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Evaluation of Regulatory Guidelines to Minimize Impacts to Seagrasses from Single-family Residential Dock Structures in Florida and Puerto Rico

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Environmental Laboratory

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Final report

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Abstract: To reduce the loss of seagrasses due to dock construction and shading, dock construction guidelines for areas containing seagrass beds were developed in 2001. This study indentifies 68 docks located in five regions throughout Florida and Puerto Rico that have been constructed since 2001. The docks are evaluated for compliance with the Seagrass Guidelines developed in 2001, compliance with permit conditions, and presence of seagrass cover. Statistical analyses are used to compare seagrass cover and irradiance in shaded areas beneath the docks with adjacent unshaded areas and examine the relationships between dock structural parameters such as height and width, seagrass cover, and light.

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Preface

This report was authorized and funded by Headquarters, U.S. Army Corps of Engineers, as part of the Wetlands Regulatory Assistance Program (WRAP). Robert L. Lazor, Environmental Laboratory (EL), U.S. Army Engineer Research and Development Center (ERDC), was the WRAP Program Manager. Funding for this study was provided by the National Oceanic and Atmospheric Administration (NOAA) Coral Reef Conservation Program and the U.S. Fish and Wildlife Service. General supervision of this effort was provided by Dr. Dave Tazik, Chief, Ecosystem Evaluation and Engineering Division, EL; and Dr. Beth Fleming, Director, EL.

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Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
inches	0.0254	meters

1 Introduction

Seagrasses are widely recognized as one of the more productive and valuable habitats in shallow marine environments. Seagrass leaves are a major source of food in coastal ecosystems, either through direct grazing of leaves and epiphytes, detrital pathways, or export to adjacent communities (Zieman and Zieman 1989). Seagrasses play an important role in nutrient cycling, through the production of detritus and transport of nutrients from the sediments to the water column (Kenworthy et al. 1982). Seagrasses also serve as nursery grounds, providing food and shelter for juveniles of many commercially important fish and shellfish species (Gilmore 1987). Accordingly, the South Atlantic Fishery Management Council (SAFMC), Gulf of Mexico Fishery Management Council (GMFMC), and Caribbean Fishery Management Council (CFMC) have designated seagrass as Essential Fish Habitat (EFH) for life stages of various species within their fishery management plans. For example, the SAFMC designated seagrass as EFH for postlarval, juvenile, and adult gray, mutton, lane, and schoolmaster snappers and white grunt; postlarval/juvenile red drum, and postlarvae, juvenile, subadult, and adult brown and pink shrimp. The GMFMC designated seagrass as part of the EFH substrates for red drum, reef fish, spiny lobster, stone crab, and shrimp fishery management plans. In the Caribbean, the CFMC has categorized seagrass as EFH in their reef fish, spiny lobster and queen conch fishery management plans. The seagrass beds in Fulladosa Bay, Culebra, which is one of the study sites, are designated as a Habitat Area of Particular Concern by the CFMC due to their susceptibility to human-induced degradation and their ecological importance.

In addition to their importance to the biological community, seagrasses may also alter the physical properties of their environment. Dense stands of grasses function as a current baffle, retarding the flow of water, increasing sedimentation rates, and inhibiting resuspension of organic and inorganic deposits (Kenworthy et al. 1982). Roots and rhizomes of seagrasses form a dense mat that binds sediments and reduces erosion (Zieman and Zieman 1989).

Florida has one of the highest rates of population increase in the United States; during the period from 1980 to 2003, the population of Florida increased by more than 7.1 million persons (75 percent). Growth rates and development pressure in the southern coastal counties, such as Broward and Palm Beach, are projected to be particularly high (Landry et al. 2008). The number of dock construction permit applications is increasing steadily along with population expansion in the coastal areas (Kelty and Bliven 2003).

Due to continuing rapid development in the coastal zone, there is a concern that the proliferation of dock structures could lead to significant cumulative impacts to seagrass resources. Potential negative impacts to seagrasses resulting from docks and piers include: seagrass mortality or reductions in seagrass density and cover, bed fragmentation, chemical contamination from treated wood surfaces, fuel and oil leakage, construction impacts such as halos around pilings, propeller scarring, and vessel shading (Shafer 1999a, 1999b; Shafer and Robinson 2001; MacFarlane et al. 2000; Kelty and Bliven 2003). Although the area of seagrass loss associated with any individual dock can be relatively small, cumulative impacts and fragmentation of seagrass beds may be significant along highly developed shorelines. For example, in Palm Beach County, Florida, more than 50 acres of seagrasses are estimated to be negatively impacted due to single-family dock structures (Smith and Mezich 1999). Declines in seagrass coverage could have important consequences for those marine animals that utilize seagrass as habitat. With seagrass populations in decline in many areas, coastal resource managers are interested in the development of consistent, defensible guidelines to reduce additional dock-associated impacts to an already stressed resource.

The amount of available light is one of the most important factors affecting the survival, growth, and depth distribution of seagrasses (Bulthuis 1983; Dennison 1987; Abal et al. 1994; Kenworthy and Fonseca 1996). The primary mechanism of dock impacts to seagrass resources appears to be reduction in ambient light or shading produced by the dock structure itself (Fresh et al. 1995). This translates into a reduction in seagrass density or biomass in the area beneath the docks, or in severe cases, a complete loss of all seagrass cover (Fresh et al. 1995; Burdick and Short 1999). The effects of shading by dock structures on seagrass resources are documented in Alabama (Shafer 1999a), Florida (Molnar et al. 1989; Loflin 1995; Beal and Schmidt 2000), Massachusetts (Burdick and Short 1999), New York (Ludwig et al. 1997; Able et al. 1998) and Washington (Fresh et al. 1995, 2006; Thom and Shreffler 1996; Thom et al. 1996). The fragmentation and loss of the physical integrity of the bed that results from complete elimination of seagrass may ultimately affect an area much larger than the original impact. Exposed edges of seagrass patches may be more vulnerable to erosion; these bare areas within seagrass beds may enlarge and 'migrate' across the bed (Patriquin 1975).

Although some reduction in seagrass density and/or biomass may be an unavoidable consequence of the placement of any dock or pier, complete loss of seagrass cover may be avoided in many cases through careful design and placement of the structures (Shafer and Robinson 2001). This will reduce patchiness and fragmentation, and contribute to maintaining the physical integrity of the seagrass beds. To reduce the loss of seagrasses due to dock construction and shading by residential docks and piers in Florida, dock construction guidelines for areas containing seagrass beds were developed by an interagency team composed of representatives from the U.S. Army Corps of Engineers (USACE), National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, and other state and local agencies. These specifications are found in a set of guidelines, known as *Dock Construction Guidelines in Florida for Docks or Other Minor Structures Constructed in or over Submerged Aquatic Vegetation (SAV), Marsh or Mangrove Habitat* (USACE and NMFS 2001) (Appendix A). Throughout the remainder of this document, these dock construction guidelines will be referred to as the "Guidelines" or "Seagrass Guidelines." These Guidelines contain criteria for dock design (including height, width, and total size of the terminal platform, orientation, the spacing between deck boards and pilings) to minimize shading of seagrass beds and to minimize impacts to mangroves and marsh habitat.

2 Objectives and Methods

Study objectives

Since the Seagrass Guidelines were implemented in Florida in 2001, regulatory agencies have been using them as a tool to avoid and minimize impacts to important nearshore habitats. However, there has been no systematic evaluation of the effectiveness of these guidelines since their development and implementation. In Puerto Rico, the USACE, in response to NMFS' recommendations, often incorporates some aspects of the Guidelines such as deck spacing and orientation in permit conditions for single-family piers. In this study, we identified a total of 68 docks located in 5 regions throughout Florida and in Fulladosa Bay, Culebra, Puerto Rico (Figure 1) that had been constructed since 2001. These docks were evaluated for: a) compliance with the Seagrass Guidelines, b) compliance with permit conditions (if available) and c) presence of seagrass cover. Statistical analyses were used to compare seagrass cover and irradiance in shaded areas beneath the docks with that of adjacent unshaded areas, and to

Figure 1: Dock study sites in Florida and Puerto Rico

examine relationships between dock structural parameters such as height and width, seagrass cover, and light. Fulladosa Bay, Culebra was selected due to a recent proliferation of single-family piers in this area, which is part of the 1998 designated critical habitat of the green sea turtle due to the importance of the seagrass beds in the area (50 CFR 226.208).

