RESTORATION, MONITORING AND MANAGEMENT OF BOAT PROPELLER SCARS IN ST. ANDREWS BAY, FLORIDA

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ABSTRACT

The Florida Fish and Wildlife Conservation Commission (FWC) partnered with the Florida Department of Environmental Protection (FDEP) to address seagrass habitat that has been severely impacted by propeller scars within St. Andrews Bay Aquatic Preserve in Bay County, Florida. This project employed multiple techniques including prop scar rehabilitation through the use of Sediment Tubes®, non-regulatory resource management actions and public education. Low altitude aerial photography was used to assess level of propeller scarring with these combined management actions in effect. After almost 3 years of monitoring, our assessment offers evidence that the sediment tubes accelerated the recovery of prop scars at our sites; however; managers should carefully consider whether the use of sediment tubes is both ecologically and economically meaningful in restoration activities planned to address propeller scarring. In conjunction with efforts to repair existing prop scars this project implemented several management strategies to reduce the reoccurrence of prop scars in this area. The study areas lay along, or were adjacent to paths used by large numbers of recreational boaters navigating to access island beaches. Based on the findings of this study, the management strategies employed were not found to be effective toward the focal project goal of reducing propeller scarring in seagrass.

ACKNOWLEDGEMENTS

We thank Tova Spector of the Florida Department of Environmental Protection's (FDEP) State Parks staff who was an integral part of this project through data collection, public outreach efforts and the placement of non-regulatory "Caution Seagrass" signs. We also thank the following contributors to this project for their efforts in data collection and analysis, Shelley Alexander and Ben Russell of the FDEP - Coastal Aquatic Management Areas (CAMA), Heather Reed of Ecological Consulting Services, Maria Merrill (FWC), and Paul Carlson and Paul Julian (FWC) for propeller scar photo interpretation and analysis.

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INTRODUCTION

One of the growing human effects on seagrass communities are losses related to propeller scarring (Sargent et al.1995). Propeller scarring can result in minor damage to above ground seagrass short shoots or it can result in more extensive damage to roots and rhizomes (Fig. 1). Deep propeller scars result in the excavation of a trench, removing sediments and pushing them along the side of the scar as overburden and severing the seagrass rhizomes. Propeller scars of this nature often require several years to recover and be recolonized by seagrasses to their original densities. This is due to a combination of photo inhibition of seagrass rhizome growth, sediment displacement along the edge of the trench, and bioturbation (Hamerstrom, et al. 2007). The slow recovery rates of turtlegrass (*Thalassia testudinum*) can lead to even further meadow degradation from boat wakes, tidal currents, or the passage of severe storms (Whitfield et al. 2002, Whitfield et al. 2004), and some disturbances may in fact never recover (Zieman, 1976).

The Florida Fish and Wildlife Conservation Commission (FWC) – Marine and Estuarine Sub-Section (M/ESS) partnered with FWC – Florida Wildlife Research Institute (FWRI) and the Florida Department of Environmental Protection's (FDEP) – Florida Park Service (FPS) and Coastal and Aquatic Managed Areas (CAMA) to address seagrass habitat

Figure 1. Numerous propeller scars are adversely affecting the seagrass beds on the bayside of Shell Island in St. Andrews Bay Aquatic Preserve.

severely impacted by propeller scars within St. Andrews Bay Aquatic Preserve.

The project site is located in Bay County, Florida on the bayside of Shell Island within the boundaries of the St. Andrews Bay Aquatic Preserve (an Outstanding Florida Water) and adjacent to St. Andrews Bay State Park. St. Andrews Bay Aquatic Preserve consists of approximately 25,000 acres of sovereign submerged land (Fig. 2). St. Andrews Bay has the largest expanse of seagrass beds in the Florida panhandle. Handley et al. (2007) reported a 17 percent decline in seagrass cover in St Andrews Bay between 1953 and 1992, and of the remaining seagrasses in St. Andrews Bay, more than 50 percent have been scarred by boat propellers.

This project employed a three-pronged approach to restore existing prop scars and address the underlying causes for the ongoing prop scarring at identified project sites. The designed approach included prop scar rehabilitation through the use of Sediment Tubes®, non-regulatory resource management actions including placement of seagrass caution signs along the deep bed edge of seagrass meadows and public education.

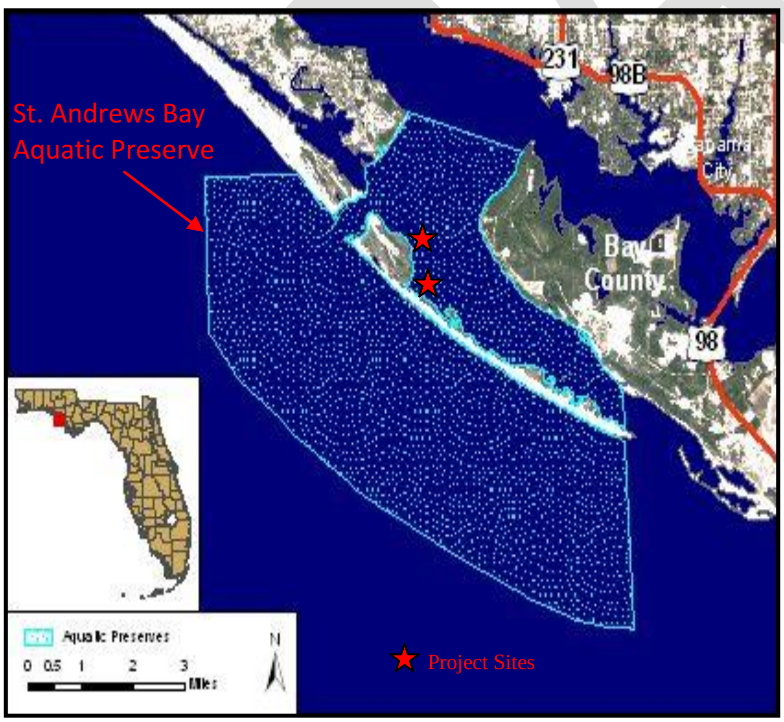


Figure 2. St. Andrews Bay Aquatic Preserve in Panama City Beach, Florida. The project sites were located on the bayside of Shell Island.

