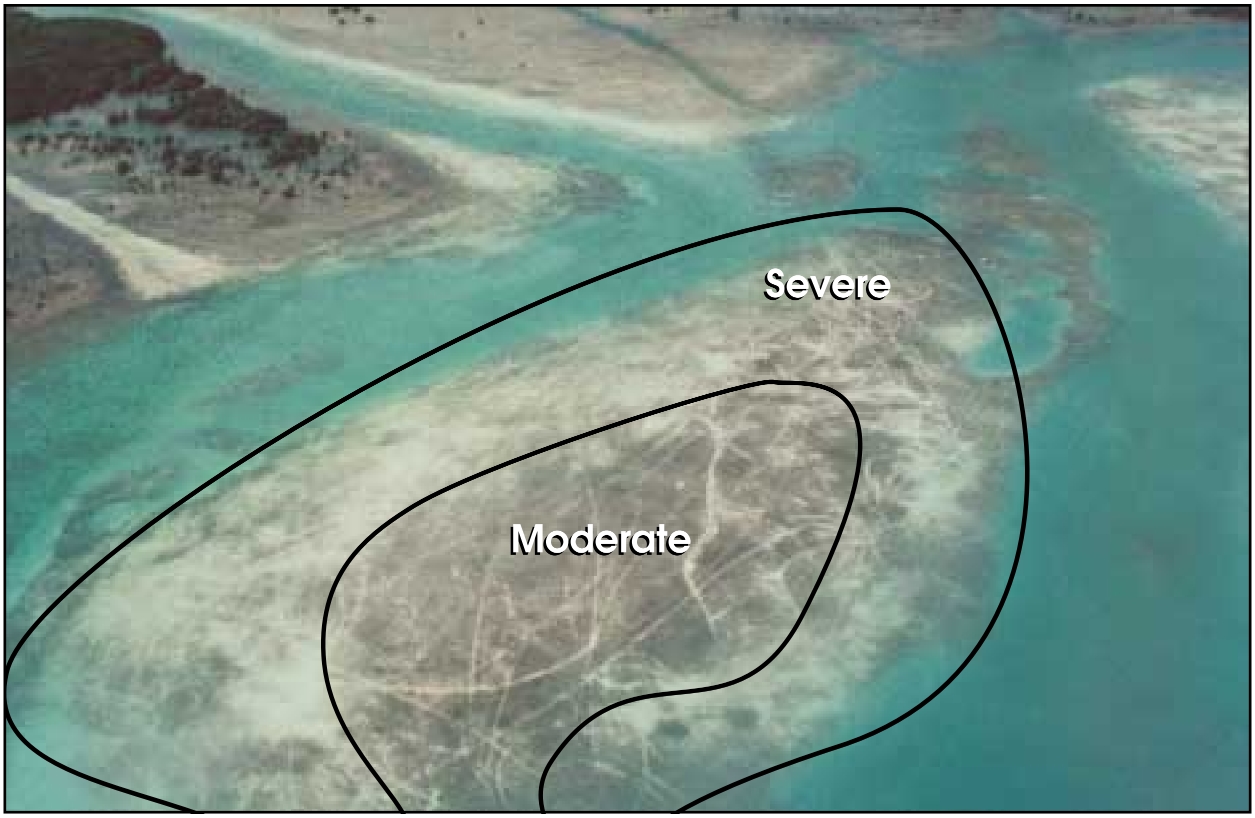

Figure 7. *Recognition of scarring intensity. Contiguous small polygons of different scarring intensities were combined into one overall intensity category. This seagrass bed would be recognized as severely scarred overall, even though part of it is only moderately scarred.*

Altitudes between 300 and 500 feet provided the best perspective for this study. Flight speeds were between 80 and 100 knots, depending on scar complexity and water clarity. Clear skies, calm seas, a vertical sun angle, and clear water were essential for conducting accurate aerial surveys. Rain and high winds made it difficult to see scars through the surface of the water. Glare from sunlight reflecting off the water in late afternoon and early morning also hampered observations. Turbidity caused by rough water during storms usually persisted for several days. Dark-colored, organically stained water—discharged from rivers during and after rain storms—greatly impeded our ability to identify scarred seagrasses during aerial surveys.

After completing the aerial surveys, we edited and recompiled the scarring data onto a clean set of base maps and then transferred the data into the Marine Resources Geographic Information System (MRGIS) at the FMRI. Complete descriptions of the MRGIS integration process, statewide map-creation techniques, and error-correction methodology are in Appendix A. ARC/INFO® software (v. 6.2.1) was used in this study to analyze scarring data and to produce output maps. Scarring information from this study is digitally stored and can easily be shared with other groups. All original base maps and photograph overlays have been archived at the FMRI.

Results

Moderately dense to dense seagrasses—i.e., excluding sparse and hardbottom seagrasses in the Florida Keys and sparse *Halophila* beds elsewhere—total approximately 1,901,000 acres. If hardbottom and sparse seagrasses in the Florida Keys are included in acreage estimates, seagrasses in Florida total nearly 2,660,000 acres (Table 2). The distribution of seagrasses in Florida coastal waters

Table 1. *NOAA nautical charts and USGS topographic maps used as base maps on which seagrass scarring in Florida was represented.*

Number	Scale	Official Name
Chart 11378	1:40,000	Intracoastal Waterway - Santa Rosa Sound to Dauphin Island
Chart 11393	1:40,000	Intracoastal Waterway - Lake Wimico to East Bay
Chart 11402	1:40,000	Intracoastal Waterway - Apalachicola to Lake Wimico
Chart 11404	1:40,000	Intracoastal Waterway - Carrabelle to Apalachicola Bay
Chart 11405	1:80,000	Apalachee Bay
Chart 11407	1:80,000	Horseshoe Point to Rock Islands
Chart 11408	1:80,000	Crystal River to Horseshoe Point
Chart 11409	1:80,000	Anclote Keys to Crystal River
Chart 11412	1:80,000	Tampa Bay and St. Joseph Sound
Chart 11413	1:40,000	Tampa Bay - northern part
Chart 11414	1:40,000	Tampa Bay - southern part
Chart 11425	1:40,000	Intracoastal Waterway - Charlotte Harbor to Tampa Bay
Chart 11427	1:40,000	Intracoastal Waterway - Fort Myers to Charlotte Harbor
Chart 11430	1:40,000	Everglades National Park - Lostmans River to Wiggins Pass
Chart 11432	1:50,000	Everglades National Park - Shark River to Lostmans River
Chart 11433	1:50,000	Everglades National Park - Whitewater Bay
Chart 11441	1:30,000	Key West Harbor and approaches
Chart 11442	1:80,000	Sombrero Key to Sand Key
Chart 11445	1:40,000	Intracoastal Waterway - Bahia Honda to Key West
Chart 11448	1:40,000	Intracoastal Waterway - Big Spanish Channel to Johnson Key
Chart 11449	1:40,000	Matecumbe to Bahia Honda Key
Chart 11451	1:80,000	Miami to Marathon and Florida Bay
Chart 11463	1:40,000	Intracoastal Waterway - Elliott Key to Matecumbe
Chart 11465	1:40,000	Intracoastal Waterway - Miami to Elliott Key
Chart 11467	1:40,000	Intracoastal Waterway - West Palm Beach to Miami
Chart 11485	1:40,000	Intracoastal Waterway - Tolomato River to Palm Shores
USGS map	1:24,000	Marquesas Keys West
USGS map	1:24,000	Marquesas Keys East
USGS map	1:24,000	Cottrell Key

is uneven; some counties have very little and others have a disproportionately large amount (see figures in Appendix B). Monroe County alone contains 54.6 percent of all Florida seagrass-bed acreage—mostly in Florida Bay and the Florida Keys (Tables 2 and 3). Much of the remaining seagrass acreage (26.4 percent) occurs in the shallow Gulf waters of Taylor, Citrus, Hernando, Levy, and Dixie counties in the Big Bend region of Florida. These counties have more seagrasses because they have extensive, shallow-water, low-energy areas with water quality that is generally good. These conditions promote rapid growth and coalescence of seagrasses. Other extensive seagrass components in deeper waters in this area are species of *Halophila,* which are usually in sparse or patchy beds. We did not include these seagrass types in this survey.

The remaining seagrass acreage (19 percent) is fairly evenly distributed among the other 25 coun-

Table 2. *Acreage of scarred seagrasses (to nearest ten acres) in each Florida coastal county in this study. Totals in scarring categories are based on calculated values, not on rounded values. Light scarring is defined as the presence of scars in less than 5 percent of the delineated polygon, moderate scarring as the presence of scars in 5 to 20 percent of the polygon, and severe scarring as the presence of scars in more than 20 percent of the polygon.*

County	Total Seagrass	Light Scarring	Moderate Scarring	Severe Scarring	Moderate +Severe	Total Scarring
BAY	10,530	4,050	820	80	900	4,950
BREVARD	46,190	4,160	1,940	110	2,050	6,210
BROWARD	0 (1)	0	0	0	0	0
CHARLOTTE	14,190	1,530	5,630	290	5,910	7,440
CITRUS	147,810	25,700	1,700	180	1,880	27,580
COLLIER	5,250	1,970	1,590	90	1,680	3,650
DADE	145,650*	2,740	3,970	4,500	8,480	11,220
DIXIE	111,130	2,470	1,020	0	1,020	3,490
ESCAMBIA	2,750	510	180	10	190	700
FRANKLIN	19,840	440	370	0	370	810
GULF	8,170	4,200	530	110	640	4,840
HERNANDO	146,870	7,790	710	0	710	8,500
HILLSBOROUGH	6,320	1,680	2,230	180	2,410	4,090
INDIAN RIVER	2,940	140	10	30	40	180
JEFFERSON	10,500	420	80	0	80	510
LEE	50,510	5,930	7,100	1,290	8,390	14,310
LEVY	132,400	9,970	120	0	120	10,090
MANATEE	12,160	2,480	2,200	780	2,990	5,470
MARTIN	2,310	20	10	0	10	30
MONROE	1,452,800*	14,560	10,430	5,060	15,490	30,050
OKALOOSA	3,450	310	80	0 (5)	80	390
PALM BEACH	2,510	50	20	0	20	70
PASCO	85,570	2,120	1,760	360	2,120	4,240
PINELLAS	22,920	3,800	3,870	2,010	5,880	9,680
SANTA ROSA	2,720	450	110	0	110	560
SARASOTA	4,160	720	300	30	330	1,050
ST. LUCIE	6,920	40	40	0	40	80
TAYLOR	162,860	8,100	60	0	60	8,160
VOLUSIA	8,490	1,430	1010	350	1,370	2,800
WAKULLA	29,630	2,060	730	0	730	2,790
WALTON	710	10	0	0	0	10
TOTAL	**2,658,290***	**109,870**	**48,630**	**15,470**	**64,100**	**173,960**

* Dade County and Monroe County totals include sparse-seagrass areas and hardbottom areas that have dense patches of turtle-grass and shoal-grass intermixed. See Table 6 for a breakdown of seagrass acreage in these counties and the text for an explanation. The total area of moderately dense, dense, and contiguous seagrasses for the state is 1,900,960 acres, excluding hardbottom and sparse seagrasses in the Florida Keys and sparse *Halophila* in the Big Bend region.

Table 3. *Relative percentages of scarred seagrasses, by intensity level, in each Florida coastal county in this study. Relative percentage is calculated for each category as the scarring in the county divided by scarring for the state multiplied by 100.* Light scarring *is defined as the presence of scars in less than 5 percent of the delineated polygon,* moderate scarring *as the presence of scars in 5 to 20 percent of the polygon, and* severe scarring *as the presence of scars in more than 20 percent of the polygon.*

County	Total Seagrass	Light Scarring	Moderate Scarring	Severe Scarring	Moderate +Severe	Total Scarring
Bay	0.4	3.7	1.7	0.5	1.4	2.8
Brevard	1.7	3.8	4.0	0.7	3.2	3.6
Broward	0.0	0.0	0.0	0.0	0.0	0.0
Charlotte	0.5	1.4	11.6	1.9	9.2	4.3
Citrus	5.6	23.4	3.5	1.1	2.9	15.8
Collier	0.2	1.8	3.3	0.6	2.6	2.1
Dade	5.5	2.5	8.2	29.1	13.2	6.4
Dixie	4.2	2.2	2.1	0.0	1.6	2.0
Escambia	0.1	0.5	0.4	0.1	0.3	0.4
Franklin	0.8	0.4	0.8	0.0	0.6	0.5
Gulf	0.3	3.8	1.1	0.7	1.0	2.8
Hernando	5.5	7.1	1.5	0.0	1.1	4.9
Hillsborough	0.2	1.5	4.6	1.2	3.8	2.4
Indian River	0.1	0.1	0.0	0.2	0.1	0.1
Jefferson	0.4	0.4	0.2	0.0	0.1	0.3
Lee	1.9	5.4	14.6	8.3	13.1	8.2
Levy	5.0	9.1	0.2	0.0	0.2	5.8
Manatee	0.5	2.3	4.5	5.1	4.7	3.1
Martin	0.1	0.0	0.0	0.0	0.0	0.0
Monroe	54.6	13.2	21.4	32.7	24.2	17.3
Okaloosa	0.1	0.3	0.2	0.0	0.1	0.2
Palm Beach	0.1	0.0	0.0	0.0	0.0	0.0
Pasco	3.2	1.9	3.6	2.3	3.3	2.4
Pinellas	0.9	3.5	8.0	13.0	9.2	5.6
Santa Rosa	0.1	0.4	0.2	0.0	0.2	0.3
Sarasota	0.2	0.6	0.6	0.2	0.5	0.6
St. Lucie	0.3	0.0	0.1	0.0	0.1	0.0
Taylor	6.1	7.4	0.1	0.0	0.1	4.7
Volusia	0.3	1.3	2.1	2.3	2.1	1.6
Wakulla	1.1	1.9	1.5	0.0	1.1	1.6
Walton	0.0	0.0	0.0	0.0	0.0	0.0

ties, mostly in embayments and lagoonal systems. Twenty-two counties have less than 50,000 acres of seagrass, and the majority of those have less than 20,000 acres. The median seagrass acreage for the 31 coastal counties in this study is approximately 10,500 acres. After Monroe County (1,452,800 acres), Taylor county has the largest seagrass acreage (162,860 acres). Of the Florida counties that contain at least some seagrass, Broward County had the smallest acreage; approximately one acre of seagrass could be recognized from seagrass-distribution sources.

The least amount of total scarring (the sum of the *light, moderate,* and *severe* categories) occurred in those counties that have little seagrass acreage (e.g., Broward, Indian River, and Walton). For scarring to be extensive, the first requirement is that a county must contain a substantial acreage of seagrass. Counties with little seagrass acreage, but with all of it scarred, would rank high in statewide scarring (Table 4). Therefore, ranking counties based on the percentage of seagrass scarred *within* the county can be deceptive.

For comparative purposes, then, counties must be ranked based on their percentages of scarring relative to scarring for the entire state. Relative to the whole state, the greatest amount of total scarring occurred, as would be expected from seagrass distributions, in Monroe and Citrus counties (Tables 2, 3, and 5). Lee, Dade, Levy, and Pinellas counties also had substantial scarring. Of greatest immediate concern is scarring in the *moderate* and *severe* categories (M/S scarring). Scarring in the *light* category in most areas is probably not of *immediate* concern in protecting seagrasses, unless the area is subject to increasing boat use. The counties with the most M/S scarring were Monroe, Dade, Lee, Charlotte, and Pinellas. Most scarring in Citrus and Levy counties was in the *light* category, so these two counties are of lower importance when only M/S scarring is considered. Fourteen counties each had less than one percent of the state's M/S scarring. Of these, Walton, Broward, Martin, Palm Beach, St. Lucie, and Indian River counties had the lowest amounts of M/S scarring because they all have low seagrass acreage. Of the counties containing substantial acreages of seagrass (i.e., those with more than one percent of statewide coverage), Taylor, Hernando, Wakulla, Dixie, and Citrus counties had the least M/S-scarring acreage. These counties are all in the Big Bend region of Florida, which is sparsely populated and has low numbers of registered boats. These five counties account for 22.5 percent of the state's seagrass acreage. Scarring extents and intensities for all 31 coastal counties in this study are illustrated in the figures in Appendix B.

Generalized seagrass distributions compiled from various sources may be misleading if data were based on different definitions for sparse seagrass or included patchy (but dense) seagrasses within a polygon. In this study, sparse and hardbottom seagrasses in Monroe and Dade counties were included in the overall seagrass distributions because substantial patches of dense and moderately dense shoal-grass and turtle-grass were intermixed and could not be separately delineated. In areas of the Big Bend and Indian River Lagoon, however, we deleted sparse-seagrass categories from mapping and analysis because they were mostly very sparse *Halophila* beds, which are usually in deeper waters and which may not be pertinent to ecological concerns addressed in this study. Nevertheless, we separated the seagrass distributions for Monroe and Dade counties into sparse/hardbottom and dense/moderately dense seagrass acreages (Table 6) for those who wish to eliminate these categories from scarring-extent calculations. All of our calculations were based on the total seagrass acreages for Monroe and Dade counties.

Polygons representing scarring in areas where sparse seagrasses had been excluded from the generalized distribution were retained in the analysis because they indicated the presence of seagrasses, as confirmed in the aerial surveys. Caution must be used when assessing the meaning of the data presented in this study. Although we have attempted to reduce distribution errors, inaccuracies remain because of the broad nature of this type of study. Mapping of seagrasses and scarring will be in constant flux as more detailed data are generated for different areas.