Site selection

In order to be considered for the study, the dock must have met the following criteria: (1) it must have been permitted since 2001 when the Guidelines were implemented; (2) it must be permitted to follow some, if not all, of the Seagrass Guidelines criteria; (3) it must be located within a relatively continuous seagrass bed (assessed through review of a pre-construction survey contained in the permit application, in the field, or using aerial photographs and information from field surveys in nearby sites); and 4) it had to be in place for at least one year (or one seagrass growing season) prior to the survey. Representative sites were selected from the following regions in Florida: Indian River Lagoon, Lake Worth Lagoon, Biscayne Bay, Florida Keys, and St. Andrew Bay (Appendix B). Fulladosa Bay, Culebra, Puerto Rico was also selected for the dock survey because the USACE has begun to include portions of the recommendations in permits issued for dock construction in Puerto Rico. Depending on availability, 8-20 docks in each of these 6 regions were examined. Sites were prioritized based on the availability of permit information. Where permits were not available, sites were selected based on a file review that identified sites that contained seagrass in a continuous bed in the vicinity of the dock. In cases where either permits or surveys were unavailable, sites were selected in the field based on evidence of recent (within the last 1–5 years) dock construction, the presence of a continuous seagrass bed in the vicinity of the dock, and adherence to height and/or width specifications of the Guidelines. The location of each dock was recorded using a Global Positioning System (GPS).

Data collection

All docks were examined between July and early September 2007. Sites within the Indian River Lagoon, Lake Worth Lagoon, and Biscayne Bay are within the known range of *Halophila johnsonii* (Sebastian Inlet to Virginia Key, Florida) and were surveyed during the sampling window of April 1 to August 31, as recommended by the Johnson's Seagrass Recovery Team (NMFS 2001). The height, width, and length of the walkway and size of the terminal platform structures were measured to determine whether structures were built in accordance with the Seagrass Guidelines, and in accordance with USACE permit conditions. In some cases, permit compliance could not be evaluated because permit files could not be located.

For each dock, the Braun-Blanquet cover-abundance (BBCA) scale (Mueller-Dombois and Ellenberg 1974) was used to estimate seagrass cover in a series of 0.25-m^2 plots. The BBCA scale was defined as follows:

5 = >75%; 4 = <75, >50%; 3 = <50, >25%; 2 = <25, >10%; 1 = <10%. A paired sampling design was employed; for each plot located in a shaded area beneath the dock, another plot located in an unshaded area at least 50 ft from the dock was sampled as a control. To minimize potential differences in seagrass cover due to depth, pairs of shaded and unshaded plots were located at the same depth. For most docks, five sets of paired plots were used under the walkway and terminal platforms. However, in some cases, the size of the dock structure necessitated the use of fewer paired plots. Other dock-associated impacts to seagrasses were also recorded, such as prop scarring, vessel shading, presence of halos around pilings, etc.

Instantaneous irradiance was measured using a LICOR LI-1000 data logger and spherical quantum sensors. At each dock, irradiance measurements were recorded on the surface in air, underwater near the seagrass canopy in shaded areas under the dock walkway, and in an adjacent unshaded seagrass area at the same depth as the shaded measurement (Shafer 1999a). If seagrass was present under the dock walkway, light sensors were placed near the deepest edge of existing seagrass under the docks; unshaded sensors were placed at the same depth in an adjacent unshaded area. Underwater irradiance levels were expressed as a percentage of the available irradiance at the surface. Light measurements were not recorded during periods of cloud cover.

Tidal corrections

Since the Seagrass Guidelines specify that docks be constructed at least 5 ft above mean high water (MHW), the distance between the surfaces of the dock and water were measured in the field at the time of the survey. Discrete Tidal Zoning (Hess et al. 1999) was used in order to determine the appropriate tidal correction for determining dock height relative to MHW tidal datum. For any location (x, y) and time (t) in a tide zone (k), the tide correction (C) is estimated by shifting the water level measured at an operating water level station (L_n) by a time increment unique to that zone (T_k) and multiplying the result by a factor unique to that zone (f_k). In equation form, this is:

$$C(x,y,t) = f_k L_n(t - T_k) \tag{1}$$

In this situation (T_k) was supplied through site inspection and the resultant mean high water value was back calculated using Discrete Tidal Zoning to the operating water level gauge (L_n) measurement (Hess et al. 1999).

Data analysis

A one-way analysis of variance (ANOVA) was used to test for differences in percent seagrass cover and percent surface irradiance between shaded plots beneath the docks and unshaded controls. For this analysis, BBCA values were replaced with the mid-point of the percent cover for each cover class (Table 1). Data were arc-sine square root transformed prior to analysis in order to stabilize group variances (Zar 1996). Spearman's non-parametric correlations were used to examine the relationships between dock height and width, light, and mean seagrass cover in the shaded plots beneath the walkway portion of the structures.

Table 1. Cover class mid-points associated with each BBCA index.

BBCA Index	Cover Class Mid-Point
0	0.0
1	5.0
2	17.5
3	37.5
4	62.5
5	87.5

3 Results and Discussion

Compliance with Seagrass Guidelines

Dock height and width

The dock construction guidelines for seagrasses specify a minimum dock height of 5 ft above MHW and a maximum width of 4 ft. Overall, 47 percent of the docks surveyed in Florida were constructed in accordance with these height and width specifications. Compliance with the height and width guideline specifications varied widely among regions, however. The highest compliance rates (80 percent) were found in the Indian River Lagoon and St. Andrew Bay regions, whereas very low compliance rates (20 percent) were observed in Lake Worth Lagoon and Biscayne Bay regions (Table 2).

Table 2. Proportion of the docks that were in compliance with Seagrass Guidelines and permit criteria.

Region	% Compliance with Guidelines			Permits	
	Height	Width	Terminal Platform	% Compliance	# Permits Available
Indian River Lagoon	100	80	90	85	7
Lake Worth	20	25	50	63	16
Biscayne Bay	20	38	0	63	7
Florida Keys	40	44	50	67	3
St. Andrew Bay	100	80	44	44	9
Puerto Rico	NA	NA	NA	33	3

The mean dock height in the Indian River Lagoon, Florida Keys, and St. Andrew Bay regions met or exceeded the minimum height of 5 ft specified in the Seagrass Guidelines, whereas the mean dock height in Lake Worth, and Biscayne Bay were below the 5-ft minimum height (Table 3). In Florida, the most pronounced deviations from the minimum height requirement were noted in the Biscayne Bay and Lake Worth regions, where dock heights as low as 2.1 to 2.6 ft were observed (Table 3).

Table 3. Descriptive statistics for dock heights and widths by region.

Region	N	Mean	Minimum	Maximum
Indian River Lagoon				
Height	10	5.4	4.6	6.2
Width	10	4.1	4.0	5.0
Lake Worth				
Height	10	4.7	2.6	8.0
Width	9	5.6	3.4	8.2
Biscayne Bay				
Height	20	4.6	2.1	6.9
Width	17	4.3	4.0	5.1
Florida Keys				
Height	10	5.0	3.0	5.9
Width	8	4.2	3.2	6.0
St. Andrew Bay				
Height	10	7.4	6.2	8.4
Width	10	4.1	4.0	5.0
Puerto Rico				
Height	10	1.6	0.8	2.2
Width	8	5.8	4.0	10.5

The mean dock width in all regions in Florida exceeded the maximum width of 4 ft specified in the Seagrass Guidelines (Table 3). In Florida, the most pronounced deviation from the maximum width requirement was noted in the Lake Worth region, where the mean dock width was 5.6 ft (Table 3).

