Effect of Hurricane Charley on smalltooth sawfish (*Pristis pectinata*) nursery habitats in Charlotte Harbor, Florida.

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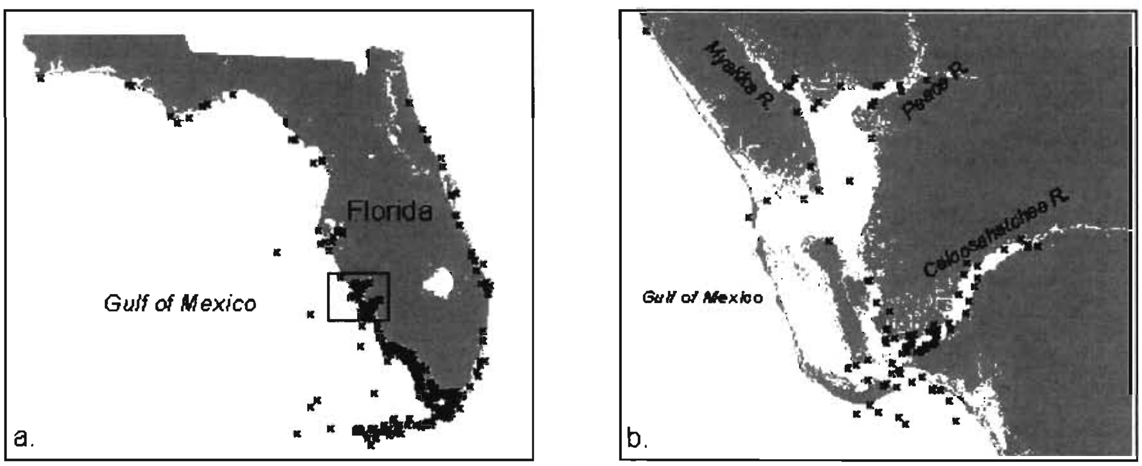
Introduction

The smalltooth sawfish (*Pristis pectinata*) is a large species of elasmobranch that was once common in Florida coastal waters, as well as much of the Gulf of Mexico and US Atlantic coast (Simpfendorfer 2002). Decades of capture in fisheries, both commercial and recreational, resulted in this species being listed as Endangered under the US Endangered Species Act (NMFS 2003). Data from public encounters (Seitz and Poulakis 2002, Simpfendorfer 2002, Poulakis and Seitz 2004, Simpfendorfer and Wiley 2005) have shown that *P. pectinata* is now restricted mostly to southern Florida. On the west coast of Florida the bulk of public encounters occur from Charlotte Harbor south (Figure 1a), and within Charlotte Harbor most occur around the mouths of the major rivers (Peace, Myakka and Caloosahatchee) (Figure 1b). The majority of these encounters are with young animals, indicating that this area serves as a nursery area for this species. As the most northerly location of substantial numbers of juvenile sawfish encounters Charlotte Harbor is an important site for rebuilding of the population and the repopulation of areas further north.

Figure 1. Distribution of public encounters with smalltooth sawfish (*Pristis pectinata*) (crosses) in (a) Florida waters and (b) Charlotte Harbor. Data from Mote Marine Laboratory's Sawfish Encounter Database.



