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Propeller Scar Monitoring Program for the Tampa Bay National Estuary Program—contract no. T95-03-A2

FINAL REPORT

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PROPELLER SCAR MONITORING PROGRAM FOR THE TAMPA BAY NATIONAL ESTUARY PROGRAM CONTRACT NO. T95-03-A2

COMPILED BY THE FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION,
FLORIDA MARINE RESEARCH INSTITUTE
100 8TH AVE. S.E., ST. PETERSBURG, FL 33701

F.J. SARGENT, T.J. LEARY,
D.E. KUHL, A.P LAMB,
M.M. COLBY, G.M. MACAULAY, and P.J. RUBEC

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Executive Summary

Seagrasses form some of the most productive communities in the world, and are aesthetically and economically valuable to humans (Zieman and Zieman, 1989). These complex, fragile communities benefit marine and estuarine animals - especially larval and juvenile fish - by providing critical shelter and sustenance. Seagrasses also have a role in providing habitat for waterfowl, marine turtles and mammals. In addition, seagrasses improve water quality by stabilizing mobile sediments and by incorporating some pollutants into plant biomass and the stabilized sediments. Seagrasses are a principal contributor to the marine food web and ultimately provide humankind with much of its seafood.

The issue of propeller scarring or propeller dredging in seagrass beds has received much attention since 1990. Personal watercraft and other types of jet driven-water propulsion type watercraft are also capable of inflicting damage to benthic resources. Time lines for regrowth of seagrass in the scars are species dependent. Estimates of regrowth are 1-2 years for *Halodule wrightii* and 3-5 years for *Thalassia testudinum* in protected, undisturbed sites. Heightened interest has instigated numerous monitoring and mapping projects on propeller scarring and regrowth characteristics within seagrasses.

In 1992 a statewide survey of propeller scar damage was conducted to assess the amount of damage that existed. This assessment used a combination of aerial photography and aerial surveys to map the scarred seagrasses. This information was incorporated into a GIS for analysis and map production. Scarring was classified into three categories, based upon percent cover of scars; Light, Moderate, and Severe. Moderate and Severe areas of damage are of greatest concern - the level of damage indicates that the seagrasses have been subjected to continual watercraft impacts and seagrass recovery may be slower.

This survey determined that Hillsborough, Manatee, and Pinellas Counties which surround Tampa Bay, ranked among the top ten counties within Florida with the most damage. Pinellas County ranked in the top five of Moderate, Severe, and combined Moderate-Severe scarred seagrass acreage. Hillsborough had 2,410 acres of combined Moderate and Severe damage; Manatee 2,990 acres; and Pinellas 5,880. The percentages of total damage of total seagrass are; Hillsborough 64.8% of 6,320 total acres of seagrass, Manatee 45% of 12,160 total acres of seagrass, and Pinellas 42.3% of 22,920 total acres of seagrass.

This NEP report deals with four tasks that involves the evaluation of existing data, the design of a prop scarring monitoring program, a pilot program to evaluate the adequacy of such monitoring devices, and the recommendation of specific actions in areas of severe prop scarring.

The FMRI sent questionaires to 10 parks and preserves located in the state to gain baseline data about their prop scar management and monitoring programs. Due to the high maintenance costs

of buoys, many programs are beginning to use pilings instead. Pilings initially cost more, but last longer and have low maintenance. Restricted access programs using tides, non-combustion zones (pole or troll), and/or seagrass caution zones had an effect on the reduction of propeller scarring. Enforcement of local and state laws by law enforcement agencies had a minimal effect on prop scar reduction.

Monitoring of scarring damage provided insight as to the effectiveness of management practices and regrowth of the seagrasses. Monitoring of scarred seagrasses was conducted biologically or spatially and varied in the level of detail.

The creation of a biological monitoring program for prop scar follow proven methods established by the University of South Florida, Clint Dawes. The use of quadrats, transects, and other research of biological components are necessary to discover the amount of time required for the regeneration of seagrasses in damaged areas and associated effects of scarring on the habitat.

Spatial monitoring is either regional or site specific in its approach to understanding the impacts created by boaters. Information gleaned from spatial analysis will also determine the effects of channel marking and signage toward reducing prop scarring. The cost of aerial photography is expensive as is the process of interpretation to final map production. The use of medium and small format cameras is a means of reducing costs. Video cameras also offer an acceptable alternative to 9" x 9" format aerial photography. Time series of data capture should be at a level that will be cost-effective and yield appropriate data for analysis.

Evaluating the effectiveness of the 35mm, digital, and video cameras was conducted in the winter of 1996. Resolution of the cameras is critical to obtaining the data required for analysis as was the flight altitude of data capture. Results discovered that the 35mm used in conjunction with an 8mm video camera is a cost effective means of mapping prop scarring damage.

Another component of the evaluation process was the use and comparison of two computer mapping softwares with GPS capabilities in order to conduct real time surveys of prop scarring damage. FieldNotes and ArcView were installed on a laptop computer with a direct GPS connection. Research found ArcView to be a more powerful software than FieldNotes. A pen-based computer would improve the production time of aerial mapping of prop scar damage, and that accurate GPS data is required to enhance the accuracy of the mapping.

The final task of the project suggested that Miquel Bay and the Shell Key area located near Ft. DeSoto be considered for specific action. Both locations could use signage and channel marking as a means of reducing prop scarring. In addition to biological and spatial monitoring, channel marking and signage costs, the programs range from $20,000 - $50,000 per year for capital expenses and maintenance.

TASK 1 - Evaluation of existing data:

Staff within the Florida Marine Research Institute (FMRI) of the Florida Department of Environmental Protection (FDEP) will evaluate existing information on the effectiveness of propeller scarring reduction methods in seagrass beds. The deliverable will be an Evaluation Report summarizing existing information to date, including (but not limited to) results from Tampa Bay (Weedon Island, Ft. DeSoto Park, Cockroach Bay) and Sarasota Bay (Sarasota National Estuary Program).

In numerous areas around the state, park and preserve managers are using different methods to reduce watercraft impact to submerged natural resources. Primarily concerned with protection of seagrasses, managers at these parks and aquatic preserves use a combination of the four-point method to reduce damage; education, channel marking, enforcement, and restricted access (Wilderness Society, et al., 1990) and Sargent et al., 1995). The use of these methods has produced positive results.

The following park and preserve managers were contacted to discuss their programs and fill out questionnaires (Appendix A) and associated reports: Shelly Allen - Cockroach Bay Aquatic Preserve (state); Keith Thompson - Weedon Island County Park (Pinellas); Eric Fehrmann - Ft. DeSoto Aquatic Management Area (Pinellas); Perry Smith - Gulf Islands GeoPark-Honeymoon and Caladesi Islands (state); Anne Deaton - John Pennekamp Coral Reef State Park (state); and Pat Wells - Lignumvitae Key State Botanical Preserve (state). Please refer to location maps in Appendix B.

SARASOTA BAY

A comprehensive project to study the damage inflicted on seagrass beds and ways to determine how propeller scarring may be reduced was conducted in Sarasota Bay by the University of South Florida, New College. The resulting report was entitled *Beds, Boat, and Buoys: A Study in Protecting Seagrass Beds from Motorboat Propeller Damage* (Folit and Morris, 1992). The study focused on researchers observing boaters and conducting interviews, mapping of propeller scars using aerial photography, and examining the placement of buoys adjacent to seagrass beds. Another facet of the project was public outreach through brochures, slide presentations, and decals to educate the public about seagrasses and how motorboats can damage seagrasses. This study was funded through the New College Foundation and the US Environmental Protection Agency through the Sarasota Bay National Estuary Program.

Researchers observed and interviewed boaters to determine how and why some boaters created prop scars. Observation of boaters are more reliable than interviews since interviewees are uncertain of their actions and tend to be less precise (Folit and Morris, 1992). Researchers interviewed over 200 boaters at local boat ramps and determined that the public is willing to participate in protecting the resource if information is distributed in an effective manner. Folit and Morris (1992) recommend marking channels, not seagrass beds. Although buoys in seagrass beds seemed to attract fishermen's attention; there was still a reduction in prop scar damage. The researchers also believe that buoys are worth the added expense over pilings.

Seagrass caution buoys were placed at Sister Keys, City Island, and Big Pass in Sarasota Bay. Selected sites of propeller scarring were mapped before and after the buoys were put in place. The *before* buoy-placement photos were obtained during May 1990 and December 1990. Buoys were placed at City Island in June 1990 and at two other sites in December 1991. Aerial photography was again obtained in November 1991 and then five months later in April 1992. Approximate scales of the photography ranged from 1:800 - 1:1,440 (~ 1" = 100 ft). There were consistency problems with the aerial photos. Although several methods were tried, true verticals with medium format film were used because of budget restrictions.
A reduction in propeller scarring was seen at Sister Keys and Big Pass after the buoys were installed. Folit and Morris (1992) thought increase in scarring at City Island was due to the configuration of the buoys. Unfortunately, only one of the 37 buoys remained at the end of the project. Buoy losses were attributed to corrosion, vandalism, or storms.

Monitoring seagrass beds using aerial photography to check the effectiveness of closing or restricting access by motorboats, and education-outreach was suggested by the authors. This study does not include enforcement as a possible mechanism for education and/or reduction of prop scar damage nor was there any biological monitoring of seagrasses.

Brochures and decals, along with slide presentations, were used to educate boater groups. In addition, signage about seagrasses and what to do if your vessel became grounded was placed at two boat ramps.

Two studies on faunal diversity within the edge of the scarred seagrass beds were completed by an undergraduate student from the University of South Florida, New College. According to R. Corletta (1992), abundance of shrimp was greater in dense *T. testudinum* beds. The results were difficult to evaluate due to the small size of the study area and lack of additional biological data, *e.g.* blade measurements, macrophyte biomass, and seagrass densities. To date, there has not been another study conducted in Sarasota Bay, although plans for faunal assessments within propeller-scarred seagrass beds are underway elsewhere in the region.

WEEDON ISLAND PRESERVE

Weedon Island County Preserve (formerly a state preserve) created the first motor exclusion zone to protect seagrasses in Florida in August 1991. Enforcement is currently conducted by the Pinellas County Sheriff's Department at a cost of $80,000 per year. With the assistance of the public, signage was placed in a few locations around the Preserve's boundary approximately 400 ft from shore. Boating within the Preserve is only by paddling, poling or electric trolling motor.

In the early '90s, recovery of seagrasses in artificial propeller scars was investigated (Durako et al., 1992). The FMRI completed this study under a Coastal Zone Management grant. Durako's study found that the recovery times for *Halodule wrightii* and *Thalassia testudinum* in propeller scars was approximately 1 - 2 years and 3 -5 years, respectively. Recovery was also dependent upon conditions in the areas around the scars, such as sediment type, orientation to water movement, and vessel traffic.

Propeller scars were mapped from aerial photography. Mapping of scars began in May 1991 after the Preserve's closure to combustion engines. It was determined that the scale of photography needed depends directly upon the amount of detail desired. For general mapping of Moderately to Severely damaged areas using polygons, 1:24,000 (1" = 2,000 ft) or 1:12,000 (1" = 1,000 ft) was sufficient (Sargent et al., 1995). For detailed mapping of propeller scars (individually and grouped together in polygons), larger scale photography - 1:2,400 (1" = 200 ft) or 1:4,800 (1" = 400 ft) was used to provide for greater detail.

Education efforts include distributing the Tampa Bay Boater's Guide and posting signage around the Preserve. Signage within the Preserve consists either of signs attached to pilings or signs attached to "stop-sign poles". The major drawback to using "stop-sign poles" is that they can be blown over in storms.

