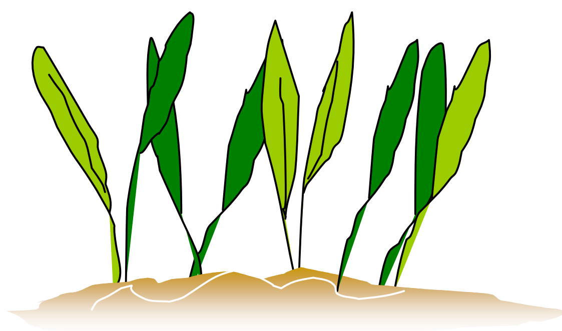
FINAL REPORT

JOHNSON'S SEAGRASS TRANSPLANTING STUDIES

Contract No. BC838



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Project Summary

Johnson's seagrass, *Halophila johnsonii*, is the subject of ongoing research because of its protected status, its rarity, and endangerment from coastal development. The goal of this project was to determine the feasibility and best methods for cultivation and transplantation in order to protect and restore this species, and to mitigate for its loss. During this research, an opportunity arose to study cultivation of the closely related paddle grass, *Halophila decipiens*. Like *H. johnsonii*, *H. decipiens* is rare and under threat from coastal development, even more so because it grows in channels and deeper waters, which subject it to damage from dredging and marina construction.

H. johnsonii was cultivated in sixty aquaria from spring of 2001 to fall 2002 and was first planted in the field in fall 2001. Growth in the field continues to the present with successes in at two sites, but with several failures due to unstable (erosional) substrates and siltation (field tests objectively compared all substrates and methods). In a recent field inspection of the most successful planting sites, Johnson's seagrass was still growing, and it had reached high densities at the Hillsboro Inlet site.

H. decipiens was collected from a local marina dredging project in October 2002 and was cultured in 60 aquaria plus tanks for reproduction and later replanting. Aquarium culture in the winter 2002-2003 months resulted in reductions in plant numbers, but this was anticipated based on previous winter field and aquarium studies, and plant numbers increased by summer in excess of initial stocking densities. Paddle grass was planted in the fall of 2002 at Bahia Mar Marina but did not survive due to siltation from dredging activities and the onset of winter temperatures. It was again planted at this marina in the spring of 2003 and a recent field inspection showed that plants were growing, and had apparently spread into adjacent areas from seeds, in one of three sites.

A comprehensive, overwintering field study was also performed on both species in 2001/2002 and this showed that both species had reduced numbers in the winter months (centered around January and February). Braun-Blanquet ratings fell by ~50% and occurrence in quadrats fell by ~40%. These numbers returned to normal by spring of 2002.

In summary, holding and cultivation in aquaria was successful, and transplantation looks promising, with good results obtained for both species.

Introduction

Johnson's seagrass (*Halophila johnsonii*) is the subject of the present culture and ecological study as a result of its protected species status and threats from coastal development. *H. decipiens* Ostenfeld is closely related to other members of the Hydrocharitaceae *H. johnsonii* and *H. englemannii* (Littler et al., 1989) by taxonomic features of leaves, stems and flowers, and also by its small, delicate shape. The contrasting member of this group is turtle grass, *Thalassia testudinum*, which shares taxonomic traits but is much larger and coarser.

Johnson's seagrass was placed on the State of Florida endangered species list (FGFWFC 1996) as a result of its rarity in coastal waters, and following the research of Eiseman (1980), Eiseman and McMillan (1980) and Dawes et al. (1989). It is currently federally threatened for the State (USFWS, 1998). The localized species was separated from *H. decipiens* which was found in deeper or more offshore waters. The plant forms rhizomatous mats in shallow water (15-30cm, 0.5-1ft). Paired leaves are linear-lanceolate with entire margins and long petioles. Culture work and field observations indicate that *H. johnsonii* is a single sex species as no male flowers have been found, although seeds were common in cultured material in the spring (this study). Its transient nature results in it being absent during the colder months of the year (NSU, 2001). Paddle grass is a small, bright green seagrass with pairs of minutely-toothed leaves arising from rhizome nodes. It grows to 5 cm tall, in water depths to 30 m, and colonies can spread by rhizomes (and seeds, present observations) to form patches to 1 m across (Littler et al., 1989).

Methods

Aquarium Culture

H. johnsonii for aquarium culture work were first collected, in spring 2001, from the NSU Oceanography marina entry channel (main donor site). Tests were performed to determine what planting method worked best for the aquaria, using three different methods:

- Staples - a single planting unit secured into the substrate with a u-shaped metal staple fashioned from a large paper clip
- Plugs - a single planting unit with native donor substrate nestled into the planting substrate.
- Sprigs - five planting units on one rhizome strand, planted bare-root, without substrate

Following tests wherein the sprigs worked best (see next section), plants were collected and installed in groups of five within sixty 0.37m^2 (2'x2'), 114L (30-gallon) glass aquaria (Fig. 1). The system is flow-through, each aquarium having its own spray jet, with filtration by sand filter. Sand filtration was not always used because of clogging problems. The bottom is covered with approximately 3cm (1.2 inch) clean beach sand. Photometer readings were taken in the water above growing seagrasses and found to be approximately 1/2 that of ambient light; therefore 50% rated shade cloth was used to cover the aquaria. *H. johnsonii* was cultured in aquaria from spring 2001 through fall 2002.

Figure 1. The 60 main aquaria used for cultivation of Johnson's seagrass and paddle grass, shown without heavy shade-cloth cover (inset shows cover).

