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AN EVALUATION OF GLASS PRISMS IN BOAT DOCKS TO REDUCE SHADING OF SUBMERSED AQUATIC VEGETATION IN THE LOWER ST. JOHNS RIVER, FLORIDA

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

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Palatka, Florida

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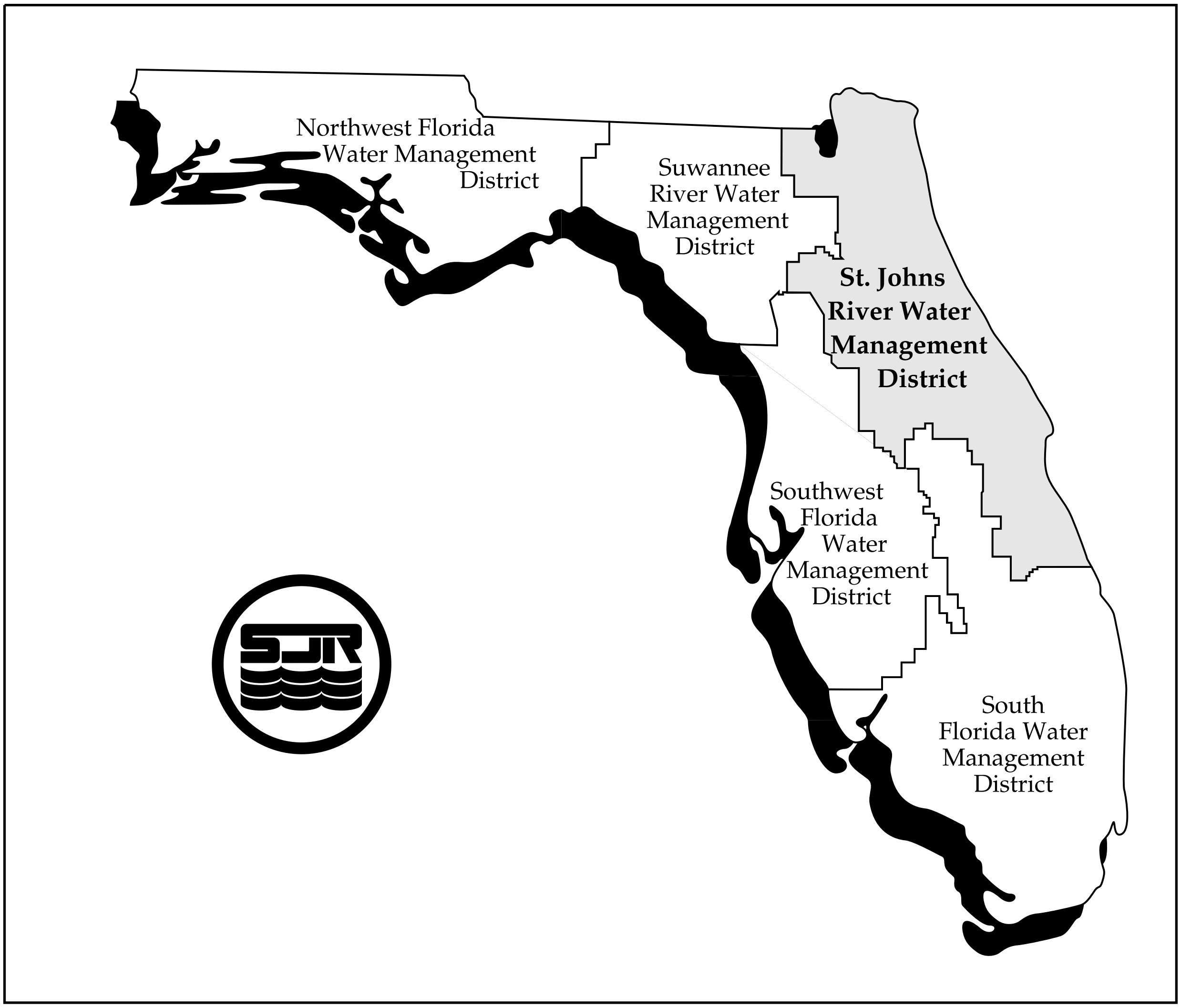

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ABSTRACT

The effectiveness of glass prisms in boat docks was assessed to determine if shading impacts to submersed aquatic vegetation (SAV), primarily *Vallisneria americana*, were reduced. Six experimental docks with and without prisms were constructed in the lower St. Johns River. SAV percent coverage, canopy height, and photosynthetically active radiation (PAR) were monitored under each dock and in an adjacent control area with no docks. Subsurface PAR was significantly higher ($p < 0.05$) beneath docks having prisms than docks having no prisms.

Post-construction SAV monitoring (February 2000 to February 2001) revealed significant differences ($p < 0.05$) in SAV percent coverage and canopy height among treatments, although there was a decline in SAV coverage in all treatments. Fourteen months after the pre-construction monitoring, median SAV percent coverage decreased 42% under docks with prisms, 61% in the control area, and 67% under docks with no prisms. Data indicate that water quality conditions at the study site may have impacted the health of the SAV habitat. It was not immediately apparent if differences in ambient light between treatments (prisms vs. no prisms) were biologically significant, given the substantial water quality and habitat changes that may have masked the potential effects of the prisms.

INTRODUCTION

Many studies have indicated that light availability is an important environmental factor controlling submersed aquatic vegetation (SAV) distribution, growth, and survival in both marine and estuarine waters (Batiuk et al. 1992; Kaldy and Dunton 1993; Neckles 1994). Poor water quality conditions can have a profound impact on SAV by limiting light available to submersed macrophytes, but over-water structures also attenuate light and have been associated with the loss of SAV habitat (Molnar et al. 1989; Loflin 1995; Thom et al. 1995; Burdick and Short 1998; Shafer 1999; Smith and Mezich 1999; Beal and Schmit 2000). In response to the continued development and construction of over-water structures (e.g., boat docks) along coastal shorelines, there has been an increasing number of studies conducted to assess the impacts of shading on sea grasses, including Molnar et al. 1989, Loflin 1995, Thom et al. 1995, Burdick and Short 1998, Shafer 1999, Smith and Mezich 1999, and Beal and Schmit 2000. Results of these studies have been used to provide a scientific basis for establishing dock construction guidelines and regulations for the protection of sea grasses.

Shading caused by over-water structures has been found to impact seagrass (*Zostera marina)* bed quality under and adjacent to boat docks in Massachusetts estuaries (Burdick and Short 1998). Burdick and Short (1998) reported that sea grasses located under and adjacent to boat docks were minimally impacted by narrow docks constructed greater than 3 meters (m) above the substrate and oriented in a north-south direction. Although some data exist on the deleterious impacts of over-water structures on coastal sea grasses, there are limited data available on the impacts of boat docks on freshwater and upper estuarine (oligohaline) SAV. Less information is available for SAV in the tidally influenced dark-water creeks and rivers that are common throughout the southeastern coastal United States.