The only source of information on prop-scar damage since 1992 is from Keith Thompson, Preserve Manager, who has seen a reduction in the amount of propeller-scar damage since closing the Preserve to combustion engines. Seagrass recovery within the scars, based on Durako's 1992 study, appears to be promising. New signage has been added to ensure that vessel operators are aware of the restricted access and combustion-engine ban. Reports of improved fishing since the closure have been received.

COCKROACH BAY AQUATIC PRESERVE

A management plan for the Cockroach Bay Aquatic Preserve was submitted to the Hillsborough County Commission in August 1992. This plan was put together by the Cockroach Bay Task Force, which was composed of people from various government agencies and concerned citizens, to ensure accessibility to the resources by all users of the Preserve. From this plan came guidelines for new rules, education, monitoring criteria, signage, and enforcement.

The plan required the establishment of restricted areas that would allow the recovery of marine wetlands stressed from physical damage. The Preserve has four such recovery areas (RA): RAs 1, 3, and 4 are currently closed to all boaters, and RA 2 is closed to boats having combustion engines. RA 2 allowed boating access depending on the tide level.

Signage includes tide markers, boat-ramp signs with pamphlet holders, and signs that inform boaters about restrictions for the specific RA. Tide markers show current tidal levels with information about entering and exiting the RA; tide markers also serve as channel markers.

Enforcement of the regulations required the creation of a full-time position within the Hillsborough County Sheriff's Department, with the Aquatic Preserve Manager acting as a Reserve Deputy Sheriff. From 1992 until January 1996, the deputy position was funded; however funding has expired, and there are no current patrols as of April 1996 (D. Alberdi and S. Allen, pers. comm.). During the time enforcement was present, warnings and citations were issued, although the judges dismissed the cases (S. Allen, pers. comm.).

Biological sampling and mapping were used in monitoring of seagrass recovery and prop-scar damage. The biological monitoring was directed by Dr. Clinton Dawes (University of South Florida), and mapping of propeller scars was done by Nicholas Ehringer (Hillsborough Community College). The first project began in January 1993 and was completed in December 1994 at a cost of $40,880 (biological) and $72,672 (mapping). An extension was granted for the spring growing season (January - July, 1995) for $9,600 and $3,800, respectively. Another contract was established which will run for a fourteen month period (beginning July 1995) at a cost of $38,085 and $41,665, respectively. The last contract will determine if voluntary compliance is sufficient to protect seagrasses in Cockroach Bay (D. Alberdi, pers. comm.).
Four reports were created from the monitoring effort. Two the these reports, "Seagrass Recovery From Propeller Cuts in Cockroach Bay, Florida - First Year Report for January - December 1993" delivered in February of 1994 and "Recovery of *Thalassia testudinum* In Boat Propeller Cuts, Cockroach Bay, Tampa Florida, Second Year Report for January 1994 -December 1994" were reviewed for this project. The initial six-month report and the report from July 1995-January 1996 were not reviewed by FMRI staff. Results from the two annual reports are summarized below.

Report 1 (January-December 1993)
Biological monitoring was established with quadrats and transects for the purpose of conducting sediment analyses, blade growth, short shoot densities, and biomass. Sediment sampling used standard techniques, *e.g.* cores taken in all sites and analyzed for particle size, calcium carbonate level, and organic content. Blade growth and leaf area index were used to measure length and widths in addition to using blade weights for new production. Short shoot density sampling used 25cm^2 quadrats for densities and %cover. Above and below ground biomass material was sorted for blades, rhizomes, and roots then were separated, dried, and weighed. Other components of the monitoring consisted of proximate constituents, macroalgae, epiphytes, temperature and salinity. Dawes' preliminary conclusion after one year revealed slow recovery rates for *T. testudinum* and a continuing increase of prop-scar damage. He stated a loss of 2.06% due to prop scarring and witnessed little regrowth of seagrass.

HCC decided to use very large-scale aerial photography to obtain baseline data for the area. With approximate scales of 1:400 (1" = 33 ft) and 1:1,000 (1" = 83 ft) the photos were enlarged and mosaiced together to calculate areas of seagrasses and the amount of propeller scar damage. According to the HCC report, there were 2,140,803 ft^2 of seagrasses. Table 16 of the report states there are 7,130,500 ft^2 of seagrasses and 31,747 ft^2 of propeller scars. Because of the discrepancy within the total figures for seagrasses and propeller scars, there is some uncertainty about the actual losses within the Preserve. Based upon Table 16, there should have been more than 145,488 ft^2 of seagrasses lost. The total of seagrasses lost at Entrances D, E-south and E-north is 140,403 ft^2, in one year. According to Ehringer (pers. comm.), there are some discrepancies within the report.

Report 2 (January-December 1994)
The biological monitoring conducted by Dawes et al. was divided into three parts: baseline information about the benthic communities within the Preserve, effects of propeller scar in adjacent seagrasses, and recovery rates of *T. testudinum*. Recovery of *Halodule wrightii* was not studied. In addition to studying existing propeller scars within permanent quadrats, artificial scars were also created and subsequently observed. Results of this thorough investigation of seagrass recovery within prop-damaged seagrasses were similar results to those of Durako et al. (1992). Dawes concluded that *T. testudinum* may require approximately 2-5 years to recover, dependent upon several "edaphic factors". Durako et al. (1992) found *T. testudinum* may recover in 3-6 years while *H. wrightii* demonstrated potential for regrowth in 1-2 years. These time frames are also similar to work completed in the Keys by Zieman (1976).

The mapping portion of the report details the spatial analysis of propeller scar damage within the four RAs of Cockroach Bay, over four periods of mapping, January - July 1993, July - December 1993, January - July 1994, and July - November 1994. There is no discussion of aerial photos taken from January to July 1994, only those acquired during the months of September and November 1994. The only cumulative information shows that RAs 1 and 3 had no new damage within one year, and RA 2 had 2,805 linear feet and RA 4 had 12,776 linear feet of scarring.

FT. DESOTO

Ft. DeSoto is a county park located in southern Pinellas County and contains a large area of seagrass beds that have been placed under three types of use restrictions: Nonrestricted, Seagrass Caution, and Boat Restricted. The County passed the required ordinances in 1992, although the actual restrictions did not take effect until 1993 when the signage was in place.

Education efforts include signage at boat ramps, and brochures and the Tampa Bay Boater's Guide that are distributed around the area. A Pinellas County Sheriff's deputy, hired by the Pinellas County Parks Department at an annual cost of $82,000, patrols the park and issue warnings and citations.

The closure areas are marked by buoys and pilings. Pinellas County discovered that buoys require high maintenance and are changing to pilings with dayboard signs. In addition to the buoys or pilings, the County is using orange ball floats to create a visual line between markers (buoys or pilings) that have been spaced far apart.

Water quality monitoring is conducted by the County's Department of Environmental Management. A five-year mapping program is being conducted by Nicholas Ehringer (Hillsborough Community College) to track progress in prop-scar reduction and seagrass recovery. There are two reports for Ft. DeSoto, 1992-93 and 1994 that discuss the procedures, results of the mapping, and maps.

Pinellas County hired a professional aerial photography company in 1993 to acquire large-format natural color diapositives 9"x 9" transparencies twice a year, at a scale of 1:2,400 (1" = 200 ft). They now acquire photos once a year at a scale of 1:4,800 (1" = 400 ft). During the initial phases of the project, it appears that the aerial photographs were less than desirable for interpretation needs. In the fall of 1993, the problem was apparently rectified, although recent sets have also been less than optimal due to water clarity and glare.

Overall, the conclusions from Ehringer's reports of 1992-93 and 1994 state a significant reduction in the amount of propeller scarring. Within the seagrass caution zone and the boat restricted zone, propeller scarring has been maintained at a minimum. Initially, the Non-restricted zone had a substantial increase, although within the last year of the mapping, it appears that propeller scarring in this area has been reduced. A combination of increased boater awareness, in conjunction with different types of restricted zones, probably assisted in the reduction of propeller-scar damage.

JOHN PENNEKAMP CORAL REEF STATE PARK (JPCRSP)

Situated in the Florida Keys, JPCRSP, in addition to protecting the coral reefs it is known for, also has to manage the other benthic communities located within its boundaries. Park managers closed off severely damaged seagrass beds, placed regulatory buoys in the channels and adjacent to seagrass beds, and provided educational information through brochures and interpretive signs as protective methods. In October 1993, the Park closed 2,578 hectares of submerged habitat to combustion engines. This effort was funded by the Coastal America Program. Education and enforcement are two programs that are still ongoing at the Park. Educational information about seagrasses and closure zones is conveyed through signage at boat ramps and pamphlets.

The monitoring conducted by the Park was to evaluate signage and regulations in addition to biological monitoring. Transects are used for biological monitoring on selected scars. Types of measurements included short shoots, length and width of the scar, seagrass density, depth, etc. Mapping of the propeller scar damage used 1:4,800 (1" = 400 ft) natural color aerial photos to create baseline information about the number of scars and total area involved. Once the scars were delineated on the aerial photos, the photo information was transferred to a base map. The scar information was then digitized from the base map into ARC/INFO, a vector-based GIS. Because of funding shortfalls, mapping of prop-scar trends has not been completed.

The Park initially used buoys (spar and can-collar type) for marking channels and closing seagrass beds but soon found the buoys to be an expensive maintenance problem (*i.e.*, $480/buoy plus $75/year/buoy for maintenance). Corrosion of the hardware seems to be the biggest problem for buoys, and painting is also required. They are now using fixed poles with regulatory signs that have minimal maintenance requirements and cost $280 each; signs are $60 each.

Enforcement is conducted by the Florida Park Patrol, who issue warnings or citations. Park personnel (*e.g.*, managers, park rangers, and attendants) may only inform violators of infractions.

A correlation in the amount of damage in seagrass beds to the number of boats within a specific area was found (A. Deaton, pers. comm.). While they are uncertain of the degree of success, Deaton states that overall, the public is aware and willing to cooperate with the new regulations.

LIGNUMVITAE KEY STATE BOTANICAL PRESERVE

Lignumvitae Key State Botanical Preserve is located in the middle Florida Keys and is composed of several large seagrass flats in an area of heavy boat traffic and fishing. In 1992, the Preserve set up a closure program due to the large amount of boating impacts. The closure areas include all seagrass flats situated in waters less than 3 ft deep. The main channels remain open.

Boater education is through signage at boat ramps and brochures distributed at local outlets. Enforcement of Preserve regulations is by the Florida Park Patrol, who are allowed to give citations. Park personnel are only allowed to inform individuals of violations.

The Preserve began using buoys to mark closed seagrass beds, but has now changed to poles/pilings and dayboard signs due to cost considerations. The Preserve spent $55,000 for 150 buoys and signs. Annual maintenance costs, since installation, have been approximately $27,000/year (*e.g.*, costs of the piling and dayboard are $1,200/year. There is currently no monitoring of damage or biological components in the Preserve due to lack of funding.

GULF ISLANDS GEOPARK - HONEYMOON ISLAND AND CALADESI ISLAND

Gulf Island GeoPark contains some of the largest seagrass beds in northern Pinellas County. Because of interest generated from the closure of Weedon Island, the Park's management and concerned public organizations, (*e.g.*, FCA), began the process of closing its seagrass beds in the interest of resource protection. In the fall of 1993, the Florida Park Service started closing the seagrass areas to combustion engines. Trolling motors, paddling and poling are acceptable.

Educational information about the closure is available in brochures and signage at boat ramps. Enforcement of the regulations is conducted by the Florida Park Patrol, who more often give warnings than citations. Closure areas are marked with pilings and dayboards. Pilings have a higher initial cost, but maintenance costs are reduced. A permit to install buoys was denied by the US Coast Guard, because they viewed the addition of buoys as a hazard. Park management wants to expand the closure signage to eventually be placed around Moonshine, Malone, and Core Islands, south of Caladesi Island.

