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CHARACTERIZATION OF ANTHROPOGENIC AND NATURAL DISTURBANCE ON VEGETATED AND UNVEGETATED BAY BOTTOM HABITATS IN THE CORPUS CHRISTI BAY NATIONAL ESTUARY PROGRAM STUDY AREA

VOLUME II:
ASSESSMENT OF SCARRING IN SEAGRASS BEDS

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EXECUTIVE SUMMARY

The distribution and intensity of scarring in seagrass beds was quantified using high resolution (1:2,400) aerial photography taken in January 1997 in the Corpus Christi Bay National Estuary Program (CCBNEP) study area. Scarring levels were defined as light (<5%), moderate (5-20%), or heavy (>20%) based on the percentage of seagrasses scarred within each of the eight distinct regions examined. Ground truthing surveys by shallow draft boat and aircraft were used to verify aerial photography and collect DGPS coordinates for rectification and registration procedures. The distribution and levels of seagrass scarring were digitally transferred onto USGS topographical charts and analyzed using Geographic Information System (GIS) techniques.

The total area of seagrass habitat surveyed among the eight regions in the study area approximated 6,600 ha. Of this total, 2,200 ha were identified as either moderately or severely scarred. Scarring of grassbeds was clearly greatest in Estes Flats, where over 97% of grassbed was scarred, with 75% rated as severe. Moderate and severe scarring is also prevalent in the East Flats (49%), Shamrock Island (35%) and Redfish Bay (23%) regions. Total scarring in all other areas, as a proportion of the seagrasses present, was less than 20% with moderate/severe scarring accounting for 15% or less.
The nature of the scarring, linear traces that are 30-60 cm in width, along with field observations, indicate that this scarring is the result of boat traffic (i.e. propeller damage).

There are several explanations that account for heavy (moderate to severe) scarring in seagrasses by boating activity. These include accidental events (misjudgement of water depth or channel location), shortcuts to access an area or maintain a channel through a grassbed through placement of illegal navigational aids, or ignorance with respect to the damage caused by propellers and the importance of seagrass habitat. Initial management priorities should focus on education and the marking of secondary channels to minimize damage to adjacent grassbeds. Future research efforts should be directed toward an understanding of the long-term effects of seagrass scarring, especially to justify the variety of management options that are available to state resource agencies to minimize continued damage to this valuable resource.

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I. INTRODUCTION

The Nation's coastal areas comprise about 11 percent of the Nation's total land area (excluding Alaska), but account for nearly 30% of the entire U.S. population (NOAA, 1990). In Texas, more than one-third of the state's population and 70% of its industrial economy (jobs and commerce) is located within 100 miles of the coastline (Moulton et al., 1997). The state's coastal areas also include some of the most rapidly growing and densely populated counties in the Nation, with increases of over 35% projected in several coastal counties between 1990 and 2010 (NOAA, 1990). Such high population density can place enormous stress on coastal ecosystems; recreational boat traffic alone accounted for over 6 million trips to the Texas coast in 1986 alone (Fesenmaier *et al.*, 1987).

The negative impact of recreational boating activities on seagrass habitat has long been recognized (Phillips, 1960; Zieman, 1976; Eleuterius, 1987). Recreational boating activity causes direct damage to seagrasses through physical destruction of seagrass leaves and below-ground tissues (roots and rhizomes) by boat propellers. Scarring tends to occur in areas less than 1 m deep at low tide (Zieman, 1976); scars are readily visible in seagrass beds from the water surface and through low altitude aerial photography. Eleuterius (1987) indicated that once a propeller scar is created, wave action leads to erosion within the scar which results in further deepening of the disturbed area. This can expose surrounding seagrass beds to further disruption and increase sediment resuspension, which inhibits seagrass growth through increases in light attenuation (Sargent *et al.*, 1995).

On the Texas coast, scarring by recreational boaters may be an important factor in loss of seagrasses near densely populated areas. Pulich *et al.,* (1997) conducted a landscape analysis of historical trends in seagrass distribution and observed widespread evidence of scarring in shallow grassbeds in the Redfish Bay/Harbor Island complex near Corpus Christi. His analysis revealed seagrass loss in this area may be escalating, due to both water quality problems and intensive mechanical damage and physical disturbances inflicted on grass beds by recreational boaters.

There is virtually no quantitative information on either the extent or severity of scarring in seagrass beds within bays and estuaries surrounding the greater Corpus Christi metropolitan area. However, the extensive seagrass meadows in this area encompass about 25% of Texas seagrasses (Pulich *et al.*, 1997). In Florida, scarring was observed in all areas of the state, but was most severe around more densely populated areas (Sargent *et al.*, 1995).