Typically, *Vallisneria americana* is the dominant submersed macrophyte in blackwater rivers and upper estuaries where the attenuation of light is high (compared to coastal seagrass systems) and salinities are often <12 parts per thousand (ppt) (Montz 1978; Titus and Adams 1979; Orth and Moore 1984; Carter and Rybicki 1985; Schloesser and Manny 1990; Brody 1994). The lower St. Johns River (LSJR) is considered a blackwater system because of the influx of dissolved humic acids from adjacent wetlands. Water color is responsible for an average 39% of light attenuation, with average light attenuation in the study area of 2.9% (Gallegos 2002). The minimum water column light requirement for SAV survival in Chesapeake Bay is estimated to be >13% for SAV in tidal fresh and oligohaline regimes, whereas sea grasses in mesohaline and polyhaline regimes require >22% light (Kemp et al. 2000).

In Florida, guidelines for boat dock construction have been established for construction over coastal sea grasses, including freshwater and estuarine macrophytes (USACE 2001). These guidelines may be appropriate for boat docks constructed over coastal seagrass habitats; however, SAV species present in the LSJR and other light-limited estuaries are tolerant of light-limited conditions and require less surface irradiance than coastal sea grasses.

This study focused primarily on V. *americana* since it is the most dominant submersed macrophyte in the LSJR and one of the more shade-tolerant species of SAV found throughout the southeastern coastal United States. The study was designed to evaluate the use of glass prisms to transmit surface light beneath boat docks and enhance light availability to SAV. The glass prisms used in the study were replicas of those originally used aboard wooden whaling ships in the 1800s to provide light below a vessel’s deck. Results of the study will improve our understanding of the practical application of glass prisms in a potential boat dock design and their effect on the survival and growth of euryhaline species of submersed macrophytes.

MATERIALS AND METHODS

Study Location

The LSJR management boundaries extend from the confluence of the

Ocklawaha River and the St. Johns River north to the mouth of the St. Johns River at Mayport, where it empties into the Atlantic Ocean. The study site is located in an oligohaline stretch of the LSJR near Green Cove Springs, Florida, adjacent to the Bayard Conservation Area (Figure 1). This site was selected because of (1) relative shallow water depth and consistent littoral slope, (2) a high degree of SAV foliar cover and no areas devoid of SAV, (3) natural shoreline and accessibility, (4) adequate area available within a defined water depth for the size and number of docks required, and (5) stable and sandy substrate.

Dock Descriptions

Six experimental docks were constructed in February 2000 in the LSJR. The docks were constructed 50 m from the shoreline to eliminate possible terrestrial shading effects. Additionally, the docks were oriented in an east-west direction to minimize the effect of seasonally variable sun angle and to maximize the shading beneath the docks to better assess light transmission through the prisms. The experimental docks measured 7.3 m in length, 1.5 m in width, and 0.90 m above mean high water. The width and height dimensions of the experimental docks represented dimensions of the majority of existing docks on the LSJR and the dimensions most requested by homeowners (R. Bowers, B & W Marine Construction, Jacksonville, Fla., 2000, pers. com.). The docks were constructed by alternating standard 2" x 6" and 2" x 10" pressure-treated boards, with no open spaces between the deck boards. Three docks (docks 1, 2, and 4) were randomly selected to contain 48 glass prisms per dock; the remaining three docks (docks 3, 5, and 6) contained no prisms. Three prisms were installed approximately 0.5 m apart in each 2" x 10" deck board of the docks selected to contain prisms. Forty-eight prisms were determined to be the maximum number needed to provide light beneath the total area of each dock. The surface area of each dock was 10.95 m^2, and the total area under the dock receiving light from the prisms was estimated to be 13.6 m^2. It was determined that each prism produced a circle of light approximately 0.6 m in diameter under the dock, relative to its height. Prism dimensions were ~10 centimeters wide and 12 centimeters long. The hexagon-shaped glass prisms were installed flush with the deck boards by routing the hexagon shape in the deck board. The prisms were held in place by a one-quarter-inch aluminum plate attached to the underside of the decking.

COLLECTION OF SAV DATA, LIGHT DATA, AND WATER QUALITY DATA

SAV monitoring at the study site was first performed in December 1999 and January 2000 to collect baseline foliar data prior to dock construction. Post-construction monitoring was conducted monthly from February 2000 to November 2000 and in February 2001 for all treatments (three docks with prisms, three docks without prisms, and three control areas). SAV monitoring was conducted in the location where the six docks were constructed and in three control areas where no docks were constructed over the SAV bed. Three line-transects were established monthly in each treatment to determine SAV percent foliar cover and SAV canopy height (Figure 2). SAV species and presence/absence of SAV were recorded continuously along each transect by a variation of the terrestrial line-intercept method. SAV was considered present if the base of the plant was within approximately 0.2 m to either side of the transect line. SAV percent foliar coverage was calculated for each of the line-transects for each treatment.