In Fulladosa Bay, Culebra, Puerto Rico, none of the docks examined met the specified height and width criteria recommended in the quidelines, which have yet to be implemented in Puerto Rico. The mean dock height in Fulladosa Bay was 1.6 ft, with a minimum of 0.8 ft (Table 3). The mean dock width in Puerto Rico was 5.8 ft, and the maximum width was 10.5 ft. (Table 3).

Other guideline criteria

The Seagrass Guidelines specify that the size of the terminal platform shall be not larger than 120 ft^2 when constructed with planks over seagrass; and 160 ft^2 if constructed with grated decking over seagrass. In Florida the most pronounced deviation from this requirement was in Biscayne Bay, with none of the terminal platforms constructed in accordance with the specification. Nearly half of the docks surveyed in the Keys and St. Andrew Bay met this requirement, whereas 90 percent of the docks in the Indian River met this specification of the Guidelines.

The Guidelines also specify that covered boat slips are not allowed in seagrass areas. However, in St. Andrew Bay, three of the docks surveyed had covered boat slips either completed or under construction. One of these was permitted, but the other two were apparently unauthorized. No covered boat slips associated with the surveyed docks were observed in any of the other regions.

Compliance with permit conditions

In the Indian River Lagoon region, 80 percent of the docks were in compliance with the permit specifications and the Guidelines (Table 2). The majority of sites in the Lake Worth Lagoon and Biscayne Bay regions were also in compliance with permit conditions (Table 1). However, in both areas, more than 60 percent of the docks met the permit criteria, but only 20 percent meet the Seagrass Guidelines (Table 2). This indicates problems with implementation of the Guidelines in these two regions. In Puerto Rico, over 63 percent of the docks surveyed in Fulladosa Bay were not authorized. This indicates a major problem with permit enforcement.

Relationships between dock height and width, light, and seagrass cover

There was a significant positive correlation between dock height and light availability in the seagrass canopy in the shaded areas beneath the dock walkway ($p = 0.016$), indicating that irradiance levels under the dock increase with increasing dock height. The negative correlation between dock width and light availability was highly significant ($p = 0.007$), indicating that as dock width increases, light availability decreases. Similarly, there was a highly significant ($p \leq 0.01$) positive correlation between dock height and mean seagrass cover. The negative correlation between dock width and mean seagrass cover was also highly significant ($p \leq 0.01$). These results lend further support to the minimum height and maximum width specifications outlined in the Seagrass Guidelines.

Comparison of light availability in shaded and unshaded areas

The minimum light requirements for *Halodule wrightii* and *Syringodium filiforme* in the eastern Gulf of Mexico are estimated at 14 to 27 percent surface irradiance (Table 4). The minimum light requirements of *Thalassia testudinum* in Florida ranged between 13 and 16 percent surface irradiance (Table 4). *Halophila decipiens* has the lowest minimum light requirements (4 to 9 percent surface irradiance), while another species in the same genus requires much higher light levels for survival (Table 4). No reports of the minimum light requirements of the listed seagrass *H. johnsonii* were located.

Table 4. Minimum light requirements of Florida seagrasses, expressed as a percentage of surface irradiance (Lee et al. 2007).

Species	Location	Minimum Light Requirement (%)	Source
Halodule wrightii	Perdido Bay, Alabama	14	Shafer (1999a)
	Indian River Lagoon, Florida	14-27[1]	Kenworthy and Fonseca (1996)
		20	Steward et al. (2005)
	Florida (various)	17.2	Dennison et al. (1993)
Syringodium filiforme	Indian River Lagoon, Florida	14-27[1]	Kenworthy and Fonseca (1996)
	Florida (various)	17.2-18.3	Dennison et al. (1993)
Thalassia testudinum	Florida (various)	15.3	Dennison et al. (1993)
	Florida Bay	13	Fourqurean and Zieman (1991)
Halophila decipiens	Cuba	8.8	Dennison et al. (1993)
	St. Croix	4.4	Dennison et al. (1993)
H. engelmanii	Cuba	23.7	Dennison et al. (1993)

[1] Values corrected for use of a sub-surface reference point.

Under ambient, unshaded conditions, more than 60 percent of the surface light reached the seagrass canopy in Fulladosa Bay, Culebra, Puerto Rico and the Florida Keys (Figure 2). The amount of light available at the seagrass canopy in unshaded control areas in St. Andrew Bay and Indian River Lagoon regions was 52 and 45 percent, respectively. In the Lake Worth Lagoon and Biscayne Bay regions, 25 percent of the surface

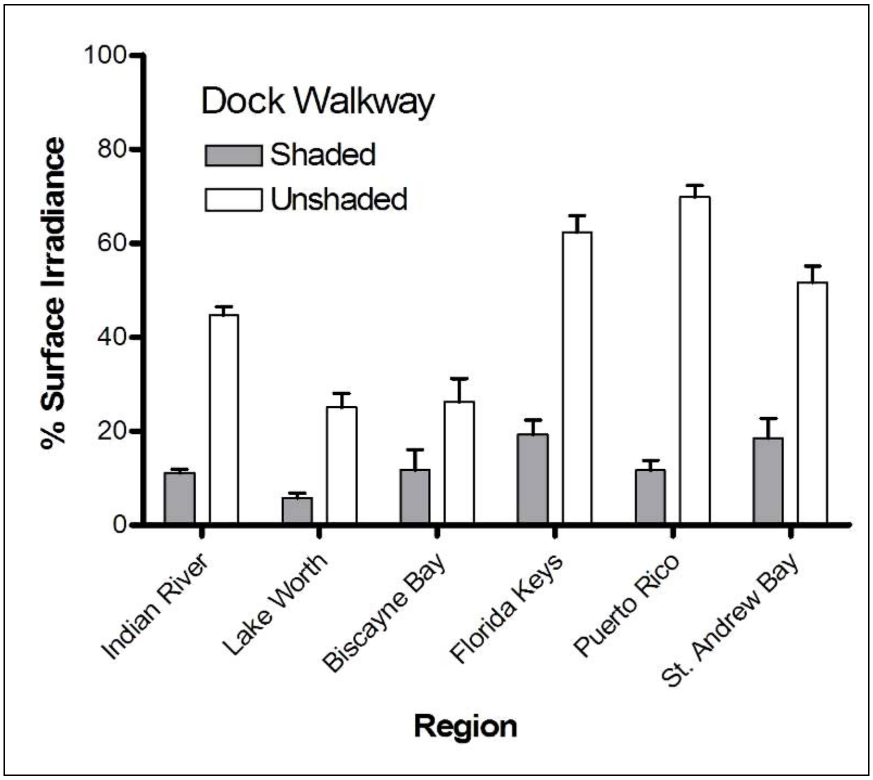

Figure 2. Comparison of light availability in shaded areas under the dock walkway with adjacent unshaded areas.

irradiance reached the seagrass canopy in the unshaded controls. Since these light levels are above the minimum thresholds for Florida seagrasses (Table 4), unshaded areas in all regions should provide sufficient light to support seagrass growth.

Percent surface irradiance was significantly lower under the docks than in unshaded controls ($p < 0.001$). In the shaded areas beneath the walkway portion of the docks, the highest light levels were observed at dock sites in the Florida Keys and St. Andrew Bay. Light levels under the dock walkway were similar in Indian River, Fulladosa Bay (Puerto Rico), and Biscayne Bay (11 percent) (Figure 2). The lowest light levels were observed under dock walkways in Lake Worth Lagoon (<6 percent) (Figure 2). Sites in the central and southern Lake Worth Lagoon suffer from poor water quality, due to reduced tidal flushing, sedimentation, and freshwater discharge (Palm Beach County Dept. of Environmental Resource Management 2007). As a result, the majority (~ 70 percent) of seagrasses in Lake Worth Lagoon are found in the northern segment. In this study, measured irradiance levels in the shaded areas beneath docks in central and south

Lake Worth Lagoon were probably too low to support seagrass growth, with the possible exception of some of the *Halophila* species (Table 4).