H. decipiens plants for aquarium culture were collected in comparatively deep water (2.6m, 8ft) at Bahia Mar Marina in Ft. Lauderdale (Intracoastal Waterway). Plants were transported in seawater to the aquaria where they were sorted into planting units (individual sprigs with a pair of leaves). They were planted at 60 per aquarium (approx. 160/m^2), and with two layers of 50% rated shade cloth. Backup supplies (commonly from broken pieces and leafless rhizomes left from collections) were cultured in 114L (300gal) plastic tanks. Photometer readings were taken in the water above growing seagrasses and shade cloth was used to approximate the light reduction in the aquaria (needed to keep down epiphyte fouling). As light levels continued to drop over the winter only one layer of shade cloth was used. In spring 2003 two layers of shade cloth were again used.

Near daily aquarium maintenance included vacuuming of algae, maintenance of water inflow jets, sprinkling beach sand over plants (to stifle algae and replace eroded material), and scraping aquarium sides. Algae problems were reduced with shade cloth and maintenance, and grazing invertebrates and fish were controlled by periodic, heavy seawater flushing and stirring sediment. In cases where seagrasses were completely decimated by grazers (direct observation), tanks were flushed with fresh water followed by a 10-min soaking in 10% bleach and another freshwater flush. These were then replanted with a backup supply located in 114L (300gal) plastic tanks. Use of a sand filter was also implemented in 2003 to deter invasion by grazers.

Methods
Transplant Studies

The 2001/2002 field planting research used Johnson's seagrass. A test planting was conducted to determine which method to use for the main planting, and this was conducted for about sixty days from July 28, 2001 to September 23, 2001. The first main field planting took place at the end of the testing. These sites were monitored for several months, and then re-examined approximately one year later (June/July 2002), and once more after another year (July 2003).

Observations of cover and survival since initial plantings were made at 5 donor/recipient sites having the following characteristics:

Site 1 Donor and recipient site
Low Energy / Moderate depth (1m, 3ft at dead low)
Within the jetty-protected outer boat basin at the NSU Oceanographic Center
N26.09117, W80.11226

Site 2 Recipient site
High Energy / Moderate depth (1m, 3ft at dead low)
Along the ICW at Port Everglades
N26.09036, W80.11262

Site 3 Recipient site
High Energy / Deep water (2m, 6ft at dead low)
45 feet (5m) west of site 2
N26.09036, W80.11262

Site 4 Recipient site
Low Energy / shallow depth (0.3m, 1ft at low tide)
Across from boat ramp in John U. Lloyd Park
N26.08146, W80.11235

Site 5 Recipient site
Shallow depth (0.3m, 1 ft at dead low)
Hillsboro inlet. On west bank of ICW just N of NE 14th St. bridge
N26.25084, W80.09016

For Johnson's seagrass, planting units (pu, entire plants in this case) consist of one pair of leaves with associated rhizome and roots. These were collected by SCUBA or snorkel and transported in water to the aquaria or the recipient site. Less than 10% of each donor bed was collected. Planting units were placed in 3 replicates of ten each at each recipient site. Because of the spreading and increased densities of some seagrass planting sites which occurred over the one-year period from July 28, 2001 to July 24, 2002, planting sites were sampled for the present study with 25cm x 25cm quadrats.(=625 cm^2 , 0.0625m^2, 1/16 m^2).

A test planting of paddle grass was conducted in November 2002 using aquarium-cultured material but less than 5% of the plantings survived through the winter of 2002/2003, presumably because of low temperatures, low light levels, and siltation from construction. For this test planting, approximately 2,700 plants were removed from tanks at the NSU Oceanographic Center (Fig. 1) which were previously collected in the north dredge area on 10/17/02. Plants were removed from tanks using a hard-tine lawn rake (Fig. 2) which proved more satisfactory than fingers or other methods tested.. The plants were transported in ice chests containing fresh sea water to the Bahia Mar site. Each planting unit consisted of 5 plants (10 leaves) on one rhizome attached with an unfolded large paper clip (Fig. 3). They were planted in marked $1m^2$ quadrats. A total of 1,820 plants (364 planting units) were installed in marked and unmarked quadrats. The remaining unused plants (~25%) were transported back to NSU and replanted in a tank because the planting units were too short or broken up.

Figure 2. Use of rake to harvest plants from NSU tanks.

The most recent (2003 May) planting of paddle grass was at the north section of Bahia Mar Marina. Plants were planted in marked quadrats (Fig. 4), along transects, in three main channels of this marina. A total of 2,160 plants (432 planting units) were installed using the 5-plant pu with large, unfolded paper clip. The unique aspect of this planting was the profusion of seeds (approximately 3 per pu) in each planting unit.

Figure 3. Typical paddle grass planting unit: 5 plants (10 leaves) secured by unfolded (large, ~5cm, 2in) paper clip.

Figure 4. Underwater planting of seagrasses in quadrat along Bahia Mar Marina transect using five plants attached with unfolded, large paper clip.

Methods
Field Studies

The primary field studies on *H. decipiens* and *H. johnsonii* were performed along the Intracoastal Waterway in West Lake Park (Broward County Parks and Recreation Division) in the vicinity of Port Everglades, Hollywood, Florida. The area (see map, Appendix A) is a shelf extending to the edge of the channel. Seven reaches were spatially selected along the shoreline and three transects were run at each reach, beginning from the shoreline and extending into deeper water (approx. 10 ft, 3 m). On each transect, three $1m^2$ quadrats were randomly placed and permanently marked. Within each quadrat 16 sub-quadrats, each measuring 25x25cm, were located, and eight were sampled in detail. Field sampling and lab analysis used separate data sheets. A total of 504 sub-quadrats were sampled monthly, beginning in December of 2001. Braun Blanquet (1985) and other cover measures were the primary plant cover data collected.