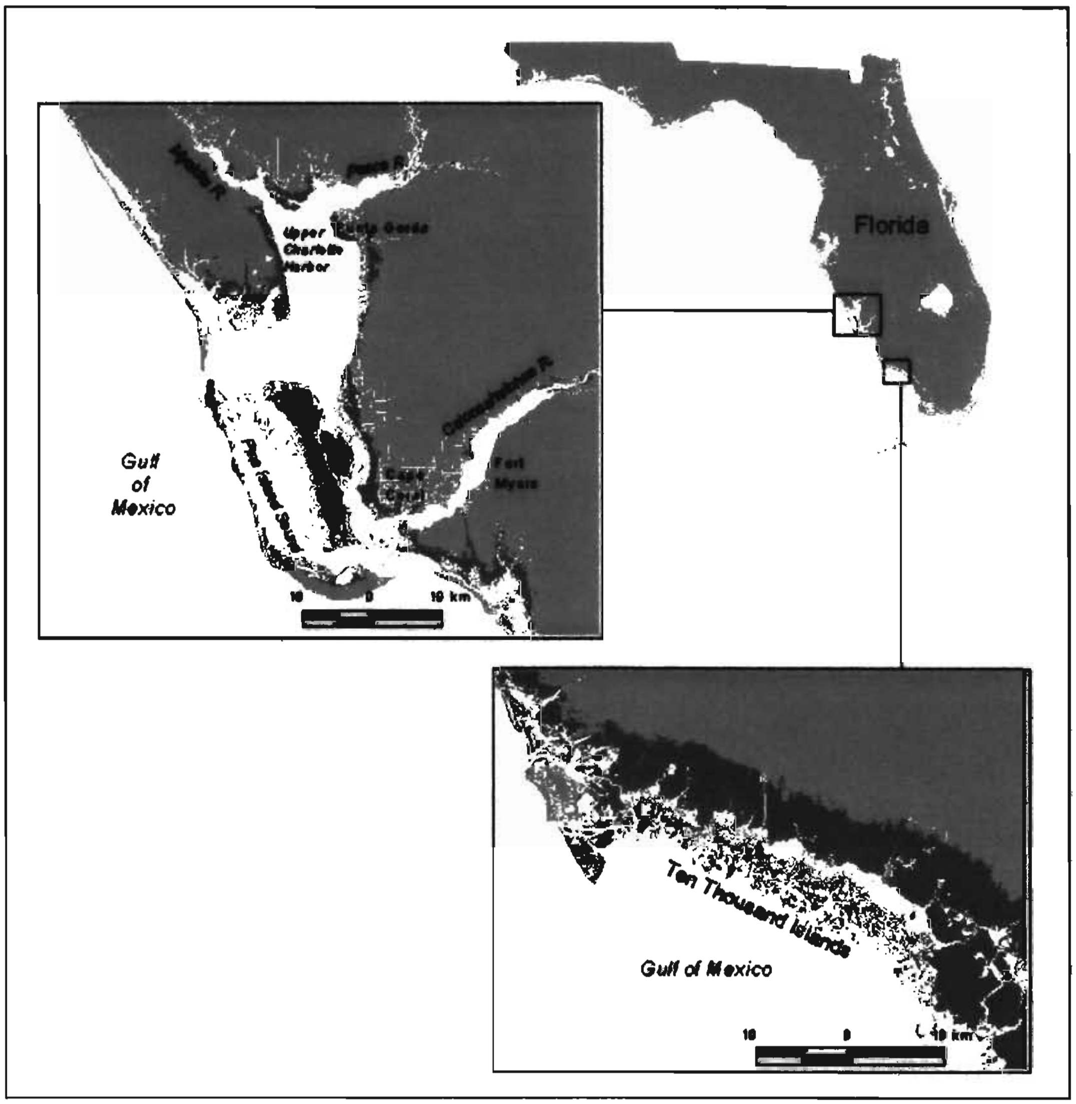
On August 13, 2004, Charley, a compact category 4 hurricane, passed over Charlotte Harbor causing considerable damage to the region. Given the importance of this region to the *P. pectinata* population there was concern that habitat damage may have negatively impacted the ability of this area to function as a nursery area. Simpfendorfer and Wiley (2004) demonstrated that small juvenile *P. pectinata* (< 200 cm long) are associated with shallow mangrove shorelines. In addition, acoustic tracking data have indicated high site fidelity of juvenile sawfish to these habitats (Simpfendorfer unpublished data). Thus to examine the potential affect of Hurricane Charley on nursery habitats a broad survey of the damage to the fringing mangrove habitats in Charlotte Harbor was undertaken.

Materials and Methods

Study area

Charlotte Harbor (Figure 2) is a large enclosed estuary on the southwest coast of Florida encompassing approximately 700 km^2 of estuarine waters. Three major rivers (Myakka, Peace and Caloosahatchee) enter the harbor, providing the bulk of the freshwater input. Native shoreline habitats are dominated by red mangroves (*Rhizophora mangle*), but in areas with greater freshwater influence shoreline habitats include *Juncus roemerianus* and *Acrostichum* spp. marshes. Human modification of the shoreline in some areas of the Harbor includes seawalls and canal developments. A control site in the Ten Thousand Islands (Figure 2) was used for comparison to the affected area in Charlotte Harbor.

Figure 2. Location of study areas. Dark grey areas indicate mangroves based on GIS data from the Florida Geographic Data Library (www.fgdl.org).



Mangrove shoreline habitat damage

To assess the damage done to shoreline mangrove habitats during the passage of Hurricane Charley a survey technique designed to cover a broad area of Charlotte Harbor was implemented. To ensure broad spatial coverage a two nautical mile grid was placed over a chart of the area (including mangrove locations) and the area of mangroves closest to the center of each grid square along lines bisecting each of the sides of the square was determined (see Figure 3 for example). Where mangrove areas did not occur on the bisecting lines, the closest mangrove location to the center in any direction was determined. In addition, mangrove areas had to be accessible by small boat in reasonable time for surveys. The control site was also sampled using the same site selection procedure. A total of 75 sites were sampled in Charlotte Harbor (Figure 4a) during February and March 2005, and 25 sites were sampled in the Ten Thousand Islands (Figure 4b) during August 2005.

Figure 3. Examples of site selection for mangrove (brown areas) surveys. One site (indicated by a solid circle) was selected in each two nautical mile grid square (solid lines). Sites were as close as possible to the center of each grid square (indicated by a solid cross) along lines bisecting the sides of the squares (dashed lines). Consideration of vessel access (due to shallow water) also dictated site selection. Sites 1, 2 and 4 represented the closest vessel accessible point with mangroves to the center of the grid square. Site 3 represented the closest accessible location within the grid square given the time constraints during sampling. Mangrove data were obtained from the Florida Geographic Data Library (www.fgdl.org).