The monitoring protocol established for this project allowed us to evaluate;

1) the efficacy of restoring seagrass in prop scars by placement of sediment tubes in propeller scar trenches (This restoration technique, which has been successfully employed in the calcareous sediment regime of Florida Bay had yet to be tested in Northwest Florida with quartz sand sediments.).

2) recovery rates of prop scars filled with sediment tubes relative to adjacent scars that were left untreated.

3) the value of non-regulatory seagrass signs in conjunction with providing the boating public with seagrass information as a strategy to reduce repetitive prop scarring.

METHODS

Treatment:

In the most severely trenched prop scars, topographical restoration of disturbed sediments to ambient grade can expedite seagrass community recovery (Hall et al. 2006). Sediment Tubes® created and patented by Seagrass Recovery, Inc. (hereafter referred to as sediment tubes), are composed of a biodegradable, cotton

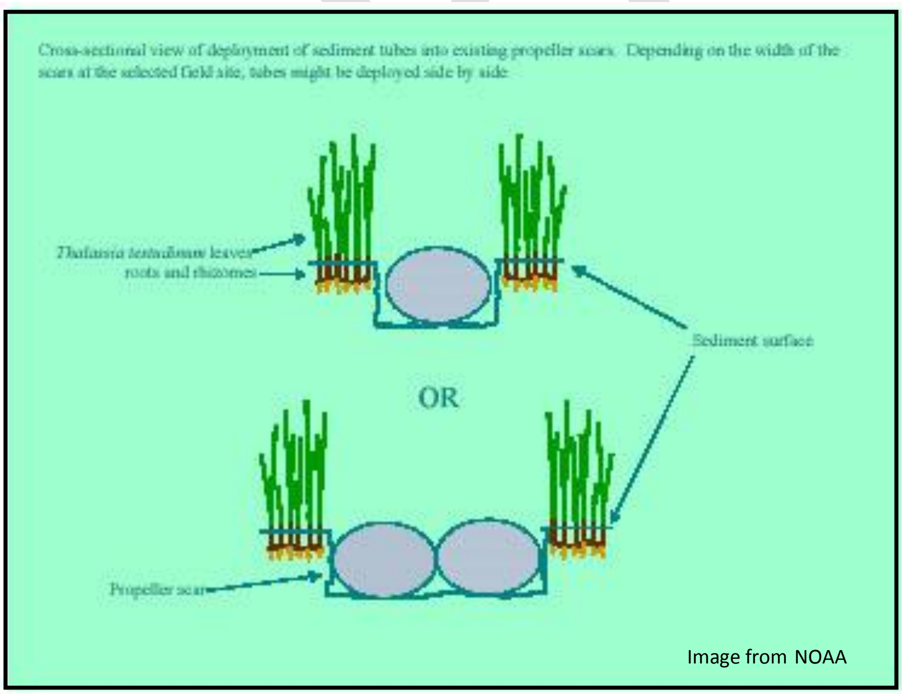


Figure 3. Cross-sectional view of sediment tubes in an existing propeller scar.

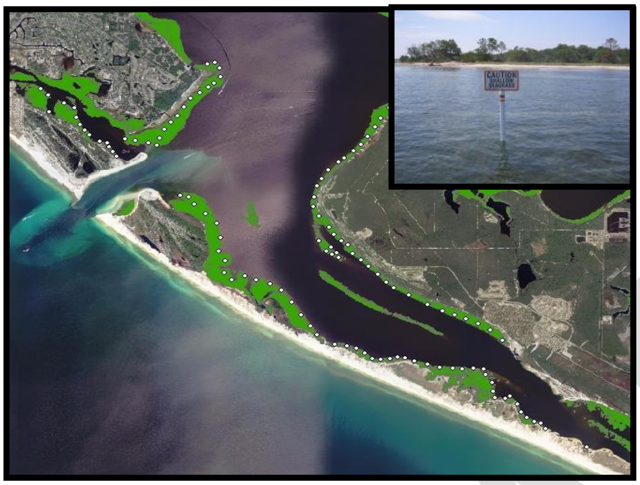
fabric that are filled with locally compatible sediments and laid directly into an excavated prop scar or a vessel grounding site (Fig. 3). Sediment tubes have been used successfully in the Lignumvitae Key Submerged Land Management Area (McNeese et al. 2006), and in Tampa Bay (Hall et. al. 2006). For this project, prop scars were selected for treatment, based on size (linear length > 3 m) and depth (> 0.15 m) criteria. Each sediment tube was 1-m in length and 0.2-m in diameter. Propeller scars that were of sufficient depth and width within the project sites were chosen for treatment. During the week of 22 October 2007, 1,200 sediment tubes were placed into a combination of 24 prop scars and boat groundings. This effectively restored each prop scar elevation to ambient grade for the purpose of creating suitable conditions for seagrass recruitment from undamaged seagrasses on either side of the scar.

Management Strategy:

In conjunction with the use of sediment tubes for seagrass restoration, the Department of Environmental Protection's State Park staff developed a two-step management strategy that included conducting a public outreach program and installing "Caution Shallow Seagrass" signs along the edge of seagrass communities within St. Andrews Bay Aquatic Preserve. During March and April of 2005, FDEP-FPS conducted 187 boater surveys at several different locations including St Andrews State Park and Carl Grey Park, and during U.S. Coast Guard Vessel inspections. This information along with observational data, collected by park staff, of vessels operating in prop scar-prone areas was used to determine the origin of vessels and operators, knowledge of the surrounding waters, seagrass resources and boater behaviors that contribute to propeller scars. A detailed account of this study is currently being drafted for publication by Tova Spector (FDEP-FPS).

In September of 2005, 120 non-regulatory seagrass markers were installed and strategically placed throughout the project area along the 1m depth contour adjacent to, or in seagrass beds threatened with potential prop scaring (Fig. 4). This established a non-regulatory seagrass protection zone at the deep edge of the seagrass bed that alerted boaters to the locations of shallow seagrass beds at eye-level on the water. This effort was supplemented with informational Kiosks that were installed at local boat ramps providing vessel operators information emphasizing the ecological benefits of seagrass and how to avoid prop scarring (Fig. 5). On 28 April 2009, the non-regulatory "Caution Shallow Seagrass" signs were individually inspected for damage or loss and then photographed by staff from FWC-M/ESS and FDEP-FPS. Replacement signs, poles, and tape were purchased with grant funds to cover future maintenance and repairs so that the program can continue for additional years beyond the timeline of the grant.