Methods
Physical Measures

Monthly water quality parameters collected were temperature, salinity, and light levels. Salinity was measured with an AES® automatic temperature compensating refractometer, calibrated to 0.0 parts per thousand (ppt) salinity with distilled water. Salinity measures were very consistent, between 30-35 ppt, and therefore were not measured throughout the study. Light was measured with a submersible HoBo® light meter and data logger, and later with a GE® portable light meter. Current measures were taken with a General Oceanics® current meter.

Results
Aquarium Culture

Results of the *H. johnsonii* aquarium studies are given in Table 1, and raw data are summarized in Table 1.1, Appendix B. As shown, plants decreased in number in the winter but began increasing as the temperature increased. Overall survival was about 100%, but survival and increase in low density culture (mean 31/tank or $84/m^2$) was 155%. An examination of aquaria with poor survival showed "contamination" by invertebrates (crustaceans and annelids) and these were believed to be the main source of mortality (confirmed with later paddle grass studies).

Beginning in mid-July 2002, and seen in previous years, a dense growth of blue green algae covers small seagrass species and any hard substrates in area waters. This also occurs in the aquaria. Based on the high densities of seagrass in tanks covered by this algae, it apparently has not affected seagrass growth thus far in the aquaria and it is not known whether effects occur in the field. General observations are that this cover of algae is not present in winter, spring, or early summer months.

Table 1. *H. johnsonii* aquarium culture study results; planting date 2/15/02.	
Low Density (<40/tank or <108/m^2)	
Date	**Mean % Survival**
2/15/02	100
3/21/02	76
7/24/02	155
Medium Density (40-49/tank or 108-132/m^2)	
2/15/02	100
3/21/02	59
7/24/02	98
High Density (>50/tank or 135/m^2)	
2/15/02	100
3/21/02	43
7/24/02	70
Mean survival = 99%	

Results of paddle grass aquarium cultivation are given in Table 2 and raw data are summarized in Table 2.1, Appendix B. As shown, plants experienced a reduction in the winter of 2002/2003, but recovery began taking place rapidly by the spring. Counts do not include 2 large tanks which totaled over 700 total plants at the 5/21/03 count.

Table 2. *H. decipiens* aquarium results (% survival) for n=60 aquaria, by sample dates, beginning with the planting date.						
Date	10/01/02	12/17/02	1/20/03	3/20/03	4/28/03	5/21/03
Total Number	3,600	2,132	1,704	999	2,039	3,615
Number/aquarium	60	36	28	17	34	60

Results
Transplant Studies

Results of the test plantings were positive for the use of strands and staples at both Sites 1 and 2. The best results were with strands (Table 3), so these were used throughout the *H. johnsonii* plantings. It was first noted in this study how quickly plants spread once they became established. This was also noticed in the aquarium studies after winter ended.

For the main plantings, counts of *H. johnsonii* planting units, by site, at the beginning of the study (fall 2001) and 1 year later, are given Table 4. Over the year, total seagrass numbers increased 369%, from 450 plants installed to 1,659 remaining and recruited. However, Site 2 never grew seagrasses since the first planting, and seagrasses died off at Sites 1 and 3. Field observations showed that Site 1 experienced heavy sedimentation over the winter of 2001/2002 and sediment at Sites 2 and 3 had completely washed away, leaving rock and gravel substrates. Sites 4 and 5 did very well, having spread to adjacent areas. Although the third replicate of a planting location at Site 4 had no surviving plants, a fourth replicate taken at another planted location of

Site 4 planting site had a count of 496/m^2. The most recent (July 30, 2003) field surveys of Sites 4 and 5 should good growth, especially at the Hillsboro inlet site. In this preliminary study, replicate, random quadrat measures of the planting area at this site showed the following numbers per square meter: 85, 127, 212, and 420.

Table 3. Test planting results for two sites.

Dates	**Site - depth**	**# Strands**	**# Plugs**	**# Staples**
7/27/2001	1 -moderate	30	30	30
8/4/2001	1 -moderate	30	30	30
8/18/2001	1 -moderate	23	17	22
8/21/2001	1 -moderate	19	12	22
9/23/2001	1 -moderate	191	148	0
7/27/2001	3 - deep	30	30	30
8/4/2001	3 - deep	25	14	30
8/19/2001	3 - deep	22	6	29
8/21/2001	3 - deep	22	4	29
9/23/2001	3 - deep	207	56	196
Totals		**599**	**347**	**418**

Table 4. Results of *H. johnsonii* plantings over the one year study (#/m^2).

Site #	**Days after planting**	**Replicate 1**	**Replicate 2**	**Replicate 3**	**Totals**
1	0	30	30	30	90
1	361	0	0	0	0
2	0	30	30	30	90
2	361	0	0	0	0
3	0	30	30	30	90
3	361	0	0	0	0
4	0	30	30	30	90
4	361	112	203	0	315
5	0	30	30	30	90
5	361	288	656	400	1,344
	Totals	**400**	**859**	**400**	**1,659**

The main donor site near Site 1 was also censused and counts per m^2 are given in Table 5. As shown, the donor site was in good condition, averaging over 1,000 plants (pairs of leaves) per square meter.

Table 5. Census of *H. johnsonii* donor site population (#/m^2) one year after plant removal.