Comparison of seagrass cover in shaded and unshaded areas

Mean seagrass cover was significantly lower under the dock walkway and terminal platforms than in unshaded controls ($p < 0.001$). In only one region, Lake Worth Lagoon, was seagrass cover found to be virtually non-existent in the shaded areas beneath the walkway and terminal platforms. Seagrass cover under the shaded dock walkways was low (<20 percent) in the Indian River Lagoon and Biscayne Bay regions, as well as in Fulladosa Bay, Puerto Rico. Slightly higher seagrass cover was observed under dock walkways in the Florida Keys (~30 percent); very high seagrass cover (~70 percent) was observed under dock walkways in the St. Andrew Bay region (Figure 3). Low seagrass cover was also observed under terminal platforms in Puerto Rico and St. Andrew Bay; seagrass cover under terminal platforms in the Florida Keys, Biscayne Bay, and Indian River Lagoon regions were less than 10 percent. In Lake Worth Lagoon, little to no seagrass was found either under the terminal platforms or in unshaded areas of equivalent depth (Figure 3), suggesting that in this region, terminal platforms are generally constructed over waters too deep to support seagrass growth.

These results show that shaded areas under dock walkways in St. Andrew Bay are still capable of supporting high seagrass cover (~70 percent) if the height and width specifications of the Seagrass Guidelines are appropriately applied. In contrast, seagrass cover under shaded dock walkways in Puerto Rico was less than 20 percent. Mean seagrass covers in the unshaded control plots were similar in Puerto Rico and St. Andrew Bay (Figure 3), and if the Seagrass Guidelines were applied consistently in both regions, the reduction in seagrass cover under dock walkway sections should be similar in both regions. The greater reduction in seagrass cover under shaded walkways in Fulladosa Bay, Puerto Rico can be attributed to the reduced height (mean = 1.6 ft) and greater width (mean = 5.8 ft) of docks in Fulladosa Bay relative to those in St. Andrew Bay. Likewise, the near absence of seagrass under dock walkways in the Lake Worth Lagoon region may be attributable to the lower height and greater width of these structures relative to other regions. Minimum height for a number of docks in the Lake Worth Lagoon and Biscayne Bay regions ranged between 2 and 3 ft, indicating the Seagrass Guidelines are not being appropriately applied in these regions.

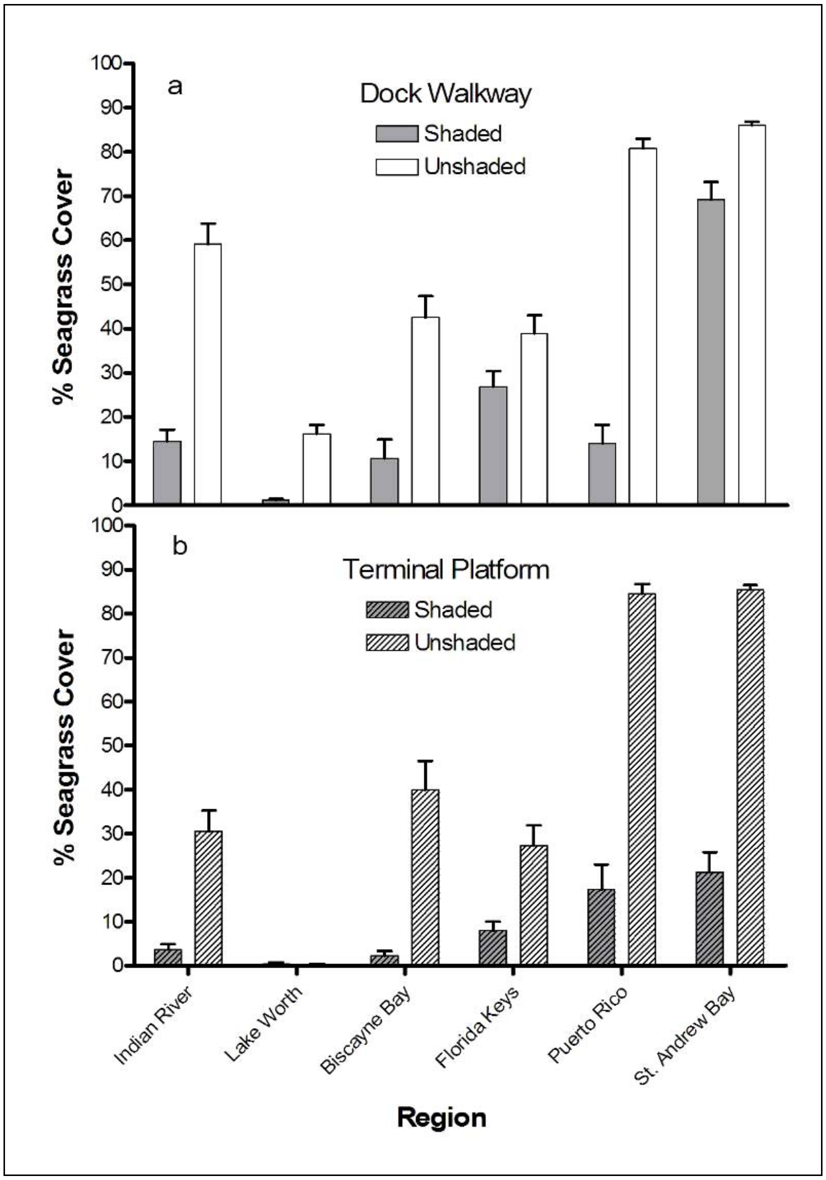

Figure 3. Comparison of seagrass percent cover in shaded areas under dock walkways (a) and terminal platforms (b) with adjacent unshaded areas.

Presence of *Halophila johnsonii*

Three regions within this study area (Indian River Lagoon, Lake Worth Lagoon, and Biscayne Bay) are within the range of Johnson's Seagrass, *Halophila johnsonii,* which was designated as a "Threatened" species under the Endangered Species Act on September 14, 1998 by the National Marine Fisheries Service (U.S. Department of Commerce/National Oceanic and Atmospheric Administration 1998). Within these three regions, the presence of *H. johnsonii* in the vicinity of the surveyed docks was recorded at 62.5 percent of the sites (Table 5). *H. johnsonii* was observed in the shaded areas under docks in under 35 percent of the docks surveyed within these three regions. The highest frequency of occurrence of *H. johnsonii* was in Lake Worth Lagoon, where it was present at 95 percent of the sites surveyed. Within this region, this species was present in the shaded area under 45 percent of the docks surveyed. However, more than 70 percent of the total number of plots that contained *H. johnsonii* were in unshaded areas. These data support the findings of other studies concluding that *H. johnsonii* can be found in a wide range of environmental conditions (Kenworthy 1997). They also demonstrate that *H. johnsonii* is capable of growing under the low light conditions found in the shaded areas beneath dock walkways. However, it should be noted that in the Lake Worth Lagoon and Biscayne Bay regions, the height and width

Table 5. Observations of *Halophila johnsonii* (*Hj*) at docks within its range.

Region	Total # of Plots where *Hj* was Observed		# Docks where *Hj* was Found in Shaded Areas
	Shaded Areas	Unshaded Areas	
Indian River Lagoon	4	7	3
Lake Worth	22	73	9
Biscayne Bay	9	14	2

specifications of the Guidelines do not seem to be consistently applied, and dock heights as low as 2.1 ft were observed in this study. Due to the relationships between dock height and width, light, and seagrass cover, it is likely that more consistent application of the dock height and width specifications could result in increased habitat suitability for *H. johnsonii*. A recent report also indicates *H. johnsonii* occurs more frequently under grated dock surfaces than those with plank wood surfaces; percent cover of *H. johnsonii* in transects under grated docks was also more similar to reference site transects than transects under docks with plank decking (Landry et al. 2008). This suggests that increased use of grated decking in docks constructed within the range of *H. johnsonii* could result in reduced dock-associated impacts to this species.