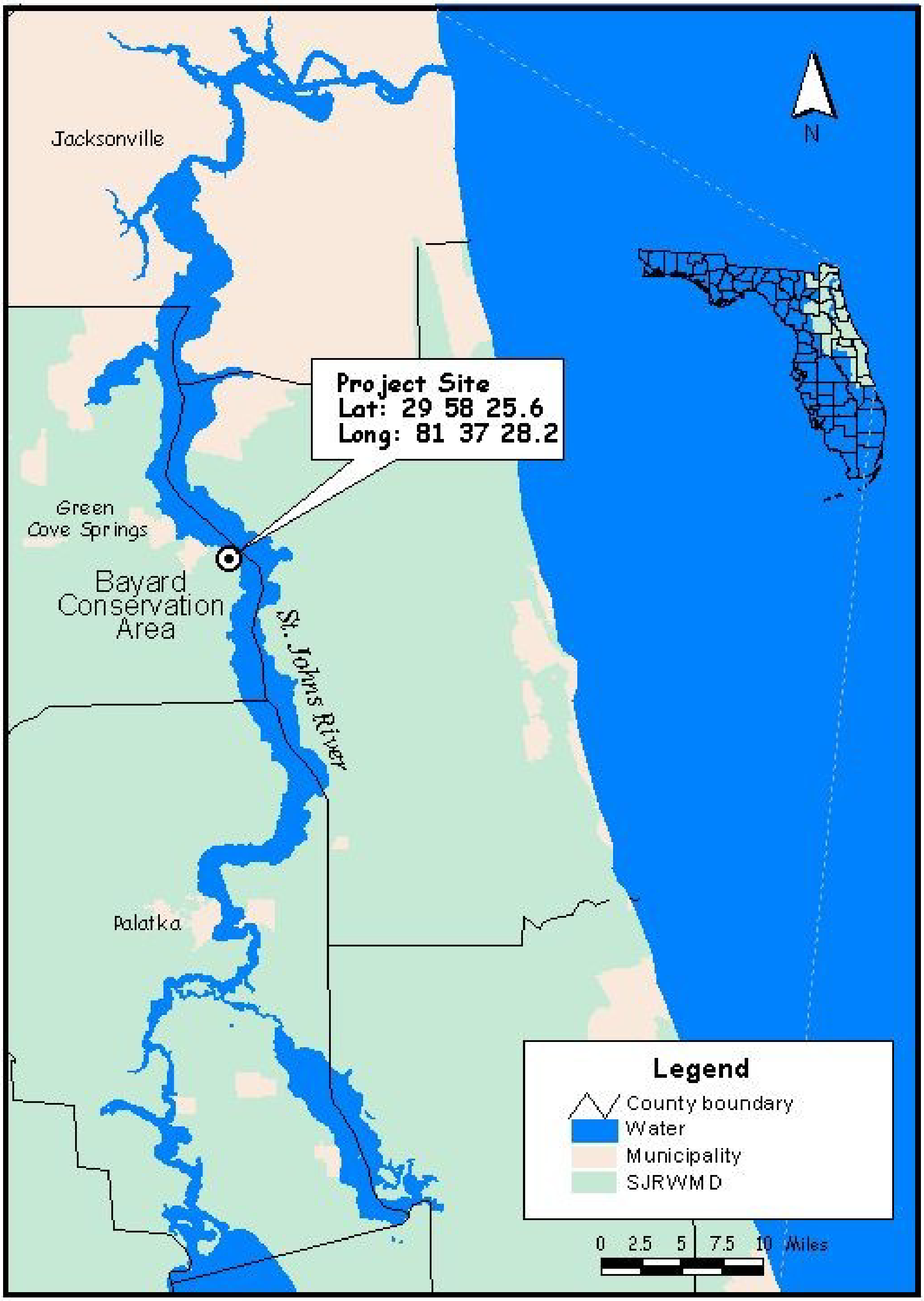

Figure 1. Location of the project site near Green Cove Springs, Florida, in the lower St. Johns River

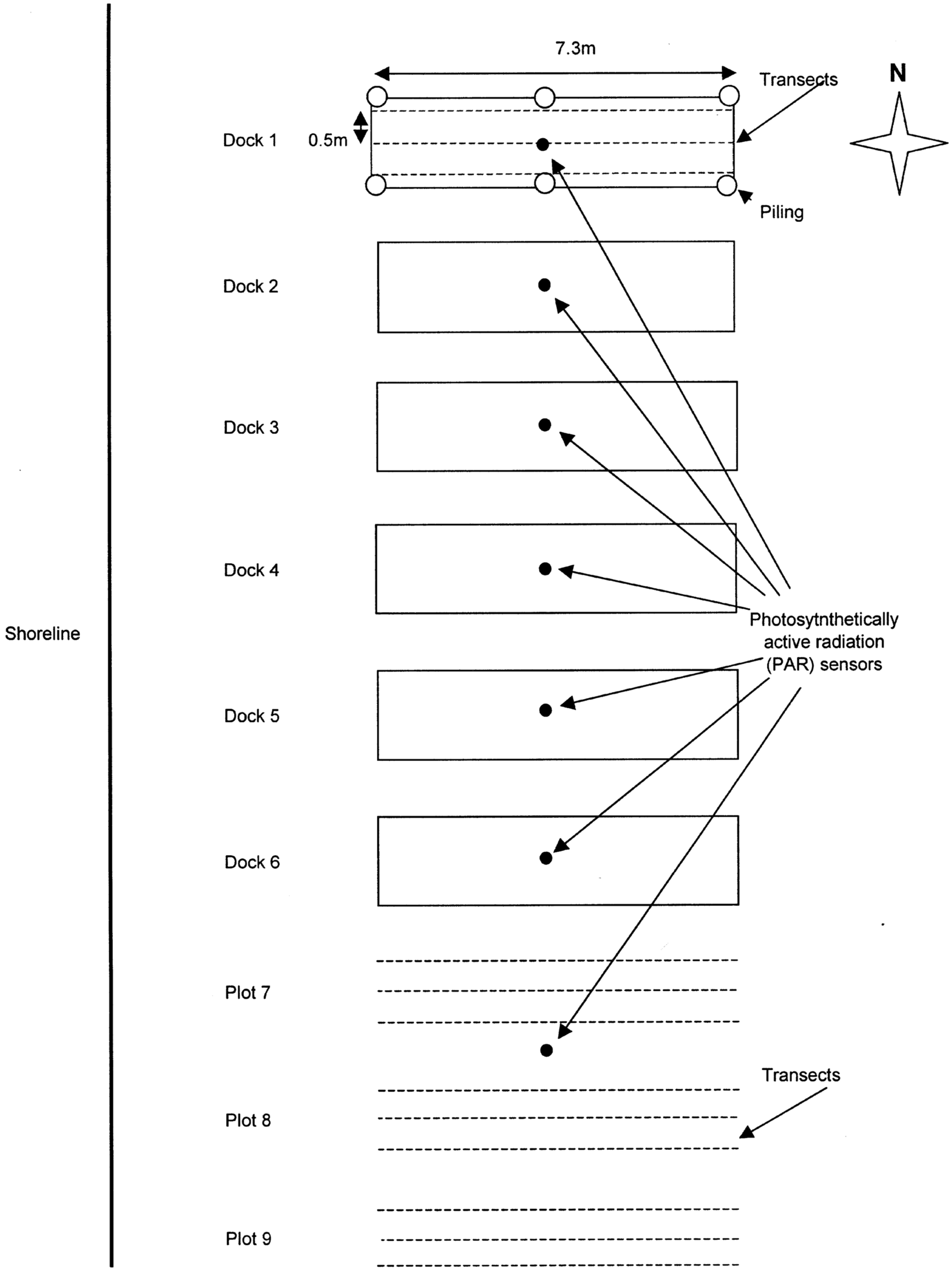

Figure 2. Diagram of experimental design

Representative canopy height measurements for each species present and water depth were also recorded at 0.5-m intervals along the line-transects.

Irradiance or photosynthetically active radiation (PAR) data were collected beginning in May 2000 in each treatment area. LI-COR dataloggers (LI-COR, Inc., Lincoln, Neb.) were attached to each of the six docks. The dataloggers were set to record PAR data that measured at least 1 micromol per square meter per second (μmol m^{-2} s^{-1}) from sunrise to sunset, every half hour, Eastern Standard Time. Subsurface PAR was measured in the water column under the middle of each of the six docks and in the control area by installing LI-193SA underwater spherical quantum sensors under the middle of each of the six docks. The sensors were secured to the substrate with PVC pipes approximately 1.5 m from the underside of the decking and approximately 0.36 m from the substrate to prevent sensors from being exposed during low tide. Ambient PAR under the six docks was also measured by attaching an LI-190SA quantum sensor to a wooden L-bracket underneath the middle of each of the six docks, approximately 0.5 m from the underside of the decking. Surface irradiance at the study site was measured using an LI-190SA quantum sensor surface-mounted on the top of dock 1. Percent subsurface PAR and percent ambient PAR under the docks were calculated using the surface irradiance measurements obtained from the surface-mounted sensor. Water quality data were collected bi-weekly beginning in January 2000, except for October and November 2000, when data were collected monthly and were collected according to the St. Johns River Water Management District's standard operating procedures.