Replicate 1	Replicate 2	Replicate 3	Replicate 4
672	1,792	1,440	928
Mean = 1,208, SD = 504			

Field observations were also made of paddle grass plantings at the marina on July 21, 2003, and one of the three main channels showed survival in quadrats and spreading outside of quadrats, presumably by seeds. However, this was a preliminary study made about two months after planting, and further, quantitative studies are necessary.

Results

Field Studies

Seven months of data were analyzed (2001 December - 2002 July), including some from the coldest periods for south Florida. A summary of B-B (Braun-Blanquet) data is given in Table 6 and raw data are presented in Table 6.1, Appendix B. Transects sometimes contained other species of seagrass besides *H. johnsonii*: *H. decipiens* (predominant) and *Halodule wrightii* (rare in the transects). Therefore B-B collection data are shown with *H. decipiens* and rare *H. wrightii* lumped together versus *H. johnsonii* alone. As shown in the B-B key, mean cover for *H. decipiens* showed numerous shoots but with <5% cover (possibly a common occurrence in small seagrass species). In contrast, *H. johnsonii* plots generally had a few shoots with very little cover (0.4-0.7).

Table 6. Seagrass field study results - plant abundance B-B* measures.

Seagrass	***H. decipiens* (with rare *Halodule wrightii*)**				
Date	6-7/2002	12/2001	1/2002	2/2002	4-5/2002
Mean B-B	1.2	1.1	1.2	1.6	1.4
SD	0.7	0.6	0.8	0.7	0.8
Seagrass	***H. johnsonii* only**				
Date	6-7/2002	12/2001	1/2002	2/2002	4-5/2002
Mean B-B	0.4	0.4	0.5	0.7	0.6
SD	0.6	0.5	0.8	0.8	0.7

***Key to B-B measures: 0.1 = solitary shoot with small cover, 0.5 = few shoots with small cover, 1.0 = numerous shoots but less than 5% cover, 2.0 = any number of shoots but with 5-25% cover.**

Further comparisons were made, between *H. johnsonii* and *H. decipiens*, using number of sub-quadrats containing each species (8 sub-quadrats per quadrat x 3 quadrats per transect = 24 maximum per transect). As shown in Table 7, and in raw data given in Table 7.1, Appendix B, approximately 15% of the sub-quadrats contained *H. johnsonii* in summer and 31% contained *H. decipiens* in summer. In contrast to casual field observations, no trends were evident in seagrass occurrence relative to depths (refer to Appendix B, T 1 being the shallowest and T 3 being the deepest). Abundance of these species over the winter season is further illustrated in Figures 5-6 which show the winter reductions and the spring increases.

Table 7. Seasonal occurrence (# sub-quadrats with *Halophila* seagrasses).					
Seagrass	***H. decipiens***				
Date	12/2001	1/2002	2/2002	4-5/2002	6-7/2002
Mean	9.1	7.2	5.2	7.6	7.5
SD	5.7	5.6	4.1	5.4	5.6
Seagrass	***H. johnsonii***				
Date	12/2001	1/2002	2/2002	4-5/2002	6-7/2002
Mean	2.8	1.8	1.8	3.4	3.1
SD	4.4	2.7	3.4	4.1	3.7

Figure 5. Braun-Blanchet Abundances

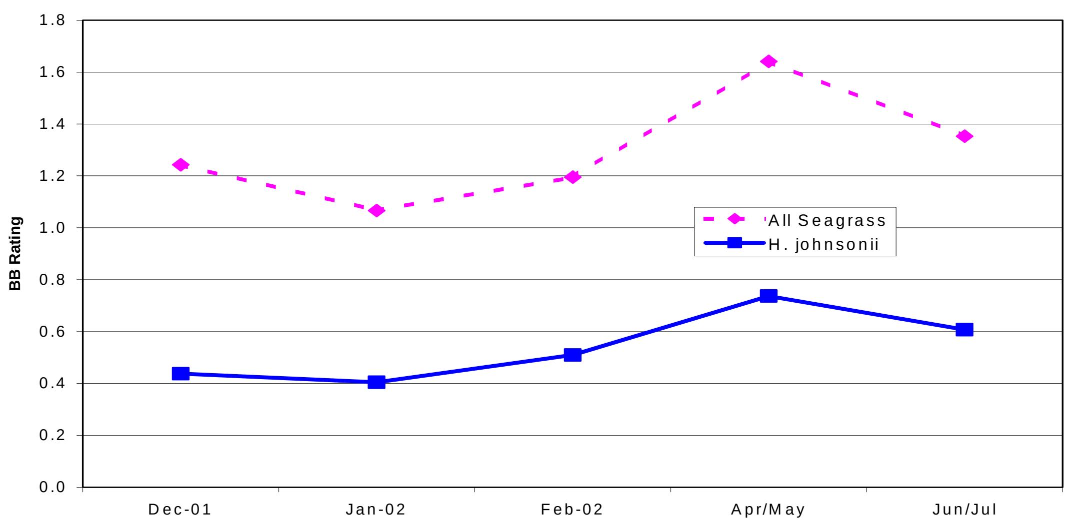
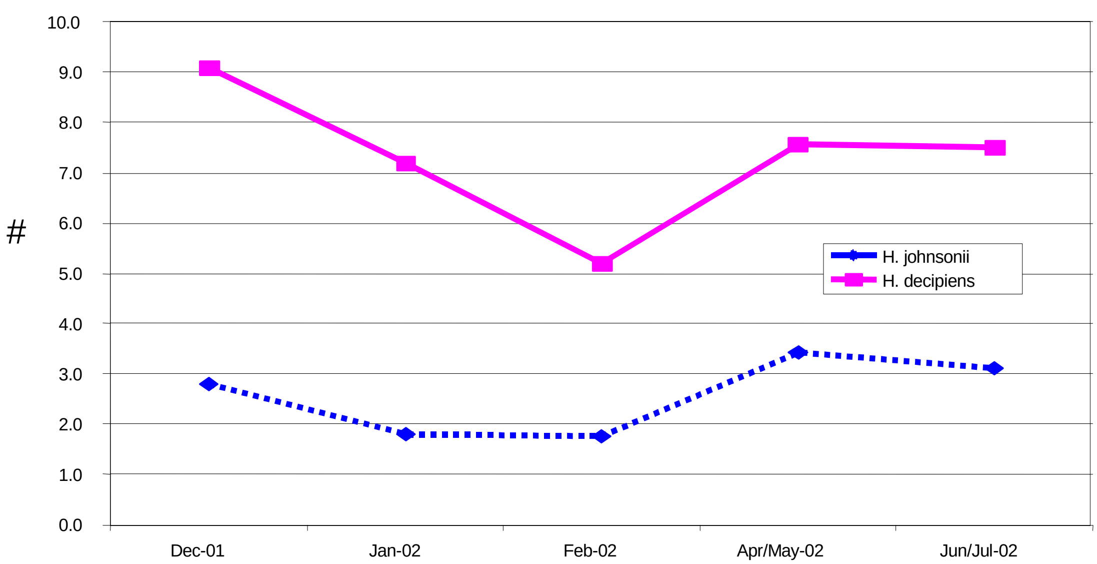