To more broadly identify differences in seagrass-scarring distribution, five regions (Figure 8)

Table 4. *Percentages of scarred seagrasses, by intensity level, within each Florida coastal county in this study.* Light scarring *is defined as the presence of scars in less than 5 percent of the delineated polygon,* moderate scarring *as the presence of scars in 5 to 20 percent of the polygon, and* severe scarring *as the presence of scars in more than 20 percent of the polygon. The percentage of scarred seagrasses for the entire state in each category is* light = *4.1%*, moderate = *1.8%*, severe = *0.6%*, moderate + severe = *2.4%*, *and* total scarring = *6.5%.*

County	Total Seagrass Acres	Percent Light Scarring	Percent Moderate Scarring	Percent Severe Scarring	Percent Moderate +Severe	Percent Total Scarring
Bay	10,530	38.4	7.8	0.7	8.5	47.0
Brevard	46,190	9.0	4.2	0.2	4.4	13.4
Broward	1	100.0	0.0	0.0	0.0	100.0
Charlotte	14,190	10.8	39.6	2.0	41.6	52.4
Citrus	147,810	17.4	1.2	0.1	1.3	18.7
Collier	5,250	37.5	30.3	1.7	32.0	69.5
Dade	145,650	1.9	2.7	3.1	5.8	7.7
Dixie	111,130	2.2	0.9	0.0	0.9	3.1
Escambia	2,750	18.7	6.4	0.3	6.7	25.4
Franklin	19,840	2.2	1.9	0.0	1.9	4.1
Gulf	8,170	51.4	6.6	1.3	7.9	59.3
Hernando	146,870	5.3	0.5	0.0	0.5	5.8
Hillsborough	6,320	26.6	35.3	2.9	38.2	64.8
Indian River	2,940	4.8	0.3	1.1	1.4	6.2
Jefferson	10,500	4.0	0.8	0.0	0.8	4.8
Lee	50,510	11.7	14.1	2.6	16.7	28.4
Levy	132,400	7.5	0.1	0.0	0.1	7.6
Manatee	12,160	20.4	18.1	6.5	24.6	45.0
Martin	2,310	1.0	0.4	0.0	0.4	1.4
Monroe	1,452,800	1.0	0.7	0.4	1.1	2.1
Okaloosa	3,450	9.0	2.2	0.1	2.3	11.3
Palm Beach	2,510	2.1	0.9	0.0	0.9	3.0
Pasco	85,570	2.5	2.1	0.4	2.5	5.0
Pinellas	22,920	16.6	16.9	8.8	25.7	42.3
Santa Rosa	2,720	16.4	4.1	0.0	4.1	20.5
Sarasota	4,160	17.2	7.2	0.8	8.0	26.0
St. Lucie	6,920	0.6	0.6	0.0	0.6	1.2
Taylor	162,860	5.0	0.0	0.0	0.0	5.0
Volusia	8,490	16.9	11.9	4.2	16.1	33.0
Wakulla	29,630	6.9	2.5	0.0	2.5	9.4
Walton	710	1.6	0.0	0.0	0.0	1.6

Table 5. *County rankings of scarred-seagrass acreage, by scarring intensity, in each Florida coastal county in this study. Rank is in decreasing order of acreage scarred. Counties with the same acreage are ranked alphabetically.* Light scarring *is defined as the presence of scars in less than 5 percent of the delineated polygon,* moderate scarring *as the presence of scars in 5 to 20 percent of the polygon, and* severe scarring *as the presence of scars in more than 20 percent of the polygon.*

	Total Seagrass	Light Scarring	Moderate Scarring	Severe Scarring	Moderate +Severe	Total Scarring
1	Monroe	Citrus	Monroe	Monroe	Monroe	Monroe
2	Taylor	Monroe	Lee	Dade	Dade	Citrus
3	Citrus	Levy	Charlotte	Pinellas	Lee	Lee
4	Hernando	Taylor	Dade	Lee	Charlotte	Dade
5	Dade	Hernando	Pinellas	Manatee	Pinellas	Levy
6	Levy	Lee	Hillsborough	Pasco	Manatee	Pinellas
7	Dixie	Gulf	Manatee	Volusia	Hillsborough	Hernando
8	Pasco	Brevard	Brevard	Charlotte	Pasco	Taylor
9	Lee	Bay	Pasco	Citrus	Brevard	Charlotte
10	Brevard	Pinellas	Citrus	Hillsborough	Citrus	Brevard
11	Wakulla	Dade	Collier	Brevard*	Collier	Manatee
12	Pinellas*	Manatee	Dixie	Gulf*	Volusia	Bay
13	Franklin*	Dixie	Volusia	Collier*	Dixie	Gulf
14	Charlotte*	Pasco	Bay	Bay*	Bay	Pasco
15	Manatee*	Wakulla	Wakulla	Indian River*	Wakulla	Hillsborough
16	Bay*	Collier	Hernando	Sarasota*	Hernando	Collier
17	Jefferson*	Hillsborough	Gulf	Escambia*	Gulf	Dixie
18	Gulf*	Charlotte	Franklin*	Broward*	Franklin*	Volusia
19	Volusia*	Volusia	Sarasota*	Dixie*	Sarasota*	Wakulla
20	St. Lucie*	Sarasota*	Escambia*	Franklin*	Escambia*	Sarasota*
21	Hillsborough*	Escambia*	Levy*	Hernando*	Levy*	Franklin*
22	Collier*	Santa Rosa*	Santa Rosa*	Jefferson*	Santa Rosa*	Escambia*
23	Sarasota*	Franklin*	Jefferson*	Levy*	Jefferson*	Santa Rosa*
24	Okaloosa*	Jefferson*	Okaloosa*	Martin*	Okaloosa*	Jefferson*
25	Indian River*	Okaloosa*	Taylor*	Okaloosa*	Taylor*	Okaloosa*
26	Escambia*	Indian River*	St. Lucie*	Palm Beach*	Indian River*	Indian River*
27	Santa Rosa*	Palm Beach*	Palm Beach*	Santa Rosa*	St. Lucie*	St. Lucie*
28	Palm Beach*	St. Lucie*	Indian River*	St. Lucie*	Palm Beach*	Palm Beach*
29	Martin*	Martin*	Martin*	Taylor*	Martin*	Martin*
30	Walton*	Walton*	Broward*	Wakulla*	Broward*	Walton*
31	Broward*	Broward*	Walton*	Walton*	Walton*	Broward*

* Relative percentage is less than one percent.

Table 6. *Acreages (to nearest ten acres) of seagrass-density categories in the Florida Keys.*

County	Total Seagrass	Moderate/Dense Seagrass	Sparse/Hardbottom Seagrass
Dade	145,650	120,680	24,320
Monroe	1,452,800	717,440	733,210
Total	1,598,450	838,120	757,530

were demarcated in the analysis of scarring extents and intensities: *Region 1. Panhandle* (Escambia County–Franklin County), *Region 2. Big Bend* (Wakulla County–Pasco County), *Region 3. Gulf Peninsula* (Pinellas County–Lee County), *Region 4. Atlantic Peninsula* (Palm Beach County–Volusia County), and *Region 5. South Florida* (Collier County–Broward County). Acreages of scarred seagrasses occurring in these regions are in Table 7.

The areas of Florida with the greatest acreages of M/S scarring were the Gulf Peninsula and South Florida regions. Based only on the severe-scarring category, however, the South Florida region had twice the scarred acreage of the Gulf Peninsula region. If the *light*-scarring category is included, the Big Bend region had the greatest total of scarred-seagrass acreage. However, the *light*-scarring category may not be of greatest concern in protecting seagrasses from scarring; therefore, the Big Bend region may not be a priority for a management program, except for protecting sites where M/S scarring occurs and ensuring that scarring does not become worse.

When M/S scarring is viewed relative to the total seagrass acreage in the region, the most threatened region is the Gulf Peninsula (23.5 percent of its seagrasses scarred); it has extensive scarring relative to the moderate acreage of seagrasses there. Because of the extensive acreages of seagrasses in the South Florida and Big Bend regions, scarring levels (1.6 percent and 0.8 percent of their seagrasses scarred) were low relative to the area of total seagrasses present. However, most of these seagrasses occur in water depths where they are unlikely to be scarred.

Region 1. Panhandle: This region has the least acreage of seagrass in the state (Table 7). Bay and

Table 7. *Acreages of scarred seagrasses (to nearest ten acres) in each region of Florida demarcated in this study.* Light scarring *is defined as the presence of scars in less than 5 percent of the delineated polygon,* moderate scarring *as the presence of scars in 5 to 20 percent of the polygon, and* severe scarring *as the presence of scars in more than 20 percent of the polygon.*

Region	Total Seagrass	Light Scarring	Moderate Scarring	Severe Scarring	Moderate +Severe	Total Scarring
1. Panhandle	48,170	9,970	2,090	200	2,290	12,260
2. Big Bend	826,770	58,630	6,180	540	6,720	65,350
3. Gulf Peninsula	110,260	16,140	21,330	4,580	25,910	42,050
4. Atlantic Peninsula	69,360	250	3,030	490	3,520	3,770
5. South Florida	1,603,700*	19,270	15,990	9,650	25,640	44,910

* South Florida total includes sparse-seagrass areas and hardbottom areas with moderately dense and dense patches of turtle-grass and shoal-grass intermixed. See Table 6 for a breakdown of seagrass acreage in these counties and the text for an explanation. The total area of moderately dense, dense, and contiguous seagrasses in the state is 1,900,960 acres, excluding hardbottom and sparse seagrasses in the Florida Keys and sparse *Halophila* beds in the Big Bend region.

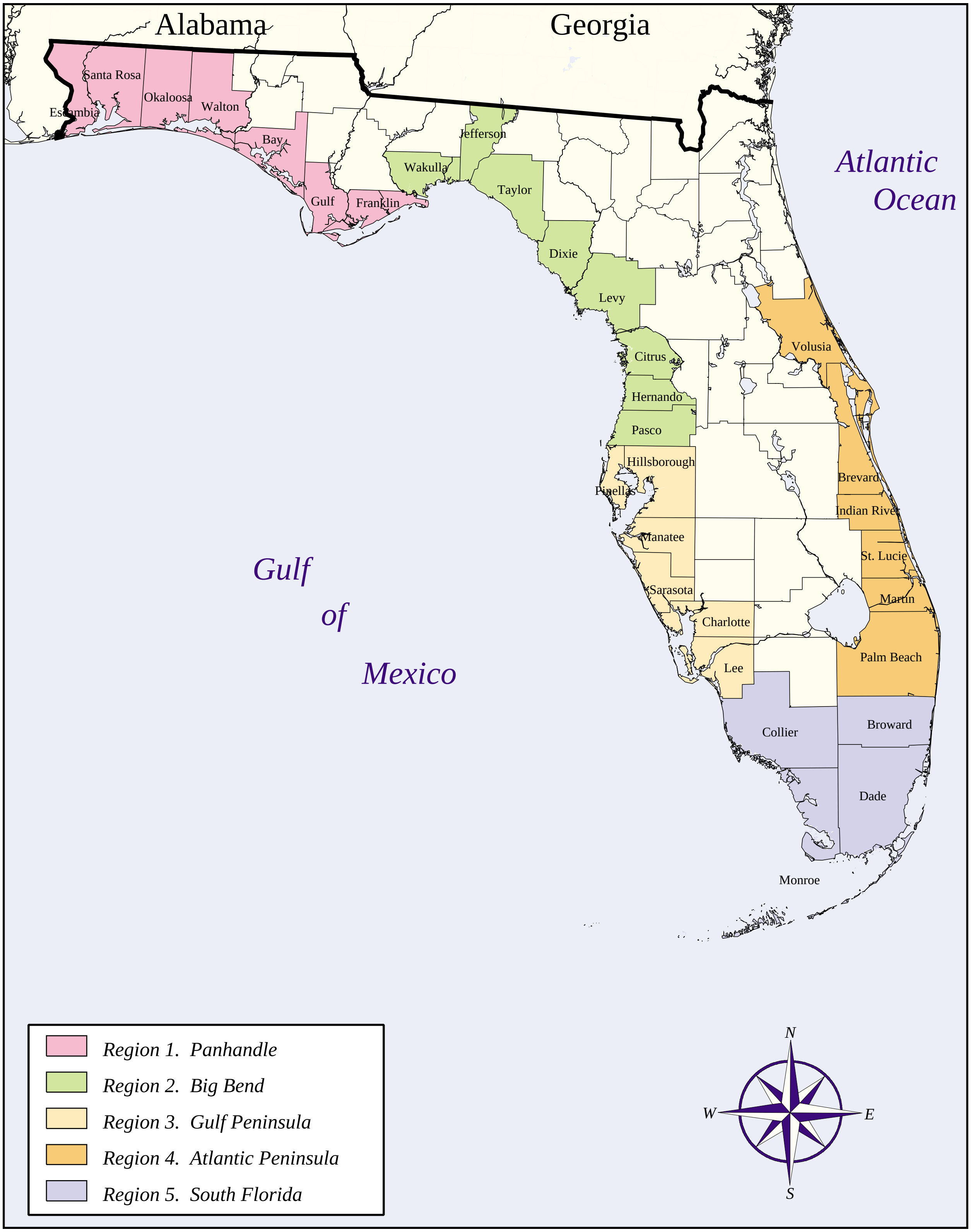

Figure 8. *Regions of Florida analyzed for scarred seagrasses.*

Gulf counties had the greatest acreages of both total and M/S scarring in this region. Scarring in this region was principally in the light category, although some of the small amount of seagrass in the more developed embayments had severe scarring. St. Joseph Bay, East Bay, and St. Andrew Bay, along with The Narrows and Santa Rosa Sound, were the principal foci for scarring. Big Lagoon in Escambia County had extensive *light* and *moderate* scarring, as did areas adjacent to Perdido Bay and Perdido Island.

Region 2. Big Bend: The Big Bend region contains extensive areas of very shallow water and intricate shorelines. Even so, not much scarring was observed (Table 7). Within this region, Citrus County had the most extensive acreage of total scarring, and Pasco County had the most M/S scarring. Levy, Taylor, and Hernando counties also had a substantial amount of total scarring, most of which was in the *light* category. The extent of scarring was unexpected because of these counties' lower population densities. However, the large amount of *light* scarring may have partially been an artifact of the small-scale maps that prevented detailed polygon delineation in this region.

Region 3. Gulf Peninsula: The total acreage of scarred seagrasses was extensive in this region (Table 7). M/S scarring totaled 25,910 acres, which was the most in the state. Lee County had the most extensive total and M/S scarring of the counties in this region. The seagrass flats of Estero Bay, Pine Island Sound, and Matlacha Pass (all in Lee County) were criss-crossed with M/S scarring. Figure 9 illustrates detailed scarring patterns around Pine Island in Charlotte County. Note the scarred area to the southwest of the marina (lower left). Even though a marked boat channel (narrow band of light blue) extends west from the marina to open water and the Intracoastal Waterway, boats leaving the marina often take a shortcut south and as a result scar shallow seagrass beds.

From Sarasota County to Pinellas County, *light* and *moderate* scarring were common. Pinellas County had the largest acreage of total and M/S scarring in the Tampa Bay region. The Gulf Peninsula region contains two extensive bay systems: Tampa Bay, which is highly developed, and Charlotte Harbor, which is much less developed. A comparison of the two bay systems shows that both total and M/S scarring were approximately the same for the two embayments. Charlotte Harbor has approximately 23,000 more acres of seagrass than Tampa Bay does, so scarring may have been more critical in Tampa Bay relative to its total seagrass acreage.

Region 4. Atlantic Peninsula: This region had the lowest total acreage of scarred seagrasses (Table 7). Most scarring occurred in the northern part of Brevard County and the southern part of Volusia County, so the northern part of this region had the most extensive scarring. Within this region, Brevard County had the most total and M/S scarring, although Volusia County also had substantial M/S scarring. Relative to the total acreage of seagrass in the county, the scarring in Volusia County may be more deleterious. Counties south of Brevard County did not have substantial acreages of seagrass; therefore, scarring there was not extensive.

Region 5. South Florida: This region has the largest acreage of seagrass in the state—most of it in Monroe County (Table 7). This region also had the greatest acreage of *severe* scarring in the state. Monroe County had by far the most scarring in all categories in this region. Of the other counties in this region, Dade County had substantial scarring in the total and M/S categories, principally in southern Biscayne Bay.

For this region, a better understanding of scarring can be obtained by viewing the Florida Keys as a single entity that crosses county boundaries. If the extensive area of seagrasses in Florida Bay is excluded from the scarring analysis, the Florida Keys contains what are probably the most egregious examples of scarring in the state. This area, which is in Dade and Monroe counties, provided a greater diversity of scarring types than any other county in the state and was surveyed in greater detail to provide an example of how to examine site-specific types of scarring (Kruer 1994).