STATISTICAL ANALYSIS

Data that did not meet assumptions of the parametric analysis of variance (ANOVA) were analyzed by nonparametric techniques. For analysis of SAV percent cover and SAV canopy height, the Friedman Repeated Measures ANOVA on Ranks test was used, with the month as the repeated measure since SAV measurements were repeated monthly on the same set of transects with treatment (docks with prisms, docks with no prisms, and control) as the factor. Treatments showing significant effects ($p < 0.05$) were further analyzed using Dunn's post-hoc test to determine which treatments differed significantly. SAV percent cover was calculated by dividing the total number of meters of SAV present along each transect by the length of the transect (7.3 m) and multiplying by 100 to obtain a SAV percent coverage value. SAV percent coverage values for each transect were then grouped by treatment for analysis since there were no significant differences between transects. SAV canopy height measurements recorded in 0.5-m intervals for each transect were also grouped by treatment for analysis. SAV percent coverage in the control area was analyzed independently to determine if there were significant differences in SAV coverage among months monitored compared to the mean SAV coverage of the pre-construction months December 1999 and January 2000. Data did not meet assumptions of the parametric ANOVA, therefore the Kruskal-Wallis ANOVA on Ranks test was used, followed by Dunn's post-hoc test, with each month compared separately to December 1999 / January 2000 to determine which months differed significantly.

Subsurface PAR for all treatments was analyzed using the Kruskal-Wallis ANOVA on Ranks test. Treatments showing significant effects ($p < 0.05$) were further analyzed using Dunn's post-hoc test to determine which treatments differed significantly. Data were grouped by treatment for analysis. PAR data collected between the hours of 1000 and 1400, Eastern Standard Time, and collected within 3 days post-cleaning of the underwater spherical sensors were used in the analyses. Data collected within 3 days post-cleaning of the sensors were used in the analyses due to fouling of the spherical sensors between cleanings.

RESULTS

SAV Percent Foliar Cover and Canopy Height

No significant differences were found in SAV percent coverage between the treatment areas prior to dock construction ($p = 0.077$). Post-construction sampling (February 2000 to February 2001) revealed significant differences in SAV coverage between all treatments ($p < 0.05$). The decline of SAV coverage was greater under docks without prisms than under docks with prisms (Table 1). *V. americana* was the dominant macrophyte species present throughout the study, with a few occurrences (<1%) of *Najas guadalupensis*. Fourteen months after the initial pre-construction monitoring, SAV coverage had decreased 42% (from 82% to 40%) under docks with prisms, 61% (from 94% to 33%) in the control area, and 67% (from 92% to 25%) under docks without prisms (Figure 3). A decline in SAV coverage in the control area suggests that factors other than experimental conditions may have affected changes in the SAV. Therefore, the control area was analyzed independently to determine when the SAV coverage in the control area was significantly different from the initial monitoring. Results of the Kruskal-Wallis ANOVA on Ranks test (Table 2) indicated that beginning in September 2000 and continuing to February 2001, SAV coverage was significantly different ($p < 0.05$) from the mean SAV coverage of December 1999 and January 2000 (the pre-construction months). Figure 4 shows that median SAV coverage in the control area decreased from 93% coverage in December 1999 / January 2000 to 33% in February 2001 (one year after docks were constructed) and declined to as low as 23% in October 2000.

Table 1. Results of the Friedman Repeated Measures Analysis of Variance on Ranks test and Dunn's post-hoc test for submersed aquatic vegetation percent cover. Data used are from post-construction months monitored between February 2000 and February 2001

Friedman Repeated Measures Analysis of Variance on Ranks Test			Dunn's Post-hoc Test		
Treatment ($p < 0.001$)	N	Median (% cover)	Comparison	Difference of Ranks	$p < 0.05$
Control	99	75.0	Control vs. no prisms	1.02	Yes
Prisms	99	49.0	Control vs. prisms	0.67	Yes
No prisms	99	30.0	Prisms vs. no prisms	0.35	Yes

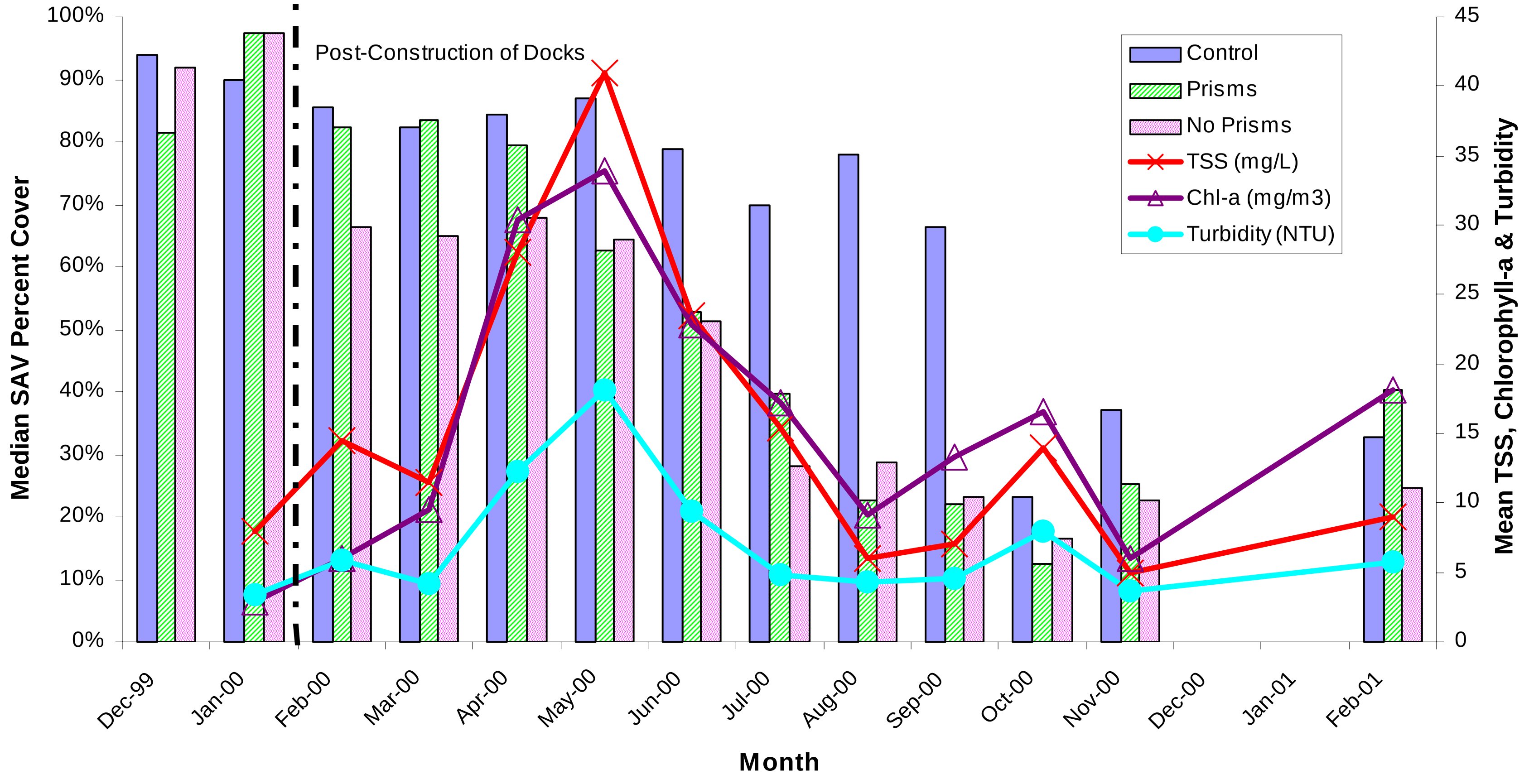

Figure 3. Monthly decline of total median submersed aquatic vegetation (SAV) percent cover for all treatments. Values represent median monthly SAV percent cover under each of the three docks for each treatment with mean monthly values for total suspended solids (TSS), chlorophyll *a*, and turbidity.