Figure 6. Occurrence of Halophilas in Quadrats.



Results

Physical Measures

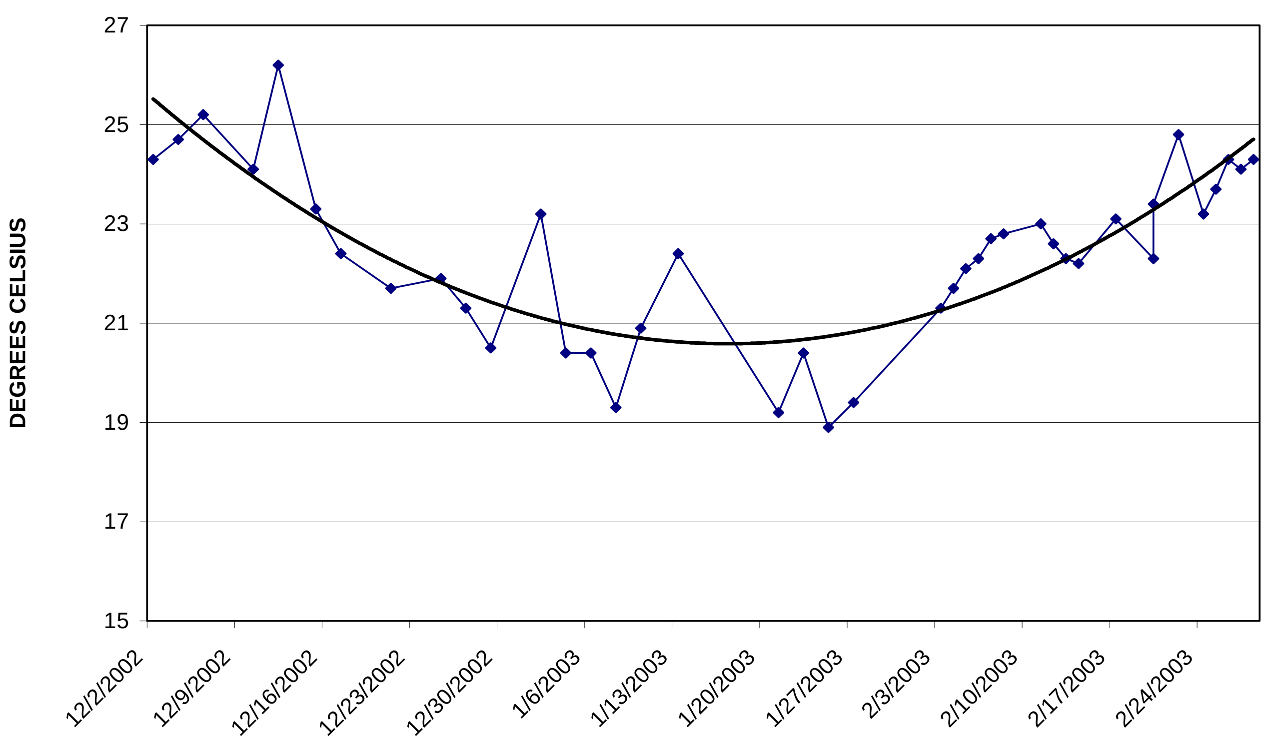
Temperature

Routine temperature monitoring was conducted throughout the study, with detailed measures taken during certain periods (especially in winter). The first series iwas based on water temperatures (winter 2001/2002) from a NOAA buoy in the vicinity (NOAA 2002), summarized in Table 8, with graphs in Appendix C. This provided an indication of water temperatures which would affect the growth of transplants.

Table 8. Low temperatures in area waters during winter 2001/2002.	
Date	**Lowest Temperature ^{o}Fahrenheit**
December 2001	46.9 (12/27/01)
January 2002	39.2 (1/4/02)
February 2002	44.6 (2/28/02)

Detailed temperature data were also collected during the period December 1, 2002 through March 21, 2003. Temperatures measured in the source water (i.e., water which is pumped directly from Port Everglades and goes through a sand filter system before entering the aquaria) were the lowest during this period, followed by a rapid rise as March began. As shown in Figure 7 (with trend line) and raw data in Table 8.1, Appendix B, coldest temperatures were from early January to mid-February.