Figure 4. St. Andrews Bay **"**Caution Seagrass" sign locations are indicated in white.



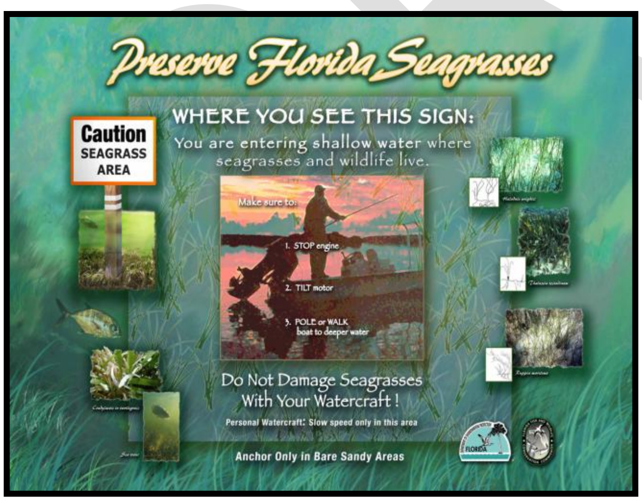


Figure 5. St. Andrews Bay **s**eagrass Information that has been placed in Kiosks at local boat ramps

Monitoring

Two separate areas of prop scars were selected for monitoring and designated as sites A (Cove) and B (Point; Fig. 5). Monitoring of this project consisted of in-water surveys of selected prop scars both treated with sediment tubes and scars left untreated, to determine if sediment tubes create conditions more suitable for rapid seagrass recovery. In addition, low-altitude aerial photographic surveys of prop scars at pre-determined locations were conducted. Aerial photographic images were then geo-referenced, analyzed and interpreted for changes in prop scar occurrence over time to assess the effectiveness of the sign installations.

In-water Transects

Of the 24 scars that were filled with sediment tubes, ten were randomly chosen and are identified as "treated". An additional four scars that did not receive sediment tubes were selected for comparison purposes, due to their similarity in length and depth and their proximity to the treated scars. These four prop scars are identified as "untreated". PVC stakes were prepared and driven into the sediment at the terminal ends of each treated and untreated prop scar to facilitate relocation of each assessed scar. GPS coordinates

Figure 6. St. Andrews Bay and the location of propeller scar treatment sites.

Figure 7. Locations of propeller scar treatment site A (The Cove) and site B (The Point).

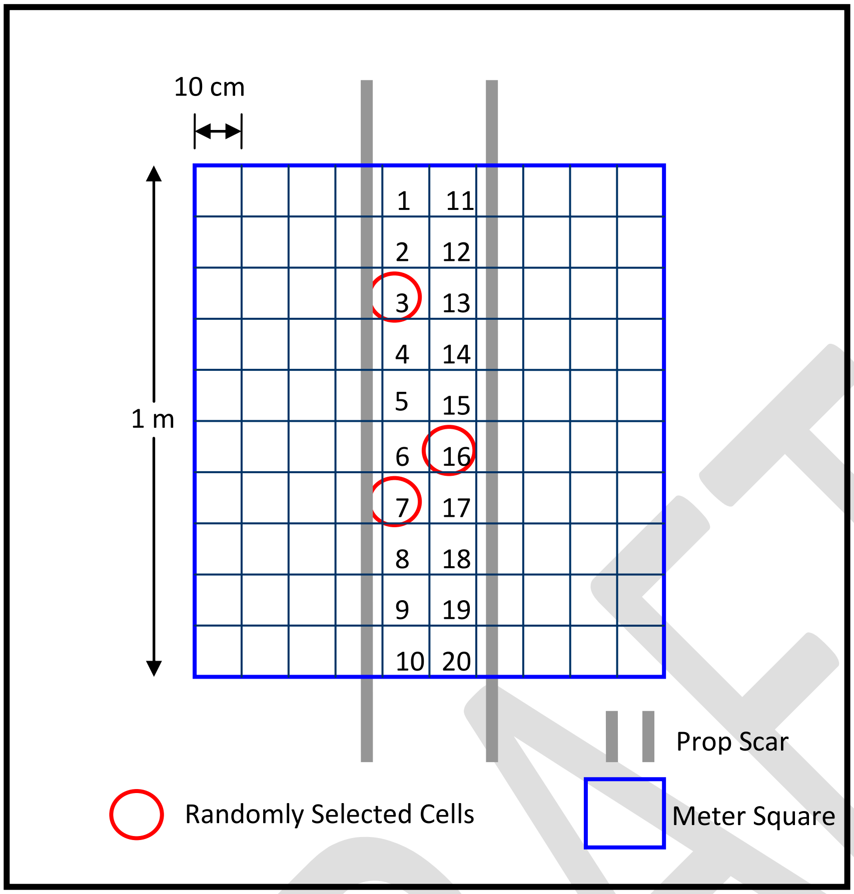


Figure 8. Example of meter square grids that were used to collect seagrass shoot counts and Braun-Blanquet assessments at control, treated and untreated propeller scar sites.

were recorded for these stakes so they could be relocated for repeated monitoring events.

All 14 scars were monitored on 16 September 2008 (11 months after the sediment tubes were placed in the treated prop scars). Replicate measurements were made at three substations within each identified scar; one was located approximately in the middle of the scar and the other two were located 1m inside of both ends of the scar. For each treated substation there was an adjacent corresponding control substation in unaffected seagrass. At each substation, a square-meter quadrat divided into 100 – 10-cm^2 cells, was placed over the treated or untreated scar. Two vertical lines of cells (20 cells total) from the center of the quadrat and fully within the boundaries of the scar (seagrass edge to seagrass edge) were identified and used for subsequent assessments (Fig. 8). At both the treated, untreated and control substations, data were collected using a modified Braun-Blanquet (1965) assessment to determine vegetative cover- abundance within twenty 10-cm^2 cells, and seagrass density was determined by conducting short shoot counts within 3 randomly selected 10- cm^2 cells at each substation. On 23 and 24 June 2010, a second monitoring session was conducted 32 months after the sediment tubes were placed in the prop scars. During this monitoring event only twelve of the original 14 scars were relocated and assessed. Data collected from these monitoring assessments has been used to document the recovery of seagrass within each treated and untreated scar over the 2.7 year time frame. The seagrass short shoot count data collected during the 2008 and 2010 monitoring events were analyzed using two-tailed paired t-tests at an experiment-wise error rate of 0.05% using Microsoft Excel software (Microsoft Office Suite, 2007, Redmond, WA). Tests of statistical differences between paired data set means were deemed significant at the 95% ($p<0.05$) confidence level.