Although degree of scarring is a function of a variety of factors (including the boater's use of navigational charts, judgement, etc.), water depth is a strong determinant of scarring (Sargent *et al.*, 1995). In the Corpus Christi area, water transparency generally restricts seagrasses to depths less than 1.2 m (Dunton, 1990, 1994). Consequently, although tidal ranges are small (generally ± 20 cm), this exposes most seagrasses in this area to scarring by recreational boat traffic.

Scarring of seagrass beds is a concern because these unique habitats are critical to local and regional economies along the Gulf coast. Using data and estimates of values for recreation and storm protection, per-acre values of seagrass habitats likely range from $9,000 to $28,000 based on a recent evaluation of wetland habitats in the Gulf (Lipton *et al*., 1995). In Texas, the total value of seagrass habitat based on current estimates of seagrass distribution, recreational value, and commercial fishery harvests is at least 12.6 million dollars annually (Dunton, unpub. data). These conservative estimates clearly show the importance of conservation measures to protect this extremely valuable resource in Texas.

The objectives of this study were to identify and quantify the extent of scarred seagrass beds throughout most of the bay and estuarine region that surrounds the Corpus Christi metropolitan area. We collected and analyzed data using aerial photography and Geographic Information System (GIS) techniques. Maps of known seagrass distribution for the region (Pulich *et al*., 1997) were used to calculate the relative impacts of scarring within the areas surveyed. Anecdotal observations made by researchers in the field were also used to help interpret prop scar patterns and relate them to navigational circumstances on the behavioral habits of the boaters.

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II. MATERIALS AND METHODS

A. Study Area

The study area extended from the northern end of the upper Laguna Madre northward through Corpus Christi, Redfish and Aransas bays (Fig.II.1). Within this area, eight specific regions of seagrass habitat were sampled. Water depths in all areas generally averaged less than 0.5 m based on published soundings on USGS topographic and NOAA nautical charts of the region.

B. Aerial Photography

The aerial mapping of seagrass scarring followed the general procedures outlined by Falkner (1995). The distribution and frequency of scarring was determined from 32 1:2,400 scale black and white aerial photographs taken on 25 and 31 January 1997 by Lammon Aerial Photography. A 1:2,400 scale was chosen based on analysis of previous aerial photographs suggesting that scars produced by boat propellers (approximate width 30 cm) are often beyond the normal limit of 1:24,000 resolution used in many aerial mapping studies (Sargent *et al.*, 1995; Pulich *et al.*, 1997). Durako *et al.*, (1992), for example, distinguished 140 times the number of individual scars using 1:2,400 compared to 1:24,000 photography at a site in Tampa Bay.

The photographic missions were flown following winter cold fronts that produced clear atmospheric conditions and negligible surface winds under neap (daily fluctuation <0.1 m) tidal conditions slightly lower than MSL on both days. Large format (23 cm x 23 cm) Kodak Double-X Aerographic 2405 black and white film was exposed at an altitude of 1,830 m to provide 1:12,000 scale. Since aerial images encompassed a variety of features (seagrass beds, open water, islands, mudflats, etc.), 3.4 km^2 quadrangles of representative seagrass beds were chosen from either separate or overlapping images of each region from 23 cm x 23 cm contact prints. The 3.4 km^2 areas were then enlarged 5 times to produce a 91 cm x 91 cm print (scale 1:2,400) for image analysis.

C. Image Analysis

C1. Ground Truthing and Rectification

Aerial images were georeferenced from ground control points (GCP's) identified on the 91 cm x 91 cm prints that were used for rectification and registration procedures. The location of GCP's was determined using a differential global position system (DGPS) with a locational accuracy of ± 5 m (Magellan Meridian XL, San Dimas, CA). Shallow draft boats equipped with outboard jet equipped engines allowed access to shallow grassflats. Over 16 separate day-trips were required for the DGPS work and to groundtruth major scarring features depicted on the photographs between spring and autumn 1997.