Figure 7. Winter Input Water Temperatures



Results

Physical Measures

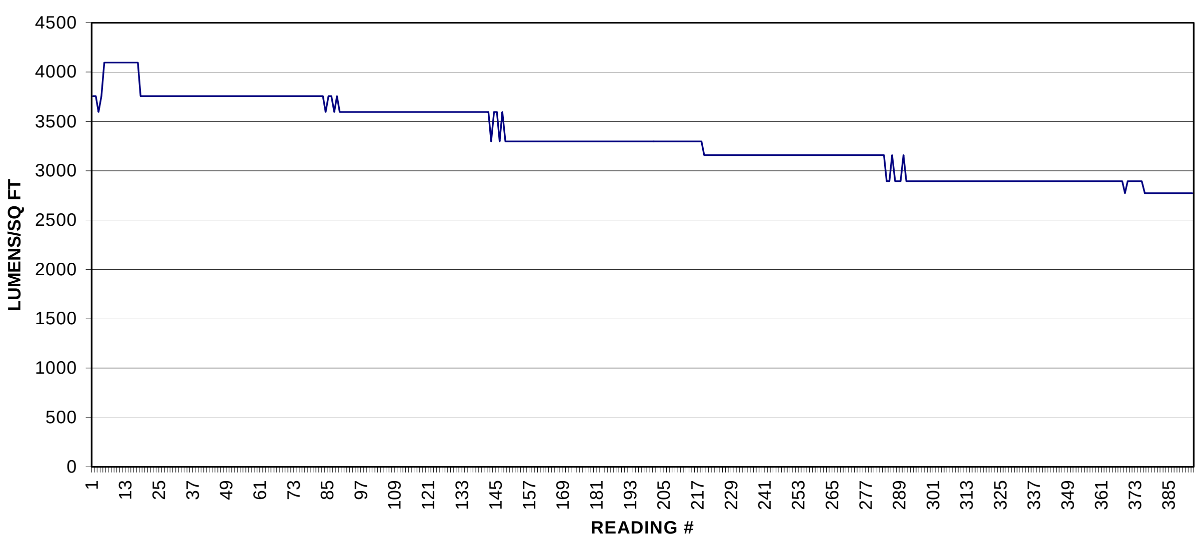
Light Readings

Latest (2003) mean light readings are summarized in Table 9 and detailed in Table 9.1, Appendix B. Light readings showed that shaded aquaria have much lower levels than ambient light throughout the study. Shade cloth was reduced to one layer in late January and then the additional layer was replaced in late February when algal epiphytes began to take over aquaria. January and February readings are means of over 400 readings taken at each layer. An example of a series of readings is shown in Figure 8. As shown, readings are highly variable, even over a 3 minute period. The March readings used a GE® United Detector 350 Power Meter, which gives results in foot-candles, because the HoBo® meter and data-logger used in January and February was unavailable. The GE light meter did not have a submersible probe so underwater measures over the basin seagrass bed could not be taken in March.

Table 9. Winter Light Readings (Lumens/sq ft).

Aquarium Numbers	Aquarium Location	January Means	February Means±SD	March Means±SD	April Means±SD
1-15	Upper east	20	95±60	233±204	410±26
16-30	Upper west	25	96±61	141±29	2920±298
31-45	Lower east	<2	23±26	83±67	7.±3
46-60	Lower west	<4	8±12	96±10	184±9
Basin		43	85±66	Not taken	Not taken
Open sky		3307±375	2036±365	1805±519	3475±1295

Figure 8. Ambient Light Readings:
Three min run of ~400 readings on 1/15/03
Mean±SD 3307±375



Results

Physical Measures

<u>Current Readings</u>

Current measures in the vicinity of the natural seagrass beds and planted sites were highly variable and not necessarily predictable by tidal flow. Readings over healthy beds and at successful planting sites ranged between 10cm/sec-7.9m/sec (0.2-15 knots).

Discussion and Conclusions

The results of these studies were positive for the concept of holding pre-dredge halophiline seagrasses in aquaria or tanks for transplantation later. However, besides further testing, a number of modifications and guidelines for aquarium culture should be implemented, as follows:

1. Avoid collection and planting during the colder months (December - February)
2. Use shade cloth simulating underwater light levels
3. Use filtered seawater water and constant flow-through systems
4. Use heat-sterilized sand as a substrate
5. Use a heated head tank for flushing to warm aquaria during coldest months
6. Aquaria require constant maintenance as described herein

Transplantation looks promising, with good results obtained for *H. johnsonii* and *H. decipiens*, when proper substrates and conditions are used. A few lessons learned about transplanting include:

1. Use of large clips, and sometimes multiple clips, to hold seagrasses in the substrate
2. Use of multiple plants (at least five) in each planting unit
3. Avoidance of areas with high siltation levels

Although these studies were not long term, a number of accomplishments were made which add to the potential for cultivating these plants. Further planting, testing and long-term monitoring should help to increase success and should advance the feasibility of using these small and rare seagrasses in restoration and mitigation.