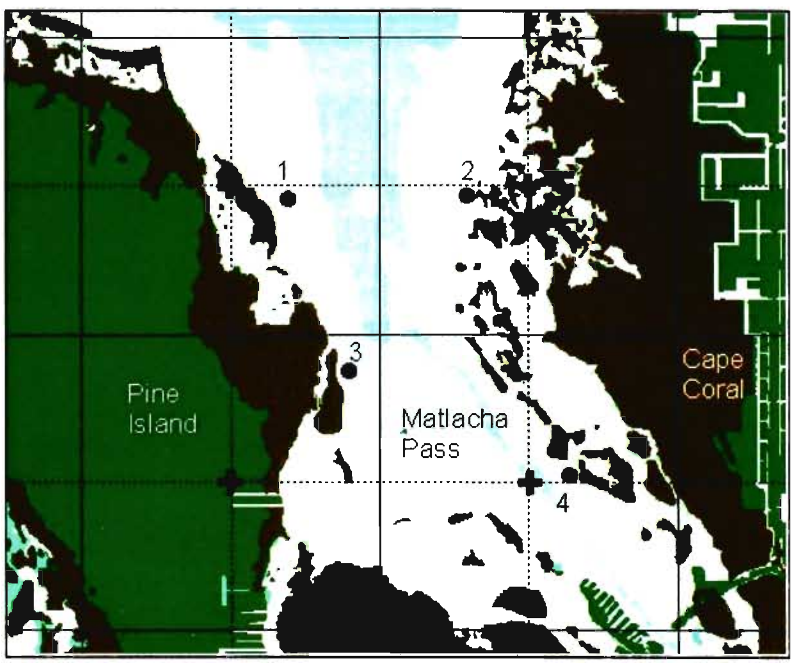
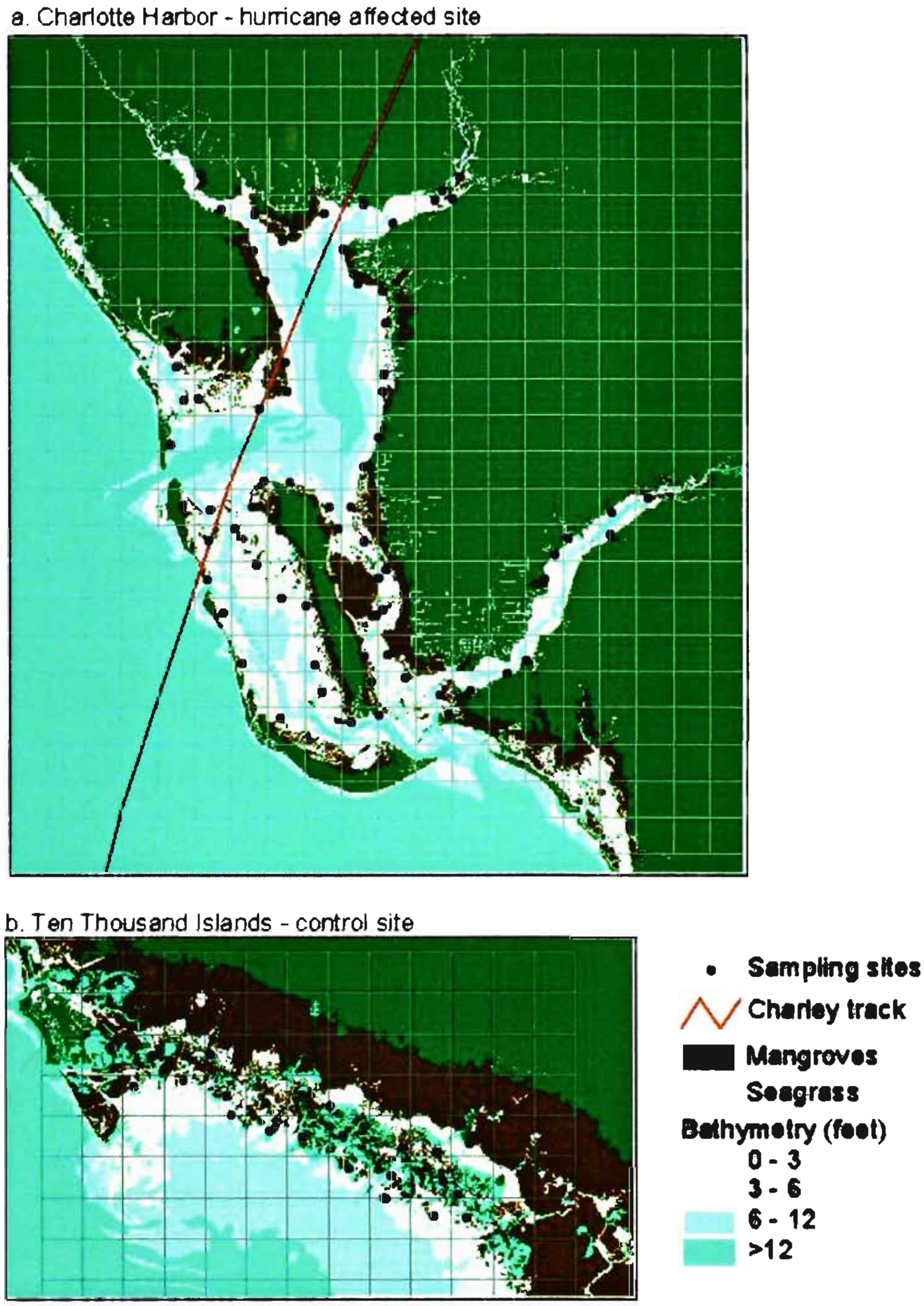