Aerial Photography

Aerial surveys were conducted using a tethered helium balloon that carried a digital camera, with a 35mm focal length lens, to an altitude between 100 m and 125 m. Each photograph encompassed an area approximately 70 m x 40 m. Within each monitoring site, five photo plots

Figure 9. FWRI staff with helium balloon used for propeller scar aerial photography in St. Andrews Bay Aquatic Preserve.

Figure 10. Balloon aerial photography of existing propeller scars at project site A (Cove) in St. Andrews Bay Aquatic Preserve.

were selected. Within each plot, four semi-permanent stakes were installed at the corners of a square with sides approximately 20 m long. A Trimble® (model: GeoXH; sub-foot accuracy) handheld device was used to obtain the geographic coordinates of each stake and the distances between stakes. Prior to each set of photos, tall stakes were installed adjacent to the semi permanent stakes, and colored, floating targets were slipped over the tall stakes. The targets serve two purposes for geo-interpreting the photographs. They 1) provide variations in the color-coded identification of individual photo plots, and 2) serve as references for known distances between targets offering an appropriate scale to rectify the imagery. Although the features are visible, they are not always easily identifiable. In this case, geo-interpreting the balloon involved identifying the individual prop scars and digitizing them onto a map. This provides a record of the locations and morphologies of each scar that is identified. Final analysis was conducted to show the changes in the number, length, and cover of prop scars providing evidence of increasing or decreasing prop scars within identified

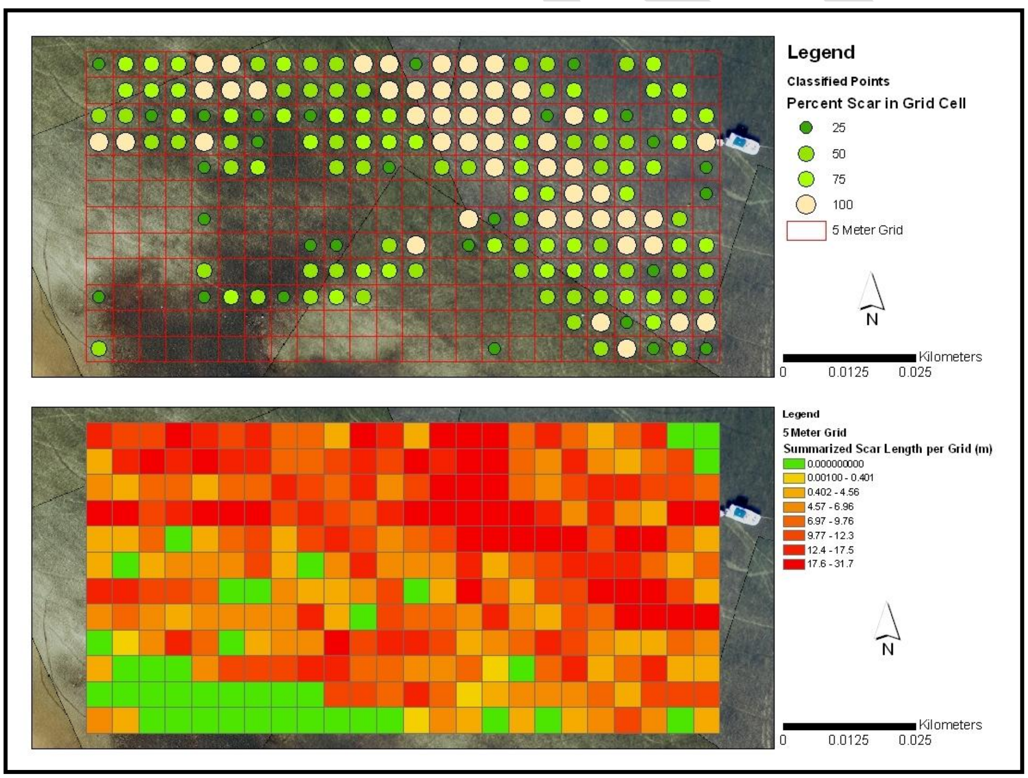


Figure 11. Two techniques used by FWRI to interpret propeller scar aerial photographs located within project sites A (Cove) and B (Point) in St. Andrews Bay Aquatic Preserve.

monitoring plots.

The low-altitude aerial photographs were taken at the project site in November 2007 and 2008 and October 2009 by staff from FWC-M/ESS and FWC-FWRI. All aerial photographs were geo-referenced, and scar patterns were analyzed and interpreted by FWC-FWRI staff. In addition to the low altitude balloon photography, prop scar analysis was also completed on 2007, 2008 and 2009 Florida Department of Transportation's geo-referenced aerial photography of the project area.

The aerial photography data were analyzed using a grid approach. All classifications were conducted at a resolution of 1:250. Project site A (Cove) was classified using a 5-m grid with Hawths Tools (Beyer 2004) in ArcGIS (ESRI, Ver. 9.3) and then converted to a point centeroids using XTools. To aid in the classification and interpretation of the scars, a 2.5m grid was produced with Hawths Tools. At project site B (Point), the images were classified in the same manner, but with the addition of a 15-m grid on the periphery of the 5-m grid. To aid in the interpretation of this site, another grid at a size of 7.5 m was generated with Hawths Tools.

Table 1. Classification categories for percent of grid cells with propeller scars.

Value	**Percent Scar Present/Description**
None	No scars present within grid
Low	25% scars present, a scar running through one section of interpretation grid
Medium	50% scars present, a scar running through two sections of interpretation grid
High	75% to 100% scars present, a scar running through three sections of interpretation grid

A second classification approach was also used categorize the data. Separate polyline shapefiles were generated for both study areas. Once the prop scars were digitized the Identity Tool ArcGIS (Ver 9.3, Yr) was used to relate the polyline data to the 5-m grid employed in the grid classification approach. The lines were clipped to the grid cells and the total length of the scars in each grid cell was calculated. Total scar length (in meters) for each cell was multiplied by 0.5 m to calculate total impact area within each cell and divided by 25 m^2 to calculate percent scarred area for each cell. Aerial prop scar data were then classified into the following categories.