Although the focus of this study was not on *H. johnsonii* or the *Key for Construction Conditions for Docks or Other Minor Structures In or Over Johnson's Seagrass* (USACE and NMFS 2002, referred to as the 'Key'), only 5 percent of the docks constructed within Lake Worth Lagoon adhere to this Key. Dock construction and non-compliance with the Guidelines and Key could hinder the Recovery Team's ability to meet delisting trajectories.

Other dock-associated impacts to seagrasses

Prop scouring in association with residential docks was noted in this study and by Burdick and Short (1999) and Shafer (1999a). This study also noted loss of seagrass cover due to vessel shading, small floating platforms used for jet skis, and in one extreme case, from a large derelict vessel that apparently sank at the dock. Growth of seagrasses around the base of pier pilings may be inhibited by changes in bottom topography or the accumulation of shell and debris (Fresh et al. 1995; Shafer 1999b). Other potential sources of impacts (not addressed in this document) include chemical contamination from leaching of treated wood products and leakage of petroleum products from moored vessels. In Fulladosa Bay, Culebra, Puerto Rico, the extent of seagrass loss related to dock and vessel shading, propeller scarring and propeller wash, and anchor damage were also documented during this study and calculated to represent a loss of 3.6 percent of the shallow seagrass beds in the bay. A detailed analysis of mechanical damage to seagrass beds around Culebra as part of this and another study indicated that 54.3 percent of the shallow seagrass beds in Fulladosa Bay have the potential to be impacted by boating based on water depths, areas of seagrass and locations of intense boating, in particular associated with docks (Otero and Carrubba 2008). Thus, the proliferation of docks leads to additional indirect and cumulative impacts that result in decreases in seagrass presence in shallow bays.

4 Conclusions and Recommendations

The following specific recommendations were developed based on the results of this study. A comprehensive list of general recommendations that apply to this study issues is contained in Appendix C.

1. **Continue to emphasize avoidance of seagrass resources where possible by relocating or realigning the structure.** Observations in this study indicate that in the majority of cases permit applicants and regulatory agencies are, when practical, generally succeeding in avoiding existing seagrass resources. In some cases, this has involved extending the length of the walkway portion of the pier so that the terminal platform/boat mooring is located over waters lacking the capacity to support seagrass growth (e.g., too deep), as recommended by the Dade County, Florida Department of Environmental Resources (Molnar et al. 1989), except in those cases where this may result in an obstruction to navigation. Avoidance should continue to be the highest priority in determining acceptable placement of docks and piers in the coastal zone. If avoidance is not possible, impacts to seagrasses may be minimized by adopting the design principles suggested in the following sections.

2. **Where practical, docks should be constructed so that the longest lengthwise axis of the dock walkway is oriented in a north-south direction.** Docks/piers oriented in a north-south direction produce less shading than those oriented in an east-west direction, resulting in increased seagrass survival and cover (Burdick and Short 1999; Shafer 1999a; Fresh et al. 2006). Therefore, the lengthwise axis of the dock walkway should be oriented in a north-south direction where possible. However, this may not be possible or practicable at many sites as property boundaries may limit alternate orientations. In this case, dock height becomes the most critical factor.

3. **All docks should be constructed to conform to the minimum height specified in the Seagrass Guidelines.** Observations indicate that very often docks are permitted to follow some, but not all, of the specified guidelines. Conversations with regulatory personnel indicate that this frequently results from a negotiation process in which the permit applicant declines to follow the height specification, for example, but

agrees to follow the board spacing and/or width guidelines. This was not the manner in which the guidelines were intended to be applied and this approach will not contribute to the conservation of seagrass habitats. Since the detrimental effects of an east-west orientation may be offset in part by increased dock height (Burdick and Short 1999), it is particularly important to adhere to the 5 ft above MHW dock minimum height specification for east-west oriented docks. Therefore, the authors suggest that the Seagrass Guidelines should be revised to prioritize orientation and height as the most important specifications for the survivorship of seagrass under docks. In contrast, board spacing is considered much less important for seagrass survival under docks since differences in light and seagrass cover could not be detected under docks with board spacing ranging from 0 to 1 in.[1]

4. **Docks should conform to the maximum widths and terminal platform size specified in the guidelines.** The guidelines allow for a 4-ft-wide access walkway and a 120-ft^2 terminal platform when constructed with planks over seagrass; and 160 ft^2 if constructed with grated decking over seagrass.

5. **Greater post-construction permit and compliance enforcement is needed.** The degree of permit and compliance enforcement in the various regions of Florida and Puerto Rico assessed in this study appeared to vary widely, likely based on staffing and workload issues and local office operating procedures. The two regions that had the highest proportion of docks that were not in compliance with the Seagrass Guidelines were Lake Worth Lagoon and Biscayne Bay.

[1] Unpublished data, Deborah J. Shafer, Research Marine Biologist, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

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Appendix A: Dock Construction Guidelines in Florida for Docks or Other Minor Structures Constructed in or over Submerged Aquatic Vegetation (SAV), Marsh or Mangrove Habitat

U.S. Army Corps of Engineers/National Marine Fisheries Service

August 2001

Submerged Aquatic Vegetation:

1. Avoidance. The pier shall be aligned so as to minimize the size of the footprint over SAV beds.

2. The height of pier shall be a minimum of 5 feet above MHW/OHW as measured from the top surface of the decking.

3. The width of the pier is limited to a maximum of 4 feet. A turnaround area is allowed for piers greater than 200 feet in length. The turnaround is limited to a section of the pier no more than 10 feet in length and no more than 6 feet in width. The turnaround shall be located at the midpoint of the pier.

4. Over-SAV bed portions of the pier shall be oriented in a north-south orientation to the maximum extent that is practicable.

5. a. If possible, terminal platforms shall be placed in deep water, waterward of SAV beds or in an area devoid of SAV beds.

b. If a terminal platform is placed over SAV areas and constructed of grated decking, the total size of the platform shall be limited to 160 square feet. The grated deck material shall conform to the specifications stipulated below. The configuration of the platform shall be a maximum of 8 feet by 20 feet. A minimum of 5 feet by 20 feet shall conform to the 5-foot height requirement; a 3 feet by 20 feet section may be placed 3 feet above MHW to facilitate boat access. The long axis of the platform should be aligned in a north-south direction to the maximum extent that is practicable.

c. If the terminal platform is placed over SAV areas and constructed of planks, the total size of the platform shall be limited to 120 square feet. The configuration of the platform shall be a maximum of 6 feet by 20 feet of which a minimum 4-foot wide by 20-foot long section shall conform to the 5-foot height requirement. A section may be placed 3 feet above MHW to facilitate boat access. The 3 feet above MHW section shall be cantilevered. The long axis of the platform should be aligned in a north-south direction to the maximum extent that is practicable. If the 3feet above MHW section is constructed with grating material, it may be 3 feet wide.

6. One uncovered boat lift area is allowed. A narrow catwalk (2 feet wide if planks are used, 3 feet wide if grating is used) may be added to facilitate boat maintenance along the outboard side of the boat lift and a 4-foot wide walkway may be added along the stern end of the boat lift, provided all such walkways are elevated 5 feet above MHW. The catwalk shall be cantilevered from the outboard mooring pilings (spaced no closer than 10 feet apart).

7. Pilings shall be installed in a manner which will not result in the formation of sedimentary deposit ("donuts" or "halos") around the newly installed pilings. Pile driving is the preferred method of installation, but jetting with a low pressure pump may be used.

8. The spacing of pilings through SAV beds shall be a minimum of 10 feet on center.

9. The gaps between deckboards shall be a minimum of ½ inch.

Marsh.