Compliance with the closure has been well received by the public and the resources seem to be benefiting from the closure (P. Smith, pers. comm.). Reports of improved fishing and birds staying in the area for longer periods of time seem to indicate protection measures are working.

The monitoring program at this park only contains a biological aspect due to a lack of funding for a mapping program. Amy Becker is responsible for conducting a long-term project that began in 1995 to review the recovery rates of prop scars in closed areas. Ten prop scars, three at Honeymoon and seven at Caladesi, are presently being monitored every three years. This time frame was chosen because of the length of time for *T. testudinum* to recover. Scars have been measured for length, width, and depth. The primary focus is seagrass recovery.

ROOKERY BAY

The Rookery Bay National Estuarine Research Reserve began a monitoring project in April of 1994 to investigate the use of different management strategies to reduce propeller scar damage from boats and personal watercraft (jet skis and wave runners). Permanent transects of 100 meters were established at four sites. Informational brochures on seagrass were distributed at local marinas, boat-rental vendors, and directly to boat operators. Observations of boaters by researches were also conducted monthly at scheduled times to coincide with specific tides and seasons. The number of vessels were calculated on a units/hour basis and identified as rental, private, Florida registered, or state.

The Rookery Bay study found a positive correlation between new scarring and total boat activity at one site, although overall, boat activity was not different among sites. There were no seasonal differences in scarring or boating activity, however increasing trends of boat activity and scarring in winter were observed. There was an increase of scarring after the removal of seagrass signage at one site. Statistical procedures were conducted using analysis of variance (ANOVA), linear regressions and power analysis.

H. wrightii is the dominant species found within the study area. The recovery of *H. wrightii* within a scar was approximately 3.1 months, although recovery times can be longer, dependent upon the amount of activity within the study site (Shirley, 1995). It should be noted that this study considered 'scar closure' to be "lack of an observable path extending to the transect or a lack of depression at the site...".

In some locations seagrass signage had been removed as planned for the project, however the US Coast Guard's plan to place additional channel markers in these area was delayed and may have influenced the outcome of the study from its original intent. Lack of funding has prevented continuing this study in this area.

SUMMARY

A variety of resource management methods are obviously working toward the reduction of propeller scarring. Using a combination of channel marking, education, restricted access, and enforcement, the parks and preserves examined have seen a variety of mostly positive results.

The use of buoys appears to have waned and the preference is now for pilings as the cost of maintaining buoys far outweighs the initial cost of using pilings. The use of pilings eliminates the requirement of additional personnel to perform maintenance on buoys. In addition, when the buoy hardware (pins, cables) corrodes, the buoy may float away; there are also instances where the buoys have been cut loose on purpose. Reducing costs or effecting minimal costs is a primary focus for all marking programs listed in this report.

Restricted access areas work, but reduce the amount of area that the public can readily use as everyone is not equipped with a trolling motor or strong enough to pole a boat or a flats boat. The gains of restricted areas outweigh the negatives, as observations by park personnel indicate increases in wildlife use and fish catch.

Observation and interviews of boaters can be a worthwhile exercise in determining why some areas are prone to propeller scarring. The Sarasota Bay and Rookery Bay studies indicate that observation is a good source of data. Observations and interviews will be important for future monitoring projects and must be designed to fit the needs of each specific area or site.

Given the different studies that have found positive responses from interviews and casual conversations with boaters, it seems that education does work in getting the attention of the average boater. Several of the parks and preserves have produced their own pamphlet-type guides. Regional boater's and angler's guides that feature maps, resources, and cultural information have been favorably received by the public.

Law enforcement on the water has gained importance because of the increasing number of accidents. These accidents have also necessitated enforcement of speed zones and manatee protection zones. As a result of increased water patrols by city and county agents in seagrass management areas, there is a reduction in propeller scarring. However, there are those whom the threat of law enforcement seems to have minimal or no effect on when creating propeller scarring. When a violation does occur, the judicial system requires clear evidence of intent. Many cases of scarring, therefore, are dismissed. There also seems to be a lack of understanding about the importance of the resource and its need for protection as witnessed by low fines and citations.

Biological and/or spatial monitoring occurred in most of the locations reviewed. Each type of monitoring has a level of detail conducive to the area of interest, (*e.g.*, Cockroach Bay and Weedon Island). The biological monitoring was very limited within the projects listed and the methods varied. Cockroach Bay had detailed biological monitoring, and Rookery Bay conducted an array of statistical information concerning boating activity. Weedon Island completed a one year study in 1992 without any follow-up. The primary reason for biological monitoring was seagrass recovery within the scarred areas. The focus, however, has now turned to methods of increasing growth production of the seagrasses and not strictly to monitoring.

Spatial monitoring also has different levels of intensity. At the highest level, it is very costly (*e.g.*, Cockroach Bay and Ft. DeSoto). Other parks or preserves with limited funding, were only able to obtain baseline data, without the possibility of consistent data collection (*e.g.*, JPCRSP). Methods of spatial monitoring varied. The primary purpose of spatial monitoring was to determine damage and/or damage increases. It was noted that seagrass recovery within scars and scarred areas might not be evident in aerial photography or imagery for several months or years, dependent upon the seagrass species. Spatial monitoring allowed resource managers to identify damaged areas within their boundaries.

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Task 2. Design Scarring Rate Monitoring Program

FMRI will design a monitoring program to evaluate the effectiveness of implementation of selected scar reduction methods. The program should include specific monitoring objectives, data collection and evaluation, data reduction and analysis.

The previous studies conducted in three aquatic preserves used different methods and different maps scales. Consequently, comparisons between these study areas cannot be made directly. In designing a consistent monitoring program, it is necessary to standardize monitoring methods and scales over the entire area of concern for management.

The FMRI needs to develop a monitoring methodology that can assess the effects of boat propeller scarring and other factors impacting seagrass beds over large areas. Various approaches need to be evaluated in terms of the time and cost associated with data collection, scientific interpretation and accuracy, and their relative utility for management.

The following methods have been proposed as potential monitoring approaches. Associated with each method, there are various technical, temporal, and/or cost limitations. It is not anticipated that it will be feasible to evaluate all of the potential approaches under the present proposal for TBNEP.

The evaluation report for this Task 2 will summarize the results from the surveys. The monitoring methods used will be compared and contrasted in terms of the time necessary for data collection and analysis, relative cost, and quality of the information obtained.

Before the monitoring program can begin, thought must be given to the type of information that is required, how the information can be obtained, and how the information can be displayed. Analysis of biological monitoring data can be accomplished with a standard personal computer (pc) and a variety of statistical software packages that create charts, graphs, and tables.

However, to conduct accurate spatial and trend analyses and work with digital imagery, more hard drive space and RAM are required (either a pc or work station). Additional hardware may include a digitizing tablet and scanner or both. Finally, the appropriate geographic information system (GIS) software must be acquired. There are numerous software applications that can do similar GIS functions and create maps. The user needs to be certain that the software is capable of conducting the GIS analysis desired.

Many of the parks and preserves have the statistical software required for biological analysis. Few however, have any GIS capability or have the personnel or funding to implement a GIS. In the absence of a GIS, a contractor would be needed to input the data and conduct the analysis desired. The costs associated with spatial analysis vary as seen in the evaluations for Task 1 and from public sector to private.

Before starting the monitoring program, some basics are required to establish the baseline data set.

The Basics

> Good baseline data are important to any monitoring effort. Current landcover/landuse maps, boundaries, marker/buoy locations (within 5 m), moorings, and boat ramps should be included. These data should meet minimum standards for the scale at which they are represented. Mapping is made easier with a detailed base map and results are more accurate. The integrity of the original data must be maintained as different information is added.

> A seagrass mapping program, conducted every two years since 1988 by SWIM, produces a baseline data set of seagrass distribution at a scale of 1:24,000 (1" = 2,000 ft) from natural color film. This facilitates a change analysis for seagrasses and other benthic communities to determine trends. Knowing the amount of seagrass that exist within any of the project areas is important to any monitoring scheme that is developed.

> Channel markers, buoys, and signage should be located using GPS units so that accurate latitudes and longitudes can be determined for use with a GIS. This information allows the resource manager to see where resources are in relation to any damage and regulatory signage. Managers can add information gathered from observations of boaters, biological monitoring, etc. to increase the value and update existing information on the maps.

> Aerial surveys should be conducted to obtain an overall view of the preserve and its geographic layout with respect to cultural and physical features. Resource managers can become familiar with the area by recognizing patterns of prop scars. A preliminary map of propeller scarring intensity can be created during a survey. Scar polygons can be drawn on a nautical chart or a seagrass map in a manner similar to that of the statewide assessment (Sargent et al., 1995). Aerial surveys offer an economical way to assess damage from scarring.

Both fixed-wing aircrafts and helicopters can be used for surveys. While fixed wing is less expensive, a helicopter is easier to maneuver with its slow speed and tight circling capabilities in areas of convoluted shorelines. Doors of the helicopter can be removed so the researchers can readily see/film their points of interest. The average rate for a fixed-wing aircraft, such as a Cessna 172 (4 seater), a typical aircraft used for aerial surveys, is approximately $80.00/hr (Bay Air). Helicopter charters range from $225/hr for a Hughes 300, a small two seater (West Coast Helicopters) to $795/hr for an Astar (Helicopter Charters and Transport) which is capable of carrying four. Because of the expense of chartering a helicopter, adequate flight planning is recommended to decrease wasted time once the flight has started. During the aerial survey, it is important to record what is seen by using a still camera or video camera.

> Different types of watercraft are responsible for varying degrees of damage. Repeated traffic through an area can also increase seagrass recovery time which is dependent upon location (*e.g.*,

either inside or outside of a preserve's restrictive zone). It has been proposed that jet skis are also responsible for either creating scars and/or keeping the scars open. Different types of user groups are also responsible for damage, (*e.g.*, tourists vs. locals), and need to be educated about the resources.

Observations of boaters is a critical component to any program. Resource manager(s) are able to see first hand who is responsible for the type of damage being inflicted on the seagrass beds. In addition to local boaters, there may be rental boats operated by inexperienced boaters/tourists, fishermen (either commercial or recreational), and/or boaters just out 'cruising' around. When on the water, the observer(s) can also gain a better understanding of the forces at work due to boat traffic under varying conditions, (*e.g.*, tides, currents, etc.). Interviews with vessel operators may be conducted to improve observation data, although this would add to the expense of the monitoring project.

Statistical Methods of Spatial Monitoring

The FMRI reviewed various studies that used different methods to evaluate propeller scarring in seagrass beds and different aerial photo scales to map scar patterns. The review also contained studies by biologists sampling seagrass growth patterns and recolonization of seagrasses in propeller scars and adjacent areas. This ground-oriented biological research allowed replication that yielded results that are amenable to statistical analyses.

A variety of parametric and non-parametric statistical methods such as analyses of variance(ANOVA),linear regressions, and multivariate techniques were applied by scientists in evaluating the effects of boat propeller scarring on seagrass beds, and to evaluate human behavior to management actions such as signage near seagrass beds, channel marking, and aquatic preserve closures. Some of the studies reviewed lacked adequate explanations of the precise statistical methods used.

Assessing changes in scarring rates in a statistical sense implies the need for replicate sampling. Monitoring of seagrass beds, on the ground, can allow replicate measurements of such variables as number of scars, scar lengths, scar widths, area of seagrass scarring, etc. This can be accomplished by line transect and/or quadrat subsampling methods. The disadvantage of surface-oriented sampling methods regarding spatial monitoring sampling is that they may not illustrate the overall conditions existing for the entire park, preserve or seagrass area.