Virtually all seagrass banks and flats in the Florida Keys have some scarring, and scar density is generally greatest near developed islands and in areas of more intensive boating activity (Matthews et al. 1991). Scarred seagrasses were observed from the high intertidal zone to a depth of approximately six feet at low tide. The scars in deeper water were near ports at Key West and Stock Island; northeast of Big Pine Key, where commercial fish-trap boats take shortcuts through

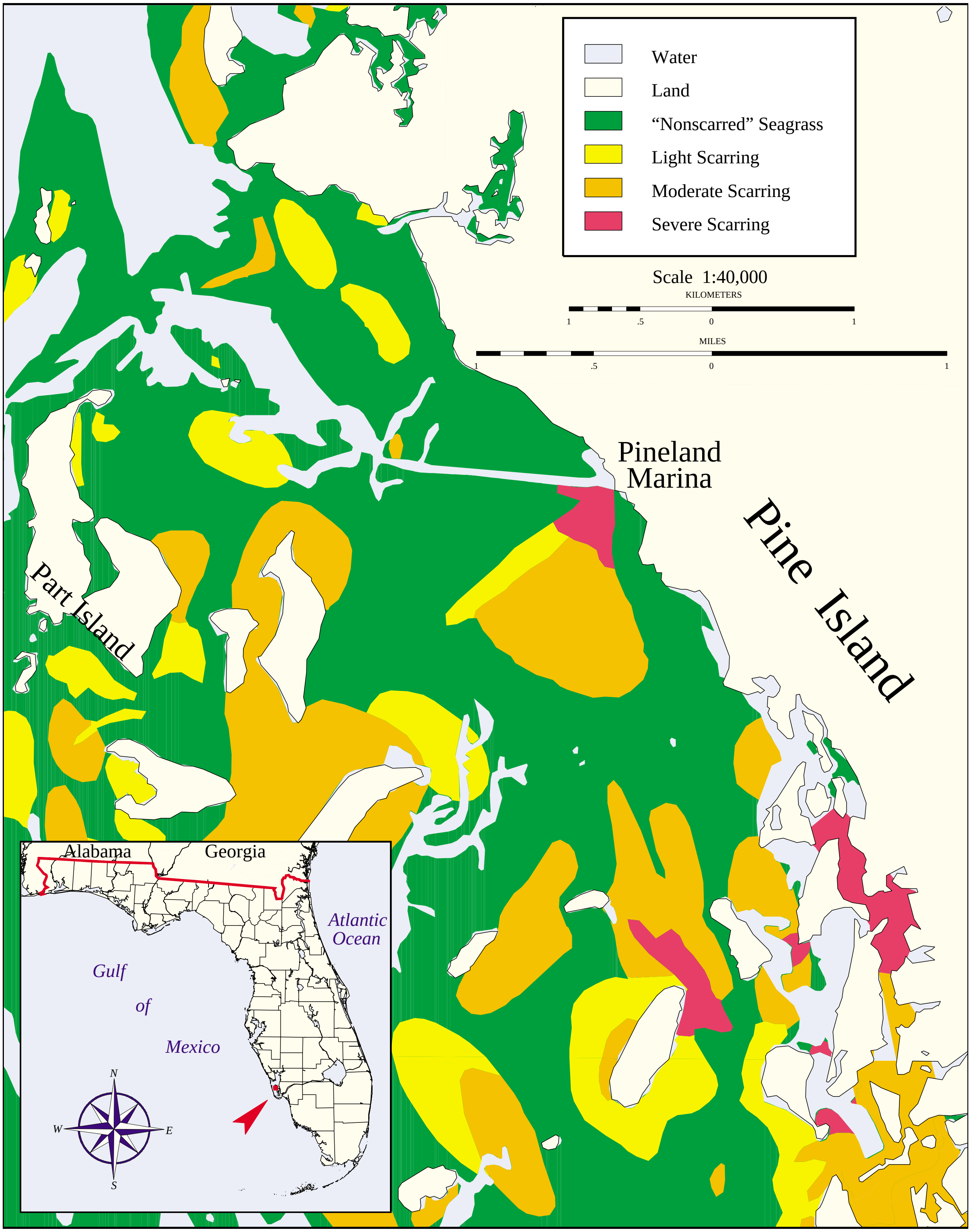

Figure 9. Detailed map of scarred seagrasses—Pine Island, Lee County.

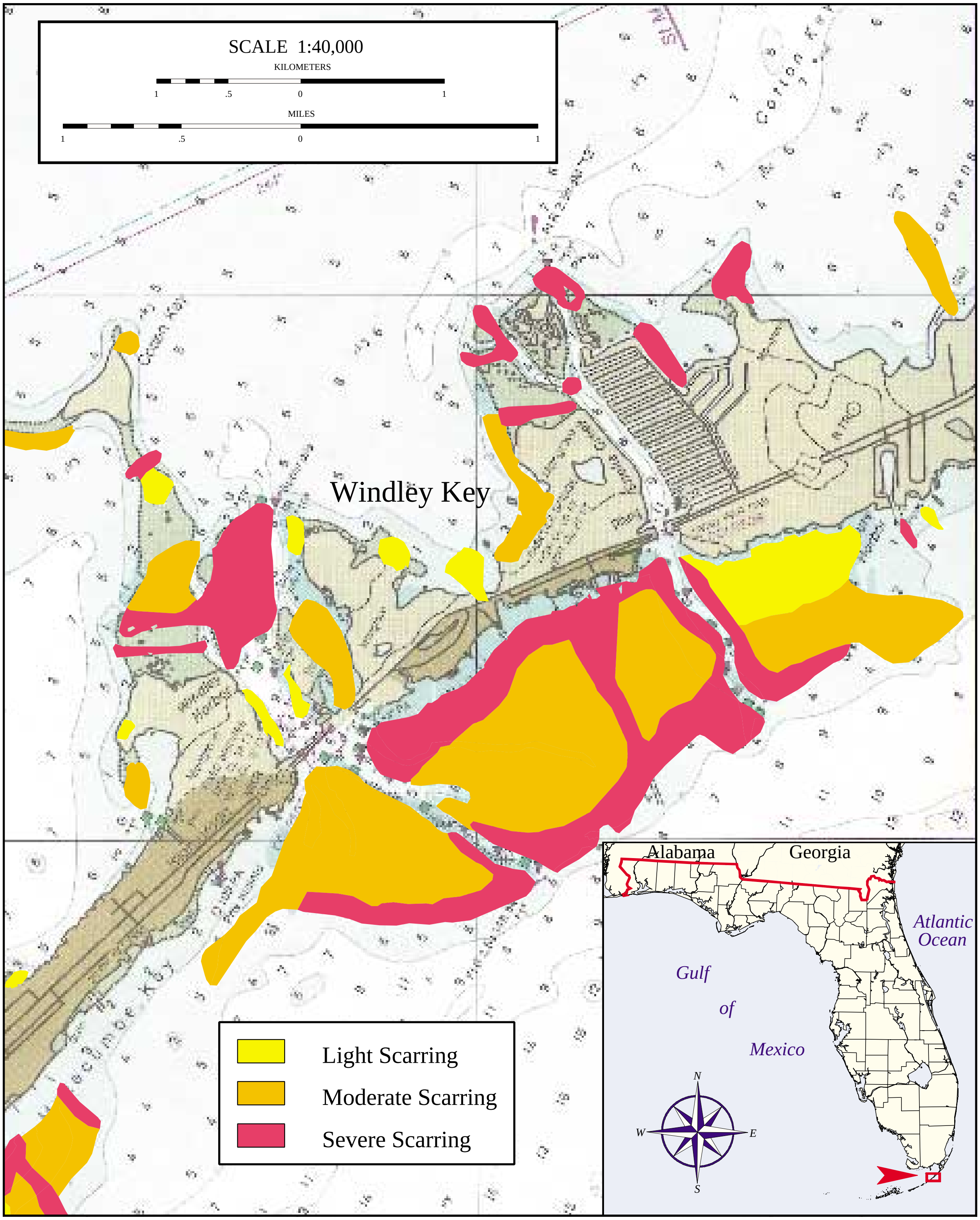

Figure 10. *Detailed map of scarred seagrasses—Windley Key, Monroe County.*

shallow channels; near Marathon and Islamorada, where large vessels dock; and in and along the Intracoastal Waterway on the Florida Bay side of the upper Florida Keys.

Approximately 900 scarred areas were identified in the Florida Keys. *Light* scarring totaled 14,650 acres, *moderate* scarring totaled 10,400 acres, and *severe* scarring totaled 5,020 acres. The greatest concentration of M/S scarring was observed in the upper Keys. Scarring intensity ranged from a few scars at some sites to numerous propeller and grounding scars at others. Some formerly vegetated areas were covered by displaced sediment from extensively scarred and destabilized seagrass beds nearby. Moderately and severely scarred sites in the lower Florida Keys from the Marquesas Keys to near Snipe Key, for which additional information was collected, are listed in Tables 8 and 9 (Kruer 1994). These sites were evaluated for probable causes of scarring based on observed boating activity, environmental characteristics of the area, personal knowledge, and discussions with many boaters.

A notable example of the intensity of scarring that occurs in some parts of Florida is around Windley Key, in the upper Florida Keys. Windley Key is in the Florida Keys National Marine Sanctuary, and its waters are designated as Class III Outstanding Florida Waters. It includes a variety of shallow marine communities and is a transitional area between high-energy oceanic waters and the more protected waters of Florida Bay and Everglades National Park. Whale Harbor and Snake Creek channels, both with relatively deep water, connect the extensive, shallow seagrass flats of Florida Bay with deeper oceanic waters. Endangered West Indian manatees, American crocodiles, and seaturtles are known to inhabit these waters. The area is also surrounded by coral reefs and hardbottom communities that attract many tourists and fishermen.

As a result of intense boating activity and lack of proper protection, the Windley Key area contains some of the most heavily scarred seagrass flats in south Florida. Figure 10 illustrates the extent of seagrass scarring around Windley Key. Kruer (1994) noted the loss of seagrasses along channel edges and that eroded sediments were being deposited on seagrasses. Unmarked channels had been cut through shallow-water seagrass flats and between mangroves. Boat wakes severely eroded seagrass beds along the offshore channel edges. Boating activity originated from facilities located at Whale Harbor Channel and at Snake Creek and from the more than 31,000 linear feet of bulkhead docks along canals in a residential subdivision.

Scarring of seagrasses in the Florida Keys has occurred for some time—probably since combustion engines (outboard and inboard) were installed in boats. However, the problem of seagrass scarring has become acute because of the increasing residential population; the increasing popularity of boating, fishing, diving, and other water sports; and increasing tourism. New prop-dredged channels continue to appear, some thousands of feet long, providing access for larger and more numerous vessels into areas not previously accessible. Many shallow flats and banks are now severely eroded due to constant scarrings, ship groundings, chronic wave action, and water-current scouring (Kruer 1994).

Discussion

The majority of Florida's moderate/severe (M/S) seagrass scarring (68.9 percent) occurred in five counties: Monroe, Dade, Lee, Charlotte, and Pinellas. These same counties contain 63.4 percent of the state's seagrass acreage. However, if Monroe County is excluded from analysis—because of its disproportionately large amount of seagrass acreage and scarring—the five counties that have the most M/S scarring contain only 9.3 percent of the state's seagrass acreage but 49.4 percent of its M/S scarring. What could be the cause of so much scarring in these counties? One important correlation exists with population density, as reflected in vessel registrations for each of the counties. For example, M/S scarring of seagrass beds is greater in the densely populated Gulf Peninsula region than it is in the sparsely populated Big Bend region.

Florida's population nearly doubled between 1970 and 1990: from 6,791,000 to 12,938,000. During the same period, the number of vessel registrations (recreational and commercial) more

Table 8. *Moderately scarred sites—Marquesas Keys to Snipe Key (1992–93). Adapted from Kruer (1994).*

Site #	Adjacent Key	Probable Cause[1]	Suggested Management[2]	Comments
13	Marquesas Keys	A, S	ED	Shallow channel between islands with popular beaches
15	Marquesas Keys	A, S	ED	Shallow channel between two islands
32	Marquesas Keys	I, S	ED	Entrance to natural channel
46	Boca Grande Key	C, S	C	At entrance to main channel, existing markers (#17 and #18) on chart, marker 18 in shallow zone, vessels pass on shallow side.
50	Boca Grande Key	C, S	C	Markers # 13 and 14 not located as shown on chart 11441
75	Archer Key	C, S	C, EN	Adjacent to single marker # 8 shown on chart 11441, oversized vessels, needs gated markers.
105	Mule Key	C, S	C, EN	Confined area between markers, used by oversized vessels
113	Mule Key	C, S	ED	Area of concentrated traffic near channel markers
121	Key West	S	ED	Isolated bank (Middle Grounds) in center of Northwest Channel
123	Wisteria Island	C, L, S	C, ED, EN	Heavily traveled anchorage on west edge of Key West Channel
127	Fleming Key	C, S	C, ED	Inadequately marked channel through large bank
142	Fleming Key	S	ED, EN	On inside of several markers
145	Fleming Key	S	C, ED	On edge of main channel near marker
150	Key West	P, S	C, ED, EN	Outside of markers in access to Garrison Bight
151	Key West	C, P, S	C, ED	Inside Garrison Bight, outside of partly marked dredged channel
152	Key West	C, P, S	C, ED	Inside Garrison Bight, outside of partly marked dredged channel
155	Sigsbee Park	S	C, ED	At end of dredged area
156	Key West	A, S	C, ED	Boats accessing dredged channel
157	Key West	C, P, S	C, ED, EN	Cow Key Channel, part marked, part unmarked, high-speed traffic
163	Stock Island	P, S	C, ED, EN	Adjacent to Safe Harbor Channel
165	Stock Island	L, P, S	C, ED, EN	Anchorage east of Stock Island in Boca Chica Channel
166	Stock Island	L, P	ED, EN	Anchorage east of Stock Island in Boca Chica Channel and near ramp
174	Boca Chica	S	ED, EN	At entrance to dredged part of Boca Chica Channel
181	Bay Keys	I, S	ED, EN	Commercial tour boats and recreational boats accessing Bay Keys from the south
201	Lower Harbor Keys	I, S	ED, EN	Long, illegally marked channel
204	Channel Key	I, S	ED	Part of old Backcountry Waterway
207	Channel Key	I, S	C, ED	Cut through bank between islands
223	Fish Hawk Key	I, S	C, ED	Cut through long linear bank
232	Geiger Key	A, I, S	ED, EN	Shallow channel leaving residential canal
236	Saddlebunch Key	C,S	C, ED	On bank near marked channel
238	Big Coppitt Key	A,C	ED, EN	Marked access to canal trailer park
245	Halfmoon Key	A, I, S	ED, EN	Access to shallow embayment
251	Mud Keys	S	C, ED	Channel leaving Waltz Key Basin

[1] *Probable Cause:* A = access point, C = poor channel markers, I = illegal aids to navigation, L = live-aboards, P = proximity, S = shortcut.

[2] *Suggested Management*: C = new or improved markers, ED = education, EN = better enforcement, R = restricted area.

Table 9. *Severely scarred sites—Marquesas Keys to Snipe Key (1992–1993). Adapted from Kruer (1994).*

Site #	Adjacent Key	Probable Cause[1]	Suggested Management[2]	Comments
7	Marquesas Keys	S	ED, EN	From large vessel in early 1980s, now enlarged
129	Wisteria Island	C, L, S	C, ED, EN	Heavily traveled anchorage on east side of Key West Channel
138	Fleming Key	I, S	C, ED	At shallow end of a natural channel
158	Stock Island	A	ED, EN	Boats accessing residential area in shallow water
160	Key West	A, L	ED, EN	Cow Key Channel live-aboard anchorage and Cow Key Channel south of bridge
170	Stock Island	S	C, ED, EN	Large vessels shortcutting into Boca Chica Channel
231	Geiger Key	A, I, P, S	C, ED, EN	Access to Geiger Key Marina and area

[1] *Probable Cause:* A = access point, C = poor channel markers, I = illegal aids to navigation, L = live-aboards, P = proximity, S = shortcut.

[2] *Suggested Management:* C = new or improved markers, ED = education, EN = better enforcement, R = restricted area.

than tripled: from 235,000 to 716,000. Clearly, not only is the population increasing, but the percentage of the population that owns boats is also increasing. Substantial increases in both population and number of vessels suggest that our state's water resources are being used at an increasing rate, and therefore its seagrasses are in increasing danger of being damaged.

By 1992–93, total power-boat registration for the 31 counties in this survey had reached 493,406 vessels (Bureau of Vessel Titles and Registrations 1994). The greatest percentage of boats in most coastal counties were registered as pleasure boats (Table 10). For the 31 counties in this study, only 6.4 percent of vessels were registered as commercial craft. The five counties with the greatest number of vessel registrations were Dade, Pinellas, Broward, Hillsborough, and Lee. These five counties contained 40.6 percent of all vessels registered in the 31 coastal counties in this study. The number of registered vessels in the five counties with the greatest acreage of M/S scarring was 156,899 in 1992–93, which is 14 times greater than that of the registered vessels in the five counties that had the least M/S scarring (11,031 acres) and that also had substantial seagrass acreage. In four of the five counties with the most registered craft, M/S scarring of seagrasses was also extensive (25,160 acres or 39 percent). In Broward County, scarring levels were low because it had only slightly more than one acre of seagrasses (based on small-scale photography).

The number of vessels registered in a county is not always a predictor of seagrass scarring in that county. Many counties with large numbers of registered watercraft lack substantial seagrass acreage. For example, Palm Beach County has 30,929 and Broward County has 42,612 registered vessels (Table 10), but each has less than 20 acres of M/S scarring (Table 2). In contrast, Monroe County has a moderate number of vessels registered (20,163) but contains the greatest acreage of M/S scarring in the state.