1. The structure shall be aligned so as to have the smallest over-marsh footprint as practicable.

2. The over-marsh portion of the dock shall be elevated to at least 4 feet above the marsh floor.

3. The width of the dock is limited to a maximum of 4 feet. Any exceptions to the width must be accompanied by an equal increase in height requirement.

Mangroves.

1. The width of the dock is limited to a maximum of 4 feet.

2. Mangrove clearing is restricted to the width of the pier.

3. The location and alignment of the pier should be through the narrowest area of the mangrove fringe.

Grid Specifications and Suppliers

The following information does not constitute a U.S. Army Corps of Engineers endorsement or advertisement for any particular provider and is provided only as an example for those interested in obtaining these materials for dock construction. A type of fiberglass grate panel is manufactured by SeaSafe (Lafayette, LA; phone: 1-800-326-8842) and FiberGrate (1-800-527-4043). Plastic grate panels are also available from Southern Pine Lumber Company (Stuart, FL; phone: 772-692-2300). Panels are available in a variety of sizes and thicknesses. For safety, the grate should contain an anti-slip texture which is integrally molded into the top surface. The manufacturer or local distributor should be consulted to ensure that the load-bearing capacity of the selected product is sufficient to support the intended purpose. Contact the manufacturer(s) for product specifications and a list of regional distributors.