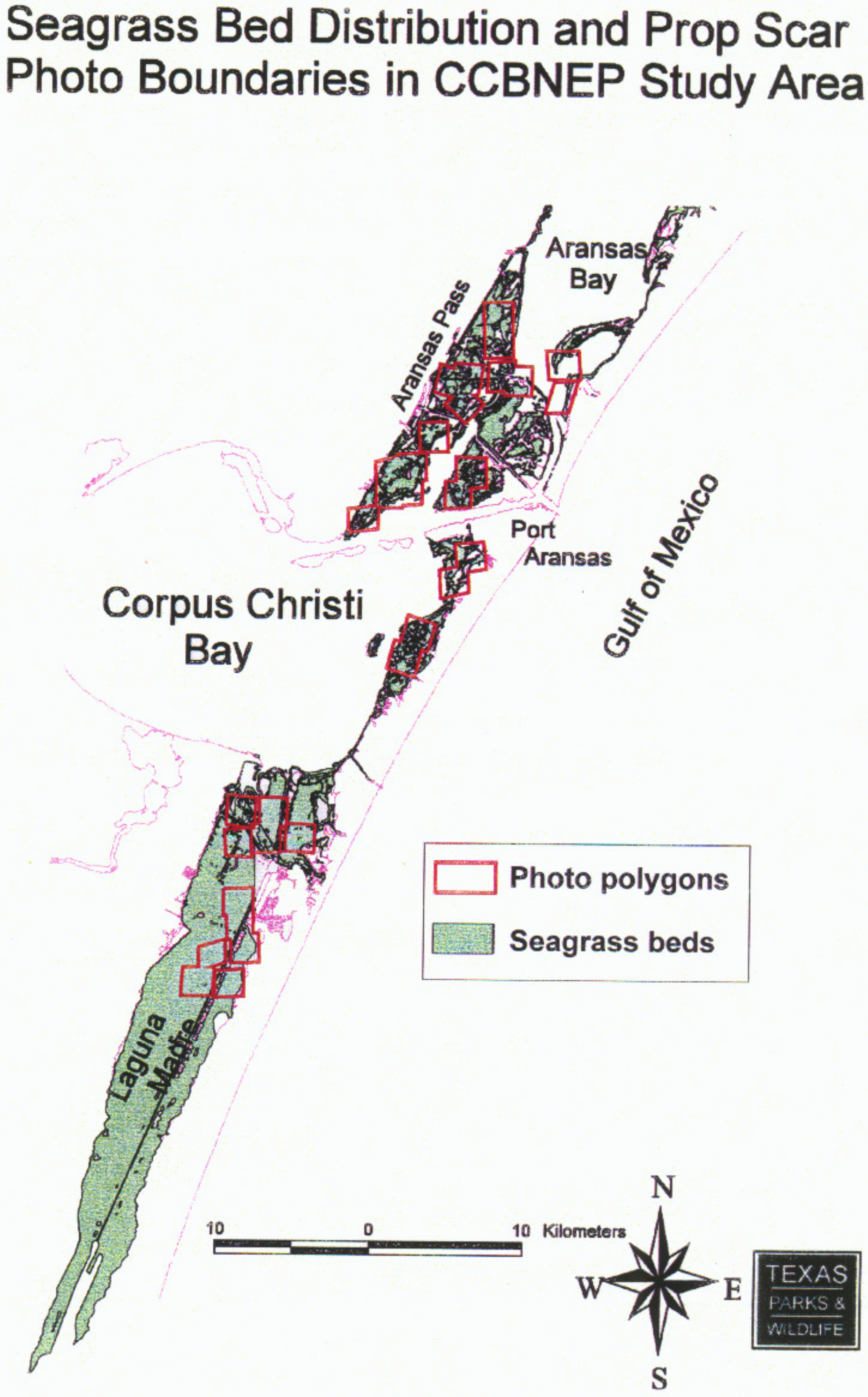

Figure II.1. Study Area. Seagrass coverage (compiled by Pulich 1997) and location of photographic polygons used to analyze seagrass scarring.

C.2. Scar Recognition and Mapping

Seagrass scarring on 91 cm x 91 cm black and white prints was easily recognizable as distinct areas of light colored lines in the darker background of seagrass beds. Scarred areas (polygons) were traced directly on all 32 photographs by one person (SVS) using a 5 power lighted magnifying lens. Polygons were drawn around groups of scars that ranged in size from tens of square meters to hectares in size. We employed a classification scheme similar to that used by Sargent *et al.* (1995) to map frequency of scarring in each polygon. Level of scarring, determined from density of scars within each polygon (i.e. percent of seagrasses impacted), and shown diagrammatically in Figure II.2, was defined as light (< 5%), moderate (5-20%), or heavy (>20%). In many cases, because of overlap among adjacent images, 3.4 km^2 quadrangles were merged into larger polygons, each of which contained irregularly shaped polygons of scarred grassbeds. Finally, to confirm locations and magnitude of scarring, we flew brief aerial surveys over East Flats, Redfish and Aransas bays using a Cessna 172 at low altitude (100-200 m).