Table 2. Results of Kruskal-Wallis Analysis of Variance on Ranks test and Dunn's post-hoc test for submersed aquatic vegetation percent cover in the control area compared to the mean submersed aquatic vegetation percent cover of pre-construction months (December 1999 and January 2000)

Month	N	Median (%)	Comparison	Difference of Ranks	$p < 0.05$
Pre-construction	9	92.8	Pre-construction vs. Feb 2000	10.056	No
Feb 2000	9	85.6	Pre-construction vs. Mar 2000	28.722	No
Mar 2000	9	82.2	Pre-construction vs. Apr 2000	24.000	No
Apr 2000	9	84.2	Pre-construction vs. May 2000	14.444	No
May 2000	9	87.0	Pre-construction vs. Jun 2000	32.500	No
Jun 2000	9	78.8	Pre-construction vs. Jul 2000	40.889	No
Jul 2000	9	69.9	Pre-construction vs. Aug 2000	25.778	No
Aug 2000	9	78.1	Pre-construction vs. Sep 2000	46.611	Yes
Sep 2000	9	66.4	Pre-construction vs. Oct 2000	81.278	Yes
Oct 2000	9	23.3	Pre-construction vs. Nov 2000	72.167	Yes
Nov 2000	9	37.0	Pre-construction vs. Feb 2001	77.556	Yes
Feb 2001	9	32.9	N/A	N/A	N/A

Note: N / A = not applicable

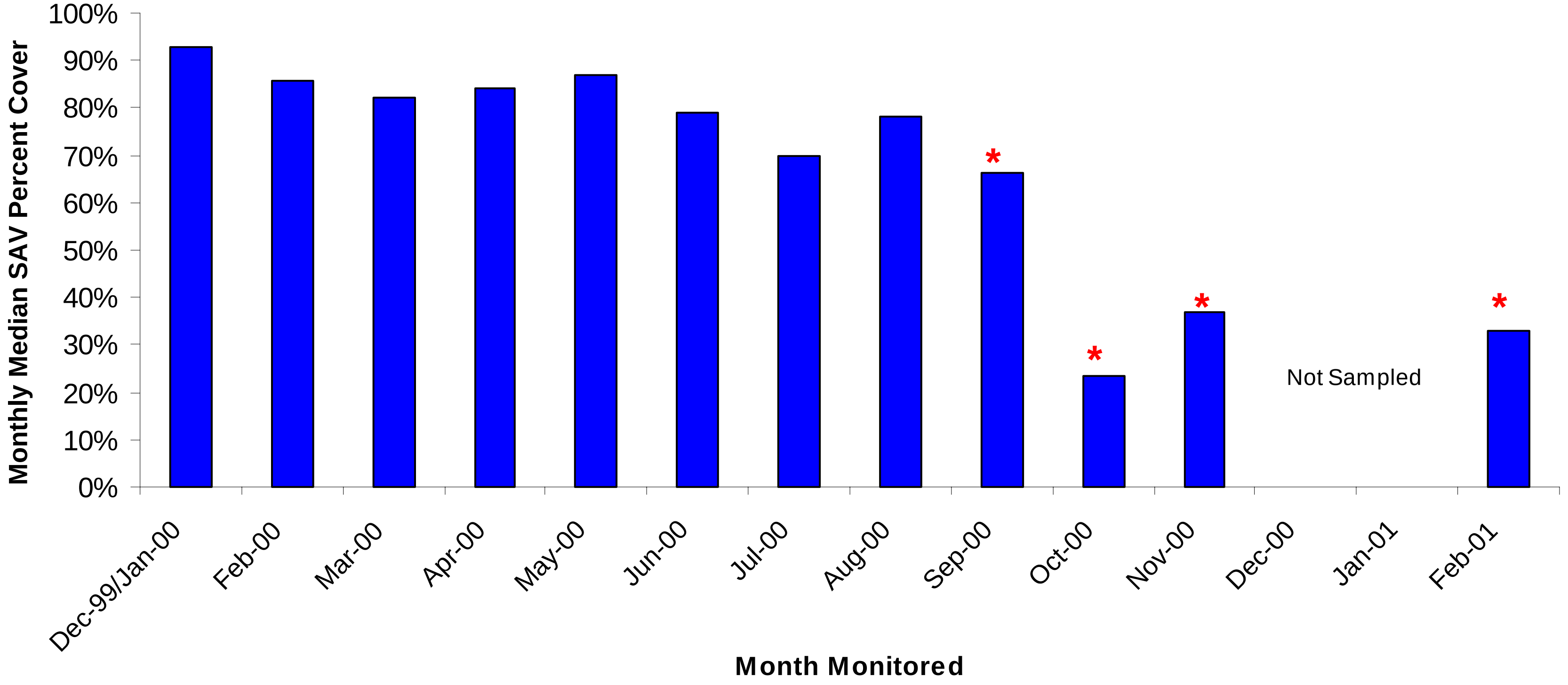

Figure 4. Significant changes in median submersed aquatic vegetation percent cover in the control area over the study period. Results of the Kruskal-Wallis Analysis of Variance on Ranks test and Dunn's post-hoc test. The asterisk denotes significant differences ($p < 0.05$) in submersed aquatic vegetation percent cover for the corresponding month compared to the mean of pre-construction months December 1999 and January 2000.

SAV canopy height declined for all three treatments over the post-construction study period (Figure 5). Additionally, median SAV canopy height was significantly different ($p < 0.05$) between all treatments (Table 3). The SAV canopy height declined to the greatest extent under docks without prisms relative to docks with prisms.

PAR Measurements

Subsurface PAR for all treatments from May 2000 to February 2001 was significantly different ($p < 0.05$; Table 4). Median PAR values were 575 µmol m^{-2} s^{-1} in the control area, 142 µmol m^{-2} s^{-1} under the docks with prisms, and 119 µmol m^{-2} s^{-1} under docks without prisms. Median values for percent subsurface PAR were 42.3% in the control area, 14.1% under docks with prisms, and 10.8% under docks without prisms. Additionally, median percent ambient PAR was 3.9% under docks with prisms and 2.5% under docks without prisms.