Remote sensing techniques may not have sufficient replication to allow statistical evaluations over time, such as trends in propeller scarring before and after a given management action. However, this does not mean that monitoring using remote sensing should not be used. The use of aerial photography for submerged aquatic vegetation, requires that a number of variables be controlled for consistent interpretable photography; water clarity, tide conditions, sun angle, sea state, cloud cover, and season. If one or more of these conditions are not met, the aerial photographs may not yield the consistent information needed to conduct interpretation or analyses and also mean a monetary loss. Ehringer discusses such problems in reports concerning Cockroach Bay and Ft. DeSoto.

Non-parametric statistics, such as the Wilcoxin (Mann-Whitney) two sample test, were suggested in the original proposal as a method to evaluate whether observed changes in the relative frequencies of scarring were statistically different before and after the implementation of protective management around Weedon Island and in the Cockroach Bay Preserves. The Kruskal-Wallis test was another method suggested to compare propeller scarring rates using data derived from selected management zones within the Cockroach Bay Aquatic Preserve, using data derived from 1:2,400 scale aerial photography (See Task 3). The software for such tests are available in statistical software packages such as the Statistical Analysis System (SAS). Time limitations and the availability of data prevented statistical analyses for the present review. Other statistical methods may be needed depending on the problems being addressed and the hypotheses being tested. Statistical procedures may not always be necessary for assessing ecological impacts to support management decisions.

Meaningful information collected by remote sensing and displayed using GIS can include the areas of most severely impacted seagrass beds displayed as images (Sargent et al., 1995). Such GIS techniques can inform management about the area of seagrass beds containing scars in relation to the total area of seagrass in a given region. Scar patterns in a limited area may be insignificant if the total area of seagrass beds is large. Likewise, the converse is true. Scar patterns in a limited area may be significant, if the seagrass beds are limited in area and lie close to cities, etc. The scientists involved in future studies, irrespective of the methods and scale of the study area, should pay more attention to presenting their results in a graphical manner that is more easily understandable by managers and the public. Examples are histograms depicting confidence intervals, pie charts to present percentage changes, and maps to depict the areal extent of the distributions of propeller scars, boats in relation to seagrass beds, photographs, etc.

The goal is not to collect scientifically rigorous data amenable to statistical analyses. The goal is to collect sufficient data to support timely management decisions. Remote sensing and GIS have the advantage that they can be used to assess ecological impacts over larger areas. The data can be visually displayed in a meaningful manner to support decision-making by managers.

Proposed Monitoring

Scarring is represented as lines or polygons (Sargent et al., 1995). Lines are single discernible scars typically found in areas of light to moderate scarring. This type of scarring is easy to monitor and map. Polygons are clusters of indistinguishable scars indicative of moderate to severe scarring (see Appendix C). Propeller scarring delineated by polygons is more complex to monitor and map than lines, because it is cumulative and seagrass recovery occurs over several years. In addition, within a scar polygon, there are varying densities of seagrass.

We recommend the following for biological and spatial monitoring of scarred seagrass beds:

Biological Monitoring

Biological monitoring should be conducted in a manner similar to that of Dawes during his Cockroach Bay research (Dawes et al., 1995). Their methods should serve as a standard so that all monitoring projects in Tampa Bay can be compared. In Cockroach Bay, Dawes ran several transects and quadrats to estimate productivity and the state of seagrass beds. Water quality data from the Hillsborough County Environmental Protection Commission and the Pinellas County Environmental Management Division, could be used to enhance the monitoring data. Of most importance, is maintaining consistency throughout the monitoring programs so data can be readily exchanged among agencies responsible for the management and health of the seagrasses.

The number of transects and quadrats would need to be calculated dependent upon the locations and size of the area monitored, and costs may range from $12,000-$25,000 per year. An example of costs is the program being conducted in Cockroach Bay which studies five components of seagrasses; biomass, short shoot density, blade growth, leaf area and rhizome growth. Using 12 quadrat sites and a series of sampling periods, Dawes expects to compare results from previous studies of Cockroach Bay to obtain information about productivity and status. The cost was ~$25,000 and included one graduate and two undergraduate (part time) students, Dawes' summer salary and benefits, equipment, lab expenses, travel, and supplies (Cockroach Bay proposal 1995). This amount may also vary depending on the contractor (private vs. education/government).

Spatial Monitoring

Spatial monitoring for the Tampa Bay region can be conducted in two ways, a regional (general) approach and a site specific (detailed) approach. Regional monitoring is for assessing the status of seagrass in Tampa Bay and for identifying 'hot spots'. After identifying 'hot spots', boat surveys can be used to confirm or deny the initial assessment. Because scarring is cumulative over time, photographs/videos should be taken at known altitudes during aerial surveys to record the damage, and determine the conditions of the site. Task 3 examines some of the types of photographic equipment available.

The mapping of propeller scar damage can be done with a variety of equipment and still meet the needs of a resource protection agency's budget. In large areas such as Tampa Bay, mapping could be general (1:24,000 scale - 1" = 2,000 ft) and still be effective for locating hot spots and potential hot spots of propeller scar damage. Resource managers can decide upon the amount of detail required to assess the damage, causes, and effect once these areas are located.

The Tampa Bay SWIM program has been mapping seagrasses in the Bay using aerial photos every two years since 1988. These natural color 9" x 9" aerial photos have a scale of 1:24,000 (1" = 2,000 ft) and the overall resolution is very good with minor exceptions. Using these photos, a general assessment can be completed in a timely manner (40 hours). Moderate and severely damaged areas (*e.g.*, Shell Key and Miquel Harbor) can be interpreted from these photos although it is difficult to delineate areas of lesser damage. If a county is interested in determining where most of the damage is occurring, an aerial survey combined with the information that can be found on the SWIM photos, is a good beginning. Approximately 200 frames would be needed at $9.00/frame = $1,800. Using criteria already established in previous studies, (*e.g.*, Durako et al., 1992 and Sargent et al., 1995), polygonal information can be digitized into an ARC/INFO vector GIS software for analysis in ARC/GRID. Cost of digitizing, analysis, and map production is estimated at $5,000. Total estimated cost of mapping the region may range from $10,000-$15,000; aerial surveys, aerial photos, interpretation and delineation, digital processes, and reports.

Nine-inch by nine-inch aerial photography is very expensive and the procedures to obtain seagrass aerial photography are stringent and time consuming. For example, Pinellas County pays $6,000 to acquire natural color 1:4,800 (1" = 400 ft) aerial photos for the Ft. DeSoto Aquatic Managed Area. This scale is acceptable to create a baseline data set. Pinellas County has acquired an annual set of aerial photos for the Ft. DeSoto Aquatic Managed Area since 1993 and will continue until 1998.

Interpretation and delineation of propeller scar damage is another expensive task that requires specific equipment, (*e.g.*, interpretation scopes, or scanners and other computer hardware). In addition, there is also the equipment required for digitizing the photo information and for map production.

The use of 70mm cameras is promising, yet not capable of delivering the same endlap - sidelap requirements of 9" x 9" aerial film cameras or the wide variety of film. The small negative requires that an enlargement be made. 9" x 9" film may be positive film or negative film. For small areas, the cost of 70mm aerial photos is conducive to monitoring. Attempts to visit with a local aerial photo company who is experienced in this field were unsuccessful.

With the conversion of vector data to raster, additional assessments can be done relatively easily. Raster analysis would include percent cover of the three damage categories in both the overall region and the selected site areas. The types of changes over time would be spatially correlated, (*e.g.*, light to severe, severe to moderate). This change information should be correlated to biological data gathered at the sample site. Distance analysis for proximity to channels, boat ramps, marinas and other coastal features are also applicable. Several of these methods would also apply to detailed monitoring.

Site-specific monitoring (detailed analysis) is for parks and preserves or other sites requiring greater information about scarring. The level of detail should include individual scarring patterns in addition to polygonal mapping of scar damage. The project should use large-scale natural-color aerial photos (1:6,000, 1" = 500 ft or greater) for the purpose of interpretation/delineation. If budget allows, stereo photography should be obtained as this enhances interpretation. This should be done to create a baseline data set if possible. Depending on budget constraints, the maximum recommendation for collecting this type of photography is once a year, otherwise every two or three years would be acceptable. The actual size of the study area will influence the selection of the aerial photos. With every increase in scale comes an increase in the number of aerial photos, photo preparation, interpretation time, quality control, digitization, map production and analysis. For example, on a 9" x 9" photo, the area covered by a 1:6,000 (1" = 500 ft) photo is approximately 4,500 x 4,500 ft. The area covered by a 1:2,400 (1" = 200 ft) is approximately 1,800 x 1,800 ft. Consideration must be given to what information the manager wants to obtain, and if the increase in scale justifies the additional costs; refer to the Durako, et al., 1992 or Ehringer studies as a guide. Detailed interpretation and delineation of the scarring information can be digitized and analyzed. Ground truthing of transects will enhance information being obtained form the photos. Project cost for site specific analysis will vary from $5,000-$25,000 depending on the study area and level of detail. Pinellas County pays $14,000 to Ehringer for interpretation and analysis of scarring data of Ft. DeSoto. Initial estimates for conducting similar analysis of small study sites at Weedon Island and Cockroach Bay were $5,000; $1,000 for 1:4,800 scale aerial photos with 60% endlap and 30% sidelap and $4,000 for interpretation, ground truthing, analysis and map production.

Summary statistics should include: number of scars (this has minimal value), average width of scars, average length of scars, average depth of scars (both within the scar itself and below the surface of the water), total area of scar damage in seagrasses, total amount of seagrasses within park/preserve boundary/study area, and total amount of other benthic communities. Analyses should quantify frequency of scarring occurrence, change over time (*i.e.*, percent increase/decrease of scarring), and percent cover of scarring. The FMRI is currently conducting aerial surveys of boating patterns in Tampa Bay, these data should be included in any final assessment.

NOTE: Because scars also occur in areas of naturally bare substrate, scars found in sediment (sand or mud) should not be considered in any calculation, unless part of a clearly stated mission. The natural migration of sediment over seagrasses should only be included in the total acreage of benthic communities, (*e.g.*, seagrass, bare substrate, hard bottom, etc.). This will yield information concerning losses or gains of one community to another.

A cost-effective method of spatial monitoring is to use a 35mm still camera with slide film and/or 8mm video camera for recording scar damage while conducting an aerial survey. These surveys can be done two or four times a year dependent upon budget constraints. These photographs can be enlarged and inspected for seagrass scarring.

We suggest that within monitoring years, and in interim years, a combination of 35mm slides and 8mm video be used to record and verify the current conditions of the seagrass beds and the propeller scar damage. This effort can be conducted twice a year at a minimal cost. Comparisons can be made against the true vertical photos for increases of propeller scar damage provided the area is not so damaged that individual scars cannot be discerned.

Another method of obtaining 35mm still or medium format photography or video is through the use of an airship. This platform allows for the acquisition of large scale data and observation of boaters over a large area.

The use of aerial photography to estimate if seagrass is recovering should be minimized. Initial growth recovery from scarring can be determined on the ground much sooner. Due to drift algae and other material that cover scars and polygonal damaged areas with little or no grass, on the ground observations of seagrass recovery are more reliable. Within Task 3 are evaluations of different cameras and mapping methods using a notebook computer.

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Task 3. Complete Pilot Program to Evaluate Adequacy of Monitoring Program

FMRI will evaluate the adequacy and accuracy of the designed monitoring program in a demonstration scale pilot study. Evaluation elements should include technical feasibility, time and effort estimates, statistical robustness, and effectiveness of meeting monitoring objectives.

Method 1. Medium and Large-scale Aerial Photography - Conducted by Marcia M. Colby and Frank J. Sargent

Large format aerial photography (9" x 9") is the type most often used when acquiring true verticals for accurate photogrammetric work. Cost is the main problem involved with this format. Costs include actual mission overflight, processing of the negative or positive film, and generation of prints or transparencies (diapositives). This cost for the Weedon Island project was $3,900. A total of 108 frames, covering the entire Preserve, were taken at three different scales. Pinellas County spends $6,000 for natural color film at a scale of 1:4,800 (1" = 400') to monitor Ft. DeSoto. The cost for interpretation/delineation of the photos for Ft. DeSoto is an additional $14,500 which also includes the transfer of photo information to a digital format and the output of hard copy products.