C.3. Digitization and Quantification of Scarring

Distribution and levels of seagrass scarring within the regions were digitally transferred onto 1975 USGS topographic quadrangle charts (Table II.1). Relevant coastal areas on topographic charts,

Table II.1. USGS topographic charts used as base maps for depiction of scarring within seagrass beds located at eight different locations in the study area (all scales are 1:24,000).

Chart Number	Quadrangle Name
2797 - 421	Pita Island
-	Crane Islands SW
2797 - 424	Oso Creek NE
-	Crane Islands NW
-	Port Ingleside
2797 - 441	Port Aransas
2797 - 443	Aransas Pass
2797 - 444	Estes

aerial image borders, and traced seagrass polygons (on 91 cm x 91 cm prints) were converted to digitized images using an Altex Datalab Pro Line 106 cm x 152 cm tablet using AutoCad (ver. 13) software. Files were then imported into ARC/INFO GIS software (ver. 7 ; ESRI Inc. Redlands, CA) to calculate aerial extent of scarring within each region. Seagrass polygons were thus transformed from a NAD27 geographic coordinate system and mapped onto a standard GIS map projection coordinate system (NAD83 stateplane South Texas zone 4205 metric).

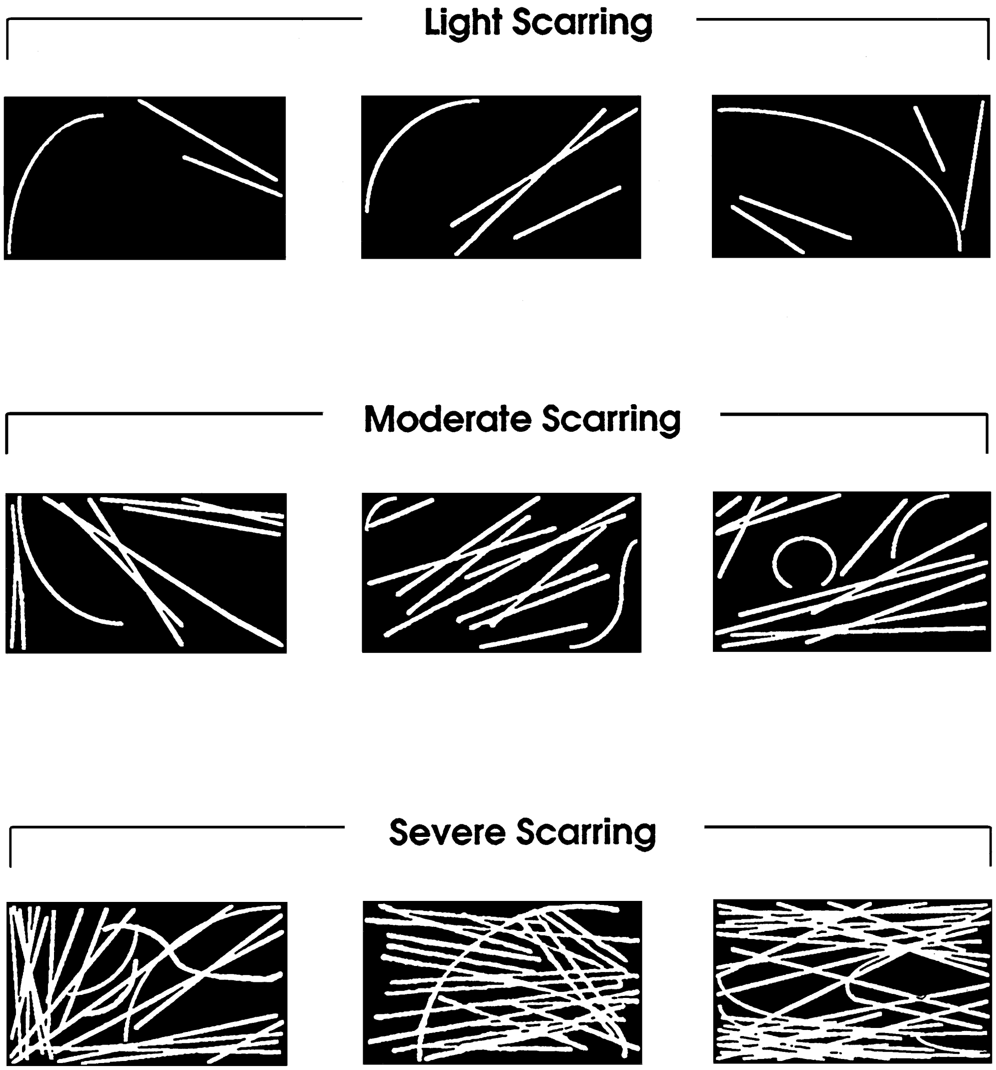

Figure II.2. Diagrammatic representation of the three primary categories of scarring intensity identified on aerial images and delimited within polygons; light (<5%), moderate (5-20%), and heavy (>20%). From Sargent, *et al*. (1995).

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III. RESULTS

The total area of seagrass habitat surveyed in this study approximated 6,600 ha from the upper Laguna Madre to the south to Estes Flats in the north (Fig. II.1). In the area north of Kennedy Causeway to Estes Flats, about 4,000 ha of grassflats were assessed for scarring, which accounts for nearly 40% of all seagrasses in this region (total 10,170 ha; Pulich *et al.*, 1997). Thus, this assessment represents a fairly comprehensive overview of the level of scarring throughout the entire study area.

Our aerial photography was concentrated within eight specific regions in the study area (Table III.1). All eight regions were characterized by having substantial (>50%) cover of seagrasses in generally shallow (<1 m), low wave-energy environments. Seagrass cover typically included *Halodule wrightii* (dominant in upper Laguna Madre), and mixed stands of *H. wrightii*, *Syringodium filiforme* and *Thalassia testudinum* in East Flats, Redfish and Aransas Bays.