Whether a vessel is used for commercial or recreational purposes may influence where it is predominantly used. Commercial vessels are usually larger, work farther offshore, and are limited to a few ports with deeper access; smaller vessels can be trailered to attractive inshore fishing and watersports areas such as the Florida Keys and Charlotte Harbor. Pleasure boats (excluding sailboats) in most counties compose more than 90 percent of registered vessels (Table 10). In Monroe County, by contrast, only 80 percent (16,152) of the vessels are registered as pleasure boats; the remainder are registered as commercial vessels. Pleasure-boat registrations indicate where trailering may likely originate. Therefore, seagrass scarring in the Florida Keys may be caused in part by smaller boats trailered in from Palm Beach, Dade, and Broward counties and elsewhere. Nevertheless, seagrass scarring is not limited to a single group of boaters; all user-groups scar seagrasses to some degree.

Table 10. *Vessel registrations in 1992–1993 in the 31 Florida coastal counties in this study. Table does not include sailboat registrations.*

County	Pleasure Craft	Percentage Pleasure Craft	Commercial and Dealer Craft	Total Watercraft	County Rank
Bay	13,212	89.9	1,488	14,700	15
Brevard	25,763	93.8	1,716	27,479	7
Broward	39,930	93.7	2,682	42,612	3
Charlotte	14,004	93.7	947	14,951	14
Citrus	11,445	91.7	1,039	12,484	19
Collier	13,791	92.2	1,171	14,962	13
Dade	44,542	95.2	2,231	46,773	1
Dixie	1,544	77.0	461	2,005	30
Escambia	15,297	96.6	537	15,834	11
Franklin	1,424	57.7	1,045	2,469	27
Gulf	1,866	86.8	284	2,150	29
Hernando	5,293	96.1	212	5,505	23
Hillsborough	35,126	97.3	973	36,099	4
Indian River	7,796	94.1	492	8,288	21
Jefferson	669	96.3	26	695	31
Lee	29,409	93.6	2,007	31,416	5
Levy	2,162	86.1	348	2,510	26
Manatee	12,865	94.5	752	13,617	17
Martin	12,041	94.0	767	12,808	18
Monroe	16,152	80.1	4,011	20,163	8
Okaloosa	13,059	94.3	795	13,854	16
Palm Beach	29,862	96.6	1,067	30,929	6
Pasco	14,800	96.6	528	15,328	12
Pinellas	41,317	94.8	2,279	43,596	2
Santa Rosa	7,377	95.4	359	7,736	22
Sarasota	16,272	95.0	848	17,120	10
St. Lucie	8,839	94.2	543	9,382	20
Taylor	2,399	91.0	237	2,636	25
Volusia	18,286	95.4	876	19,162	9
Wakulla	3,221	86.4	509	3,730	24
Walton	2,308	95.6	105	2,413	28

Table 11. *Vessel registrations in 1992–93 (Bureau of Vessel Titles and Registrations 1994) in the five regions of Florida demarcated in this survey (see Figure 8). Table does not include sailboat registrations.*

Region	Total Watercraft	Pleasure Craft (PC)	% Pleasure Craft	Regional Rank PC	Regional Rank %PC
1. Panhandle	59,156	54,525	92.2	4	4
2. Big Bend	44,893	41,533	92.5	5	3
3. Gulf Peninsula	156,799	148,993	95.0	1	1
4. Atlantic Peninsula	108,048	102,587	94.9	3	2
5. South Florida	124,510	114,415	91.9	2	5
Total	493,406	462,053	93.6	—	—

On a regional basis, vessel registrations were greatest in the Gulf Peninsula region (Table 11). Vessel registrations in the Panhandle and Big Bend regions were insignificant compared to those in the other three regions. The Gulf Peninsula region not only had the greatest number of registered vessels, it also had the greatest percentage registered as pleasure craft (95 percent) and the most M/S scarring. The South Florida region was second in the number of registered vessels and nearly equal to the Gulf Peninsula region in M/S scarring. The Gulf Peninsula and South Florida regions contained 57 percent of all registered vessels in the 31 coastal counties in this study. The lowest number of registered vessels was in the Big Bend region (9.1 percent).

Many authors have speculated on the situations in which seagrasses are scarred (e.g., Woodburn et al. 1957, Godcharles 1971, Eleuterius 1987, Zieman and Zieman 1989, Wilderness Society et al. 1990). Our discussions with boaters, as well as our personal experiences, suggest that scarring of seagrasses could result when one or more of the following situations occur:

- when boaters misjudge water depth and accidentally scar seagrass beds;
- when boaters who lack navigational charts or the skill to use them stray from poorly marked channels and accidentally scar seagrass beds;
- when boaters intentionally leave marked channels to take shortcuts through shallow seagrass beds, knowing that seagrasses may be scarred;
- when boaters carelessly navigate in shallow seagrass beds because they believe scars heal quickly;
- when inexperienced boaters engage in recreational and commercial fishing in shallow seagrass flats, thinking that their boat's designed draft is not deep enough to scar seagrasses or that the design will prevent damage to their boat;
- when boaters overload their vessels, causing deeper drafts than the boaters realize;
- when boaters anchor over shallow seagrass beds, where their boats swing at anchor and scar seagrasses;
- when boaters intentionally prop-dredge to create a channel; and
- when inexperienced boaters, ignorant of what seagrasses are and the benefits they provide, accept as the behavioral norm local boating customs that disregard the environment.

The situations that promote scarring can be grouped into two general categories: (1) All too often, boaters accidentally or intentionally pass through water that is too shallow for the draft of their vessels. The average size, draft, and power of vessels are increasing; therefore, bigger, more powerful vessels are being navigated through shallow waters and are scarring more seagrass acreage. Also, water sports often occur in shallow water, although suitable deeper water may be found nearby. Boaters use flats boats, which are designed to operate in shallow water, to gain access to more remote, shallow seagrass beds. However, inexperienced users of *flats* boats, ignorant of the proper use of such boats and the great value of seagrasses, may extensively scar shallow seagrass beds in areas near marinas and launching ramps.

Inexperienced boaters, unfamiliar with the location of channels and often lacking navigational charts, travel through areas where official channel markers are infrequent or poorly located. Some channel markers are not located as shown on charts, and many are immediately adjacent to shallow-water seagrasses. Furthermore, many boaters are unfamiliar with the meanings of U.S. Coast Guard Aids to Navigation; hence, a single marker may confuse an inexperienced boater who is unable to read either the marker or water depth. Running aground is more likely if a boater passes on the wrong side of a marker located on the edge of a seagrass flat. Markers in some channels do not extend an adequate distance beyond the ends of channels to discourage boaters from crossing the edges of seagrass beds. Notably, many M/S-scarred seagrasses are in or adjacent to the ends of officially marked channels.

Illegal aids to navigation (e.g., PVC, wood, or metal posts and marker buoys) are widespread, especially in the Florida Keys. Only those who place these markers know what is intended. Often these illegal markers indicate where prop-dredging has deepened shallow areas so small boats can get between deeper areas. Boaters in larger vessels may attempt to use such markers and unexpectedly pass through water too shallow for their boats.

(2) Coastal property is popular because it allows direct access to the water. Extensive shoreline development in shallow bays and adjacent to shallow seagrass flats results in increased scarring. Some seagrass scarring is caused by boaters who attempt to gain access to shoreline development and by coastal landowners—and their families and friends—boating in nearby shallows. Many dredged canals leading from residential areas terminate in relatively shallow water (Figure 11). Current state and county rules in many areas limit new docks to waters greater than a specific depth at low tide, but many old docks are located in shallow water and have poorly defined access channels, if they have them at all.

Many older access channels in open water are subject to sedimentation and are maintained by prop-dredging. Development is not just restricted to uplands. The number of live-aboard vessels has increased in some areas. Scarring of seagrasses by hulls, anchors, and chains occurs as live-aboard vessels (and other boats) swing at anchor over shallow seagrass beds (Kruer 1994).

The increasing number of access points—such as boat launching ramps—has also contributed to seagrass scarring. Boating-access areas are usually located in sheltered areas, where seagrasses are more likely to occur. Hundreds of commercial marinas, watercraft rentals, and public boat ramps are near shallow seagrass beds where few channel markers exist. Because these channels are usually subject to heavy sedimentation, regular dredging is often needed to keep access open. Some of the most severely scarred areas in Florida are near marinas catering to flats fishermen in the Florida Keys.

Management Options

When state funds for seagrass management are limited, the money should be invested in those counties that have the greatest acreage of M/S-scarred seagrasses (e.g., Monroe County). However, if the severity of seagrass-habitat loss in a county is related to the extent of seagrasses in that county, then counties with both moderate seagrass acreage and more intense scarring may merit similar attention when management programs are being developed. Based on a scarring index (SI) in which the relative percentage of M/S scarring in a county is divided by the relative percentage of total seagrass acreage for that county (Table 3), the more threatened counties are Hillsborough (19.0), Charlotte (18.4), Collier (13.0), Pinellas (10.2), Manatee (9.4), Volusia (7.0), and Lee (6.9).

When assigning management priorities, however, other aspects of scarring extent must also be considered. Because extensive areas of seagrasses are in water depths greater than six feet, where they are unlikely to be scarred, including these acreages in SI calculations lessens the apparent extent of scarring in some counties. If deeper seagrass beds are excluded from the SI calculations, then county rankings would be considerably different. For example, Monroe County—which has a high degree of M/S scarring—would rank low using only an SI value because of the county's

Figure 11. *Example of a channel serving a residential area and ending in a shallow seagrass bed.*

extensive seagrass acreage, much of which is not vulnerable to scarring. Therefore, common sense must be used in determining where state management monies are spent. Basing decisions on both the extent of M/S scarring and on an SI value suggests that the principal foci for scarring-management programs should be Charlotte, Dade, Hillsborough, Lee, Manatee, Monroe, and Pinellas counties. Also ranking high in concern are Brevard, Citrus, Collier, Pasco, and Volusia counties.

Four-Point Approach

Ample justification now exists to reduce scarring of seagrasses. A multifaceted approach is necessary to deal with the wide variety of user-groups, activities, and types of physical perturbations. Below is a four-point approach, used by some local governments (e.g., Barker and Garrett 1992), that can form the basis for an effective statewide management program. Effective implementation of this comprehensive approach in plans designed for specific locales should initially reduce seagrass losses at *moderately* and *severely* scarred sites and slow the increase in scarring at sites having only light scarring. Modifications to management programs developed for specific areas should reduce seagrass scarring, over the long term, to levels that do not significantly affect habitat quality.

1. Education

Education is an essential part of any effort to make all boaters—tourists and residents alike—understand the sensitive nature of Florida's shallow seagrass communities. Florida, with its millions of visitors each year, is one of the most popular boating, diving, and fishing destinations in the world. These boaters can be educated through informative pamphlets available at marinas and boater-registration locations; through boating classes; through boat-user's guides and maps; through public-school seminars; through signs at launching ramps; and through organizations such as the Florida Conservation Association (FCA), the Organized Fisherman of Florida (OFF), and the U.S. Coast Guard Auxiliary and Power Squadron (Kenworthy et al. 1988, Barker and Garrett 1992, Folit and Morris 1992). Shallow-water fishing guides and commercial fishermen—who have strong interests in the health of Florida's seagrass resources—should use peer pressure to reduce any scarring that is caused by their user-groups. Power Squadron and Coast Guard Auxiliary boating courses should include educational information on the importance of seagrass beds and should emphasize their protection as part of a safe-boating curriculum.

In areas where new visitors and seasonal residents are in continual flux, however, additional approaches to accomplish resource-management goals should be explored. Government agencies need to be persistent in communicating the problem of seagrass scarring to the public. Single-year efforts do not have the same effect on seasonal populations—which change year to year—that long-term, regular programs do. Aerial photographs that show scarred seagrass beds in graphic detail have proven useful in educating managers, decision-makers, and the public. This approach could be used to communicate seagrass-protection needs to seasonal residents and tourists at areas they are likely to visit (e.g., at boat-launching ramps). Communicating the need to limit the size, draft, loads (tonnage), and power of vessels in shallow seagrass beds is an important educational goal.

2. Channel Marking (Aids to Navigation)

Conventional USCG-approved markers are helpful in deeper channels, but markers should be located away from the edges of shallow seagrass flats to provide a wider buffer against scarring. Markers should be gated (paired) in most locations and should extend well beyond the ends of channels. Marking channels clearly—especially with easily visible, reflective arrows—will benefit all boaters by showing them the correct passage, which would improve boating safety and at the same time minimize incidental scarring of seagrasses by boaters who stray out of unmarked channels.

Simple, easily installed and maintained markers with reflective directional arrows could be effective deterrents to seagrass scarring but may not conform to official USCG requirements. The channel-marking system used by Everglades National Park has directional arrows and is successful, but it needs some refinement (Skip Snow, personal communication). Monroe County has addressed the need for additional channel marking through their Department of Marine Resources, which released a draft Boating Impact Management Plan (Barker and Garrett 1992). It will eventually be incorporated, in part, into the management plan for the Florida Keys National Marine Sanctuary (FKNMS).

As channel-marking criteria are established and new markers are put in place, illegal aids to navigation should be removed. Often, channels are prop-dredged through seagrasses and between mangroves, even though an existing channel is available just a short distance away. In some cases, existing prop-dredged channels should be closed off by installing reflective pilings to block access and thus allow scarred seagrasses to recover. The benefits to the resource brought by an effective channel-marker system are negated if illegal markers and prop-dredged channels are allowed to proliferate.

3. Enforcement

Voluntary compliance has not proven effective in the past in resolving many resource-damage problems. Prop-dredging and other vessel-related damage to seagrasses should be viewed as destruction of protected public resources and as a form of unsafe boating. Past actions by all levels of government provide legal authority to enforce rules and regulations prohibiting prop-dredging (e.g., U.S.A. and FDER v. M.C.C. of Florida and Michael's Construction Co., Case No. 81-2373-CIV-EBD, Southern District of Florida). Citations and warnings for scarring seagrasses must be issued if an enforcement program is to be effective. Scarring of seagrasses would be substantially reduced, without placing undue hardship on the boating public, if existing legal authority were fully exerted.

Scarring of seagrasses is often willful, particularly when it is repetitive. Florida has laws that can protect natural resources from willful and reckless damage (e.g., Reckless or careless operation of a vessel. F.S. 327.3; "Duty of the Board of Trustees of the Internal Improvement Fund to protect, etc., state lands…", F.S. 253.05; "State attorneys, other prosecuting officers of the state or county…county sheriffs and their deputies…" to assist in protecting state lands F.S. 253.04; and even F.S. 380.05, "Areas of critical state concern…"). The Florida Administrative Code, Chapter 18-14 discusses fines for damaging state lands.

4. Limited-Motoring Zones

Programs initiated by the FDEP, the U.S. Fish and Wildlife Service, and several counties use moderate restrictions, such as idle-speed or limited-motoring zones, to protect sensitive resources while allowing public access compatible with environmental protection. Shallow channels, flats, and embayments near developed areas should be protected before scarring problems become severe. Areas set aside as preserves could be incorporated into a zoning program that limits certain types of access and offers protection (Barker and Garrett 1992). Weedon Island State Preserve (Pinellas County) has experienced a 95 percent reduction in the number of scars since it was closed to combustion engines—electric trolling motors are still allowed—in October 1990 (Folit and Morris 1992).

Limited access and closure are effective ways to reduce the scarring of seagrass beds; however, many issues must be considered when closing areas to watercraft. Work groups or task forces should be created to address issues that concern areas being considered for limited access or closure. Boating-effects studies, boating-use surveys, and collaboration with affected parties must always be considered. Involving all sides in planning at the beginning is imperative when closing an area to powered vessels. Task forces such as the one for Cockroach Bay Aquatic Preserve (Cockroach Bay Seagrass Task Force 1992) and the one for Fort DeSoto Park in Pinellas County are good examples of cooperation among user-groups in formulating boat-access restrictions to protect seagrasses.

The seagrass-management plan for Cockroach Bay Aquatic Preserve, located on the eastern shore of Tampa Bay, was implemented by Hillsborough County in August 1992. In certain areas, the plan limits vessel access and prohibits the use of combustion engines in waters that are less than 18 inches deep at mean low water. Also, the public is being educated using a number of approaches (e.g., through signs, posted at boat-launching ramps, that discuss seagrass protection). Channel markers will eventually have depth information posted. Law enforcement was increased in the preserve by adding a Hillsborough County Sheriff's Deputy and by deputizing the manager of the preserve. Seagrass recovery from scarring is being studied, and aerial photography is being used to monitor the amount of scarring in the preserve (Cockroach Bay Seagrass Task Force 1992).

Despite these steps, however, initial reports of their effectiveness are in some respects disappointing. Scarring extents in Cockroach Bay have increased by about 5000 linear feet in the first year (Dawes et al. 1994). Also, around entrances to the preserve, approximately 145,000 square feet of additional scarring was discovered, despite its cryptic nature (i.e., hidden by sedimentation). Overall, an additional 3.3 acres of seagrasses were scarred in one year within the preserve. In some areas of the preserve, voluntary compliance has not worked, and total closure has been implemented to alleviate scarring. Managers are looking into further measures to reduce scarring losses, such as proactive restoration and more rigorous regulation.

Pinellas County is implementing a similar program for Fort DeSoto Park, which is near the mouth of Tampa Bay. Motoring has been limited or completely restricted in some areas. Fort DeSoto Park has three types of limited-motoring zones: 1) *slow/minimum-wake zones* are intended to improve safety and reduce boat-wake effects, 2) *seagrass caution zones* inform of seagrass presence and encourage caution in boating, and 3) *boat-restriction zones* allow only poling and electric motoring. As in Cockroach Bay Aquatic Preserve, semiannual aerial surveys will be conducted so that changes in seagrass densities and scarring can be monitored and photographed for analysis. A final report is being prepared on the effectiveness of the program.