Table 2. Classification categories for total impact area from propeller scars in each of grid cell.

Category	Description
None	0.0% scar impact area for each cell
Light	0.01% to 10% scar impact area for each cell
Moderate	10% to 20% scar impact area for each cell
Heavy	>20% scar impact area for each cell

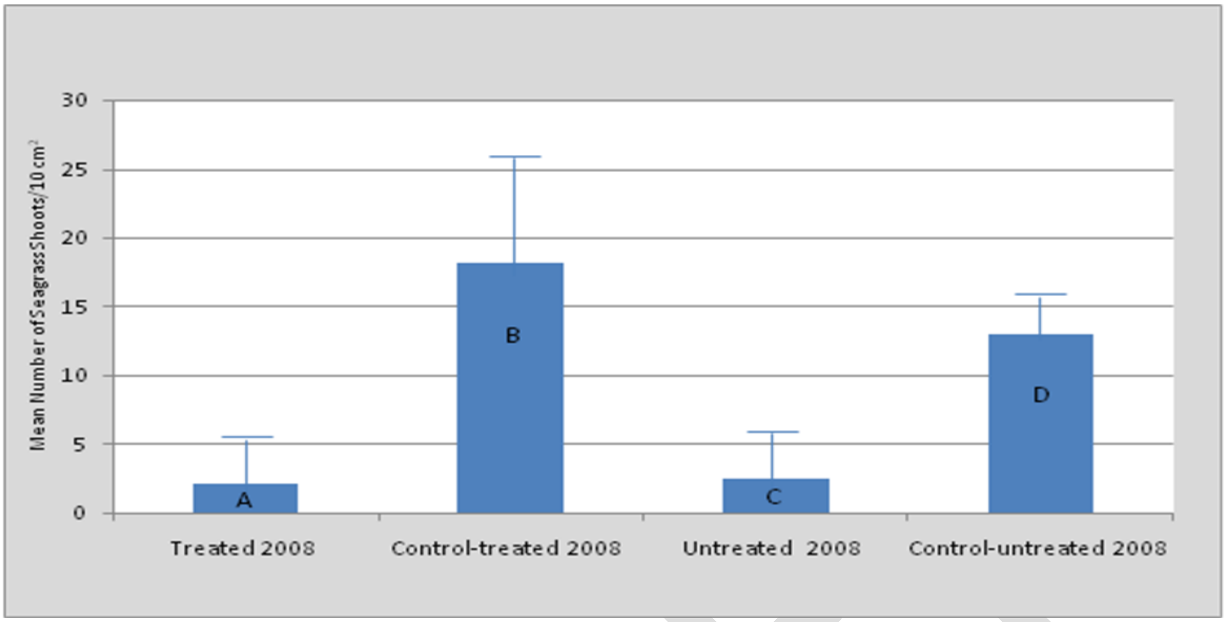
RESULTS

Treatment

Project sites A (Cove) and B (Point) were sampled on 16 September 2008, 11 months after 24 existing prop scars were treated with sediment tubes. Data collected during this initial monitoring consisted of short shoot counts of 2 species of seagrass, Turtlegrass and shoal grass (*Halodule wrightii*), which are displayed in Figure 12. At this time, no significant difference ($n - 1 = 11$, $p = 0.75$) was discerned between the mean number of seagrass short shoots that were counted within those scars treated (Column A) with sediment tubes versus those that were untreated (Column C). Means for short shoot counts for both the treated propeller scars ($n – 1 = 23$, $p = 0.0000000002$) and the untreated propeller scars ($n – 1 = 11$, $p = 0.0000016$) were highly significantly different from their respective control (unaffected seagrass adjacent to the scars) shoot count means (Column A vs. Column B, and Column C vs. Column D).

A second sampling effort was conducted on 23 – 24 June 2010, 19 months after the first monitoring event and 2 years and 6 months after placement of the sediment tubes in treated

Figure 12. Mean number of seagrass shoot counts in treated and untreated propeller scars in 2008.



scars. Data for this sampling effort are displayed in Figure 13. Means for seagrass short shoot counts between the sediment tube treated (Column E) and untreated (Column G) propeller scars were significantly different from one another ($n - 1 = 11$, $p = 0.010350031$) at this time.

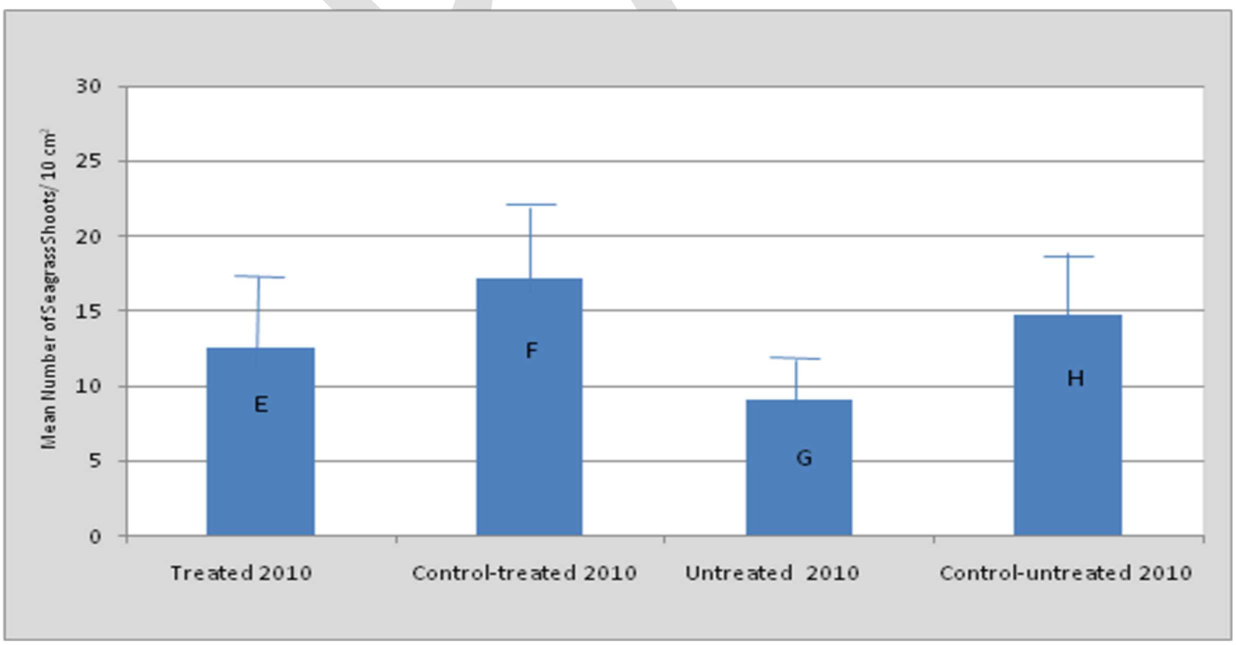


Figure 13. Mean number of seagrass shoot counts in treated and untreated propeller scars in 2010.