FMRI contracted with I.F. Rooks and Associates, Inc. to obtain large-format aerials of two study areas - one at Weedon Island and the other at Cockroach Bay, during January or February. The photos were to be natural color and have a scale of 1:4,800 (1" = 400 ft). Unfortunately, the company was not able to acquire the photography because the weather conditions never met the standard criteria for obtaining seagrass photography.

In the absence of this new photography, aerial photos from the 1991 Weedon Island collection were used to conduct a review of the prop scar damage in the passes along the eastern shoreline of the Preserve. Using 35mm color prints obtained in April 1996, a comparison to the 1991 1:2,400 (1" = 200 ft) natural-color transparencies showed a tremendous reduction in the number of scars. Some of the passes had no visible scars in the color prints. This exercise suggests that the closure program is working and that 35mm film can be used for analysis of prop scar data.

Method 2. Photography with 35mm, digital and Hi8 video camera from an Aircraft - Conducted by Derrick E. Kuhl

This evaluation was conducted to determine a cost-effective means of periodically monitoring propeller scarring in seagrasses. Three different types of cameras were evaluated for their usefulness in monitoring propeller scarring: a Sony 8mm video camera, a Kodak DC 40 digital camera, and a Pentax A3000 35mm camera. Aerial surveys were conducted over a two-month period in various weather conditions. Altitudes ranged from 500 to 1000 ft and the results from each camera were compared (Table 1). A flight log was kept for all of the flights and appears at the end of Method 2.

2.0 Methods

2.1 Study Areas

Many locations in the Tampa Bay area were used to evaluate monitoring techniques: Weedon Island, Cockroach Bay, and Ft. DeSoto. Gulf Islands GeoPark of Honeymoon and Caladesi, was included because of its recent closure to combustion engines. Surveys were conducted from a Cessna 172 Skyhawk II aircraft on the following dates: 3/10/96, 3/20/96, 3/31/96, 4/6/96, 4/11/96, and 4/14/96. The altitude of the plane varied between 500 and 1000 ft for each camera to obtain the best resolution for taking pictures of prop scars. Surveys were conducted under weather conditions ranging from 0-100 percent cloud cover during low and high tides. Two types of cameras were generally used on each flight. The conditions for each flight are recorded in the flight log.

True vertical photography, in conjunction with known camera parameters, is required for accurate measurement of ground features. Special wing or door mounts or even a hole in the floor of the plane, depending upon the camera, are needed to acquire true vertical photography. This project used near vertical photography, which meant it was necessary to lean out of the plane's window with the camera to take photos. This was done to limit data confusion towards the edge of an oblique image. Attempts were made to collect a continuous coverage of an area in order to evaluate the areal extent of prop scars.

2.2 Camera Characteristics

2.2a Sony CCD3X 8mm Video Camera

The Sony CCD3X 8mm video camera has 1:12 zoom capabilities with a variable 20mm to 200mm lens. This camera was used on all but the 4/14/96 flight. The usefulness of 8mm video in monitoring seagrass beds was tested under different weather conditions and altitudes.
The average costs for the 8mm camera are:

Camera		$2,500.00
Tapes		$ 14.00 per tape
Batteries		$ 60.00 per battery
	Total	$2,574.00

2.2b Kodak 40 DC Digital Camera

The Kodak 40 DC digital camera contains a 42mm lens and is capable of 48 frames at 24-bit resolution or 96 frames at 8-bit resolution. We only used 24-bit resolution. The digital camera includes a 24mm wide-angle lens and a 55mm zoom lens, which were compared with the normal lens to examine their effectiveness. The digital camera was used on 3/31/96/, 4/11/96 and 4/14/96.

The average costs for the Kodak 40 DC digital camera are:

Camera	$ 800.00
486 PC computer	$2,000.00
Wide angle lens	$ 70.00
Zoom lens	$ 70.00
Total	$2,940.00

2.2c Pentax A3000 35mm Camera

The Pentax 35mm camera was used with a 35-70mm lens with a 1:4 zoom. Kodak color print film ASA 100 was used to obtain 3" x 5" prints for evaluation. This camera was used on 4/6/96, 4/11/96 and 4/14/96.

The average costs for the Pentax A3000 35mm camera are:

Camera body	$175.00
Lens	$175.00
Processing	$ 7.00 (36 exposure)
Film cost	$ 4.00 (36 exposure)
Total	$361.00

2.3 Prop Scar Image Analysis

Images were obtained using the 8mm video and digital camera to determine if these instruments could be used in the detection and measurement of prop scars. By converting the images into a specific graphics or image file format, analysis can be performed within a variety of graphic or image processing software thus facilitating the analytical process.

For the 8mm video, the computer/video system for analysis included: a PC with Adobe Premiere and Adobe Photostyler software, a monitor and an 8mm video tape deck. Minimum requirements for this video method would be the camera and a monitor - an 8mm tape deck is not necessary if the camera has the ability to play back tape. These components were connected in a series that allowed the user to view the tape on the monitor and simultaneously capture segments of video needed for analysis. The use of Adobe software was necessary to get a common TIFF image format for comparison to other digital images. This image format was also required for the classification attempts that were made using ERDAS Imagine 8.2 software on a UNIX workstation.

Once the imagery was captured, an 8mm video player was connected to a PC and a TV monitor. Several 'screen grab' images showing scarring were made using Adobe Premiere software. The images were saved as bitmap files. These bitmap images were then imported into Adobe Photostyler software and converted into TIFF format 24-bit files. These files were transferred over to the UNIX environment through file transfer protocol (FTP) and then imported into the Imagine software where attempts were made to classify the images. The classification process is described below.

Images from the Kodak digital camera were loaded into Kodak Photoenhancer 1.6 software (included in the price of the camera) to obtain 24-bit TIFF images. These images were also imported into Imagine. The digital camera is equipped with software that is compatible with both Apple 'MacIntosh' and PC computers. The minimum requirements for this system are the camera, software, and a computer capable of image processing.

Once the images were imported into the Imagine software, standard image processing techniques were employed including: unsupervised classifications, edge detection algorithms, and principal component transformations.

An unsupervised classification was attempted to detect prop scars. The unsupervised classification technique involves categorizing the pixel values within the image into a number of categories, or classes. These classes are set up at equal intervals across the entire range of pixel values for the image. For example, if an image contained 100 unique pixel values, then an unsupervised classification with 20 classes would set up a class at every 5th pixel value. This is done to group those pixel values that are spectrally similar into a defined class that can then be spatially and quantitatively manipulated. The user determines the number of times the unsupervised classification process will evaluate the pixel values in each class relative to the other classes. During this iterative process, the computer may reorganize certain pixels based on their similarity to other classes. The video and digital camera TIFF format images were classified with both 30 and 20 classes with 9 iterations.

Results of the unsupervised classifications showed signature confusion between the scars and the land because the pixel values for land and prop scars were very similar. A technique known as masking was attempted in order to eliminate land from the image. Basically, masking converts a selected area of the image into a region where no data are represented. Masking the land was accomplished using a shoreline composed of pixels in the infrared band (0.76 - 0.90 micrometers) with a digital number that was equivalent to 50% land and 50% water. The land-masked images were then run through another unsupervised classification with 30 classes and 9 iterations.

Edge detection algorithms were also used in an attempt to classify prop-scarred areas. This process searches for linear features, such as prop scars, and defines them in a separate image.

Sun glint caused problems with this technique because waves take on a linear appearance in the digital data and were, therefore, incorrectly identified as scars.

Principal component transformations were then conducted. Principal component analysis defines a series of perpendicular axis that identify the maximum variation within the data. These components are perpendicular to one another and are represented as individual bands of data, with each subsequent component representing the next largest variation of data. This method can distinguish differences in similar spectral pixel values, such as seagrass and prop scars filled with algae. The first principal component, with the widest amount of variance, showed some results for prop-scar analysis. However, not all of the prop scars were detected.

Time considerations: The set up of the Hi8 player, TV monitor and the PC took only a few minutes. The screen grabbing process in Adobe Premiere required about 15 minutes for each frame that was grabbed. The conversion of the bitmap files to TIFF images in Adobe Photostyler required approximately 5 minutes for each frame. The FTP process from the PC to the UNIX system was approximately 20 minutes for 8 of the TIFF images. Ten hours were spent on the image processing with Erdas Imagine image processing software.

3.0 Results

3.1 Weather Conditions

Weather conditions affected the quality of the photographic data. Data collected during cloudy and overcast conditions did not yield enough information to accurately discern the prop scars. Wave effects on the water surface caused a disturbance in the light return signal and inhibited correct exposure of the video. The best data were collected when winds were calm and cloud cover was 30 percent or less.

3.2 Sony CCD3X 8mm Video Camera

Advantages -
A video camera offers two options in monitoring, first as a qualitative assessment where the viewer can determine the extent of prop scar damage, the second option is to process the video through 'screen grabs' and try to obtain a quantitative determination of prop-scar extent. The video camera provided good resolution when flying at 500 ft however, more transects had to be flown to adequately cover the area. The video data from 1000 ft allowed for good areal coverage to orient the user within the study area. Resolution deteriorated at the higher altitude, but the zoom lens compensated for this. The ability to zoom into areas of high vessel traffic or scarring was a benefit. The most appealing aspects of the video monitoring method are its flexibility with altitude, ability to manipulate screen grabbed images and the interactive control the user has during data collection.

Disadvantages -
Problems associated with the video monitoring included loss of scale, instability of the camera platform, auto-focusing of the camera, and loss of resolution in the processed data. There is a loss of scale information associated with zooming in and out. The video camera had a tendency to become unstable due to wind when the window was opened to allow the operator to lean out of the plane. The video camera is equipped with auto focus that became confused when there was 100 percent cloud cover and, consequently, would not focus on the seagrass beds. The 'screen grabbing' process involved digitally resampling image data, which caused some deterioration of resolution. However, these problems did not interfere with the overall quality and flexibility of the qualitative video assessment.

3.3 Kodak 40 DC Digital Camera

Advantages -
The digital camera exhibited the fewest advantages of the three monitoring methods. The processing time for the digital camera was limited to 5 minutes for each image downloaded from the camera. This compares to 15 minutes for each video image and up to two days for film processing. The image resolution for the digital camera at 500 ft was better in comparison to digital images from the video camera. However, this advantage is lost at 1000 ft. Another advantage to the digital camera is no film or developing costs are associated with down loading the images to the PC.

Disadvantages -
There were several disadvantages to the digital camera. The digital camera can only store 48 images (24 bit). After this limit is reached, the camera must be downloaded to a PC before more pictures can be taken. This is not practical for aerial surveys unless a laptop computer is available to download information during the flight. The digital camera has a 4.2 second time lapse between consecutive shots/frames. This is too long for continuous coverage from a plane that is travelling at 80 knots. The operator must shoot behind their position instead of immediately adjacent. The resolution of this camera at 1000 ft is inadequate for discerning prop scars. The digital camera requires a computer to display the images. A color printer is necessary or a commercial printing company should be used to create the prints from disk, both adding costs up front.

3.4 Pentax A3000 35mm Camera

Advantages -
The Pentax 35mm camera had the best resolution of all three cameras from both 500 and 1,000 ft because of the digital nature of the 8mm video and digital camera. The small time interval between consecutive frames sets this camera apart from the digital camera by allowing for continuous frames to create photo mosaics. Such a mosaic of a damaged area provides good qualitative information and can be easily repeated. A variety of different film is available dependent upon the need (slide vs. print). The 35mm camera could be operated from inside the plane and still provide photos that were adequate for prop-scar monitoring.