Concluding Remarks

Management programs to control seagrass scarring have been implemented by several local governments. Additional programs are needed for counties that have severe scarring problems. Allocating monies for these programs may be a low priority in some counties, however, and a more general statewide program may be justified. Currently, the state manages scarring in only a few state parks (e.g., Lignumvitae Botanical Site and John Pennecamp Coral Reef State Park). A statewide management program should be developed to protect seagrasses from scarring while still allowing for traditional water-related recreational and commercial activities. Combined with county programs, statewide management of scarring could effectively protect seagrass habitat.

Overregulating where scarring does not substantially alter system productivity may strain government budgets and needlessly irritate those attempting to enjoy the resource. Therefore, focusing resources in areas that are extensively scarred or that are vulnerable to increased scarring is of paramount importance. Educating the public about the more severely scarred areas will also reduce the extent of light scarring in other areas as citizens are made aware of the value of seagrasses. Nevertheless, management plans should ensure that site-specific seagrass protection does not shift M/S scarring to other, less scarred areas.

A single management approach, such as channel-marking alone, only partially addresses the problem of seagrass scarring. A combination of management techniques, along with long-term commitment, must be used to reduce the frequency and degree of scarring in seagrass beds. Some programs being implemented and tested use multifaceted approaches such as better educating the boating public, better marking of channels, limiting powerboat access in certain sensitive areas, and more effectively enforcing existing laws. Monitoring managed areas, both from the air and on site, is critical in determining the effectiveness of a management program.

Florida's waters are of special value for many reasons and are important at a national as well as state level. Florida's fishing industries depend on the health and vitality of shallow seagrass beds, as do diverse animal species—many of which are of endangered, threatened, or sensitive status. With the loss of seagrasses to scarring comes degradation and loss of critical animal habitat and, in some areas, a decrease in water quality. Nevertheless, preventing *all* seagrass scarring is impossible. With proper management, scarring can be reduced to a level that will reverse the cumulative damage to this critical resource. This report contributes knowledge that was lacking in past regulatory and management programs mandated to protect Florida's marine resources. Although the data presented in this report are of a broad nature, the report provides a basis for further and more refined management of areas subject to an increase in seagrass-resource use.

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APPENDIX A

Methodology for Analyzing Scar Data

MRGIS Integration

Geographic Information Systems (GIS) and related technologies have emerged as fundamental tools for synthesizing and analyzing complex spatial and statistical data. In our study, the final data taken from paper maps and charts were integrated into the Marine Resources GIS (MRGIS) at the Florida Marine Research Institute (FMRI) by the Coastal and Marine Resources Assessment (CAMRA) group.

In consideration of the geographic extent of the study, the varied scales of the base maps, and the data-collection methodology, CAMRA staff determined that the data would be better represented as a single, statewide coverage with a scale of 1:40,000. One factor that significantly influenced that decision was the existence of a 1:40,000-scale land coverage already within the MRGIS. Using this land coverage, digitization effort was minimized without substantially compromising the integrity of the information. The polygons delineating scarring were digitized and attributed to their appropriate scarring intensities. The resultant scarring coverage was registered to the 1:40,000-scale shoreline coverage.

After completing the digitization and attribution process, check plots were produced and compared to the original source maps to verify the presence and proper attribution of the polygons. Polygons that were inadvertently omitted from the coverage were added, and incorrect attributes were changed. A second iteration of this quality-assurance process was performed to ensure the completeness of these preliminary data on scarring.

In the next step of the integration process, we used the 1:40,000-scale land coverage to *erase* any portion of a polygon that had been drawn onto the land and subsequently digitized. *Erase* is an ARC/INFO command that creates a new coverage by removing portions of the polygons from one coverage that are within an *erase* region. In this case, the polygons in the land coverage define that *erase* region, and the portions of the digitized polygons that overlapped the land were removed. In essence, this procedure removed any portion of a polygon that was coincident with a land feature. This process was used to ensure the appropriate spatial coincidence between the polygons and the land features without having to digitize them. This minimized operator error on subsequent areal comparisons by ensuring coincidence of all arcs with other data sets contained in the MRGIS.

Following the *erase* process, the resultant coverage was *intersected* with a modified county coverage and used to calculate acreages scarred by class and county. *Intersect* is one of several overlay commands available in ARC/INFO. *Intersect* was used because the polygons in the coverage *(input* coverage) split where the polygons of the county boundaries *(intersect* coverage) overlap. Only those portions of polygons coincident between both *input* and *intersect* coverages were saved in the *output* coverage. All feature-attribute items from both coverages were carried in the attribute tables of the *output* coverage. If duplicate items were encountered, the item from the *input* coverage was maintained, and the one in the *intersect* coverage was dropped.

The original county coverage was obtained from the 1990, 1:100,000 TIGER census data for the state of Florida. The shoreline features were removed, and where required, the county boundaries were extended offshore to enclose the data just created and all the existing seagrass-distribution data. On the Atlantic coast, the three-mile offshore extensions of the original County Jurisdictional Boundaries were sufficient to meet our standards. On the Gulf coast, county boundaries were extended out to the nine-mile State Jurisdictional line. For Dade and Monroe counties, the offshore lines required further extension to ensure enclosure of all mapped seagrasses.

Creating a Statewide Seagrass Coverage

A statewide seagrass database consisting of the most recent seagrass data available was assembled. Data were obtained from various sources and integrated into the MRGIS (Appendix Table 1). Disparate seagrass data sets from such a wide variety of sources created integration difficulties. Data collected were of various dates, scales, seagrass classifications, and formats. For example, seagrass classifications ranged from species-specific values for the density of bottom cover to unique coding schemes. Although data created in-house or by one

Appendix Table 1. *Sources of data used to compile seagrass distributions for the 31 Florida coastal counties in this study.*

Coverage Name*	Counties Included	Date	Scale	Source
BENDGRASS	Citrus, Hernando, Jefferson, Levy, Pasco, Pinellas, Taylor	1983	1:40,000	Minerals Management Service (MMS)
CHARGRASS	Charlotte, Collier, Lee, Manatee, Sarasota	1982, 1987	1:24,000	Florida Dept. of Transportation, Florida Dept. of Environmental Protection, Mangrove Systems, Inc., FMRI
IRLGRASS	Brevard, Broward, Indian River, Martin, St. Lucie, Volusia	1992	1:24,000	St. Johns River Water Management District
PALMGRASS	Martin, Palm Beach	1990	1:24,000	Palm Beach County
PANGRASS	Bay, Escambia, Franklin, Gulf, Okaloosa, Santa Rosa, Wakulla, Walton	1982–1985	1:24,000	FMRI
SFGRASS	Dade, Monroe	1982–1986	1:40,000	Marszalek, Dade County, MMS, FMRI
TBAYGRASS	Hillsborough, Manatee, Pinellas, Sarasota	1990	1:24,000	Southwest Florida Water Management District, FMRI

* Identifying name for seagrass-coverage data in the Marine Resources Geographic Information System at the Florida Marine Research Institute (FMRI).

of the water-management districts were in ARC/INFO format, data from some sources were AutoCAD line files, which required conversion. This situation is not unique to this study. GIS and remote-sensing disciplines are currently investigating theoretical and technical difficulties associated with integrating data from disparate sources.

Some seagrass source data were distorted and required correction (e.g., data for Charlotte Harbor and the Big Bend region). In addition to correcting existing seagrass data sets and integrating non-ARC/INFO data, several gaps in the statewide seagrass-data coverage were identified and filled. Data needs for the area from Indian Rocks Beach to Anclote Key and a portion of Sarasota Bay were filled using 1990 SWFWMD 1:24,000-scale CIR aerials. Some minor gaps in the seagrass data from south Florida and the southern half of Estero Bay were interpreted from 1:24,000-scale CIR aerials borrowed from the SFWMD. The final statewide seagrass coverage was created in such a way that all of the seagrass attributes were combined and simplified to a single code that indicated presence or absence of seagrass. This coverage was then *intersected* with the same county coverage described above and used to calculate an acreage of mapped seagrasses for each coastal county represented in this study.

Error Reduction

A mapping effort of this scale and geographic extent cannot contain sufficient detail to account for subtle changes in bottom type. In many cases, polygons were not exclusively coincident with seagrasses but included areas of bare substrate, tidal flats, hardbottom, and channels. To evaluate the ramifications of this phenomenon, a comprehensive assessment of the potential overestimation of scarring was conducted, and suspect areas were identified. A new series of 1:40,000-scale checkplots were created that overlaid the erased polygons on the presence-absence seagrass data now contained in the MRGIS.

Digital coverages were combined and analytic tools in the GIS were used to calculate the degree of coincidence and shrinkage. *Shrinkage* describes the reduction in size of polygons so that they coincided with known seagrass-distribution data already in the MRGIS. In some regions of the state (e.g., the Big Bend region), the differences between the original scarring calculated and the corrected scarring values were minimal (coincidence approximately 100 percent). However, in other areas (e.g., Tampa Bay), corrected values decreased the original scarring calculations by nearly 40 percent. A series of 1:40,000-scale test plots were run to evaluate the cause of this variability and to determine if our correction methodology was sound.

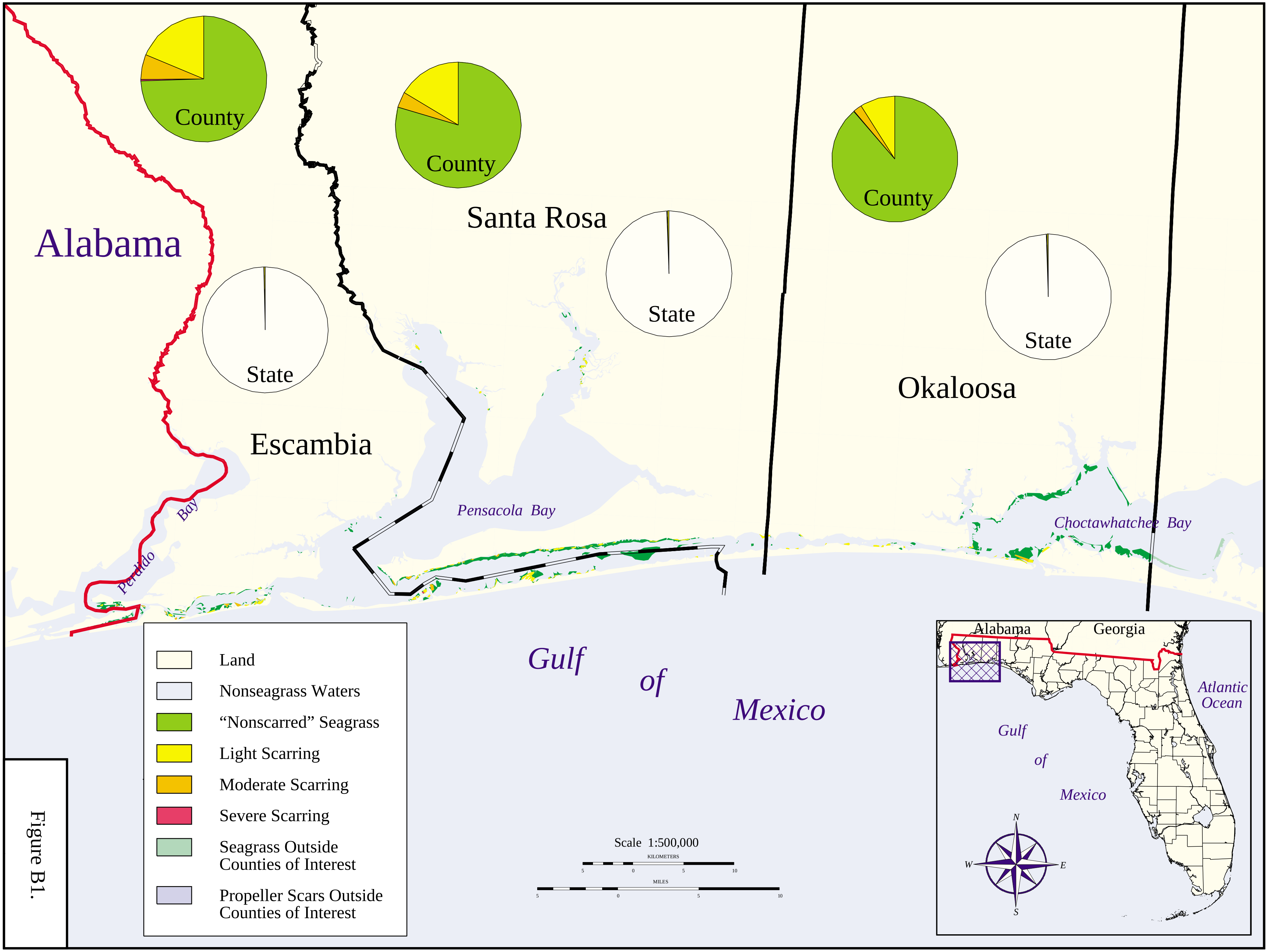
Variability between areas can be explained by several factors. For areas such as Tampa Bay—where the seagrass data were mapped with a high level of detail from high-resolution aerial photography (1:24,000)—polygons could be corrected with a great deal of confidence. In contrast, for regions like the Big Bend—where seagrass data were mapped from less detailed, smaller-scale photography—polygons were almost completely coincident with mapped seagrasses, and shrinkage was minimal. Seagrass distributions also affected the amount of correction needed. The more discontinuous (the patchier) the seagrass beds were, the greater the shrinkage was. Similarly, the shrinkage may be adversely affected by temporal differences between the seagrass source data and data from the aerial surveys. For example, seagrass-distribution data used in Charlotte Harbor date back to 1982, ten years before the aerial surveys were conducted for this study. Changes in seagrass distribution probably occurred during that time period. The effects of these potential influences could not be controlled with the methodological approach used in this study.

Polygons coincident with mapped seagrasses were categorized as Type I. Despite the shrinkage method used, these polygons would have remained in the data. In areas with questionable seagrass and scarring coincidence, each case was individually evaluated for accuracy. Most of the assessment in the Florida Keys was accepted without secondary evaluation because the survey was done under the auspices of the FMRI, and polygons that were generated were subjectively classified as Type II. Polygons were classified as Type II if they were not coincident with pre-existing, mapped seagrass distributions but were obviously present as part of existing seagrasses. Type-II polygons were included in the final data on scarring.

APPENDIX B

Geographic-Distribution Charts

Figures B-1 to B-13 show the geographic distributions of seagrasses and scarring in the 31 Florida coastal counties in this study. On each map are two pie diagrams for each county. The pie labeled *County* shows the percentage of scarring in each intensity category in that county. Consult Table 2 for acreages and Table 4 for percentages. The pie labeled *State* shows the percentage of scarring in that county for each intensity category relative to the total acreage of scarring in the state for each intensity category. Consult Table 3 for relative percentages for each county.



Alabama
County
State
Escambia
County
Santa Rosa
State
County
State
Okaloosa
Perdido
Bay
Pensacola Bay
Choctawhatchee Bay
Gulf
of
Mexico
Land
Nonseagrass Waters
"Nonscarred" Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Scale 1:500,000
KILOMETERS
5 0 5 10
MILES
5 0 5 10
Alabama
Georgia
Atlantic Ocean
Gulf
of
Mexico
N
S
E
W

Figure B1.