Comparison of the means of shoot counts for the treated (Column E) scars and their respective controls (Column F) continued to be significantly different ($n - 1 = 23$, $p = 0.002780829$), as did that for the untreated (Column G) scars and their respective controls (Column H) ($n - 1 = 11$, $p = 0.002188639$).

Mean shoot counts for collected data were compared between the 2008 and 2010 monitoring periods (Figure 14) in order to assess the relative level of seagrass recovery for both treated and untreated scars. Scars treated with sediment tubes in 2010 (column E) had mean shoot counts that were significantly different from those measured at the same locations in 2008 (column A) ($n - 1 = 23$, $p = 0.000000039$). The same was true for mean shoot counts between untreated scars in 2010 (Column G) vs. those measured in 2008 (Column C) ($n - 1 = 11$, $p = 0.00012$). These results are contrasted with the finding that mean shoot counts for both sets of controls were statistically indiscernible over the same comparative time period (Column F vs. Column B; $n - 1 = 23$, $p = 0.59$, and Column H vs. Column D; $n - 1 = 11$, $p = 0.34$).

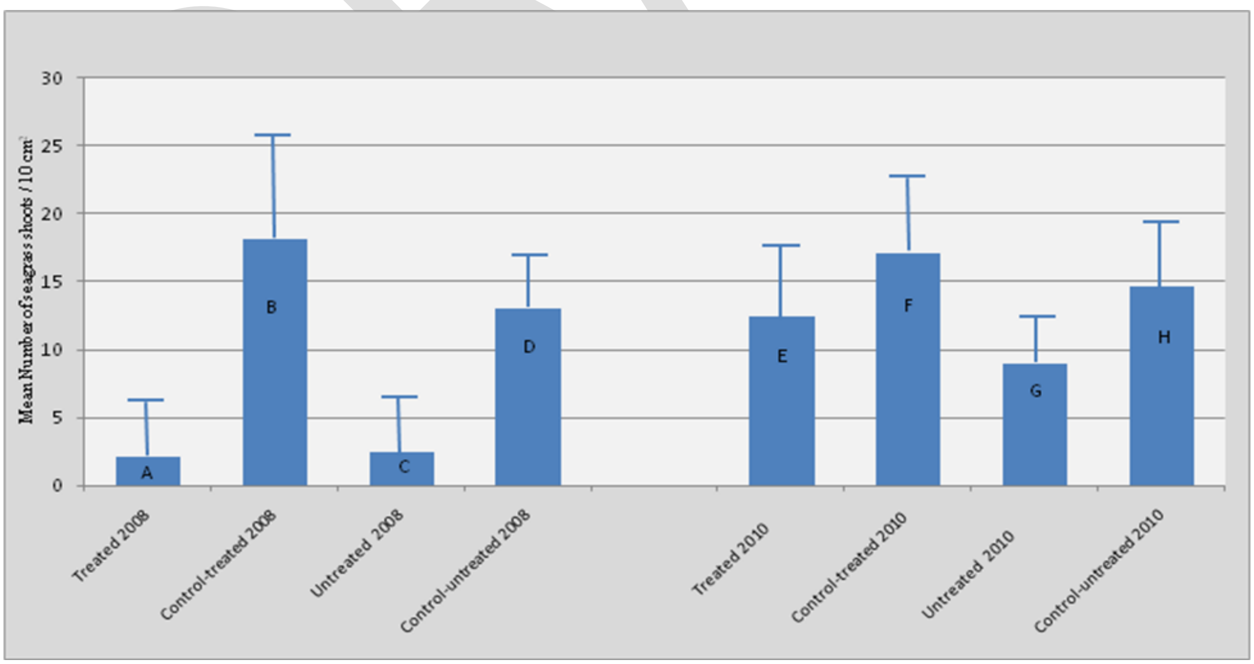


Figure 14. Mean number of seagrass shoot counts in treated and untreated propeller scars in 2008 and 2010.

Collected and analyzed data indicate a trend toward recovery for both the scars treated with sediment tubes and those that were left untreated. By the third seagrass growing season post treatment, both the treated (Columns A & E) and untreated prop scars (Columns C & G) continue on seagrass shoot density trajectories that would lead to eventual recovery. However, between the first and second monitoring events, the treated prop scars (Column E) show a significant difference ($n - 1 = 11$, $p = 0.010$) in the mean number of seagrass shoots documented within the prop scars when compared to the mean shoot count for the untreated scars (Column G).

Aerial Photography

Aerial imagery from 2007, 2008 and 2009 was acquired from an FWC-FWRI ground based helium balloon camera system at known aerial photo stations. The imagery was then analyzed each year for both Site A and Site B to document the occurrence of prop scars in individual cells created through the grid classification system. This prop scar data indicates that light prop scaring decreased from 2007 to 2009, but moderate and heavy scaring increased over the same period of time (Fig, 15). In addition, the percent of cell that did not have prop scars decreased overall from 2007 to 2009, which also supports the premise that