Appendix B: Locations of Docks Surveyed by Region

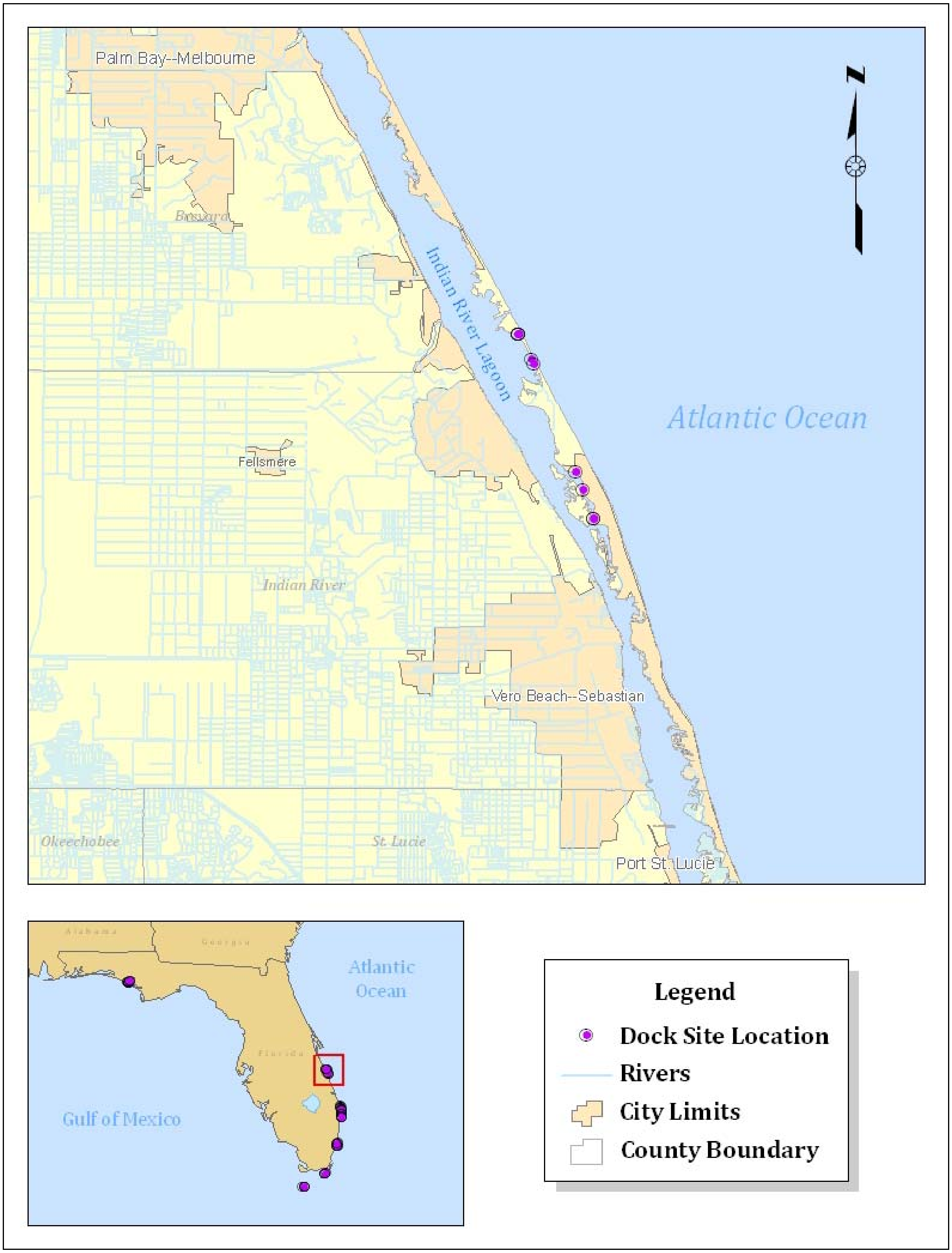

Figure B1. Indian River Lagoon sites

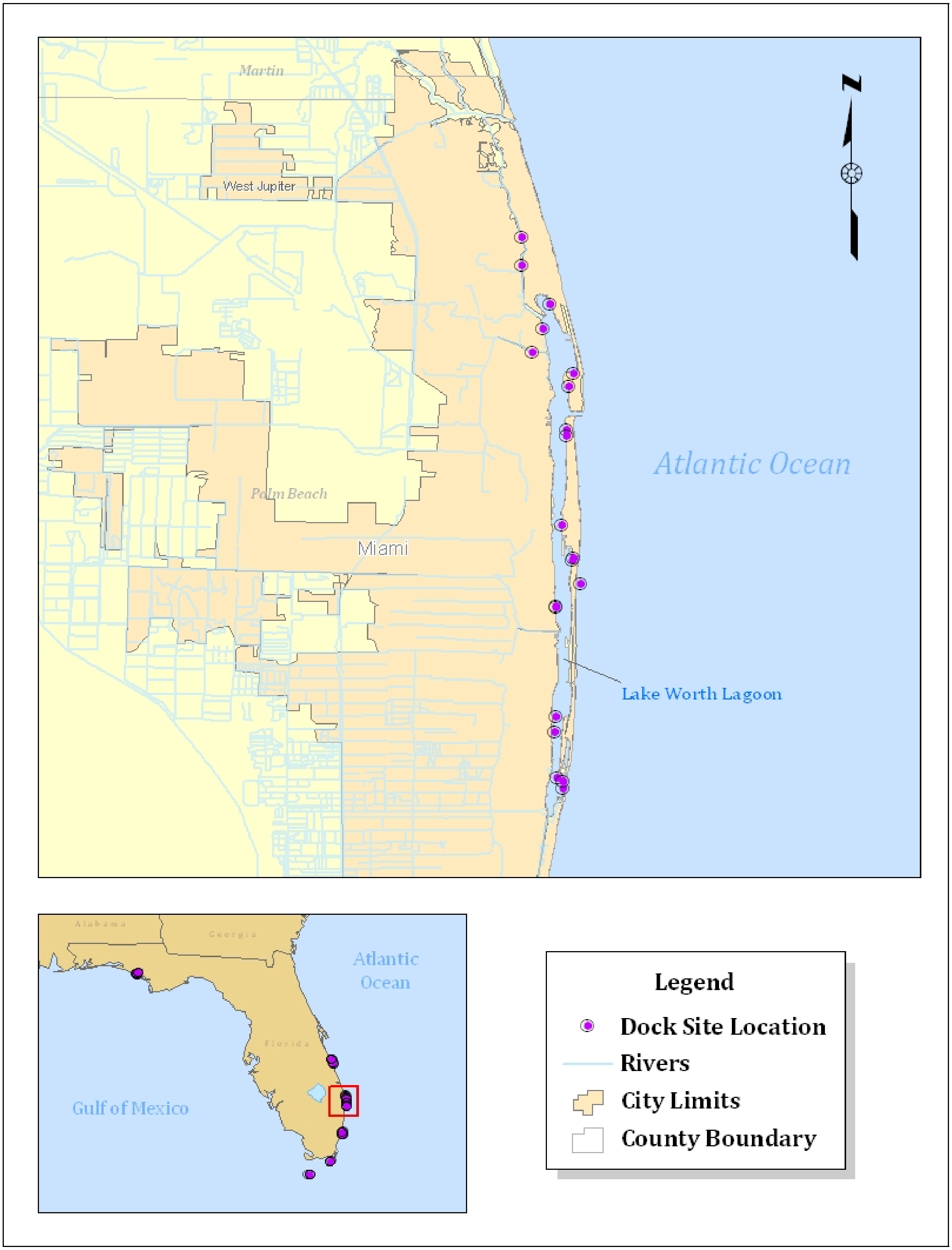

Figure B2. Lake Worth Lagoon sites

Figure B3. Biscayne Bay sites

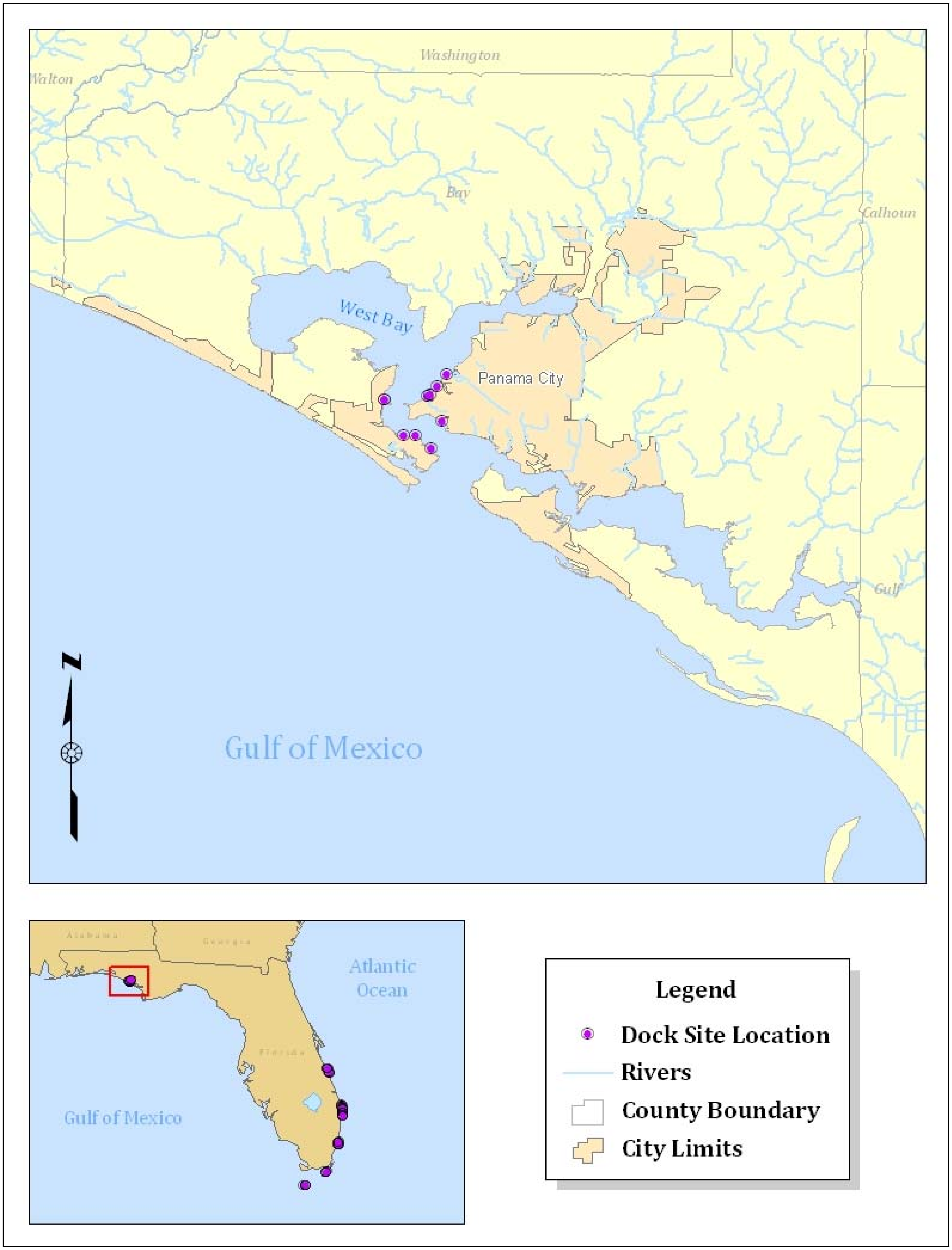

Figure B4. St. Andrew Bay sites

Figure B5. Florida Keys sites

Figure B6. Culebra, Puerto Rico sites

Appendix C: General Recommendations for the Design and Construction of Docks and Piers in Seagrass Habitat

1. **Continue to emphasize avoidance of seagrass resources where possible by relocating or realigning the structure.** Observations in this study indicate that in the majority of cases, permit applicants and regulatory agencies are, when practical, generally succeeding in avoiding existing seagrass resources. In some cases, this has involved extending the length of the walkway portion of the pier so that the terminal platform/boat mooring is located over waters lacking the capacity to support seagrass growth (e.g. too deep), as recommended by the Dade County, Florida Department of Environmental Resources (Molnar et al. 1989), except in those cases where this may result in an obstruction to navigation. Avoidance should continue to be the highest priority in determining acceptable placement of docks and piers in the coastal zone. If avoidance is not possible, impacts to seagrasses may be minimized by adopting the design principles suggested in the following sections.

2. **Where practical, docks should be constructed so that the longest lengthwise axis of the dock walkway is oriented in a north-south direction.** Docks/piers oriented in a north-south direction produce less shading than those oriented in an east-west direction, resulting in increased seagrass survival and cover (Burdick and Short 1999; Shafer 1999a; Fresh et al. 2006). Therefore, the lengthwise axis of the dock walkway should be oriented in a north-south direction where possible. However, this may not be possible or practicable at many sites, as property boundaries may limit alternate orientations. In this case, dock height becomes the most critical factor.

3. **All docks should be constructed to conform to the minimum height and maximum widths specified in the Seagrass Guidelines.** Observations indicate that very often docks are permitted to follow some, but not all, of the specified guidelines. Conversations with regulatory personnel indicate that this frequently results from a negotiation process in which the permit applicant declines to follow the height specification, for example, but agrees to follow the board spacing and/or

width guidelines. This was not the manner in which the guidelines were intended to be applied and this approach will not contribute to the conservation of seagrass habitats. Since the detrimental effects of an east-west orientation may be offset in part by increased dock height (Burdick and Short 1999), it is particularly important to adhere to the 5 ft above MHW dock minimum height specification for east-west oriented docks. Therefore, the authors suggest that the Seagrass Guidelines should be revised to prioritize orientation and height as the most important specifications for the survivorship of seagrass under docks. In contrast, board spacing is relatively unimportant for seagrass survival under docks, since differences in light and seagrass cover could not be detected under docks with board spacing ranging from 0 to 1 in.[1]

In situations where it is necessary to construct a dock walkway wider than the 4-ft maximum recommended by the Seagrass Guidelines, the dock height can be increased by a corresponding amount to offset the increased shading effects of the wider dock walkway (e.g., a 1-ft increase in dock width above the maximum 4 ft recommended by the Seagrass Guidelines should be accompanied by a 1-ft increase in dock walkway height—a 5-ft-wide walkway should be elevated at least 6 ft above MHW).