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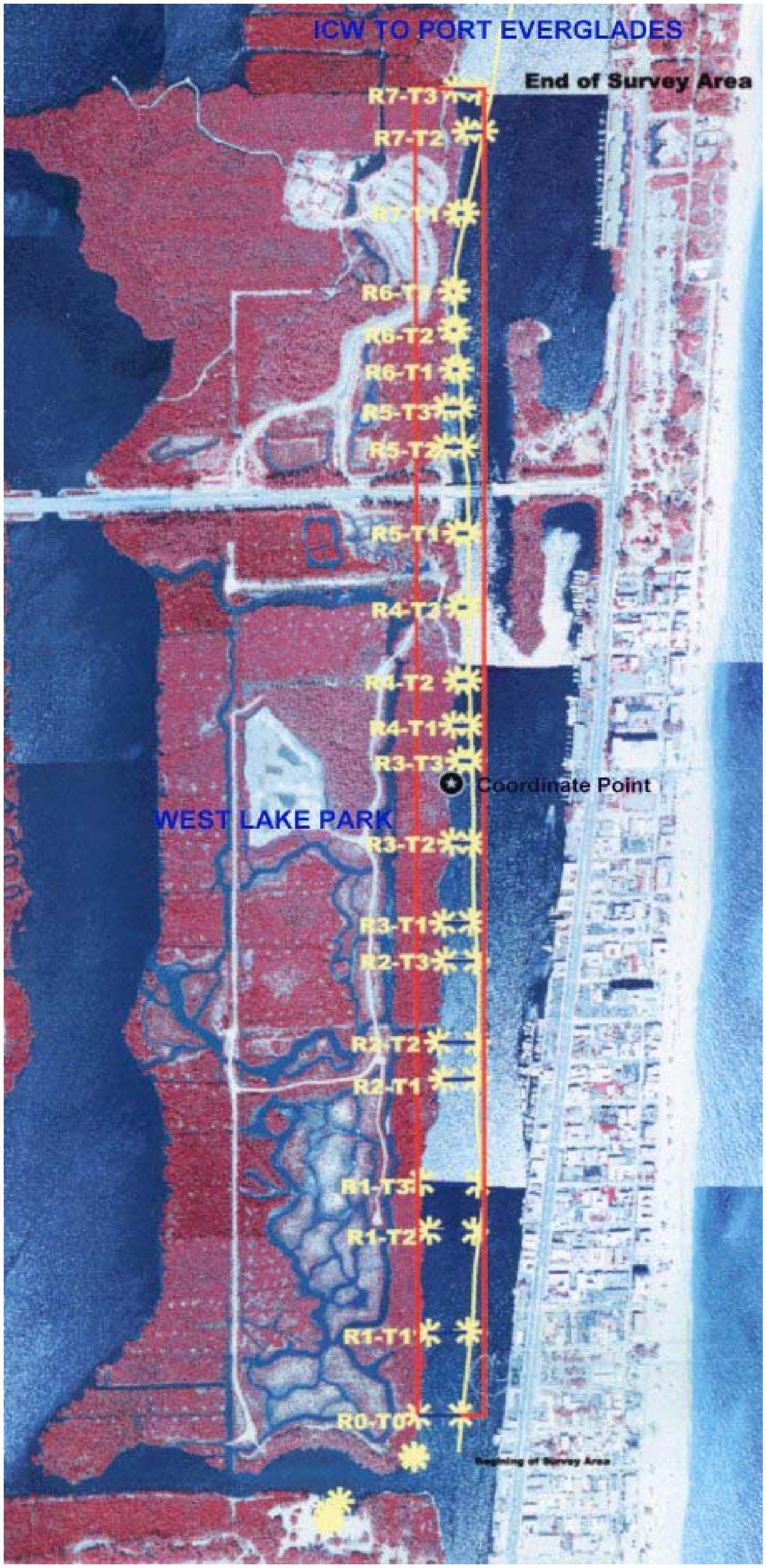
APPENDIX A. Map of field study sites in Ft. Lauderdale.


ICW TO PORT EVERGLADES
End of Survey Area
R7-T3
R7-T2
R7-T1
R6-T3
R6-T2
R6-T1
R5-T3
R5-T2
R5-T1
R4-T3
R4-T2
R4-T1
R3-T3
Coordinate Point
WEST LAKE PARK
R3-T2
R3-T1
R2-T3
R2-T2
R2-T1
R1-T3
R1-T2
R1-T1
R0-T0

APPENDIX B. Tables with Raw Data and Data Summaries

Table 1.1 H. johnsonii aquarium culture study results.										
Aquaria 4 sq ft, 30 gal (0.37 sq m, 114 L)										
Date planted 2/15/02			Date counted 3/21/02				Date counted 7/24/02			
Tank #	# Planted	Mean #	# Survived	% Survival	Loss/ gain	Mean % Survival	# Survived	% Survival	Loss/ gain	Mean % Survival
LOW DENSITY (<40)		31				75.6				154.6
19	22		17	77.3	-5		80	363.6	58	
20	26		41	157.7	15		0	0.0	-26	
18	27		16	59.3	-11		33	122.2	6	
14	32		17	53.1	-15		21	65.6	-11	
16	34		14	41.2	-20		55	161.8	21	
4	37		14	37.8	-23		55	148.6	18	
30	39		40	102.6	1		86	220.5	47	
MEDIUM DENSITY (40-49)		44				58.8				89.1
17	40		13	32.5	-27		33	82.5	-7	
29	40		31	77.5	-9		69	172.5	29	
2	44		19	43.2	-25		0	0.0	-44	
5	44		41	93.2	-3		13	29.5	-31	
11	44		31	70.5	-13		36	81.8	-8	
27	44		24	54.5	-20		0	0.0	-44	
15	46		37	80.4	-9		71	154.3	25	
10	48		25	52.1	-23		61	127.1	13	
28	48		12	25.0	-36		74	154.2	26	
HIGH DENSITY (50+)		58				43.3				70.1
6	50		21	42.0	-29		40	80.0	-10	
8	50		47	94.0	-3		39	78.0	-11	
21	50		9	18.0	-41		26	52.0	-24	
23	50		15	30.0	-35		59	118.0	9	
26	50		21	42.0	-29		84	168.0	34	
7	52		14	26.9	-38		59	113.5	7	
3	53		28	52.8	-25		0	0.0	-53	
9	62		39	62.9	-23		0	0.0	-62	
25	81		19	23.5	-62		56	69.1	-25	
22	83		34	41.0	-49		19	22.9	-64	
Totals	1196		639		-557		1069		-127	
Means	46.0		24.6	57.3	-21.4		41.1	99.5	-4.9	99.5

Figure 2.1. Paddle Grass Aquarium Growth and Survival Results.