Table 3. Results of the Friedman Repeated Measures Analysis of Variance on Ranks test and Dunn's post-hoc test for submersed aquatic vegetation canopy height. Data used are from post-construction months monitored between February 2000 and February 2001

Friedman Repeated Measures Analysis of Variance on Ranks Test			Dunn's Post-hoc Test		
Treatment	N	Median (meters)	Comparison	Difference of Ranks	$p < 0.05$
Control	1,485	0.11	Control vs. no prisms	0.44	Yes
Prisms	1,485	0.08	Control vs. prisms	0.27	Yes
No prisms	1,485	0.00	Prisms vs. no prisms	0.16	Yes

Table 4. Results of the Kruskal-Wallis Analysis of Variance on Ranks test for subsurface photosynthetically active radiation for all treatments. Data used are from May 2000 to February 2001, 1000–1400 Eastern Standard Time, for 3 days post-cleaning of spherical sensors

Kruskal-Wallis Analysis of Variance on Ranks Test			Dunn's Post-hoc Test		
Treatment	N	Median (µmol m^{-2} s^{-1})	Comparison	Difference of Ranks	$p < 0.05$
Control	322	575.4	Control vs. no prisms	778.6	Yes
Prisms	1,082	142.5	Control vs. prisms	665.2	Yes
No prisms	973	119.4	Prisms vs. no prisms	113.4	Yes

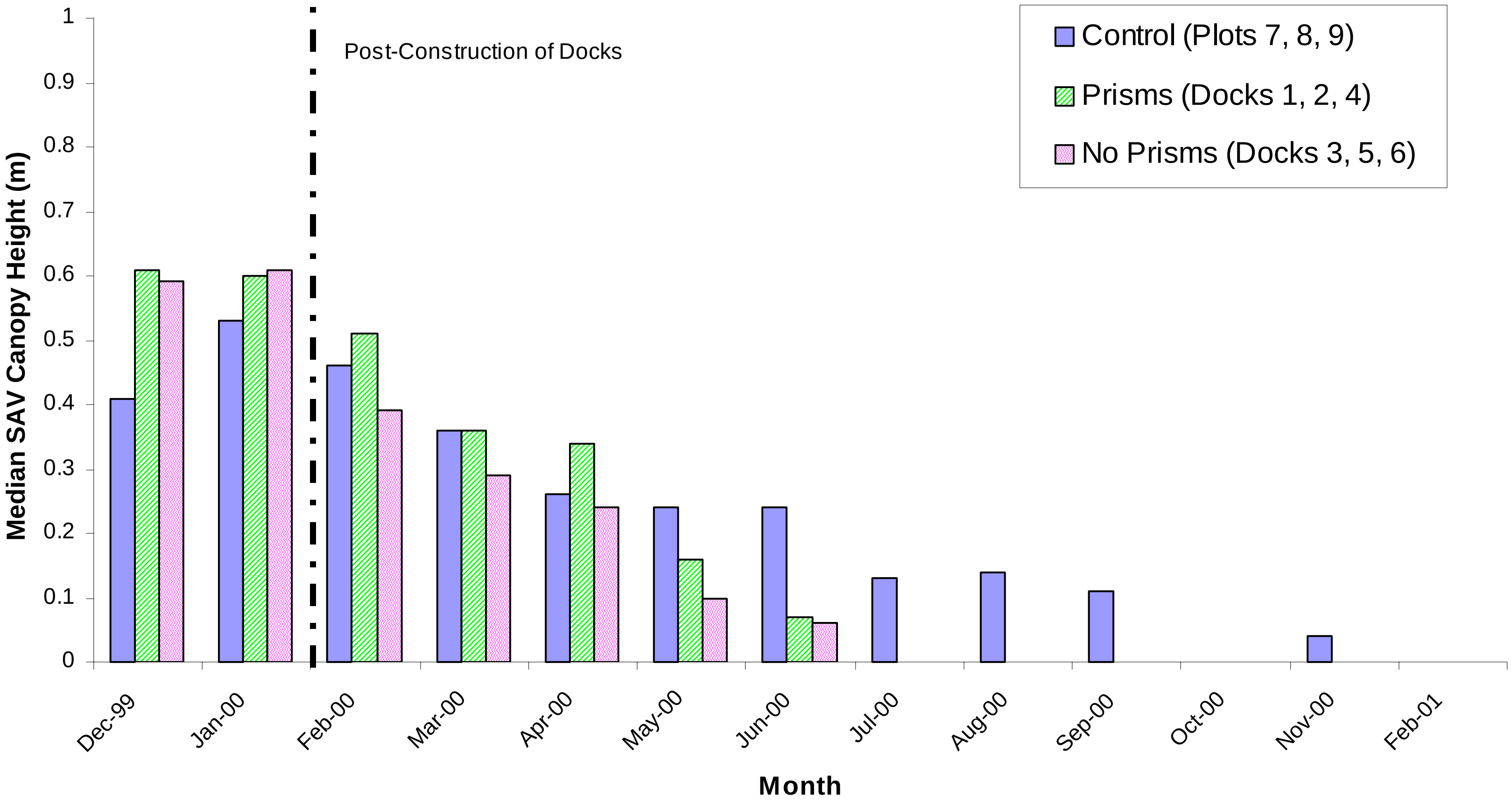

Figure 5. Monthly decline of total median submersed aquatic vegetation canopy height for all treatments. Values represent median monthly canopy height in 0.5-meter intervals under each of the three docks for each treatment.

Water Quality

Levels of total suspended solids, chlorophyll *a*, and turbidity began to increase in April 2000 and reached maximum concentrations of 41 milligrams per liter (mg l^{-1}) , 34.0 milligrams per cubic meters (mg/m^3), and 18.1 NTU (nephelometric turbidity units), respectively, during May 2000 (Figure 3). Elevated levels of these water quality constituents persisted through June 2000 and began to decrease by July 2000 (Figure 3). Salinity levels remained less than 0.5 ppt through March 2000 and increased to ~1 ppt in April 2000 (Figure 6). Over a 1-month period, in June 2000, salinity levels increased to ~5 ppt. Salinity levels began to decrease after June 2000, averaging ~3 ppt until October 2000 (Figure 6). Concomitant with increased salinity levels, color decreased in March 2000 from approximately 150 CPUs (cobalt-platinum units) to approximately 100 CPUs, where it remained from April to September 2000.

DISCUSSION

Loss of SAV can be caused by degraded water quality or shading by over-water structures. These are important factors that need to be considered when developing management goals for the protection of SAV. While enhancing water quality and light availability may provide a favorable environment to support SAV communities, the impacts of over-water structures on SAV are independent of water quality effects and should also be considered due to littoral zone acreage covered by boat docks and marinas. Identifying cost-effective boat dock construction practices that would provide waterfront homeowners with functional docks while satisfying SAV light requirements specific to coastal systems or freshwater/upper estuarine SAV would benefit both waterfront homeowners and resource managers in the protection of submersed habitats.

The use of glass prisms in experimental docks demonstrates that ambient light can be redirected under docks and that underwater light irradiance can be increased under docks beyond estimates required for SAV survival and growth. The minimum light requirement for SAV survival and growth is estimated to be >13% for SAV in tidal fresh and oligohaline regimes of Chesapeake Bay (Kemp et al. 2000). However, the loss of SAV within all treatments in this study suggests that SAV light requirements were not met and/or other water quality and habitat changes may have altered the potential positive effects of increased light provided by the prisms. Providing the necessary light climate required by SAV under over-water structures is not exclusive of water quality. For example, management strategies that improve only water quality as a method for improving underwater irradiance will fail in areas shadowed by over-water structures. Moreover, dock requirements that reduce underwater irradiance by shadowing will also fail in the absence of appropriate SAV water quality requirements.