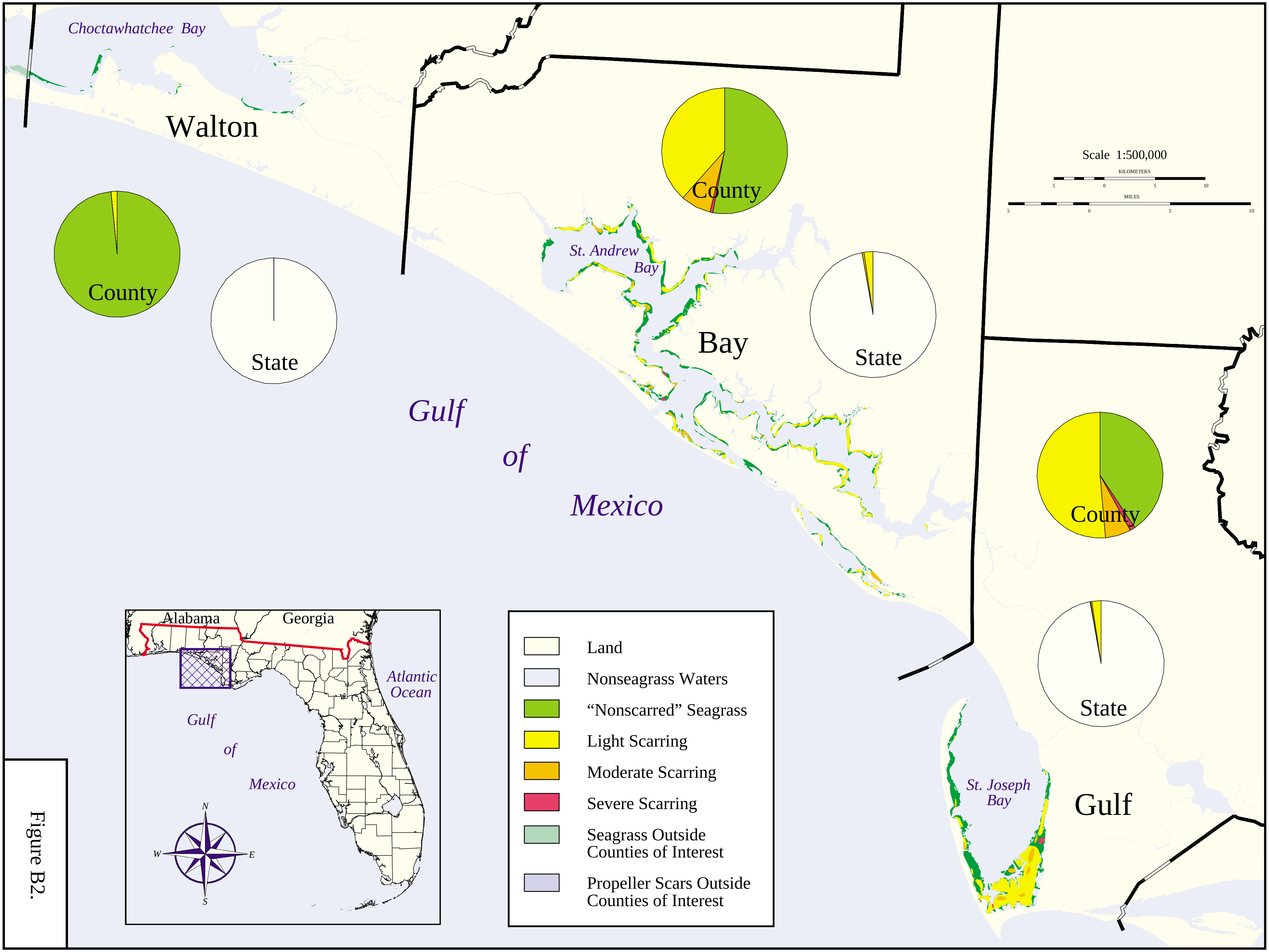

Choctawhatchee Bay
Walton
County
State
Gulf of Mexico
St. Andrew Bay
Bay
County
State
Scale 1:500,000
KILOMETERS
5 0 5 10
MILES
5 0 5 10
County
State
St. Joseph Bay
Gulf
Alabama
Georgia
Atlantic Ocean
Gulf of Mexico
N
W
E
S
Land
Nonseagrass Waters
“Nonscarred” Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest

Figure B2.

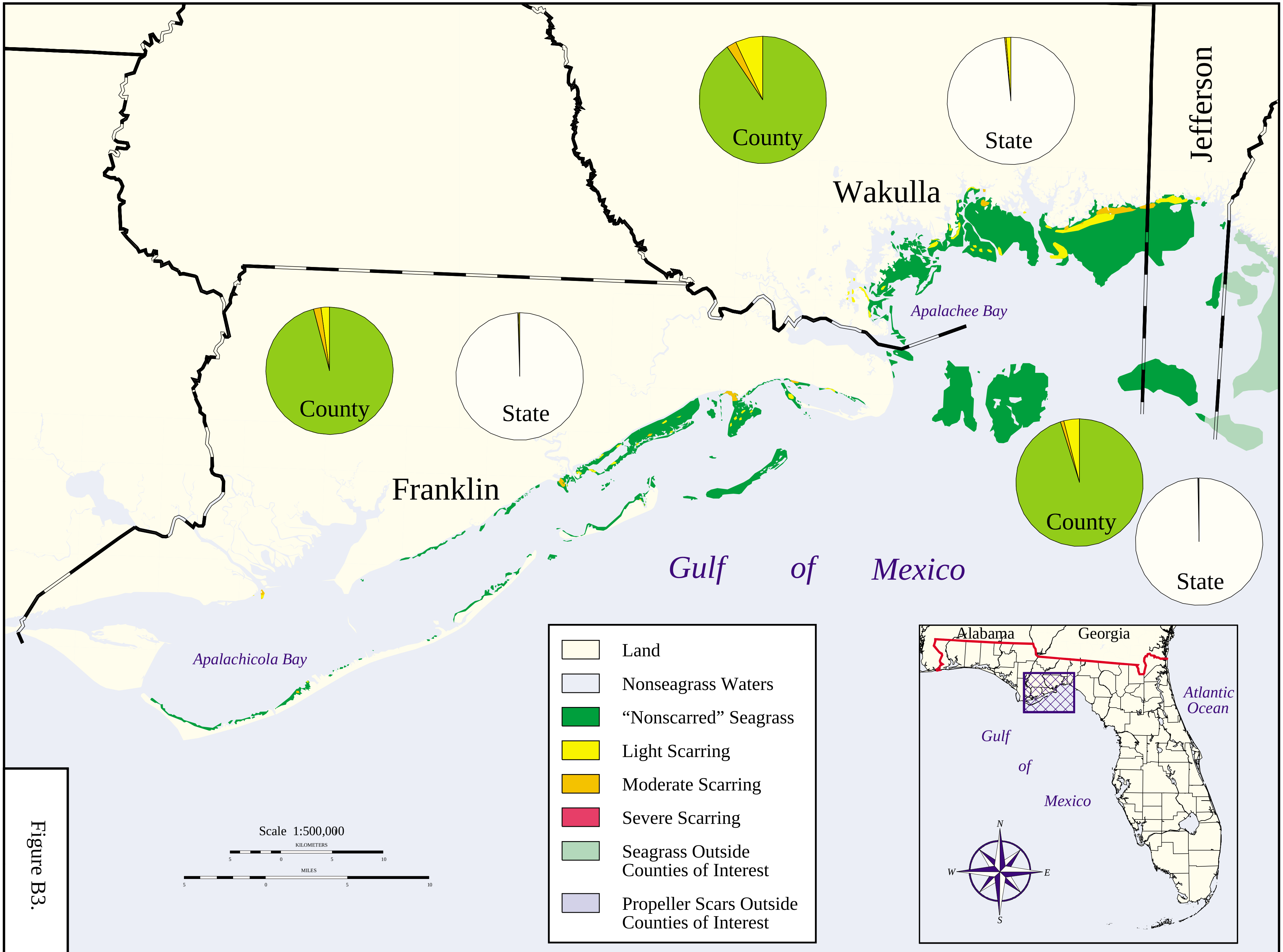
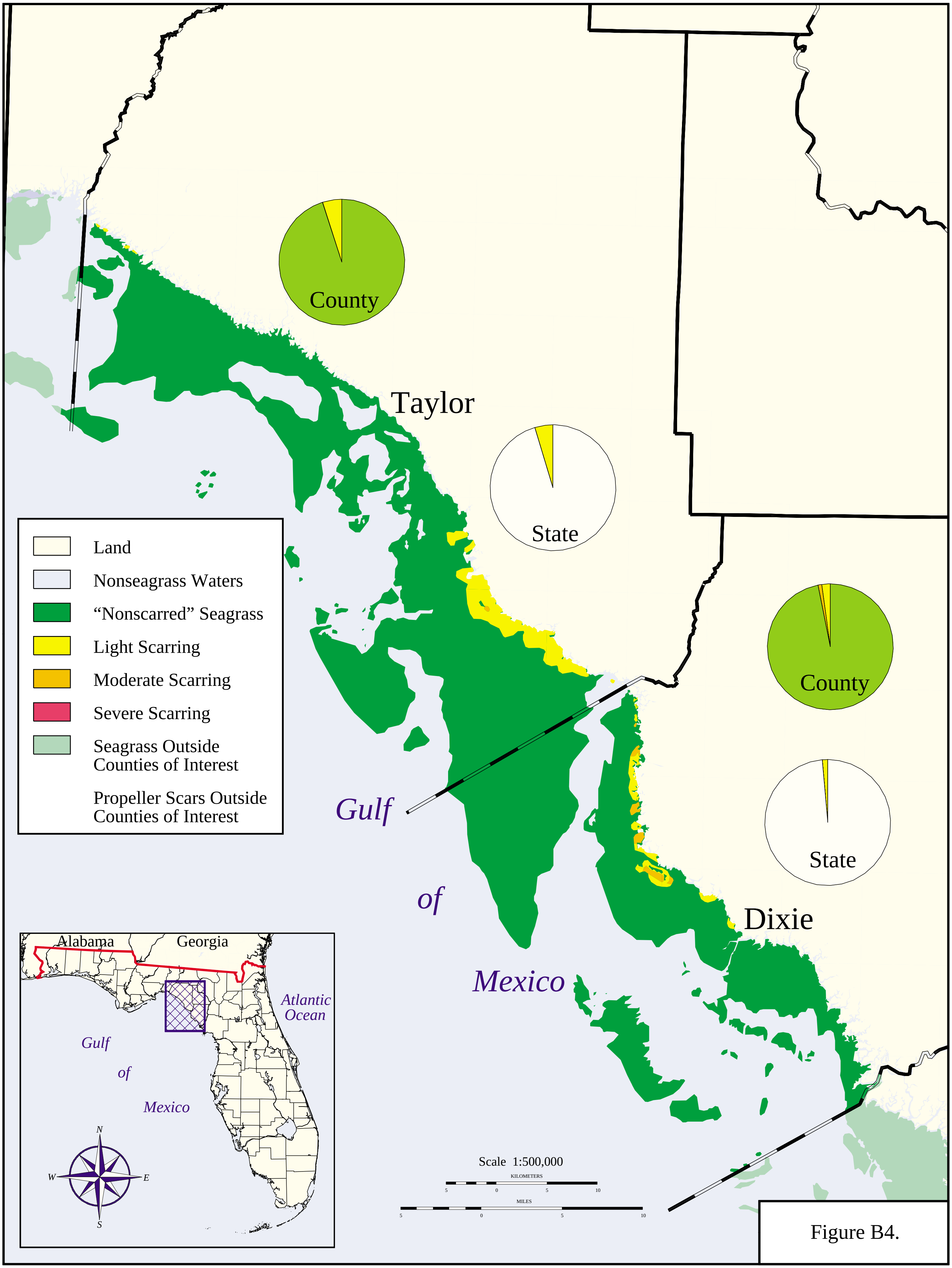
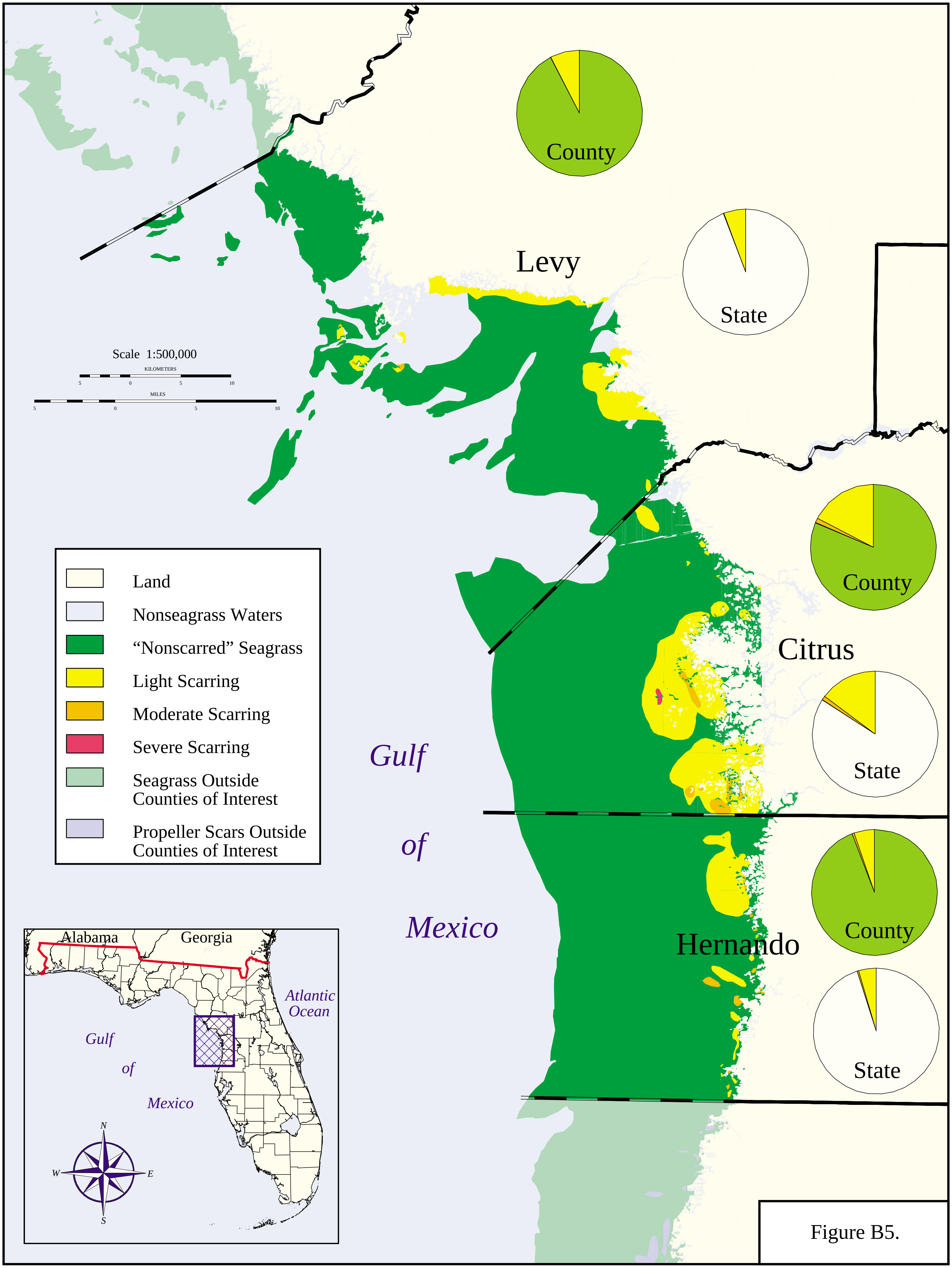

Jefferson
Wakulla
Franklin
County
State
County
State
County
State
Apalachee Bay
Apalachicola Bay
Gulf of Mexico
Land
Nonseagrass Waters
"Nonscarred" Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Alabama
Georgia
Atlantic Ocean
Gulf of Mexico
N
S
E
W
Scale 1:500,000
KILOMETERS
MILES

Figure B3.



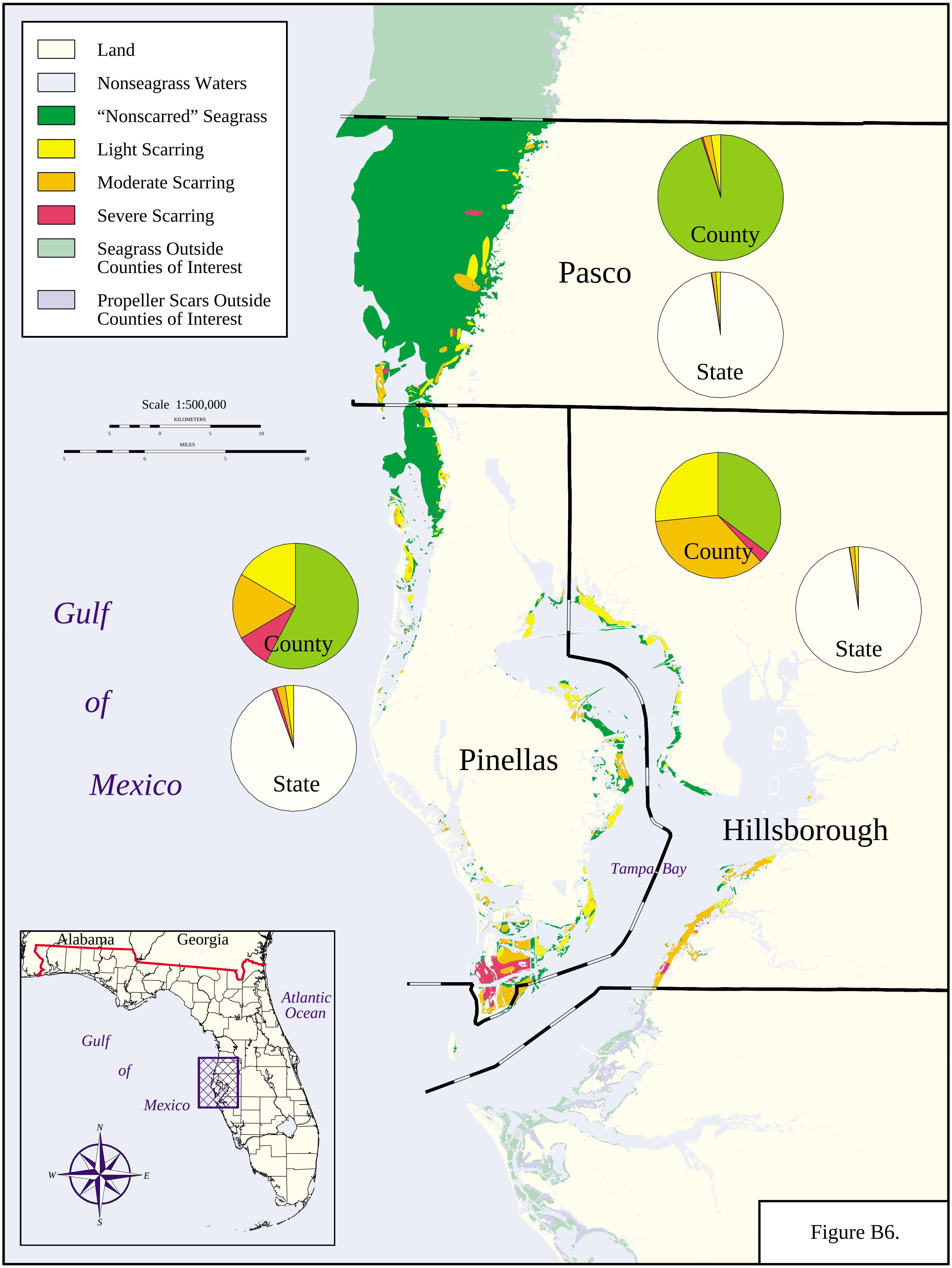
Taylor
County
State
Dixie
County
State
Gulf
of
Mexico
Land
Nonseagrass Waters
“Nonscarred” Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Alabama
Georgia
Atlantic Ocean
Gulf
of
Mexico
N
W
E
S
Scale 1:500,000
KILOMETERS
5
0
5
10
MILES
5
0
5
10

Figure B4.