Figure 4. Location of mangrove damage and trash accumulation sampling sites (black dots) in (a) Charlotte Harbor and (b) the Ten Thousand Islands.



At each of the determined points a 100 m section of mangrove shoreline was visually surveyed to determine the proportion of mangrove trees along the shoreline that fell into a five-point qualitative index of damage (Table 1). To obtain a single measure of mangrove damage the mean of the damage scores, weighted by the proportion of each, was calculated. This mean value was referred to as the mangrove damage index. The proportion of trees that appeared to be dead or completely defoliated (Figure 5) within each 100 m transect was also estimated. Mangrove damage index values and the proportion of dead/defoliated trees were plotted on maps of the study area using ArcView 3.3. Distances from each of the sampling locations in Charlotte Harbor to the track of Hurricane Charley were calculated using the Nearest Features (v3.7) extension for ArcView. Distances were used to calculate relationships with mangrove damage and the proportion of dead/defoliated trees. A t-test assuming unequal variances was used to test for differences in the mangrove damage index and proportion dead/defoliated between Charlotte Harbor and the Ten Thousand Islands.

Table 1. Mangrove damage index used to evaluate the affect of Hurricane Charley.

Index value	Description
0	No apparent damage
1	Major leaf loss, but not major damage to branches
2	Branches broken
3	Trunk broken
4	Tree uprooted

Figure 5. Example of a completely defoliated red mangrove trees near Punta Gorda.

Trash accumulation

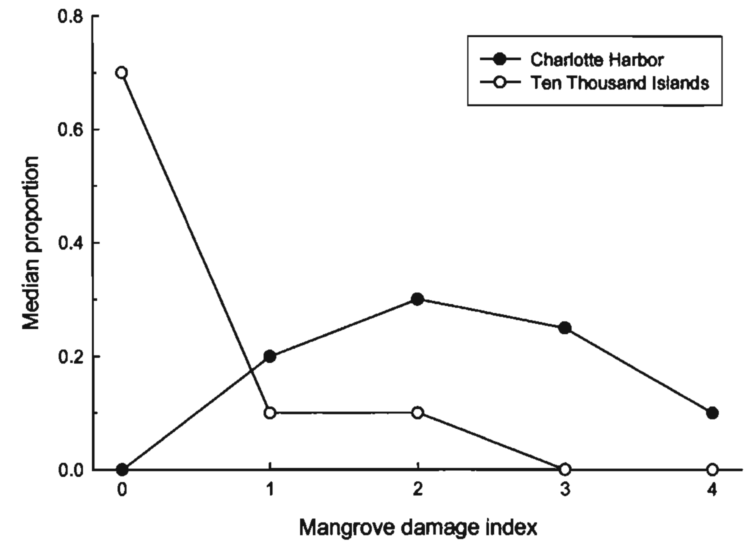
The number of trash items (larger than an aluminum drink can) in each of the 100 m transects surveyed for mangrove damage were counted. Trash counts were summarized into five bins (0-10, 11-20, 21-30, 31-40, 40+) and plotted on maps of the study area using ArcView 3.3.

Results

Mangrove damage

Mangroves at all sampling sites, both within Charlotte Harbor and the Ten Thousand Islands control area, showed some level of damage. The median proportion of trees with no damage was much greater in the Ten Thousand Islands, while median proportions of all other damage categories were higher in Charlotte Harbor (Figure 6). In Charlotte Harbor 56% of sites had damage in categories 3 or 4 and in the Ten Thousand Islands only 7% had damage in the same levels. The mean mangrove damage index in Charlotte Harbor (2.03) was significantly larger (t-test, $t = 1.69$, $df = 33$, $p < 0.001$) than in the Ten Thousand Islands (1.04).

Figure 6. Median proportion of mangrove trees at each damage index value for the two study areas.



Greatest values of the mangrove damage index and the proportion dead/defoliated occurred closest to the track of Hurricane Charley and higher values extended further east of the track than to the west (Figures 7a, 8a). The highest values of mangrove damage index were clustered around the northern half of Pine Island Sound. Highest proportions of dead/defoliated mangroves occurred on the east side of the track in both northern Pine Island Sound and upper Charlotte Harbor. There were significant relationships between mangrove damage index and the distance from the track of Charley ($MDI = -0.033d + 2.445$, $r^2 = 0.248$, $p < 0.0001$, Figure 9a) and the proportion dead/defoliated and the distance from the track ($PDF = 0.651e^{-0.056d}$, $r^2 = 0.316$, $p < 0.0001$, Figure 9b). Both the mangrove damage index and proportion dead/defoliated decreased with increasing distance from the hurricane track. The mangrove index values decreased in a linear fashion, while the proportion dead/defoliated decreased exponentially. There was a dramatic drop in the occurrence of high values of proportion dead/defoliated at approximately 15 km from the hurricane track.