The reason for the decline of SAV is uncertain, but several interacting factors are suspected to have contributed to its decline. Deleterious water quality conditions at the study site first became apparent in the spring of 2000 when algal blooms (*Cladophora* sp.) formed thick mats over SAV within the study site. Light attenuation [K_d (PAR)] was at a high of 4.65 m^{-1} in late April 2000 and 4.16 m^{-1} in May 2000 during algal bloom events. Further, it is a possibility that K_d(PAR) was higher than that estimated by the optical model, given the presence of algal mats over the SAV. Elevated total suspended solids, chlorophyll *a*, and turbidity during late

April and May 2000 resulted in an (Figure 3). These water quality constituents at the study site far exceeded the suggested habitat requirements for total suspended solids (<15 mg l^{-1}) and chlorophyll *a* (<15 mg / m^3) for the growth and survival of SAV in tidal fresh and oligohaline regimes of Chesapeake Bay (Kemp et al. 2000). Additionally, Dennison et al. (1993) reported that water quality parameters such as total suspended solids, chlorophyll *a*, dissolved inorganic nitrogen, dissolved inorgranic phosphorus, and light attenuation coefficients had interacting effects on the survival of submersed macrophytes in the Choptank River (Maryland), but there were also other factors that could have influenced SAV survival.

Increased salinity levels at the study site were also considered a potential factor that may have further stressed the SAV community. Due to drought conditions, salinity began to rise from less than 1 ppt to almost 5 ppt during a 1-month period (May to June 2000) and did not fall below 1 ppt until October 2000 (Figure 6). However, several studies indicate that V. *americana* can tolerate salinities higher than those at the study site (Haller et al. 1974; Twilley and Barko 1990; Doering et al. 1999). V. *americana* has been reported to grow in salinity concentrations up to 12 ppt (Twilley and Barko 1990). Other studies indicate V. *americana* growth ceased above 6.0 ppt (Haller et al. 1974). Doering et al. (1999) reported that increased growth of V. *americana* in the Caloosahatchee estuary occurred at salinities less than or equal to 3 ppt and exhibited decreased growth at 9 ppt or greater during the dry season. Varying levels of salinity tolerance by V. *americana* may be dependent upon physiological conditions of the plants and duration of exposure to elevated salinities. Alternatively, genetic differences among geographically distinct populations may approximate 6-week exposure time contribute to these reported differences in salinity responses. It is possible that the interaction of increased salinity coupled with concurrent poor water quality conditions and macroalgal growth may have had a profound impact on the SAV habitat at the study site and could have collectively masked SAV response to additional light supplied by the prisms.

The threshold at which SAV can no longer survive poor water quality and exacerbated light limitation has yet to be determined for LSJR SAV communities. The morphology and physiological condition of submersed macrophytes can also differ spatially, potentially affecting the response time of submersed macrophytes to poor water quality. Jeansonne et al. (2001) reported that water quality conditions in the LSJR were found to differ spatially along an estuarine gradient and between channel and nearshore environments. Morphological and physiological variation may explain disparities in the apparent response time of SAV at the study site to water quality degradation. Although SAV declined in all of the treatments, SAV in the control treatment exhibited a higher tolerance of environmental stressors in comparison to SAV in the prisms and no-prisms treatments. The decline of SAV in the control treatment was slower compared to the loss of SAV in the prisms and no-prisms treatments, suggesting that SAV in these two treatments may have been initially stressed by light-limitation (Figure 3).

Although more light was available beneath the docks with prisms, there may not have been sufficient light to sustain and promote SAV growth. V. *americana* growth rates in pond experiments by Blanch et al. (1998) were found to be zero at a daily average PAR of 26 µmol m^{-2} s^{-1} where PAR was controlled by planting depth and

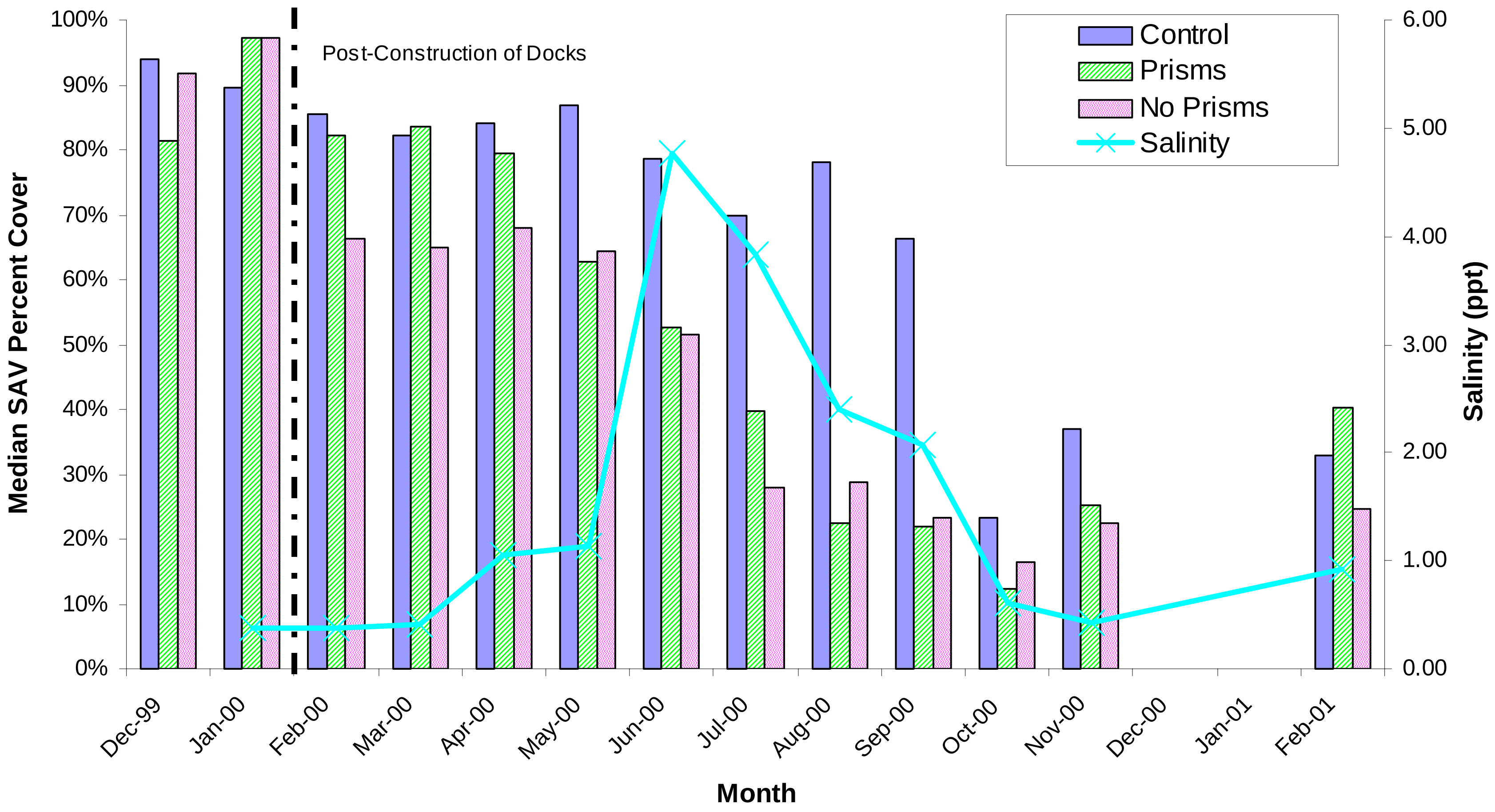

Figure 6. Median monthly concentration of salinity with total median submersed aquatic vegetation percent cover over the study period