Table III. 1. Regions of the study area in which seagrass scarring was quantified from aerial photographs taken in January 1997. The number of aerial images used to assess seagrass scarring, predominant species present, and approximate depth ranges compiled from ground-truthing and NOAA and USGS charts for each region are also noted. *Hw: Halodule wrightii; Sy: Syringodium filiforme; Tt: Thalassia testudinum.*

Region	Number of Aerial Photographs	Predominant Species	Depth Range (m)
Upper Laguna Madre	6	Hw	0.3-0.5
JFK Causeway	5	Hw	0.3-0.5
Shamrock Island	2	Hw	0.3-0.5
East Flats	2	Hw/Sy/Tt	0.3-0.5
Redfish Bay	6	Hw/Sy/Tt	0.3-1.0
Harbor Island	2	Hw/Sy/Tt	0.3-1.3
Lydia Ann/Mud Island	2	Hw/Sy/Tt	0.3-1.0
Estes Flats	7	Hw/Sy/Tt	0.3-0.5

There was evidence of scars in grassbeds throughout the study area (Figs. III.1-III.8), although frequency and intensity of scarring varied considerably between regions and was independent of seagrass acreage of the survey area. For example, seagrass cover in four regions, upper Laguna Madre, JFK Causeway, Redfish Bay, and Estes Flats ranged between about 1,100-1,500 ha, but was characterized by total scarring levels that varied five-fold, from 240 to 1,227 ha (Table III.2). In the remaining four regions (seagrass cover 150 to 530 ha), total scarred area ranged from 29 ha to as much as 175 ha, nearly as great as upper Laguna Madre and JFK Causeway. The greatest amount of scarring was recorded in Estes Flats, with over 1,200 ha of grassbeds impacted. The second highest level (288 ha) was recorded in Redfish Bay.

With the exception of the Estes Flats region, the majority of grassbeds were classified as "moderately scarred". Most of the scarring in Estes Flats was rated as severe and was highly visible from boats as well as aerial ground truthing surveys. In addition, we frequently witnessed scarring by recreational craft during our surveys, especially in the Estes and East Flats regions.

Table. III. 2. Area of scarring (ha) in each region of this study. For definition of scarring levels, see Fig. II.2.