Disadvantages -
The disadvantages of the 35mm camera included the time required for changing film, processing time, and film and processing costs. Changing film only delays the survey a few minutes. This is minor compared to the digital-camera-to-PC download time while on a survey. The 35mm camera had the longest processing time. Processing of print film is between one hour and two days, while slides require four hours to one week, dependent upon the vendor and film type. Processing cost is the primary difference among the other cameras.

The advantages and disadvantages for each of the cameras are summarized in Table 1.

3.5 Prop Scar Image Analysis

Preliminary investigations of prop scar image analysis did not prove to be as effective as planned. Problems encountered included: wave state, light attenuation in water, sun glint, oblique edge confusion, and similar signatures between objects in the image. Wave state depends upon weather conditions as does light attenuation, which may also be affected by phytoplankton blooms or turbid water. The best way to avoid these problems is to fly on calm sunny days. Sun glint and oblique edge confusion are the result of angle. Sun glint in an image can be limited by positioning the camera as close to vertical as possible. Also, sun angle effects can be minimized by designing a flight plan that files directly into or away from the sun. Oblique edge confusion, a problem associated with a large camera angle from vertical (nadir), can be corrected by adjusting the camera angle closer to nadir. The similarities of image feature signatures confused many of the machine (digital) classification techniques. This signature similarity resulted in different features (*e.g.*, mangroves, shadows, and seagrass) being grouped into one class. Other methods of image analysis should be examined, and the potential for image analysis not discounted. For image analysis to be a cost effective method of prop-scar monitoring, an algorithm needs to be developed that would perform the analysis in the fewest steps possible.

4.0 Conclusion and Recommendations

The purpose of this evaluation was to recommend a feasible method for periodic monitoring of prop scars in seagrasses. The three methods - 8mm video, digital camera, and 35mm film camera - all had advantages and disadvantages. Some of the disadvantages could be attributed to weather and not the cameras. Aspects of monitoring that were most critical were resolution, continuity of coverage and processing time. Based on this evaluation, the best survey method would include a combination of both an 8mm video and 35mm cameras. Weather conditions for the survey should be a calm day with 30 percent cloud cover or less. The 35mm camera is most effective at 500 ft and would be used to collect a series of photos to be mosaiced together. An 8mm video camera, used in combination with a 35mm camera, greatly enhances the monitoring of a prop scarred area. A video camera with a 12:1 zoom lens gives the best results at 1000 ft. This method was utilized on the 4/11/96 over flight and allowed the user to determine areas of seagrass beds with a high frequency of vessel traffic that can lead to prop scar damage. The combination of 35mm and 8mm video provides a cost-effective mechanism to manage a seagrass area that is susceptible to the adverse impacts of prop scarring.

Flight log:

3/10/96 Sunday: Takeoff at 1:00 pm. Conditions were windy and overcast with about 70% cloud cover. Tide was low. Made one pass heading north over Weedon Island: Video capture was poor due to obliqueness and instability of the camera. Results can be attributed to the fact that it was the first try. Made 2 passes over Cockroach Bay: Video capture was satisfactory, and showed some contrast for seagrass beds. However, the imagery was still too oblique and there was a significant amount of sun reflectance interfering with the data collection. Made another pass over Weedon Island: Video capture showed some contrast. Overcast conditions did have an adverse effect on the video. There was not enough light for a definitive contrast between seagrass and sand.

3/20/96 Wednesday: Takeoff at 8:55 am. Conditions were mostly sunny with about 30% cloud cover. Winds were calm. Tide was close to low. Made 2 passes around Weedon Island, including the Hole in the Wall Pass. Conditions were much better for video capture than on 3/10. The lower sun angle caused some problems heading south. The results showed a high degree of differentiation for the seagrass beds. A better angle for video was made possible by leaning out the window. It was noted later that areas of interest were between the signs and the shore. The video was shot from outside this area. Made pass over Caladesi Island: Conditions noticeably worsened. Winds picked up at 10:10 am. Video was unsuccessful for this area because of low batteries.

3/31/96 Sunday: Takeoff at 9:32 am. Conditions were mostly sunny with about 20% cloud cover. Winds were calm. Slack tide.

Hi8: Made 2 passes over Egmont Key in the Fort DeSoto area. The batteries died by 10:15, eliminating further video capture. It was noted that a good familiarity of the area of interest is helpful when trying to identify the area from the air.

Digital camera: Several shots were taken between the Skyway and Fort DeSoto area.

4/6/96 Saturday: Takeoff at 1:15 pm. 100% cloud cover. The water had a small chop that gave it a rippling effect, making it difficult to see the bottom.

Fort DeSoto: Made a pass over the area north of Bunces Pass. Then we circled Tarpon Key. A pass over Mullet Key Bayou completed the survey. The video capture for these areas was poor due to the low light and the chop on the water. The limited light reflectance from the bottom made it difficult to distinguish the bottom and therefore confused the auto-focus on the camera. This capture was out of focus.

35mm: Several shots were also taken with a 35mm camera. The results were disappointing because of the overcast conditions and the camera was out of focus.

4/11/96 Thursday: Takeoff at 10:05 am. Conditions were sunny with 0% cloud cover. The plane flew at about 1000 ft. When the video was taken, the plane was slowed down to about 80 knots. The higher altitude was better than 500 ft because a greater area could be recorded and the zoom lens could compensate for high altitude in areas of particular interest. The flight path included Fort DeSoto, Bishops Harbor, Weedon Island, Honeymoon Island and Caladesi State Park.

A transect of 35mm photos was also shot from 500 ft. These pictures were taken from inside the plane. They showed good differentiation of prop scars.

4/14/96 Sunday: Takeoff at 1:15 pm. Conditions were mostly sunny with about 10% cloud cover. The flight path included some of the Cockroach Bay area, Fort DeSoto, Honeymoon Island and Caladesi Island. The 35mm and the digital camera were used. Some photos were taken at an altitude of about 200 ft in the Cockroach Bay area with both cameras. The rest of the photos were taken at 500 ft.

Method 3. Computer Mapping - Conducted by Andrew P. Lamb

3.0 Introduction

Two separate software packages were tested on a Window's based notebook for their functionality in delineating propeller scars from a fixed wing aircraft. The software packages used were Direct GPS for ArcView 2.1a and FieldNotes 3.0. To test the software, both packages were installed on a laptop with a mobile Trimble GPS gold card that is installed through one of the PCMCIA slots. The hardware specifications were a Pentium 60MHz laptop with an active matrix color screen, 40mb RAM, 800mb hard drive, trackball, and two PCMCIA Type II slots.

The minimum hardware requirements of the softwares for this project included the following:

- 486 66MHz CPU
- 16mb RAM (32mb would be necessary with Windows '95)
- 540mb hard disk drive (dependent on the number and size of data layers to be used)
- 2 PCMCIA slots
- 2 hour battery life, dependent on the amount of hard drive used and duration of the flight survey.

3.1 Study Areas

Two surveys were made from a Cessna 172 Skyhawk II airplane, each survey used only one of the software packages. The aircraft flew at an altitude of 500 ft with an average air speed of approximately 100 knots.

A. The first survey was performed April 5, 1996 and lasted for three hours. The main test area was Tampa Bay stretching from the Skyway Bridge moving northeast to the Courtney Campbell along the southern and eastern shoreline and returning southward along the St. Petersburg shoreline. The Direct GPS for ArcView was used in this survey and emphasis was placed on two study areas within Tampa Bay where prop scarring was known to exist: Cockroach Bay just south of the Little Manatee River and Weedon Island just south of the Gandy Bridge on the St. Petersburg side of the Bay.

B. The second survey was performed April 10, 1996 and lasted for three hours. The test area included the Clearwater area, Pinellas County Aquatic Preserve, Ft. DeSoto, Anna Maria Island, Manatee River, Terra Ceia Bay and the eastern St. Petersburg shoreline stretching north from the Skyway Bridge to the Courtney Campbell Causeway.

3.1 Survey A, Using ArcView2.1a Software

Software Description/Test Flights

ArcView allows for the relatively easy import, display, and analysis of large geospatial datasets with a Graphical User Interface (GUI) that is easy to operate. ArcView was developed by Environmental Systems Research Institute, Inc. (ESRI), California.

A 1:40,000 scanned NOAA navigation chart was used for the purpose of this survey and testing of the ArcView software. The software used to extract these scanned charts is called 'Sure!MAPS Raster' and is available from Horizons Technology, Inc. (HTI) for $495.00. It was developed for use on a PC-based platform using Windows. The DEP/FMRI funded the scanning of all NOAA navigation charts for the coastal areas of Florida, which are also available free of charge through HTI. The Sure!MAPS software, however, must be purchased to extract these navigation charts.

When a navigation chart area is extracted using this software, it is written to a TIFF image format and also has a Tiff World File (.TFW) associated with it that contains header information. ArcView automatically reads this header information when the TIFF file is loaded. This is a very useful utility as time is not wasted on rectification and projection of raw image files. The approximate size of an image containing the Tampa Bay region is 25mb. An example image can be seen in Figure 1 (these are usually in color). Two subset images of about 3mb were taken from the overall image to reduce memory usage and speed up drawing time. This was found to be unnecessary due to the relatively quick redraw rates provided by ArcView and the hardware used.

Before the survey, an overall project file was created that contained the base TIFF image and a number of themes featuring the three classes of prop scarring - severe, moderate, and low. In addition, views that might be helpful during the flight were included. Themes are the basic building blocks within ArcView and can represent any spatial dataset such as features with locational attributes. Various data sources that can be represented as themes include images, ARC/INFO coverages, and tabular data with locational information (Hutchinson and Daniel, 1995). Themes can also be created and edited. Three levels of damage included light, moderate, and severe prop scarring polygons. Lines or points can be easily added through editing if needed for other features.

When the Direct GPS for ArcView is executed, the GPS unit is automatically connected with ArcView and a few final settings are made using the GPS Control Panel that is provided. In ArcView, once the basemap is loaded, a GPS cursor is displayed on the screen at the current geographic location of the GPS unit. If the GPS unit moves out of the currently displayed basemap, a new view is created that contains the current position. This is useful because the operator can concentrate on drawing polygons in the appropriate themes and not worry about locating the current position on the overall basemap or image. Within the Trimble ArcView software, the user can specify the minimum satellite signal strength along with the maximum PDOP (Position Dilution of Precision) which allows for more consistent tracking and avoids the problem of losing satellites.

Problems associated with the ArcView test flight included the following:

1. The differential correction did not operate, resulting in difficulty assessing the exact location of prop scars. When the plane is traveling at a low altitude (500 ft) at 100 knots, the observer needs accurate GPS positioning on the laptop to delineate these scars.

2. The polygons themselves were relatively hard to draw with a trackball due to the nature of the device itself, limited working space, and the plane movement due to turbulence.

3. The classification of light, moderate, and severe prop scarring is difficult to accomplish in a single pass. Subsequent passes for each damage category are recommended.

4. The battery life is only about 2 hours. It is recommended that a replacement battery be carried.

5. The small computer screen displays very little image information. To delineate prop scars accurately, a high resolution map of the study area is necessary. The problem with high resolution images is that as the plane moves at a relatively high rate of speed, the screen must redraw quite frequently. To alleviate this problem, it is recommended that the largest possible screen size be used. It was found that color is not important, but it does help to distinguish the different polygons used for the three types of scarring.

The total time for someone familiar with GIS to connect the GPS, install and learn all the necessary software, including ArcView, is about two days. For someone unfamiliar with GIS this could take as long as one week. For someone unfamiliar with GIS, but who has the appropriate technical support, these tasks should take about two days for the one application of delineating seagrass prop scarring using direct GPS. These estimates could change depending on ones computer skills, and GIS and technological background.