turbidity. Yet PAR measurements at the study site exceeded those values with a growing-season mean daily PAR of 78 µmol m^{-2} s^{-1} for docks with prisms, 70 µmol m^{-2} s^{-1} for docks without prisms, and 432 µmol m^{-2} s^{-1} for control. Though the PAR values at the study site were higher than the values in the pond experiments by Blanch et al. (1998), higher values may be required to compensate for production losses in the natural environment due to factors such as herbivory, competition, and poor water quality. The additional light to the plants provided by the prisms may not have been sufficient to counteract effects from environmental stressors. An additional stress factor under consideration, but not measured, was human disturbance from the monthly sampling regime. The frequently monitored and closely spaced transects may have been an additional, unintentional impact to plants already stressed by water quality and light limitation. Therefore, monitoring of SAV will continue on a less frequent basis to further evaluate the potential re-growth of SAV at the study site.

LITERATURE CITED

Batiuk, R.A., R.J. Orth, K.A. Moore, W.C. Dennison, J.C. Stevenson, L. Straver, V. Carter, N. Rybicki, R.E. Hickman, S. Kollar, S. Bieber, P. Heasly, and P. Bergstrom. 1992. *Chesapeake Bay submerged aquatic vegetation habitat requirements and restoration goals: A technical synthesis.* Annapolis, Md.: U.S. Environmental Protection Agency, Chesapeake Bay Program.

Beal, J.L., and B.S. Schmit. 2000. The effects of dock height on light irradiance (PAR) and seagrass (*Halodule wrightii* and *Syringodium filiforme*) cover. In *Seagrasses: Monitoring, ecology, physiology, and management*. S.A. Bortone, ed. Boca Raton, Fla.: CRC Press.

Blanch, S.J., G.G. Ganf, K.F. Walker. 1998. Growth and recruitment in *Vallisneria americana* as related to average irradiance in the water column. *Aquatic Botany* 6:181–205.

Brody, R.W. 1994. *Vol. 6 of the Lower St. Johns River Basin reconnaissance: Biological resources*. Technical Publication SJ94-2. Palatka, Fla.: St. Johns River Water Management District.

Burdick, D.M., and F.T. Short. 1998. The effects of boat docks on eelgrass beds in coastal waters of Massachusetts. *Environmental Management* 23(2):231–240.

Carter, V., and N.B. Rybicki. 1985. The effects of grazers and light penetration on the survival of transplants of *Vallisneria americana michx* in the tidal Potomac River, Maryland. *Aquatic Botany* 23:197–213.

Dennison, W.C., R.J. Orth, K.A. Moore, J.C. Stevenson, V. Carter, S. Kollar, P.W. Bergstrom, and R.A. Batiuk. 1993. Assessing water quality with submersed aquatic vegetation: Habitat requirements as barometers of Chesapeake Bay health. *BioScience* 43:86–94.

Doering, P.H., R.H. Chamberlain, K.M. Donohue, and A.D. Steinman. 1999. Effect of salinity on the growth of *Vallisneria Americana michx* from the Caloosahatchee Estuary, Florida. *Florida Scientist* 62(2):89–105.

Gallegos, C.L. 2002. “Development of an optical water quality model for the lower St. Johns River.” Final report for the St. Johns River Water Management

District. Smithsonian Environmental Research Center, Edgewater, Md.

Haller, W.T., D.L. Sutton, and W.C. Barlowe. 1974. Effects of salinity on growth of several aquatic macrophytes. *Ecology* 55(4):891–894.

Jeansonne, M., A.M. Steinmetz, E.S. Gordon, and J. Burns. 2001. *Comparison of lower St. Johns River estuary mid-channel and near shore water quality conditions.* 16th Biennial Conference of the Estuarine Research Federation 2001: An Estuarine Odyssey Conference Abstracts. St. Petersburg Beach, Fla.

Kaldy, J.E., and K.H. Dunton. 1993. *The light requirements of growth and photosynthesis in sea grasses with emphasis on Texas estuaries: A literature survey.* Dallas, Texas: U.S. Environmental Protection Agency, Region 6.

Kemp, M., R.A. Batiuk, and P. Bergstrom. 2000. *Chesapeake Bay submerged aquatic vegetation habitat requirements and restoration goals: A second technical synthesis.* Annapolis, Md.: U.S. Environmental Protection Agency, Chesapeake Bay Program.

Loflin, R.K. 1995. The effects of docks on seagrass beds in the Charlotte Harbor Estuary. *Florida Scientist* 58(2):198–205.

Molnar, G., S. Markley, and K. Mayo. 1989. *Avoiding and minimizing damage to Biscayne Bay seagrass communities from the construction of single family residential docks.* Technical Report 89-1. Miami, Fla.: Metro Dade Department of Environmental Resources Management.

Montz, G.N. 1978. The submerged vegetation of Lake Pontchartrain, Louisiana. *Castanea* 43:115–128.

Neckles, H.A., ed. 1994. *Indicator development: Seagrass monitoring and research in the Gulf of Mexico.* Gulf Breeze, Fla.: U.S. Environmental Protection Agency.

Orth, R.J., and K.A. Moore. 1984. Distribution and abundance of submerged aquatic vegetation in Chesapeake Bay: An historical perspective. *Estuaries* 7:531–540.

Schloesser, D.W., and B.A. Manny. 1990. Decline of wild celery buds in the lower Detroit River, 1950–85. *Journal of Wildlife Management* 54(1):72–76.

Shafer, D.J. 1999. The effects of dock shading on the seagrass *Halodule wrightii* in Perdido Bay, Alabama. *Estuaries* 22(4):936–943.

Smith, K., and R. Mezich. 1999. “Comprehensive assessment of the effects of single family docks on seagrass in Palm Beach County, Florida.” Draft report for the Florida Fish and Wildlife Conservation Commission. Tallahassee, Fla.

Thom, R.M., D.K. Shreffler, and J. Schafer. 1995. “Mitigation plan for impacts to subtidal vegetation associated with reconstruction and expansion of the ferry terminal at Clinton, Whidbey Island, Washington.” For Washington Department of Transportation, PNL-10844. Olympia, Wash.

Titus, J.E., and M.S. Adams. 1979. Coexistence and the comparative light relations of the submersed macrophytes *Myriophyllum spicatum* and *Vallisneria americana. Oecologia* 40:273–286.

Twilley, R.R., and J.W. Barko. 1990. The growth of submersed macrophytes under experimental salinity and light conditions. *Estuaries* 13(3):311–321.

[USACE] U.S. Army Corps of Engineers, National Marine Fisheries Service. 2001. “Dock construction guidelines in Florida for docks or other minor structures constructed in or over submerged aquatic vegetation (SAV), marsh or mangrove habitat.” N.p.