Region	Seagrass[1] Total	Light Scarring <5%	Moderate Scarring 5-20%	Severe Scarring >20%	Scarring Total
Upper Laguna Madre	1485.9	45.0	173.9	22.0	240.8
JFK Causeway	1366.8	38.8	193.6	19.4	251.8
Shamrock Island	469.3	10.0	132.1	32.8	175.0
East Flats	298.2	0	101.2	45.0	146.2
Redfish Bay	1063.2	44.8	185.1	57.8	287.6
Harbor Island	532.9	24.6	34.1	18.8	77.5
Lydia Ann / Mud Island	149.1	9.0	18.1	1.7	28.8
Estes Flats	1258.2	50.9	227.9	948.7	1227.5

[1] from Pulich *et al.* (1997)

Percentage of scarred seagrass beds within each of the eight regions also showed that severity of scarring was clearly greatest in Estes Flats (Table III.3). In this region over 97% of the area was scarred, with 75% of scarring rated severe. Moderate and severe scarring was also prevalent in East Flats (49%), Shamrock Island (35%) and Redfish Bay (23%). Otherwise, total scarring in all other areas, as a proportion of the seagrasses present, was less than 20% with moderate/severe scarring accounting for 15% or less.

Table III.3. Percentage of scarred seagrasses at different levels of intensity as a function of total seagrass cover within each sampling region. Total grass cover within each sampling area was determined by Pulich *et al.* (1997).

Region	Scarring Light	Scarring Moderate	Scarring Severe	Scarring Total
Upper Laguna Madre	3.0	11.7	1.5	16.2
JFK Causeway	2.8	14.2	1.4	18.4
Shamrock Island	2.1	28.1	7.0	37.3
East Flats	0	33.9	15.1	49.0
Redfish Bay	4.2	17.4	5.4	27.0
Harbor Island	4.6	6.4	3.5	14.5
Lydia Ann / Mud Island	6.0	12.1	1.1	19.3
Estes Flats	4.1	18.1	75.4	97.6