The advantages of ArcView include:

1. ArcView is becoming a standard in GIS technology.

2. ArcView has additional modules that increase its functionality, (*e.g.*, Trimble's Direct GPS).

3. Much of ArcView is written with an object-oriented programming language called Avenue. This allows for the custom development of applications specific to individual needs, such as the GPS module mentioned above.

4. ArcView has direct access to ARC/INFO coverages. ARC/INFO is the leading UNIX-based GIS software.

5. ArcView is relatively inexpensive. The total list price for ArcView 2.1a, the Trimble Direct GPS software (WinMobile) and the Trimble DGPS gold card is $2,450.00 (as of April, 1996).

6. The software is able to manage large data sets with relative ease. Image and coverage drawing and refresh rates are relatively fast.

7. Editing of polygons and data is relatively straightforward in ArcView.

The disadvantages of ArcView include:

1. ArcView has a relatively steep learning curve. There is however, a useful tutorial that is quite thorough and self- explanatory.

2. Presently, ArcView does not allow for any image processing, rectification, or registration. Upcoming releases of ArcView will have the ARC/INFO Grid tools incorporated, which should allow for the rectification of geospatial data layers.

3. A larger screen is necessary to allow higher resolutions to be viewed without the GPS cursor continually moving off the screen and resulting in the basemaps being redrawn, which slows down operation.

3.2 SURVEY B, Using FieldNotes 3.0 Software

Software Description/Test Flight

"FieldNotes is a software package that brings much of the functionality of GIS to desktop, laptop, and pen-based computers. It allows the user to work with drawings, images, and database records all in the same environment." (FieldNotes User's Manual, 1994). This software is mainly designed to assist in the collection and processing of field data. There are two other utilities that make FieldNotes unique: FieldForms and FieldPack. FieldForms provides a simple and straightforward tool for the user to customize and build database forms during data collection. This provides functionality when a pen-based laptop is used because pick list and check boxes do not require typing or a keyboard. FieldPack is used for database access, allowing the user to view, edit, and browse the databases used in FieldNotes, which are stored in a tabular format. FieldNotes can also read a number of drawing fields and image formats. A few of these formats include DWG and DXF drawing files and TIFF, IMG and BMP image formats.

Test Flight

The navigation charts used in the ArcView survey were imported into FieldNotes. It was noted that FieldNotes was unable to access the header information, resulting in an unregistered TIFF image. To overcome this, a DXF file containing the shoreline coverage for the Tampa Bay area was loaded and the TIFF image was then registered to this shoreline coverage. The registration is quite straightforward; however, only two points can be used to register the image. Fortunately, the navigation charts have latitude/longitude lines which can easily be used to register the image. If a scanned photograph was used, a problem would arise when trying to register it to the shoreline vector coverage because FieldNotes is only able to display the latitude/longitude coordinates to an accuracy of minutes. If the registration point lies between two whole minutes, the user must approximate the seconds for that location. This introduces a considerable error into the registration of the image.

As in ArcView, before the survey a project file was created within which the shoreline DXF drawing was loaded along with the NOAA navigational chart that was registered to the DXF shoreline coverage. A new drawing was created, overlaid and given three layers called light, moderate and severe prop scarring. This drawing was edited during the overflight and prop-scar polygons were added. The GPS was connected as in the ArcView survey.

Problems associated with the FieldNotes test flight included:

1. The satellite signal strengths were not as strong as during the ArcView survey and FieldNotes is not capable of enhancing GPS data collection.

2. The differential correction did not operate, resulting in loss of accuracy. It is assumed that this problem is not part of the FieldNotes software, but instead is either a hardware or software problem associated with Trimble. We are in the process of working with Trimble and FieldNotes to resolve this problem.

3. The prop scar polygons were relatively difficult to draw using a trackball within the relatively rough environment of the aircraft.

4. FieldNotes has a slower draw rate than ArcView and appears to take almost twice as much time to draw the same images and drawings. This causes a problem when opening and closing various windows within the software during the overflight, because the user has to wait for the background image to draw up.

5. When the GPS setup or initialization is opened and the logfile is set to record, the software loses the satellites and can take up to five minutes to regain contact.

6. After the creation of a polygon, the user must select the 'Polygon Draw' button each time. This is time consuming and can result in mistakes.

The total time for someone familiar with GIS to connect the GPS, install all the necessary software and become familiar with the software is about one day. In general, FieldNotes is much more straightforward to learn than ArcView, however it lacks the integration and application that ArcView possesses.

The advantages of FieldNotes include:

1. FieldNotes is relatively simple to learn, set up and operate.

2. FieldNotes can work on a pen-based laptop. Pick lists and check boxes can be created to facilitate the use of a pen.

3. The GPS tracking system can overlay a drawing file of the flight path taken, which is useful for reviewing the flight path.

4. The technical support is easy to contact and very cooperative.

The disadvantages of FieldNotes include:

1. ARC/INFO coverages must be converted into another format. Vector layers must be converted to the AutoCad DXF drawing format using a separate software package.

2. FieldNotes cannot read in the header information associated with TIFF images contained in the associated TFW file.

3. Image registration only allows for two control points to be used. An accuracy of only minutes can be returned in layers where the cursor must be used to return geographic location.

4. FieldNotes is relatively slow, especially when dealing with large data layers.

5. A larger screen would be useful to display increased basemap resolution and reduce the amount of time necessary to redraw new screens.

6. Overall, FieldNotes had a number of processes that slowed down the operation during the overflight.

3.3 CONCLUSION AND RECOMMENDATIONS

Having tested both ArcView and FieldNotes, we think that ArcView is the superior software package. The primary advantages are the ability to incorporate ARC/INFO coverages (data layers) and most image formats without any format conversions. ArcView also provides the user with a useful interface to GIS databases. This is an important consideration because both FieldNotes and ArcView are priced similarly. Ideally, ArcView should be installed on a pen-based laptop. This allows for more control over the delineation of the prop scar polygons.

A methodology developed during the aerial survey used the first pass to delineate light scarring, and then a second pass to delineate moderate scarring, and a final pass to delineate severe scarring. This is necessary due to the speed of the plane (80-100 knots) and the limited time available to switch among the three prop scar classification themes used in ArcView. It is also important that the GPS is differentially corrected to allow for accurate positioning (±5m). The ideal differential correction is a Type I transmitter. A Type 9 can typically take up to 1 minute for an accurate positioning and a Type 16 does not provide any real application to a moving aircraft.

The major disadvantage of this technique is the subjectivity associated with the observers definition of light, moderate, and severe prop scarring. This subjectivity is increased by the speed that the aircraft travels, hence resulting in rushed decision making. In addition, different observers will increase data subjectivity.

Ideally, a pen-based system would be easier to use because it allows more control over the delineation of the prop scars onto the computer screen. We sought the demonstration of a pen-based system, however a system capable of running ArcView was not readily available.

NOTE:
Because of the investigators' belief in cost-effective spatial monitoring and that implementation of an accurate monitoring program requires at least one year, a purely quantitative statistical design was not feasible.

Task 4. Provide Recommendations for Implementation of Specific Actions Where Seagrass Scarring is <u>Severe</u>.

Based on the results Tasks 1, 2, and 3, FMRI will provide recommendations for specific management actions for areas of severe seagrass scarring within TBNEP boundaries. This section of the Evaluation Report will identify estimated costs, personnel needs, capital expenses, installation maintenance responsibilities, and other tasks as needed for each specific area within the TBNEP project boundaries.

Management measures implemented both locally and elsewhere will be reviewed and evaluated in support of the propeller scar management strategy being recommended for the Tampa Bay area. One of the questions that needs to be addressed is the relative roles that state, local governments, and/or non-government organizations should play in protecting seagrass habitats. The report will address the various aspects such as laws, regulations, enforcement, permitting, education programs, media campaigns, funding of preserves etc.

1. **Estimated cost of a program**
   a. **personnel costs** - No additional costs, as these areas are already located within or adjacent to the confines of managed areas.

   b. **capital expenses** - Poles (pilings), signs, boat ramp signs - The number of signs and/or poles is dependent upon actual ground surveys for proper placement and permitting from the appropriate agencies. Aesthetics are very important to the outdoor experience and should be a major consideration in planning and placement of signage and poles. Our suggestions of capital expense are minimal and found within the selected areas for proposed management.

   c. **installation maintenance responsibilities** - see below

   d. **other task needed for each specific area within TBNEP project boundaries** - see below

2. **Management measures supported by evaluation**

   Some of the management measures supported by the evaluation in Task 1 include the following:

   • observations/interviews of boaters,

   • seagrass mapping - based upon SWIM Program (every 2 years),

   • biological monitoring - for qualitative aspects- two or four times/year, for quantitative aspects - two to four times/year with transects and quadrat sampling. GPS with real-time or navigation beacon attachment should be used for accurate location determination of stations and transects.

• Scar mapping - 35mm and video, for qualitative assessment. Medium (70 mm) or large format (9"x9") aerial photography, if budget allows. Aerial surveys - at initiation of project and then twice a year or seasonally.

3. Roles of government agencies and the public

For every managed area within the Tampa Bay NEP boundary, all planning and decision making concerning the restriction of boater access was a joint effort between state and local agencies and public organizations and citizens. This cooperative approach is a must. When an agency responsible for a managed area is planning to use restricted access as an option, it is imperative that all parties that use the waters be involved in the process.

We are fortunate to have numerous agencies and active public organizations within the Tampa Bay region (*e.g.*, Tampa BayWatch, Florida Conservation Association, Florida Audubon, etc.). These organizations stay abreast of the conditions within the Bay.

4. Miscellaneous - Laws, enforcement, permitting, education, media, and funding of preserves.

Laws - The following laws are found in the State Statutes:

• F.S. 327.3 Reckless or careless operation of a vessel;

• F.S. 253.05 "Duty of the Board of Trustees of the Internal Improvement Fund to protect, etc., state lands...";

• F.S. 253.04 "State attorneys, other prosecuting officers of the state or county ... county sheriffs and their deputies ..." to assist in protecting state lands; and

• F.S. 380.05, "Areas of critical state concern ...".

• The Florida Administrative Code, Chapter 18-14.001-005 discusses fines for damaging state lands (Sargent et al., 1995).

Enforcement - While laws do exist within the State Statutes, local law enforcement officials have difficulty convicting offenders in the court system. In Cockroach Bay, for example, all of the citations issued have been dismissed in court. One of the biggest problems is proving the intent of the damaging party. Another problem is a general lack of understanding of the magnitude of the resource impacts inflicted by careless boaters. This appears to vary within Florida. In the Tampa Bay area, for example, judicial system officials are perhaps not as cognizant of the impacts to resources inflicted by careless operation of watercraft or terrestrial vehicles as their contemporaries in the Florida Keys, where there have been numerous prosecutions.

Permitting - Permitting varies among counties and agencies, thus we did not attempt to document the processes required. Much is dependent upon the types of markers and signage to be used, (*e.g.*, Gulf Islands GeoPark was approved by local agencies, but denied permission by the USCG to add buoys to areas with existing pilings that marked closure areas).

Education - Distribution of materials and lectures about seagrasses and other benthic communities can be conducted during US Coast Guard Auxiliary boating classes or Power Squadrons, and during meetings of public organizations (*e.g.*, Florida Conservation Association (FCA) and Tampa BayWatch), in addition to the Tampa Bay NEP. State and local government can distribute material using several methods, (*e.g.*, through the mail with vessel registrations, during purchases of fishing licenses, and during boating shows or similar outdoor/recreational events).