4. **Docks should conform to the terminal end size and configuration specified in the guidelines.** With respect to the terminal end platform, the guidelines currently specify the following:

5. a. If possible, terminal platforms shall be placed in deep water, waterward of SAV beds or in an area devoid of SAV beds.

b. If a terminal platform is placed over SAV areas and constructed of grated decking, the total size of the platform shall be limited to 160 square feet. The grated deck material shall conform to the specifications stipulated below. The configuration of the platform shall be a maximum of 8 feet by 20 feet. A minimum of 5 feet by 20 feet shall conform to the 5-foot height requirement; a 3 feet by 20 feet section may be placed 3 feet above MHW to facilitate boat access. The long axis of the platform should be aligned in a north-south direction to the maximum extent that is practicable.

[1] Unpublished data, Deborah J. Shafer, Research Marine Biologist, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

c. If the terminal platform is placed over SAV areas and constructed of planks, the total size of the platform shall be limited to 120 square feet. The configuration of the platform shall be a maximum of 6 feet by 20 feet of which a minimum 4-foot wide by 20-foot long section shall conform to the 5-foot height requirement. A section may be placed 3 feet above MHW to facilitate boat access. The 3 feet above MHW section shall be cantilevered. The long axis of the platform should be aligned in a north-south direction to the maximum extent that is practicable. If the 3feet above MHW section is constructed with grating material, it may be 3 feet wide.

6. One uncovered boat lift area is allowed. A narrow catwalk (2 feet wide if planks are used, 3 feet wide if grating is used) may be added to facilitate boat maintenance along the outboard side of the boat lift and a 4-foot-wide walkway may be added along the stern end of the boat lift, provided all such walkways are elevated 5 feet above MHW. The catwalk shall be cantilevered from the outboard mooring pilings (spaced no closer than 10 feet apart).

However, it seems that in many cases, only the total square foot criteria is met, without regard to the other criteria, such as length, width, and orientation. The authors suggest that the guidelines be modified to include the following text:

5. a. If possible, the terminal end shall be placed in deep water, waterward of SAV beds or in an area devoid of SAV beds. The terminal end shall be the same width (4 feet) and height (5-feet above MHW) as the pier.

b. If the 4-foot-wide terminal end is over SAV areas and constructed of grated decking, an additional width of 1-foot for the last 20 feet (5' x 20') of the pier shall be authorized along with a 3-foot by 20-foot section that may be placed at 3 feet above MHW to facilitate boat access and boat lift operations. The 3 feet above MHW section is to be cantilevered. The grated deck material shall conform to the specifications stipulated below.

c. If the 4-foot wide terminal end is placed over SAV areas and constructed of planks, no additional width the 5-foot height is allowed. An additional 2-foot by 20-foot section that may be placed at 3 feet above

MHW to facilitate boat access and boat lift operations. The 3 feet above MHW section shall be cantilevered.

6. One uncovered boat lift area is allowed. A narrow catwalk (2 feet wide if planks are used, 3 feet wide, if grating is used, no less than 3-feet above MHW) may be added to facilitate boat maintenance along the outboard side of the boat lift and a 4-foot wide walkway may be added along the stern end of the boat lift, provided all such walkways are elevated 5 feet above MHW. The catwalk shall be cantilevered from the outboard mooring pilings (spaced no closer than 10 feet apart).

5. **Use the minimum number of pilings required for structural integrity.** The presence of dock pilings results in detrimental impacts to seagrasses from both direct and indirect sources. Placement of pilings in seagrass beds results in the direct physical removal of seagrass during dock construction. The accumulation of debris and shell from barnacles, molluscs, and other marine organisms at the base of the pilings may inhibit the ability of seagrasses to recolonize the area surrounding the pilings (Fresh et al. 1995; Shafer 1999b). The presence of pilings can also alter sediment distribution and bottom topography, creating small depressions that preclude seagrass growth (Fresh et al. 1995). In addition, shading is produced not only by the surface of the dock, but also by the pilings themselves. Therefore, the number of pilings should be limited to the minimum necessary, and the spacing of the pilings should be as far apart as possible, in order to maintain structural integrity of the pier.

   Numerous cases were observed throughout Florida where the walkway portion of the dock is supported by a single row of pilings, centered under the walkway, rather than the more traditional two sets of pilings (one set on each side). This approach is not only more economical, but results in a 50-percent reduction in the amount of disturbance to the bottom, and the amount of area removed from potential seagrass colonization. Other potential benefits include the potential for reduced leaching of chemicals from treated wood surfaces. Due to the numerous benefits associated with the single piling walkway construction technique, this approach should be strongly considered for all future dock construction.

6. **A standardized definition of grated decking is needed**. The use of grated or grid decking materials to increase the amount of light received by the seagrasses below has been shown to be effective as a mechanism to

reduce loss of seagrass due to shading impacts. However, observations in the field coupled with permit application reviews concluded that a wide variety of different materials and designs of grated decking are available for use in dock construction. This variation affects the amount of light that is transmitted through the docks, and accordingly the survivorship of seagrass under the docks. Therefore, the authors recommend adopting the definition that is contained in the USACE/NMFS *Key for Construction Conditions for Docks or Other Minor Structures In or Over Johnson's Seagrass* (USACE and NMFS 2002), which acknowledges that light-transmitting materials are made of various materials shaped in the form of grids, grates, lattices, etc., to allow the passage of light through the open spaces. The authors also recommend that the following statements be added to the existing Seagrass Guidelines under the heading *Grid Specifications and Suppliers*: "All light-transmitting materials used in construction for minor piling-supported structures shall have a minimum of forty-three (43) percent open space. A type of plastic grating is manufactured by ThruFlow Interlocking Panels (1-888-478-3569)."

7. **Floating platforms should not be used in seagrass areas.** This study observed several instances of small floating structures attached to the docks for use with jet skis. These structures effectively block all light transmission and result in the complete elimination of seagrasses under all floating structures examined. Likewise, in Massachusetts, Burdick and Short (1999) reported a nearly complete loss of eelgrass cover under all floating platforms examined. Therefore, the authors recommend that some mechanism be employed to discourage their use in areas that support seagrass habitat. Since in some cases these floats were not described in the permit documentation, this seems to be more of an enforcement issue than Guideline compliance.

8. **Use compensatory mitigation to offset the loss of seagrass where the height and width specifications are not fully met.** Individually, the impacts from docks may seem minimal, but cumulatively, the impacts are significant. The authors recommend that federal, state, and local agencies take a regional approach to mitigation for small, single-family projects. This could be achieved through the establishment of environmental restoration trust funds or an in-lieu fee program for seagrass restoration, enhancement, or creation projects.

9. **Reduce cumulative impacts.** In order to reduce the cumulative impacts associated with the placement of docks and piers, incentives could be used to encourage property owners to build shared facilities rather than multiple individual docks. This could be accomplished through the use of a more streamlined permitting process (e.g., a new category of work for a nationwide permit that authorizes docks that are in full compliance with the Guidelines), or other incentives. Regulatory agencies charged with permitting or reviewing dock applications should also regularly (e.g., every 5 years) track and evaluate cumulative impacts from dock construction.

10. **Greater post-construction permit and compliance enforcement is needed.** The degree of permit and compliance enforcement in the various regions of Florida and Puerto Rico assessed in this study appeared to vary widely, likely based on staffing and workload issues and local office operating procedures.

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14. ABSTRACT
To reduce the loss of seagrasses due to dock construction and shading, dock construction guidelines for areas containing seagrass beds were developed in 2001. This study identifies 68 docks located in five regions throughout Florida and Puerto Rico that have been constructed since 2001. The docks are evaluated for compliance with the Seagrass Guidelines developed in 2001, compliance with permit conditions, and presence of seagrass cover. Statistical analyses were used to compare seagrass cover and irradiance in shaded areas beneath the docks with adjacent unshaded areas and examine the relationships between dock structural parameters such as height and width, seagrass cover, and light.

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