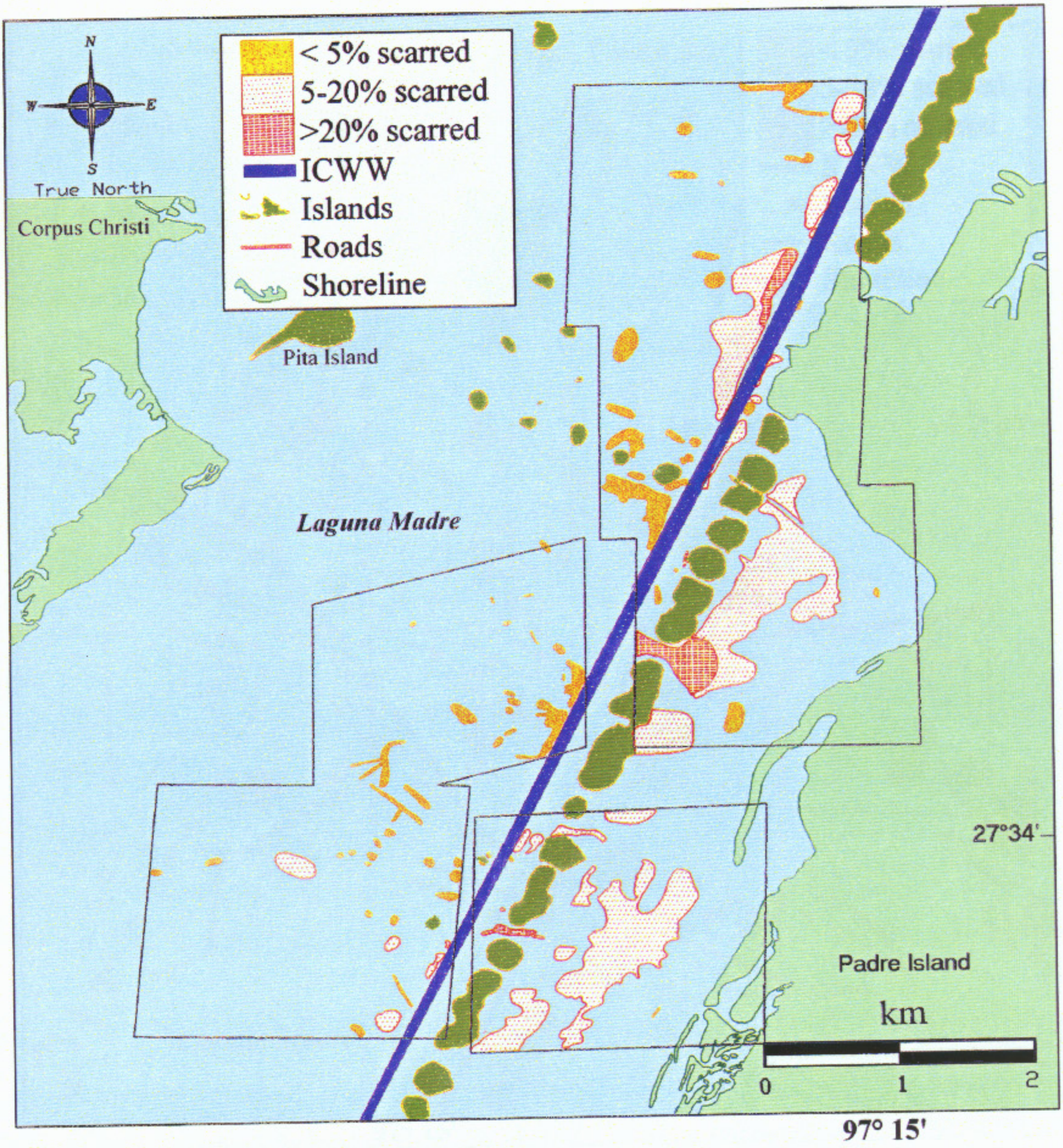

Figure III.1. Upper Laguna Madre. Distribution and intensity of seagrass scars.

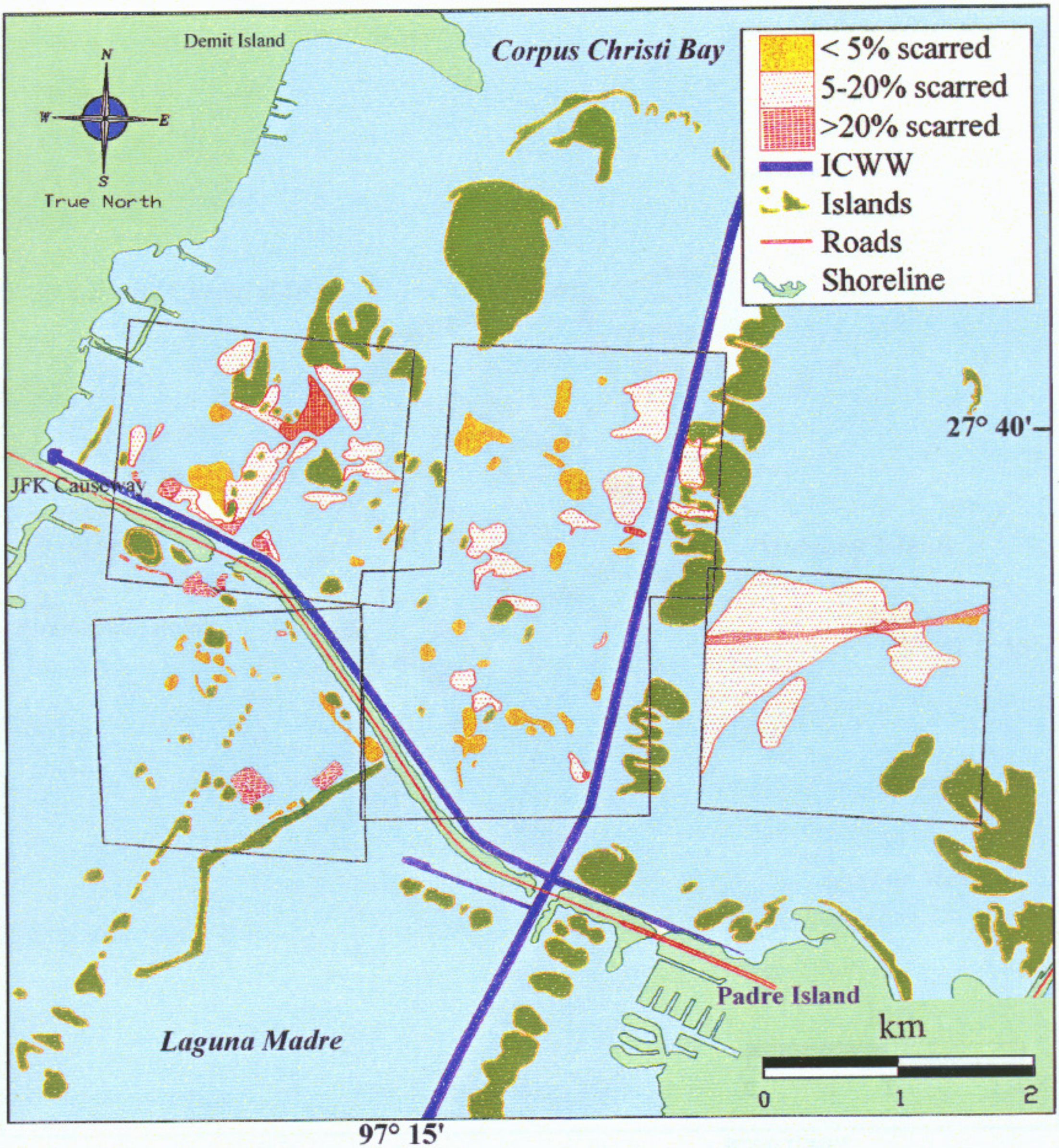

Figure III.2. JFK Causeway. Distribution and intensity of seagrass scars.