Media campaigns - Public outreach can be performed through the appropriate departments within the different agencies by using the media, (*e.g.*, newspaper, radio, and television). Local newspaper and television coverage has been very supportive of the various programs for resource protection around the Bay. The Tampa Bay NEP also plays a role in keeping the public informed about the resource. A recent example is the insert about the Bay that appeared in the newspaper.

Funding of preserves - Funding is dependent upon state or local preserves and the responsibility of the legislature and/or local government to ensure continued support. However, it is equally important that the public be kept aware of the preserves and their goals. This can be accomplished by the various agencies and others, such as the Tampa Bay NEP, who have an interest in the preserve. Other sources of additional funding may involve charging admission, increasing user fees, boat ramp/launching fees, etc.

PROPOSED AREAS FOR SPECIFIC MANAGEMENT ACTION

After reviewing all of the data, FMRI staff are recommending that Miquel Bay and the area between the Tierra Verde Causeway and Shell Key (adjacent to Ft. DeSoto Park) be considered for specific management action. Over the years, both areas have suffered damage from boating impacts.

These two locations were selected after conversations with Shelly Allen of Terra Ceia Aquatic Preserve - Miquel Bay, and Eric Fehrmann of Pinellas County Environmental Management Department - Shell Key. Aerial surveys conducted for this study and aerial photography from 1990, confirmed the existence of severely damaged seagrasses resulting from propeller scarring. The amount of damage does not appear to have lessened since 1990.

Miquel Bay, Manatee County

Miquel Bay is situated along the south side of the Sunshine Skyway Bridge Causeway in Manatee County. The Bay has a mix of developed areas on its eastern side with mangrove islands dotting the middle, southern, and western side. The northern portion of the Bay seems to have minimal damage, while the southern portion is severely damaged from east to west. There is a short cut through the southern part of the Bay to get out the Gulf and/or back into Terra Ceia Bay. Within the Bay are numerous areas of severely scarred seagrasses, probably the results of boaters using the short cut. The northerly route has deeper water, but is almost double the distance of the first short cut. In some places there are natural channels, but they are under utilized. See attached map in Appendix D.

The following is an example of a possible program to reduce propeller scar damage in Miquel Bay:

1. Place seagrass information signs (4) in appropriate locations both inside and outside of the main entrances to the Bay. Dayboard signs on pilings (4 signs @ $195 ea. = $780); plus (50 ft of pilings @ $35/linear ft = $1,750) = $2,530 total.

2. Install a sufficient number of channel markers (approximately 12 @ $35/lin. ft, 25 ft overall length = $10,500) to guide boaters through the Bay in a safe manner, keeping in mind the aesthetics of the area. Arrows on top of the pilings could be used in the same manner as Everglades National Park does in Florida Bay. The arrows point in the direction the vessel should move to stay within the channel. We realize there are some shallow areas within the main route, but the idea is to focus the damage into a narrower area rather than distribute prop scarring all over the seagrass beds. It may be difficult to have channel markers approved by the US Coast Guard because the Bay is shallow (S. Allen, pers.comm.).

Channel markers and seagrass information signage are also suggested for Bishop's Harbor, as most of the damage (moderate-light) occurs on the seagrass flats closest to the entrance of the Harbor. If this is not plausible, then information signs about seagrasses and the effects of propeller scarring should be posted.

3. Observations of watercraft should be conducted to discern the actual situations of how and why the damage occurs. These observations should be conducted during optimal periods of vessel traffic. Interviews of boaters may be conducted to determine why they are taking short cuts or navigating in shallow waters. Interviews could be conducted by the responsible agency with assistance from public organizations such as Tampa BayWatch or Florida Conservation Association in order to minimize costs. Results from these observations should be incorporated into any decision regarding restricted access or caution zones.

4. Monitor appropriate areas using transects. The number of scars and rate of recovery (if any), should be monitored on a bi-annual (minimum) or quarterly (maximum) basis, as determined by the researcher. Fixed transects can be GPS'ed in an accurate manner using the real-time navigation beacon from Egmont Key. If funding permits, quantitative biological methods similar to that of Dawes at Cockroach Bay should be used. The time frame for seagrass recovery in prop scars has been studied, so biological monitoring should focus on the inspection of regrowth and status of the resource.

5. The severity and number of prop scars require that this area be mapped using damage polygons as opposed to depicting individual scars. It would be difficult to follow trends within the damage polygons unless the polygon's overall damage rating is changed either by recovery or increased scarring, which alters the amount of bare substrate. We suggest the use of either 8mm video or 35mm stills to record the damage twice a year and to create a baseline data set. If funding is available, medium or large format aerial photography at a scale ranging from 1:6,000 (1"=500 ft) or 1:12,000 (1"=1,000 ft) is recommended. Overflights should conform to criteria for acquiring photography of seagrasses by the Tampa Bay SWIM program and FMRI.

6. The Florida Marine Patrol should enforce the regulations by issuing warnings and citations.

Estimated Cost -

a. No additional Preserve personnel other than as already required or under contract. Volunteer organizations can assist with observations of boaters and interviews, in addition to other monitoring aspects.

Contractors could be hired for biological and mapping components. Based upon costs from the Cockroach Bay and Ft. DeSoto projects, prices will range from $12,000-$40,000 for biological monitoring, dependent upon the time frame and sampling regime of monitoring and areal extent.

b. Capital and other expenses - Signage, channel markers, other associated materials and installation - $13,030. The cost of aerial surveys twice a year at 2 hours/survey = $160. Additional costs would be incurred with 35mm film and 8mm video tape for less than $50. Cost of mapping and analysis may range from $5,000 - $15,000 per year dependent upon the size of the area and the detail of analysis.

c. Maintenance responsibilities - By using pilings, maintenance requirements are minimized. Approximately $1,000 per year, depending upon the number of units and areal extent. (See Task 1 of this report).

d. Creation of boaters guides and/or pamphlets of specific managed area. Please refer to 6.d below.

Ft. DeSoto Aquatic Managed Area, Pinellas County

Located west of the Pinellas Bayway South and east of Shell Key is an area of seagrass beds with severe damage. While this area is contained within the Pinellas County Aquatic Preserve, it is not part of the seagrass protection program in place at Ft. DeSoto Aquatic Managed Area, located east and south of the damaged area (see Appendix E).

Based upon recent aerial surveys and aerial photos (1990, 1:24,000), this area continues to be impacted by vessels of all types. NOAA Nautical Chart 11414, depicts the deepest sounding in this area as 2 ft. The average depth is 0.5 ft. Aerial photos show a dredged channel extending north from Bunces Pass along the east side of proposed monitoring area that abruptly ends on the seagrass flat near the south end of Sawyer Key. Approximately 2,000 ft north of the first channel, another channel begins adjacent to shoreline development and continues to the north end of the study area.

The following program should be implemented to reduce propeller scar damage in the Shell Key area:

1. Place channel marking and appropriate signage. The area should be restricted to pole or troll, and combustion engines should be banned because of the shallow depths. In addition to restricted measures, channel marking will assist vessels in moving north or south through the area immediately west of the causeway when tide heights permit. This channel marking would also focus the seagrass damage on a narrow area for those interested in taking a short cut to Pass-A-Grille. A minimum speed zone may be necessary to minimize wave action damage to the numerous docks along the shoreline. Seagrass information signage should be placed on the northern edge of the seagrasses and also on the south edge adjacent to Bunces Pass.

The remaining area surrounding Summer Resort Island and Sawyer Key should be restricted in some manner. A restricted zone would be ideal, however due to the other closed (restricted access) areas, this may be met with some resistance from the public. While evidence shows (Task 1-Cockroach Bay and Ft. DeSoto) that seagrass caution zones are capable of reducing prop scarring, this would require monitoring in order to determine effectiveness.

2. Place seagrass information signs in appropriate locations both inside and outside of the main entrances to the Bay and at local boat ramps, (*e.g.*, Pass a Grille and Ft. DeSoto Park). Approximately 6 signs would be sufficient to inform boaters. In an effort to reduce the amount of damage inflicted by birds, signs should be tilted forward at the top, allowing bird droppings to fall behind the sign or directly into the water. This keeps the signs much cleaner and legible. The cost of dayboard signs on pilings is (6@ $195 ea. = $1,170) plus (pilings 6@ $35/linear ft and 25 ft lengths = $5,250). Total cost = $6,420.

Install a sufficient number of channel markers (approximately 12 @ $35/lin. ft, 25 ft overall length = $10,500) to connect the channels along the east side of the area. Perhaps arrows on top of the pilings could be used in the same manner as Everglades National Park does in Florida Bay (*i.e.*, arrows point in the direction the vessel should move toward to stay within the channel). We realize there are some shallow areas within the main route, but the idea is to focus the damage into a narrower area rather than allow prop scarring all over the seagrass beds. Because the waters within this area are shallow, it may be difficult to have channel markers approved by the US Coast Guard (S. Allen, pers. comm.).

3. Observe watercraft to discern how and why prop scar damage occurs. Observations should be made during optimal periods of vessel traffic. Interviews of watercraft operators may be conducted to discover why they are taking short cuts or navigating in such shallow waters. The interviews could be conducted by the responsible agency, with assistance from public organizations such as Tampa BayWatch or Florida Conservation Association in order to minimize costs. Results from these observations should be incorporated into any decision regarding restricted access or caution zones.

4. Monitor appropriate areas using transects. The number of scars and rate of recovery (if any), should be monitored on a bi-annual (minimum) or quarterly (maximum) basis, as determined by the researcher. Fixed transects can be GPS'ed in an accurate manner using the real-time navigation beacon from Egmont Key. If funding permits, quantitative biological methods similar to that of Dawes at Cockroach Bay should be used. The time frame for seagrass recovery in prop scars has been studied, so biological monitoring should focus on the inspection of regrowth and status of the resource.

5. Severity and the large number of prop scars in this area, necessitates the mapping of polygons of damage as opposed to mapping individual scars. It would be difficult to follow trends within polygons of damage unless recovery takes place, or scarring becomes greater than the current situation.

At a minimum, we suggest either 8mm video or 35mm stills to record the damage twice a year and to create a baseline data set. The maximum mapping effort recommended is an annual overflight to obtain 9"x9" format 1:6,000 (1" = 500 ft) or 1:12,000 (1" = 1,000 ft) scale photos for tracking trends on a yearly basis, budget permitting.

Overflights of Ft. DeSoto should conform to criteria for acquiring seagrass photography established by the Tampa Bay SWIM program and FMRI. The County is already flying aerial photography at a scale of 1:4,800 for the other managed area, so it should be relatively easy to expand these efforts to include this additional area.

6. Enforcement is by Florida Marine Patrol and/or Pinellas County Sheriff's Office (already under contract) for warnings and citations. Peer pressure may also be another effective means of reducing infractions.

Estimated Costs -

a. No additional personnel other than as already required or under contract.
Contractors could be hired for biological and mapping components. Based upon costs from Cockroach Bay and Ft. DeSoto projects, prices will range from $12,000-$40,000, depending on the time frame and sampling regime of biological monitoring and areal extent.

b. Capital and other expenses - Signage, channel markers, associated materials, and installation = $16,920. The cost of aerial surveys twice a year at 2 hours/survey = $160. Additional costs would be incurred with 35mm film and 8mm video tape for less than $50. Costs of mapping and analysis may range from $5,000 - $15,000 per year dependent upon the size of the area and the detail of analysis.

c. Maintenance responsibilities - By using pilings, maintenance requirements are minimized, approximate costs are $1,000, see Task 1 of this report.

d. Creation of boaters guides and/or pamphlets of specific managed area. According to H. Norris, of FMRI staff, the cost of printing 30,000 copies of the Tampa Bay Boaters Guide on waterproof paper was $20,981. 30,000 copies on recycled paper were printed at a cost of $9,246. The guides measure 22" x 34", and used a 4-color process on both sides. Costs for data development and map design were not included.

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