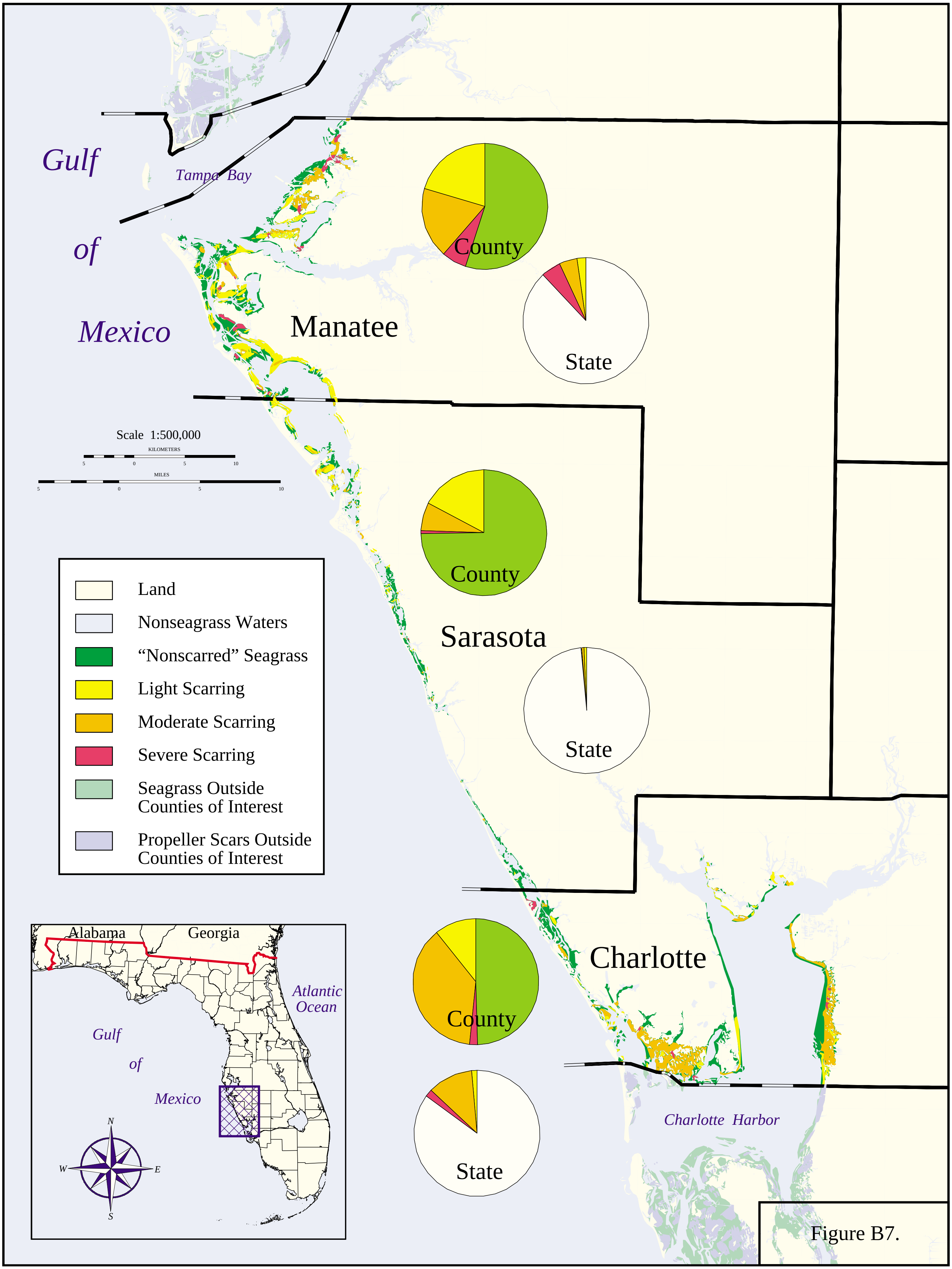
County
State
Levy
Scale 1:500,000
KILOMETERS
MILES
County
Citrus
State
Land
Nonseagrass Waters
"Nonscarred" Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Gulf
of
Mexico
County
Hernando
State
Alabama
Georgia
Atlantic Ocean
Gulf
of
Mexico
N
S
E
W

Figure B5.



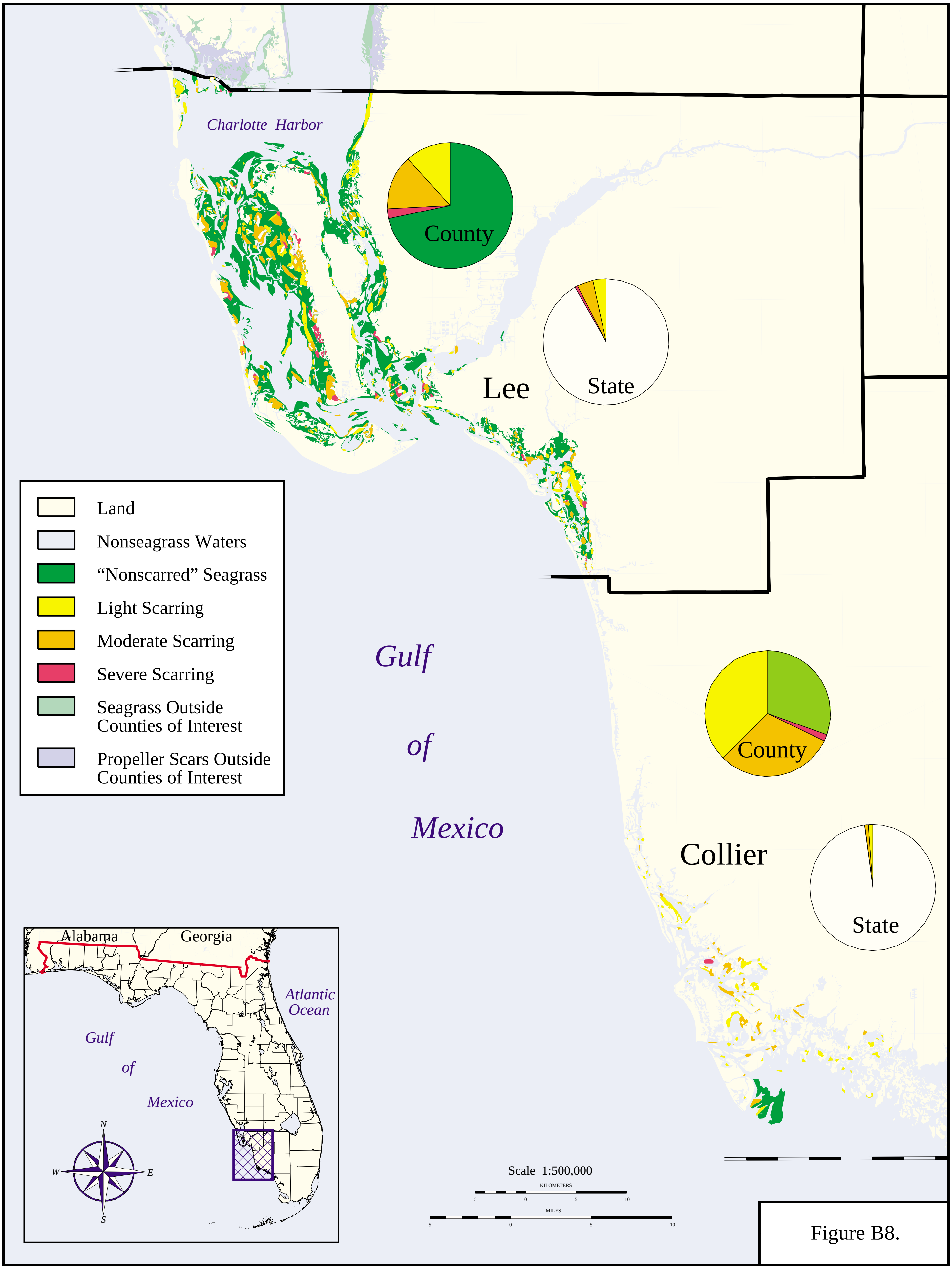
Land
Nonseagrass Waters
“Nonscarred” Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Scale 1:500,000
KILOMETERS
MILES
Pasco
County
State
Pinellas
Hillsborough
Gulf of Mexico
Tampa Bay
Alabama
Georgia
Atlantic Ocean
N
S
E
W

Figure B6.



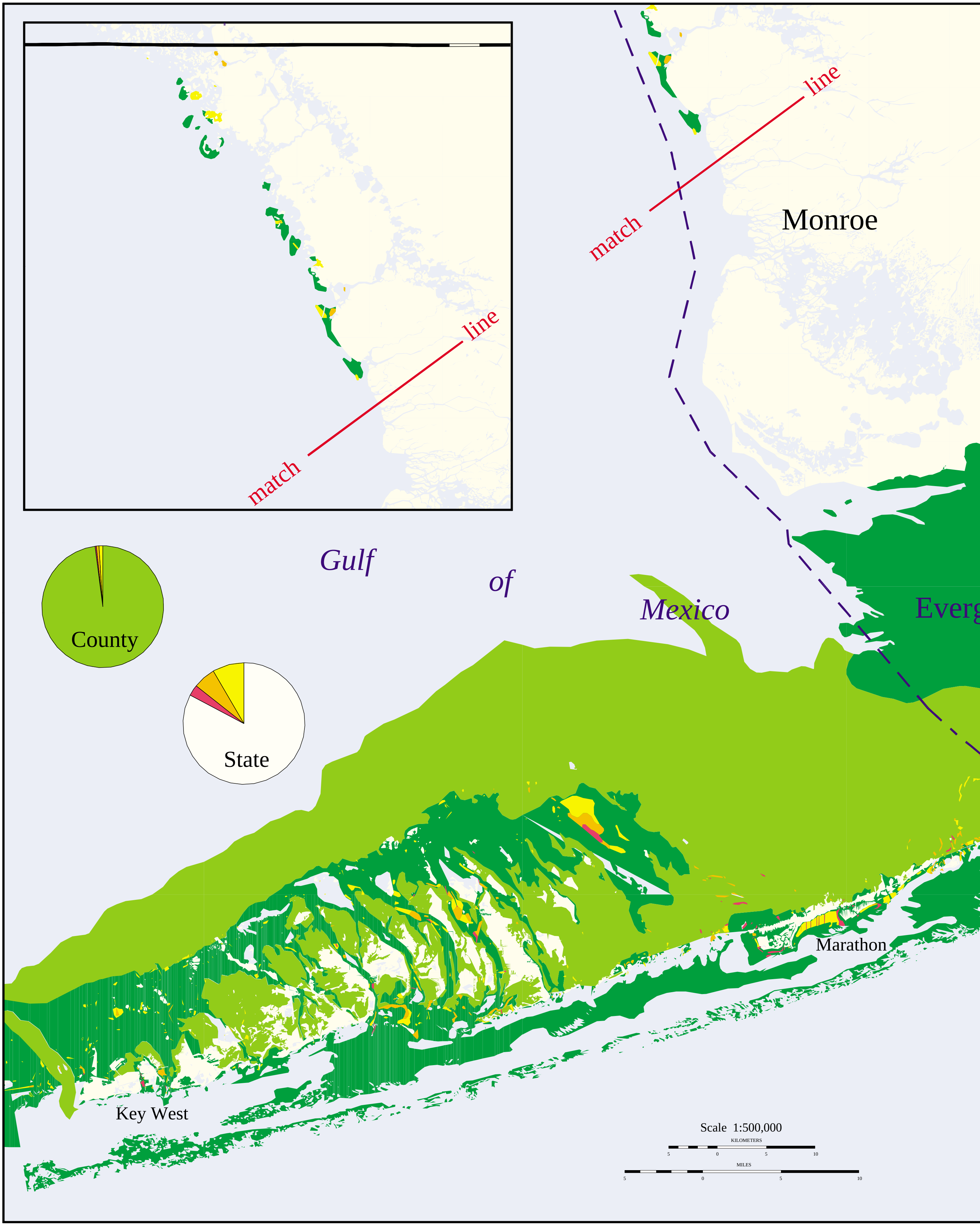
Gulf
of
Mexico
Tampa Bay
Manatee
County
State
Sarasota
County
State
Charlotte
County
State
Charlotte Harbor
Scale 1:500,000
KILOMETERS
5
0
5
10
MILES
5
0
5
10
Land
Nonseagrass Waters
"Nonscarred" Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Alabama
Georgia
Atlantic Ocean
Gulf
of
Mexico
N
W
E
S

Figure B7.



Charlotte Harbor
County
State
Lee
County
State
Collier
Gulf
of
Mexico
Land
Nonseagrass Waters
"Nonscarred" Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Alabama
Georgia
Atlantic Ocean
Gulf
of
Mexico
N
W
E
S
Scale 1:500,000
KILOMETERS
5 0 5 10
MILES
5 0 5 10

Figure B8.


match line
Monroe
Gulf
of
Mexico
Everg
County
State
Key West
Marathon
Scale 1:500,000
KILOMETERS
5 0 5 10
MILES
5 0 5 10

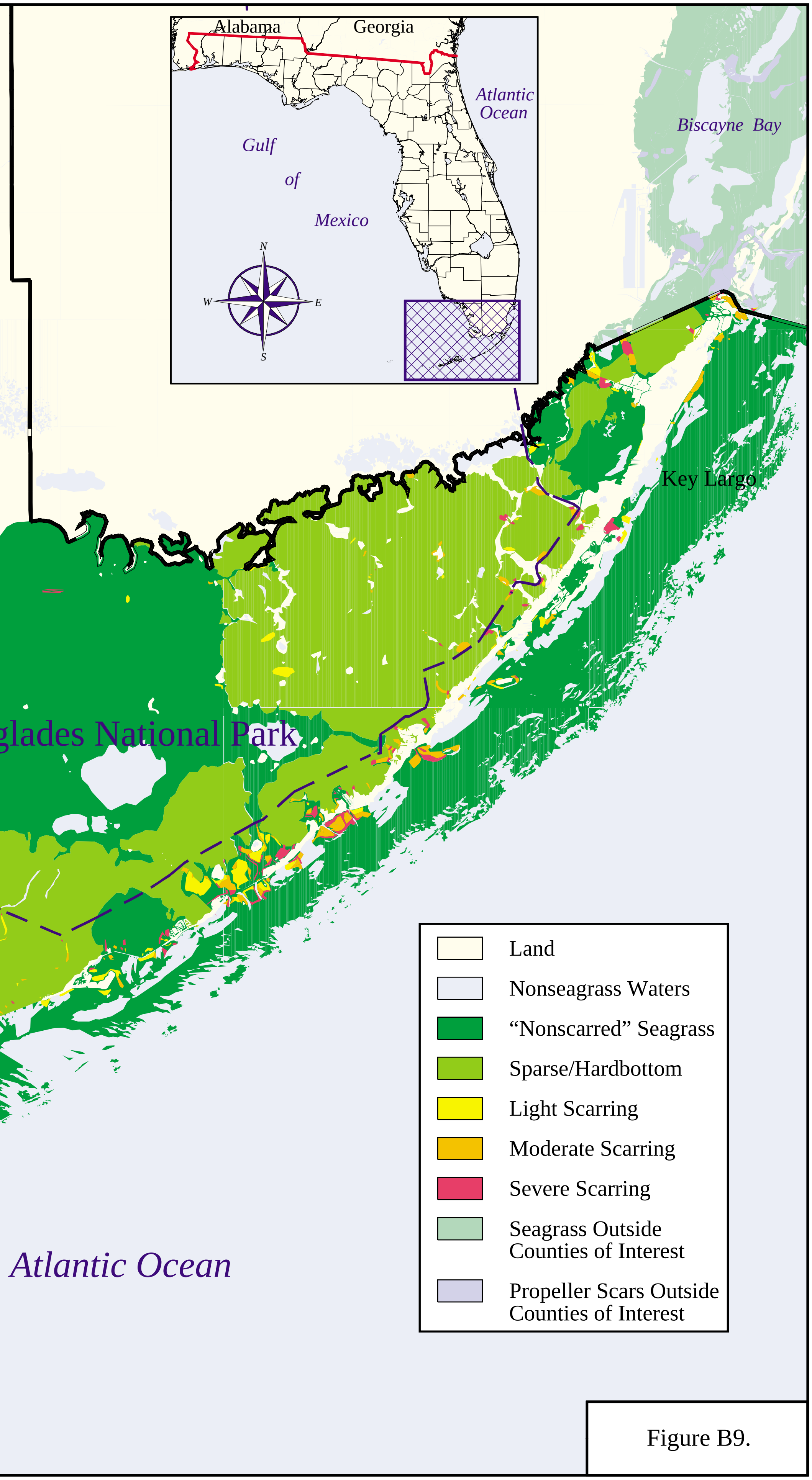

Alabama
Georgia
Atlantic
Ocean
Gulf
of
Mexico
N
W
E
S
Biscayne Bay
Key Largo
glades National Park
Atlantic Ocean
Land
Nonseagrass Waters
“Nonscarred” Seagrass
Sparse/Hardbottom
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside
Counties of Interest
Propeller Scars Outside
Counties of Interest

Figure B9.