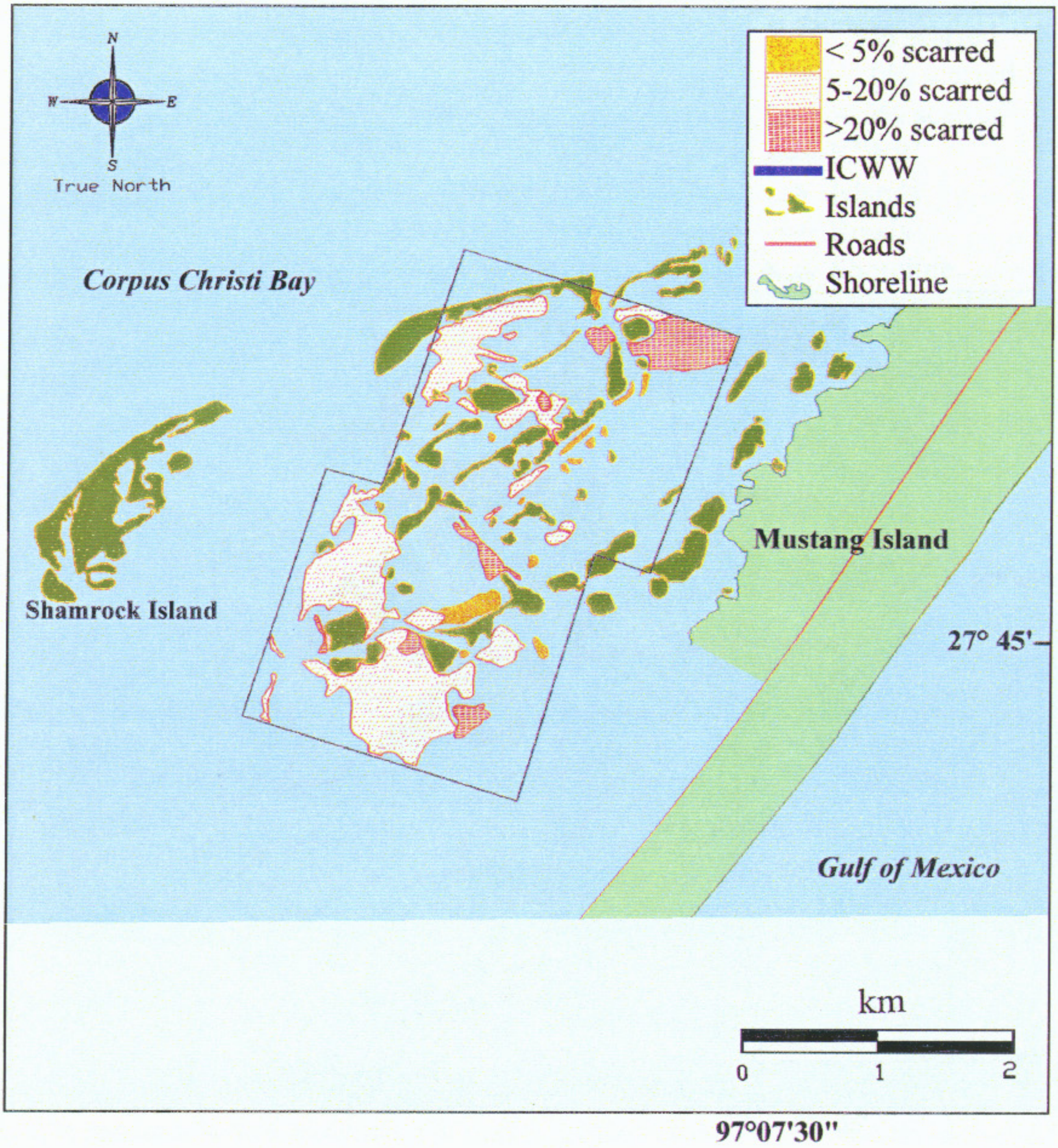

Figure III.3. Shamrock Island. Distribution and intensity of seagrass scars.

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