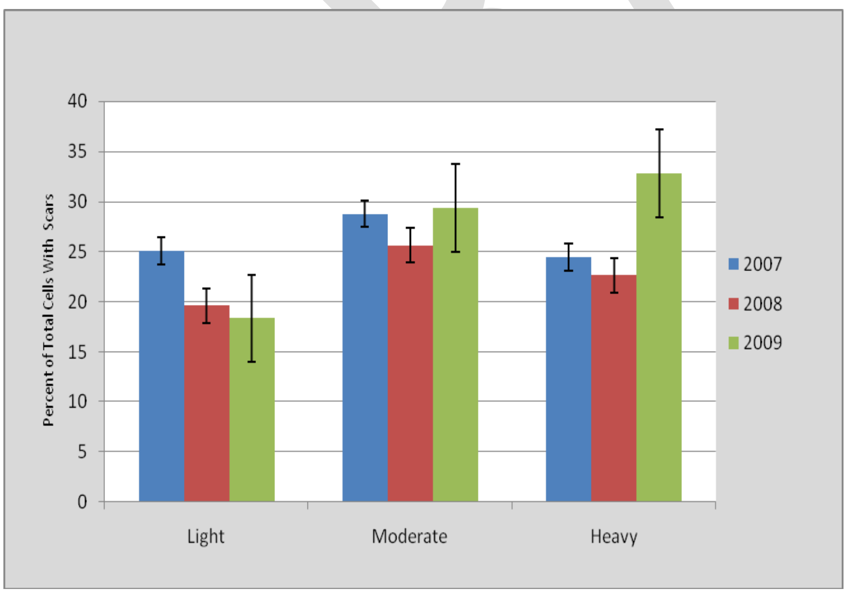
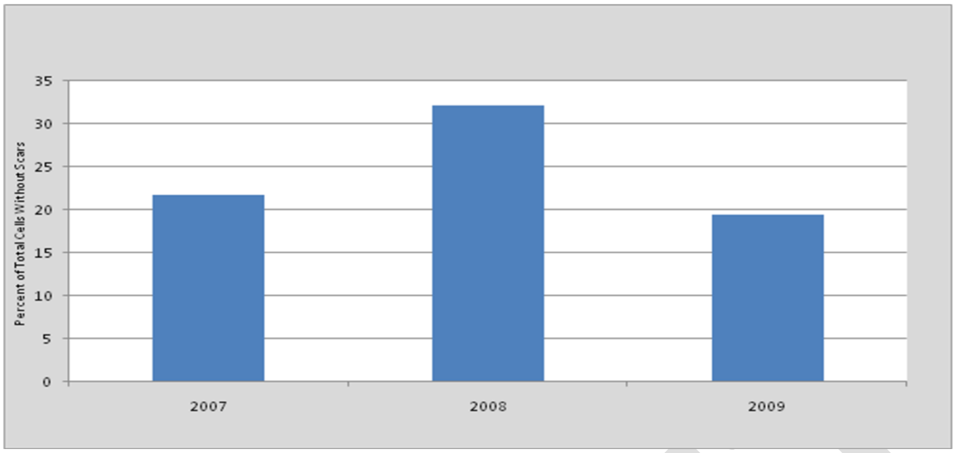


Figure 15. Balloon aerial photography indicating percent of cells containing propeller scars during 2007, 2008 and 2009.

Figure 16. Percent of total grid cells without prop scars at Site B (2007 – 2009)



that there was no reduction in the occurrence of prop scars during the study period (Fig. 16).

FWC-FWRI also acquired FDOT aerial imagery to determine if these products could be used in a similar fashion to analyze the occurrence of prop scars over time. A comparison of the FWRI balloon imagery and the FDOT aerial imagery was conducted to determine if there was a bias in either photographic methodology. Figure 17 illustrates that both techniques compared favorably in identifying prop scars within designated grid cells within known locations.

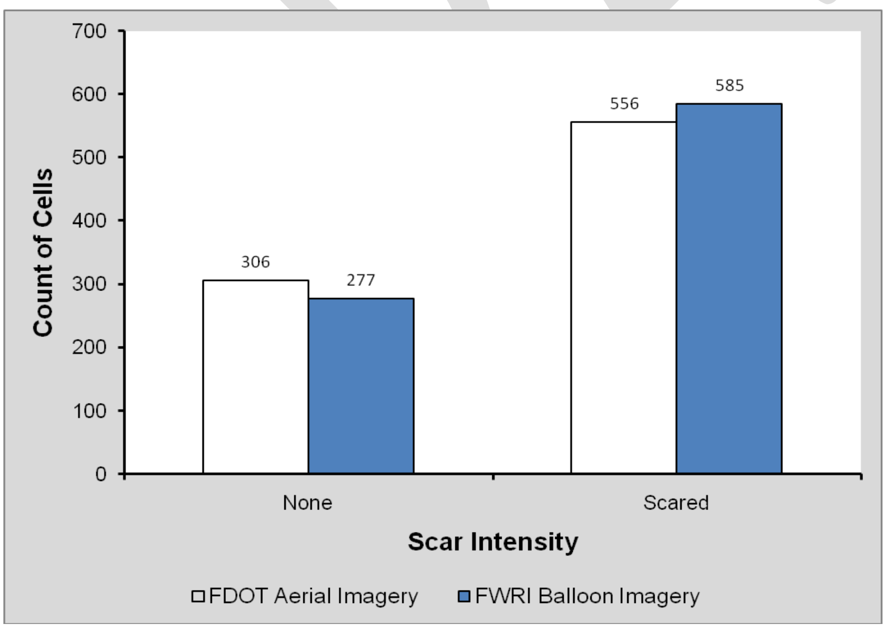


Figure 17. Comparison of propeller scar cell counts of FDOT aerial surveys and FWRI balloon aerial surveys.

After analyzing the data from both the FWRI balloon imagery and the FDOT aerial imagery, it was determined that there was no significant decrease in the occurrence of prop scaring or the intensity of prop scars in the study sites.

DISCUSSION

This project was initiated in part to test the viability of placing sediment tubes into propeller scars as a technique to facilitate and enhance the regrowth of seagrasses in these damaged areas. Data collected during this study demonstrates that sediment tubes over time provided a benefit in the form of more seagrass short shoot growth within recovering prop scars when compared to prop scars that were left untreated. Although both treated and untreated scars were on a trajectory for recovery, a significantly greater number of short shoots were counted in prop scars treated with sediment tubes than those without tubes. How this relates to the total time for recovery for either type of scar is unknown since this project did not follow treated and untreated scars to the point of full recovery, though in both cases it appeared that they would reach recovery within the 3 to 7 year time frame suggested in past studies (Durako et al. 1992, Hall et al., 2006). Managers deciding whether to expend funds for sediment tubes to expedite prop scar recovery will need to determine whether the quicker recovery is ecologically meaningful enough to warrant the added cost of treating the scars with sediment tubes. For this study, costs were approximately $15 per linear foot of sediment tube installed, but expenses can be expected to

Figure 18. St. Andrews Bay Aquatic Preserve propeller scar with recently placed sediment tubes.

vary based on access to appropriately permit-authorized sediment, mobilization and labor. An added consideration for managers is determining if the prop scars are in areas where there is an increased probability of further seagrass bed degradation due to waves, boat wakes, currents or frequent storm conditions. In these cases sediment tubes would offer added stabilization and provide an additional incentive that may warrant their use.