Within the Ten Thousand Islands the mangrove index values tended to be highest in the east and in areas closest to the open Gulf of Mexico (Figure 7b). The proportion dead/defoliated tended to be highest in areas closest to the open Gulf (Figure 8b).

Figure 7. Damage to mangrove areas in (a) Charlotte Harbor, and (b) a control site in the Ten Thousand Islands following Hurricane Charley. Damage was assessed using a 5 stage qualitative index (see methods for details).

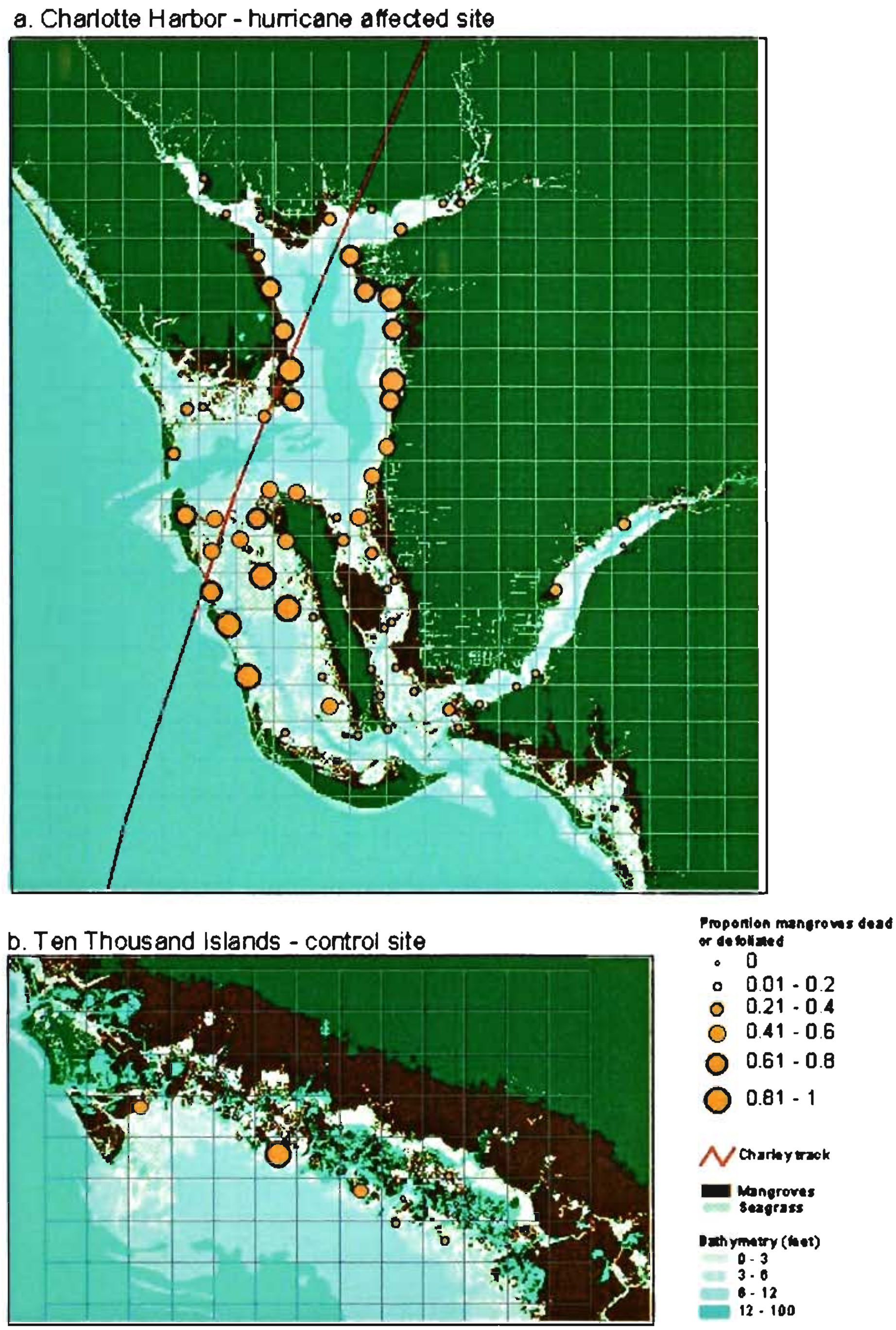


Figure 8. Proportion of shoreline mangrove trees dead or completely defoliated in (a) Charlotte Harbor, and (b) a control site in the Ten Thousand Islands following Hurricane Charley.