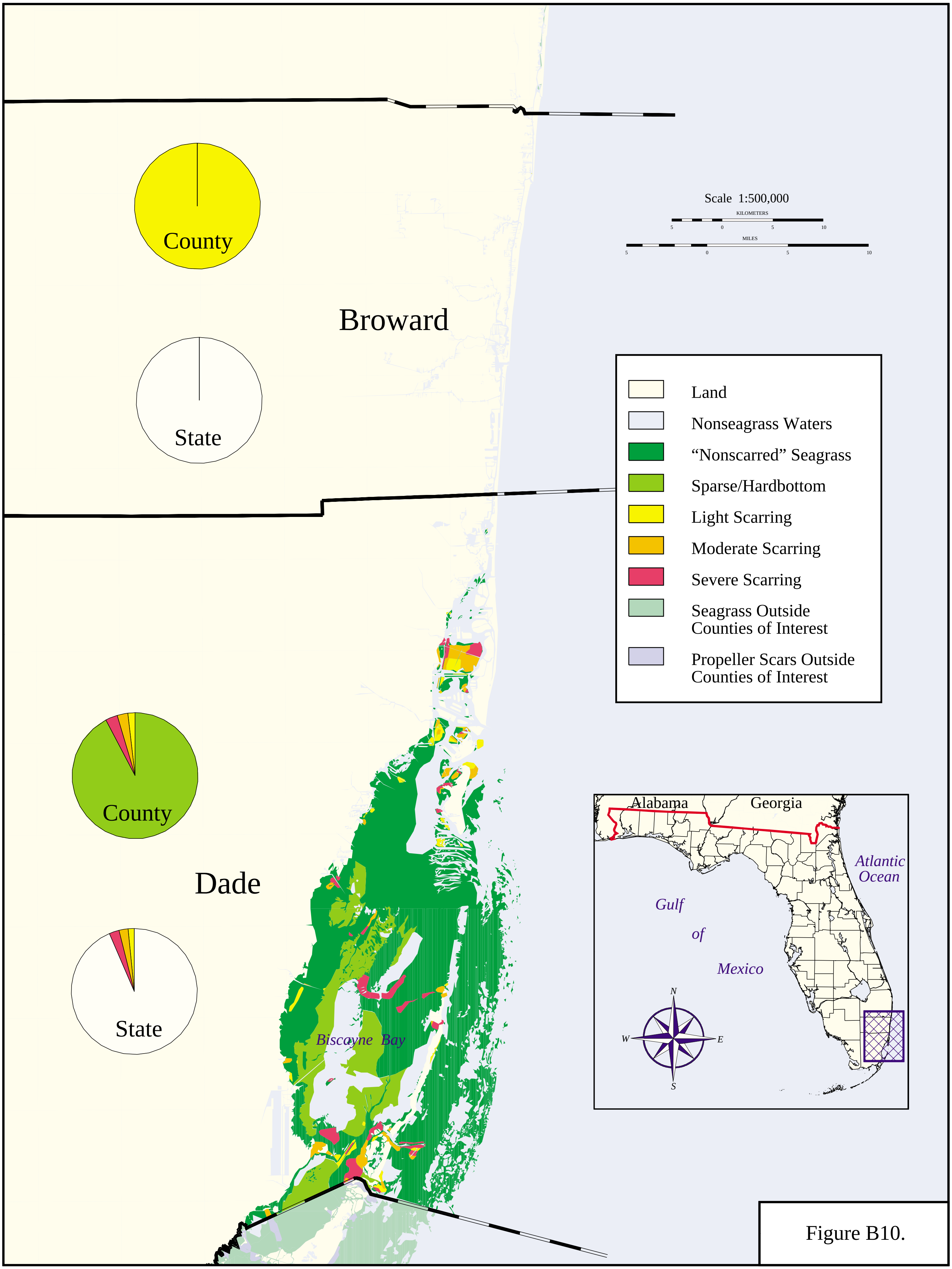
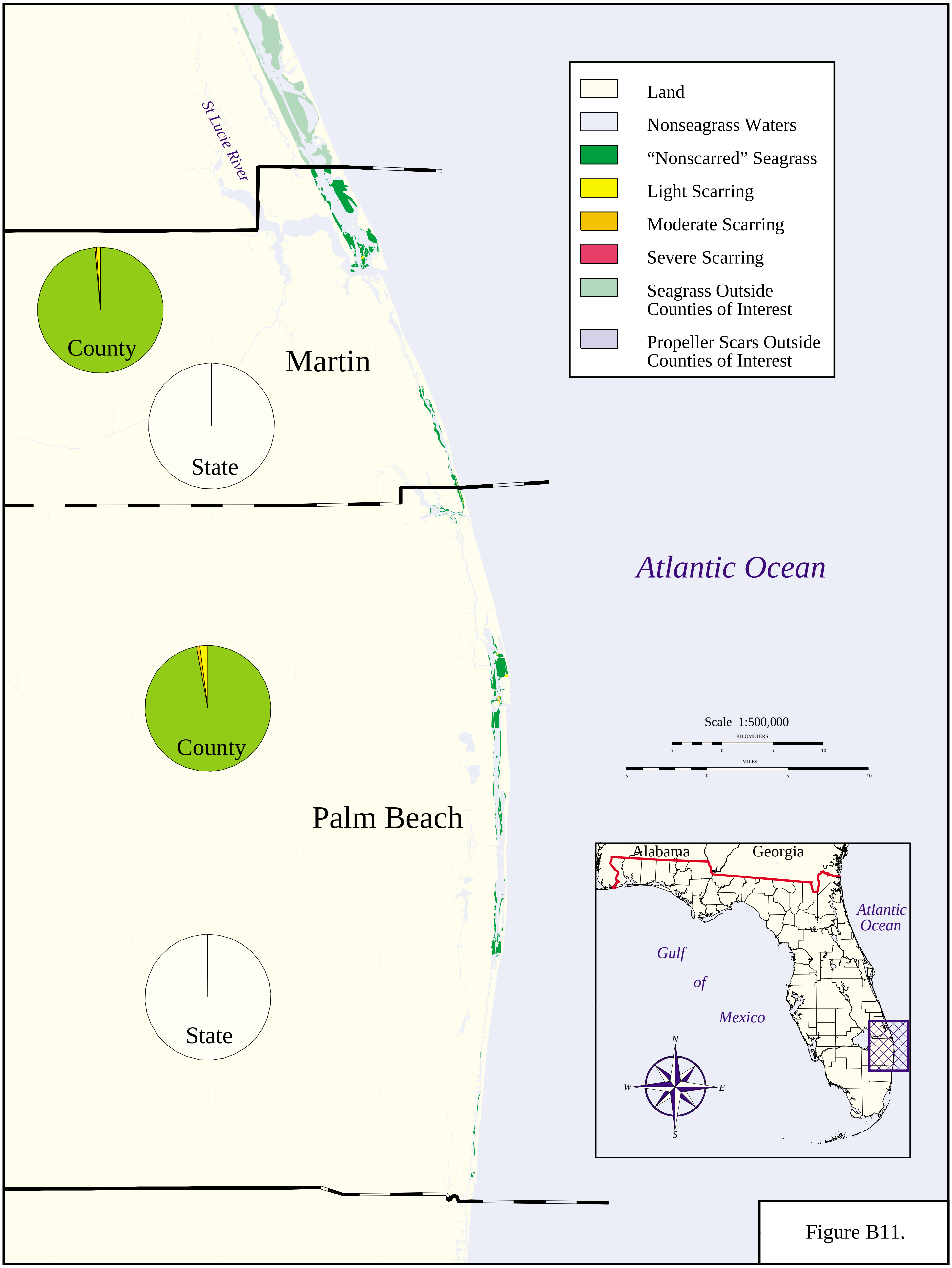
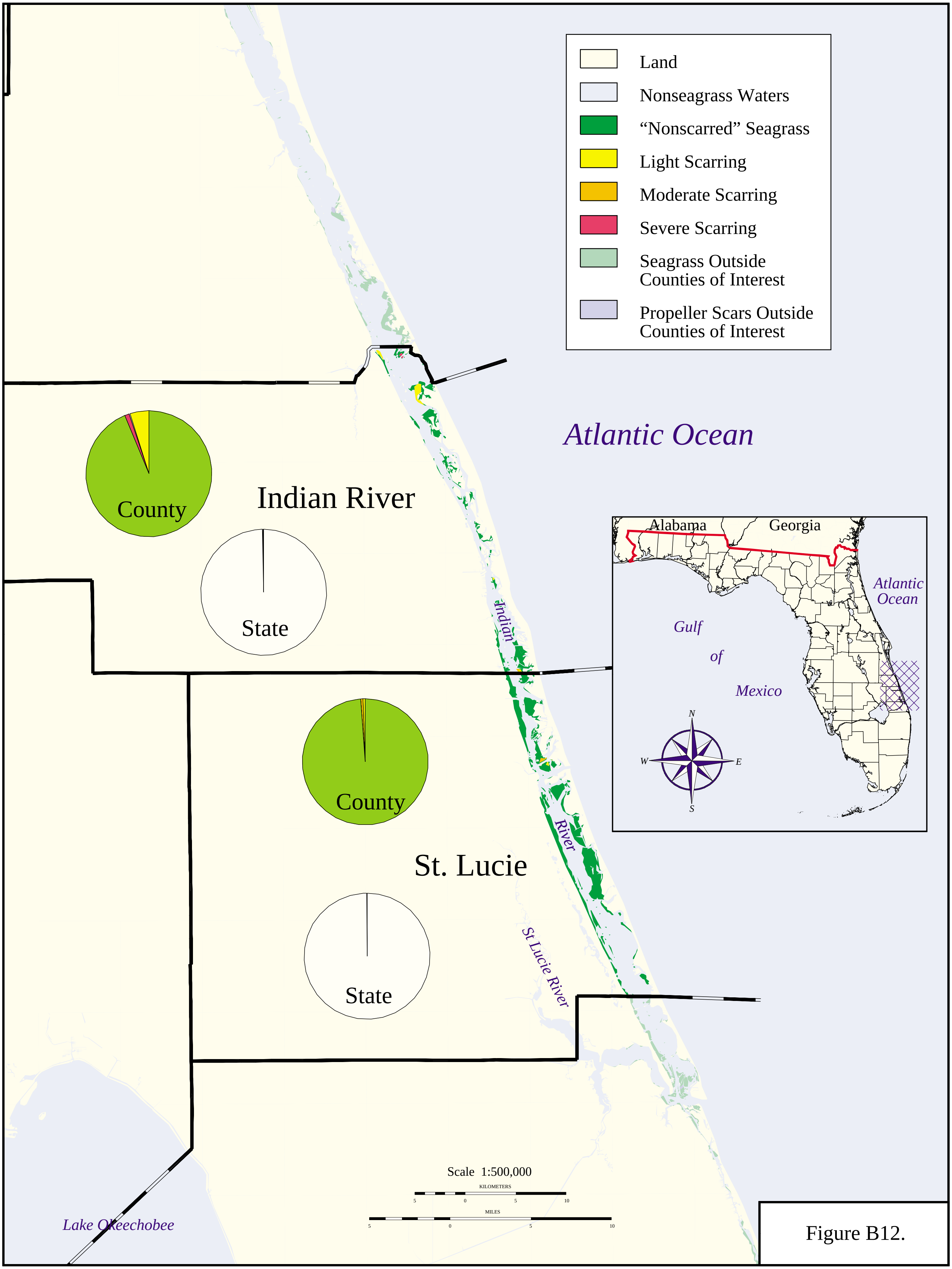

Broward
County
State
Dade
County
State
Biscayne Bay
Scale 1:500,000
KILOMETERS
5
0
5
10
MILES
5
0
5
10
Land
Nonseagrass Waters
"Nonscarred" Seagrass
Sparse/Hardbottom
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Alabama
Georgia
Atlantic Ocean
Gulf of Mexico
N
W
E
S

Figure B10.



Land
Nonseagrass Waters
“Nonscarred” Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
St Lucie River
Martin
County
State
Palm Beach
County
State
Atlantic Ocean
Scale 1:500,000
KILOMETERS
5 0 5 10
MILES
5 0 5 10
Alabama
Georgia
Atlantic Ocean
Gulf of Mexico
N
S
E
W

Figure B11.



Land
Nonseagrass Waters
"Nonscarred" Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Atlantic Ocean
Indian River
County
State
St. Lucie
County
State
Indian River
St Lucie River
Lake Okeechobee
Alabama
Georgia
Atlantic Ocean
Gulf of Mexico
N
E
S
W
Scale 1:500,000
KILOMETERS
5
0
5
10
MILES
5
0
5
10

Figure B12.

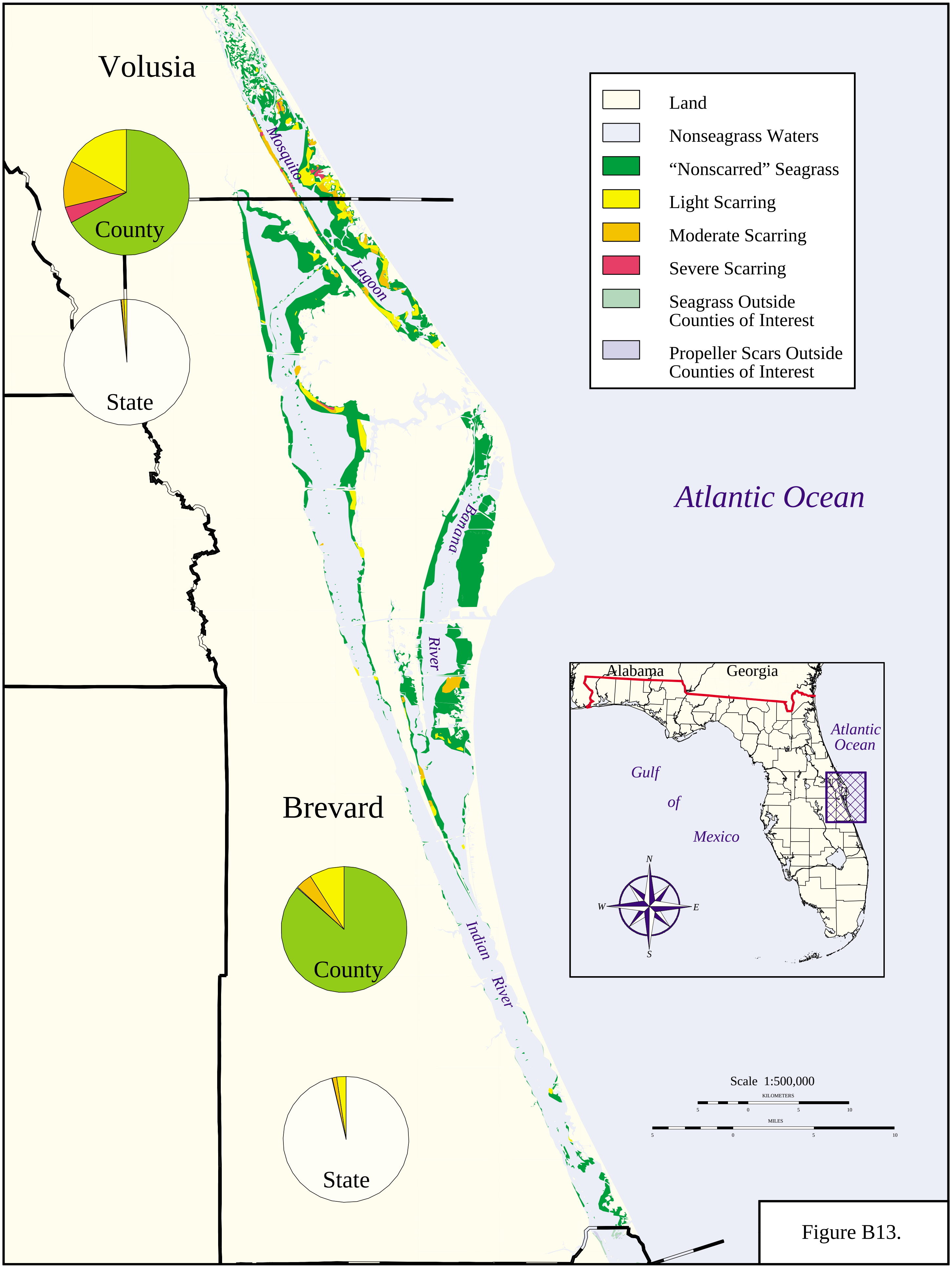

Volusia
County
State
Mosquito
Lagoon
Banana
River
Brevard
County
State
Indian
River
Atlantic Ocean
Land
Nonseagrass Waters
“Nonscarred” Seagrass
Light Scarring
Moderate Scarring
Severe Scarring
Seagrass Outside Counties of Interest
Propeller Scars Outside Counties of Interest
Alabama
Georgia
Atlantic Ocean
Gulf
of
Mexico
N
W
E
S
Scale 1:500,000
KILOMETERS
5 0 5 10
MILES
5 0 5 10

Figure B13.