Several management actions were taken prior to implementing the prop scar restoration portion of this project to educate vessel operators of the importance of seagrass communities and to warn them of the environmental damage resulting from boating damage to shallow seagrasses in the project area. In this case, 4 years after the initiation of FDEP's boater education efforts and over 3-1/2 years after the placement of seagrass protection signs, our monitoring efforts related to the occurrence of prop scars in focally assessed areas has provided strong evidence that these educational efforts were unsuccessful. The observed lack of prop scar reduction may be due to several factors. Project site A is a destination area for recreational boaters who want to reach Shell Island beaches from the bay side and then cross over the dunes by foot to the ocean side. Many of the recreational boaters are using rental pontoon boats, which indicates the vessel operators are not local and are likely unfamiliar with the shallow nature of the waters in the area. The Point project area may be receiving repeated prop scars because it is within the vessel transit zone to the cove for many of these boaters. Managers working to resolve prop scar issues need to consider the root cause for prop scarred area under their jurisdiction. In some cases, boater education and non-regulatory signs may be appropriate, but as we found in this case, these management actions were insufficient and our project area continues to receive repeated prop scar insults which nullifies the benefits of the restoration activities we employed. As recommended by Sargent et al. (1995), management programs that address scarring of seagrasses should be based on an approach that involves education, channel marking, increased enforcement and limited-motoring-zones. Not all of these options are viable in this instance. Channel marking and limited-motoring zones solely for the protection of seagrasses are not feasible due to statutory restrictions that do not allow for these techniques to be employed only for the purpose of resource protection. However in this case, the project area is in a Florida Aquatic Preserve. Under current Florida law, vessel operators that are responsible for damaging seagrasses can be fined using a uniform citation process. Occasional directed education and enforcement efforts by marine enforcement officers may heighten awareness of the problems of the area and lead to a reduction of the incidence of prop scars.

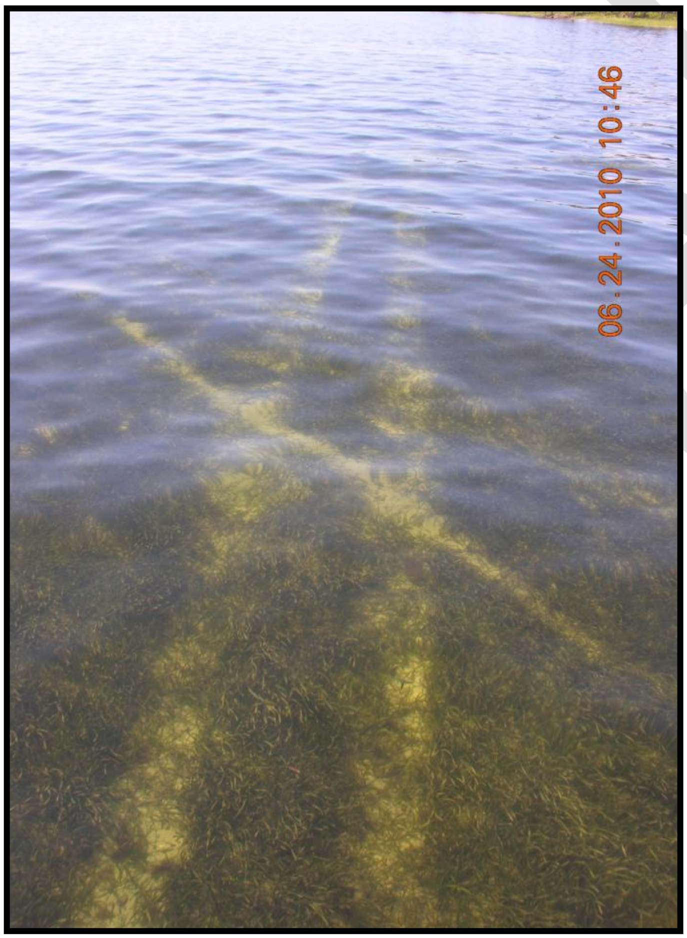


Figure 19. Recovering treated propeller scar at project site B with new intersecting propeller scar.

MANAGEMENT IMPLICATIONS

This assessment does offer evidence that the seagrass recovery process for prop scars accelerated with the use of sediment tubes. However, managers should carefully consider whether the use of sediment tubes is both ecologically and economically meaningful in restoration activities planned to address propeller scarring.

Effective reduction of the area of visible propeller scars was not achieved during the duration of this study using non-regulatory "Caution Shallow Seagrass Signs" placed at the edge of the seagrass community. The region of this study is in a highly visited warm season boating destination, and sampling locations lie along or adjacent to paths used by recreational boaters to access Shell Island beaches. Based on the findings of this study, the management strategies employed were not found to be effective toward the focal project goal of reducing propeller scarring in seagrass.

CONCLUSIONS

The monitoring protocol established for this project was designed to evaluate three questions; 1) whether sediment tubes are effective in repairing propeller scars in NW Florida, 2) if scars treated with sediment tubes recover more quickly than untreated prop scars, and 3) if informational seagrass signs and vessel operator education efforts reduce propeller scar occurrence. We believe those questions were answered during this project as follows:

Figure 20. Recent propeller scar located in project site B in St. Andrews Bay Aquatic Preserve.

Propeller scars without sediment tube augmentation show recovery based on increased abundance and density of seagrass, but those augmented with sediment tubes demonstrate significantly greater seagrass recovery over the same

same period of observation.

Non-regulatory shallow seagrass informational signs placed in the configuration and at the depth for this assessment did not result in reduced aerial densities of recognizable propeller scars.

Aerial photography to monitor prop scars at the two projects is an effective technique to examine the occurrence and density of propeller scars over time.

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