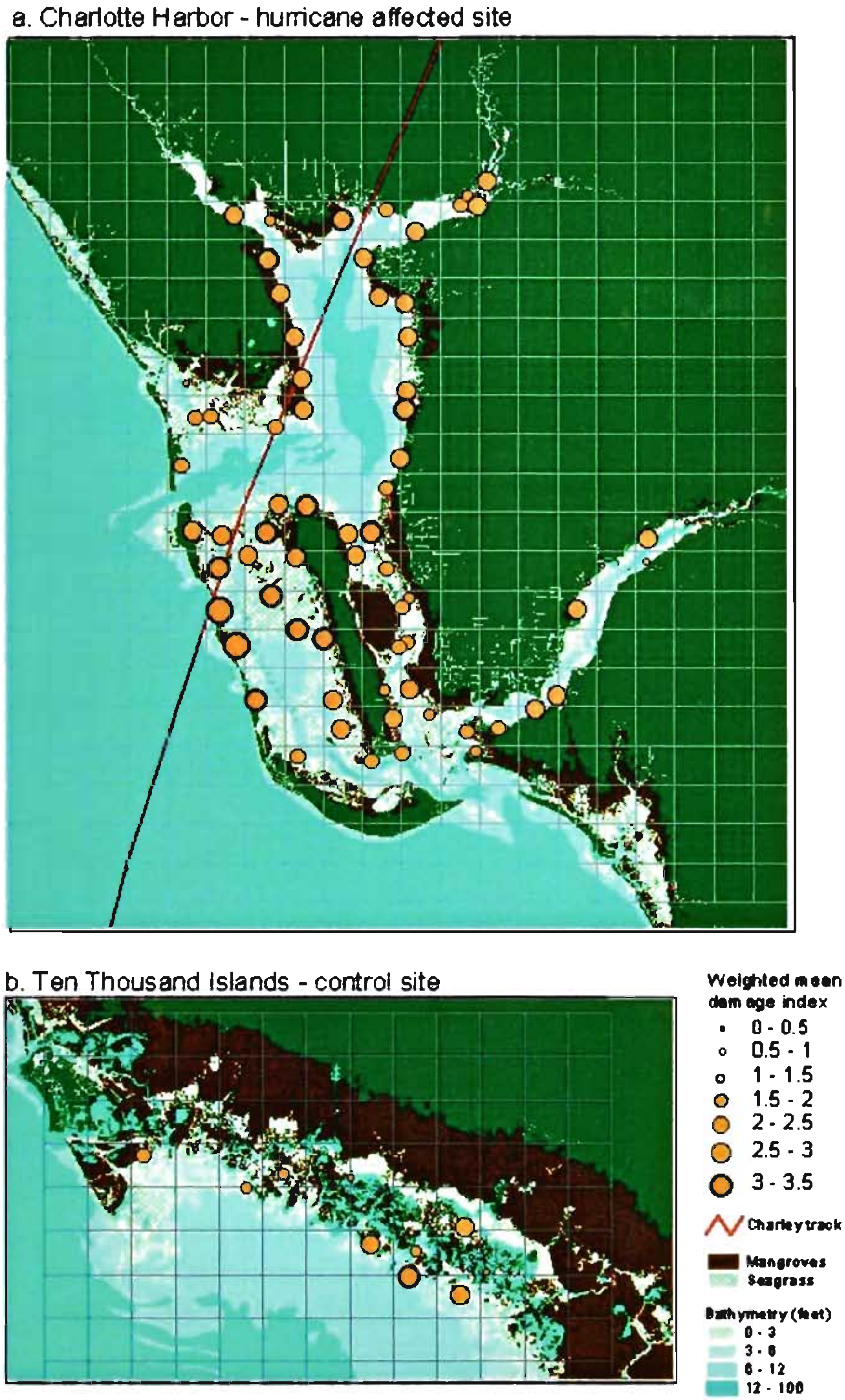
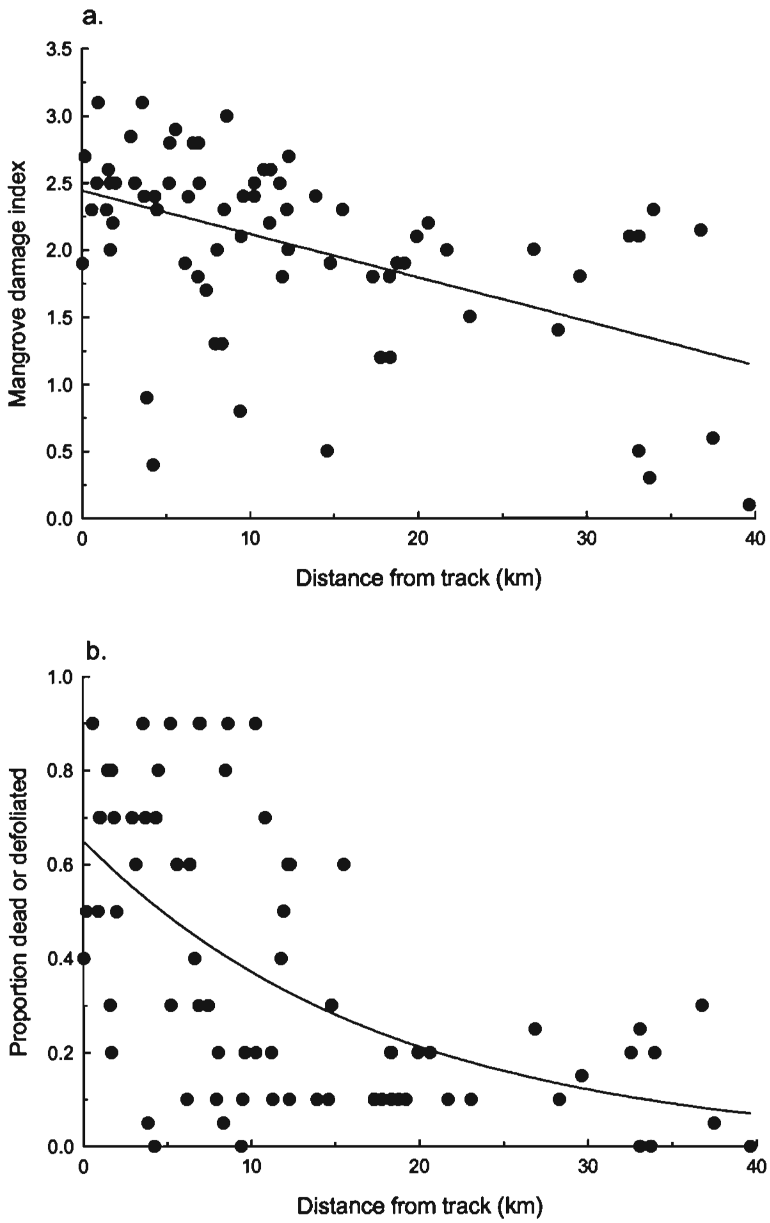


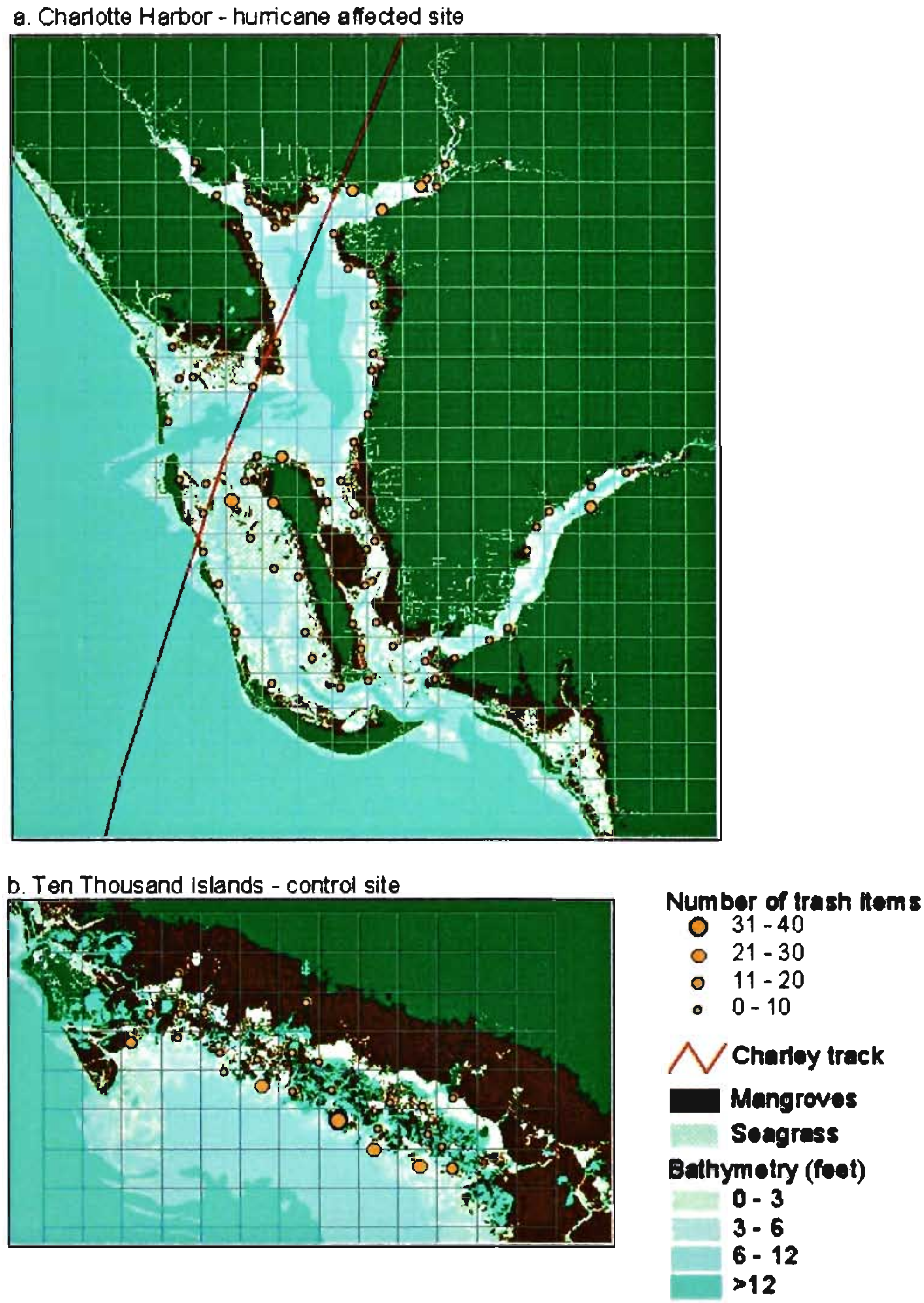
Figure 9. Extent of damage to mangrove areas in Charlotte Harbor by distance from the track of Hurricane Charley. (a) Mangrove damage index and (b) proportion dead or defoliated.



Trash accumulation

Limited amounts of trash were accumulated in most of the areas surveyed in both Charlotte Harbor and the Ten Thousand Islands (Figure 10). Only seven sites in Charlotte Harbor (10%) and five sites in the Ten Thousand Islands (20%) had more than 10 trash items. In Charlotte Harbor all areas with greater than 10 trash items were on the east side, and within a few kilometers, of the track of Hurricane Charley. All areas in the Ten Thousand Islands area that had more than 10 trash items were at the sites along the edge of the Gulf of Mexico.

Figure 10. Trash accumulation in shoreline mangrove habitats in (a) Charlotte Harbor, and (b) a control site in the Ten Thousand Islands following Hurricane Charley.



Discussion

The passage of Hurricane Charley through the Charlotte Harbor region caused extensive damage to the mangrove shoreline habitats. The worst damage occurred closest to the hurricane's track and decreased with increasing distance. Damage ranged from leaf damage to broken trunks, with severe damage (broken trunks or uprooted) occurring commonly within 15 km of the track. There were limited amounts of trees that were actually uprooted, and most of these were in the Caloosahatchee River where bank erosion appeared to be the major cause rather than the storm. The damage caused by the storm was consistent with that reported after other hurricanes with wind speeds in excess of 200 km hr^{-1} where massive destruction to mangroves has been reported (e.g. Craighead and Gilbert 1962, Roth 1992, Smith et al. 1994).

Damage from Hurricane Charley resulted in a large amount of death or complete defoliation of red mangroves. Areas with the highest levels of this type of damage occurred mostly east, and within 15 km, of the hurricane's track. Outside of this area this type of damage was limited. Although the survey method was not able to determine definitively if completely defoliated trees had actually suffered mortality experience from other hurricanes found similar levels of mortality. Smith et al. (1994) reported mortality rates of up to 90% in some size classes of red mangroves in the Ten Thousand Islands after Hurricane Andrew. Not all mortality associated with the hurricane damage occurs immediately after the passage of a storm, with Smith et al. (1994) reporting a further 20% mortality after a year. Thus the level of potential mortality estimated by the current survey may in fact be low given that they occurred less than a year after the storm.

The damage and mortality pattern associated with the passage of Hurricane Charley through Charlotte Harbor was consistent with the compact nature of the storm. Charley was a compact hurricane with the maximum sustained winds extending only 11 km from the center of the storm (Pasch et al. 2004). Thus the highest levels of damage and potential mortality occurred within the band of most destructive winds. If Charley had been a large storm the damage to the mangroves in Charlotte Harbor would have been far more extensive. The concentration of the highest levels of potential mortality east of the hurricanes track is also consistent with the strongest winds occurring on the east side of a north-traveling system.

The survey did not find a significant amount of trash accumulated in the shoreline mangrove habitats of Charlotte Harbor. Trash levels were in fact higher in the control site, possibly because there was greater potential for trash to drift ashore from the Gulf of Mexico. Since the survey was conducted several months after the storm trash accumulated during and immediately after the storm may have been removed during cleanup operations or broken down.

At present it is unclear if the damage to the mangrove shoreline habitats in Charlotte Harbor have, or in the future will have, negative impacts on its ability to act as a sawfish nursery area. Survey and telemetry studies currently underway are assessing the habitat use patterns of juvenile sawfish in this region and comparing them to the control area in the Ten Thousand Islands. The impact of the damage to the shoreline mangrove habitats on smalltooth sawfish is likely to depend on which components of the habitat are most important. For example, if it is the shallow depth of the habitats that sawfish prefer then the mangrove damage may have limited impact unless the degradation of the old trees leads to erosion. Alternatively if the sawfish prefer the mangroves because of the high prey density that occurs because of the high primary productivity then impacts would likely be much greater until the mangroves recover. It has also been hypothesized that juvenile sawfish use the prop roots of red mangroves to help in predator avoidance (Simpfendorfer 2003). In this case immediate impact may be limited as most of the prop root habitat appeared to remain after the storm, but with high mortality the decay over time may reduce its availability.

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