AQUARIA	DATES 10/1/2002	12/17/2002	% SURV	1/20/2003	% SURV	3/20/2003	% SURV	4/28/2003	% SURV	5/21/2003	% SURV	Results vs Stocking
27	60	84	140	152	253	136	227	190	317	280	467	increase
22	60	93	155	8	13	0	0	55	92	260	433	increase
25	60	35	58	40	67	0	0	81	135	245	408	increase
48	60	55	92	35	58	47	78	113	188	235	392	increase
26	60	11	18	4	7	0	0	75	125	218	363	increase
21	60	90	150	33	55	6	10	74	123	210	350	increase
28	60	54	90	12	20	36	60	143	238	170	283	increase
18	60	45	75	27	45	0	0	62	103	160	267	increase
34	60	26	43	11	18	0	0	43	72	142	237	increase
15	60	17	28	5	8	15	25	86	143	119	198	increase
17	60	79	132	11	18	22	37	41	68	110	183	increase
47	60	38	63	26	43	11	18	42	70	108	180	increase
49	60	23	38	7	12	2	3	59	98	105	175	increase
56	60	57	95	48	80	0	0	57	95	87	145	increase
1	60	46	77	79	132	130	217	82	137	76	127	increase
59	60	18	30	15	25	6	10	56	93	72	120	increase
44	60	17	28	10	17	6	10	43	72	64	107	increase
24	60	10	17	0	0	3	5	0	0	63	105	increase
4	60	143	238	176	293	73	122	102	170	62	103	increase
16	60	41	68	38	63	15	25	58	97	59	98	decrease
5	60	24	40	6	10	2	3	42	70	53	88	decrease
55	60	39	65	48	80	7	12	28	47	53	88	decrease
36	60	8	13	0	0	12	20	0	0	53	88	decrease
32	60	2	3	1	2	10	17	0	0	52	87	decrease
11	60	18	30	28	47	12	20	14	23	51	85	decrease
9	60	76	127	49	82	0	0	45	75	47	78	decrease
53	60	24	40	12	20	28	47	18	30	47	78	decrease
42	60	27	45	33	55	11	18	38	63	39	65	decrease
50	60	6	10	5	8	4	7	0	0	39	65	decrease
35	60	39	65	2	3	12	20	0	0	38	63	decrease
39	60	17	28	24	40	9	15	47	78	36	60	decrease
13	60	20	33	0	0	20	33	41	68	36	60	decrease
33	60	8	13	2	3	8	13	0	0	30	50	decrease
23	60	22	37	41	68	32	53	48	80	25	42	decrease
19	60	33	55	3	5	21	35	19	32	24	40	decrease
31	60	10	17	3	5	10	17	0	0	23	38	decrease

2	60	63	105	98	163	4	7	20	33	20	33 decrease
30	60	27	45	20	33	6	10	17	28	18	30 decrease
45	60	19	32	8	13	4	7	8	13	15	25 decrease
10	60	0	0	0	0	0	0	0	0	15	25 decrease
41	60	36	60	54	90	21	35	5	8	9	15 decrease
57	60	20	33	9	15	15	25	0	0	9	15 decrease
29	60	34	57	16	27	9	15	18	30	8	13 decrease
7	60	15	25	0	0	24	40	5	8	8	13 decrease
20	60	18	30	4	7	8	13	8	13	6	10 decrease
38	60	23	38	18	30	12	20	6	10	4	7 decrease
43	60	47	78	49	82	13	22	2	3	3	5 decrease
3	60	100	167	151	252	18	30	0	0	3	5 decrease
51	60	36	60	4	7	30	50	0	0	3	5 decrease
8	60	84	140	89	148	4	7	67	112	2	3 increase
60	60	19	32	33	55	35	58	52	87	1	2 decrease
14	60	40	67	23	38	15	25	15	25	0	0 decrease
40	60	43	72	57	95	29	48	6	10	0	0 decrease
37	60	58	97	47	78	16	27	3	5	0	0 decrease
58	60	29	48	23	38	4	7	3	5	0	0 decrease
46	60	28	47	2	3	23	38	2	3	0	0 decrease
6	60	0	0	0	0	0	0	0	0	0	0 decrease
12	60	9	15	0	0	0	0	0	0	0	0 decrease
52	60	3	5	0	0	3	5	0	0	0	0 decrease
54	60	26	43	5	8	0	0	0	0	0	0 decrease
TOTALS	3600	2132		1704		999		2039		3615	19 increase
MEAN/AQ	60	35.5		28.4		17		34		60	
% SURV	100		59.2		47.3		28		57		100

Table 6.1. Seagrass field study results - plant abundance B-B measures.										
H. DECIPIENS ETC.						H. JOHNSONII ONLY				
SITE	Dec-01	Jan-02	Feb-02	Apr/ May	Jun/ Jul	Dec-01	Jan-02	Feb-02	Apr/ May	Jun/ Jul
R1T1	1.3	1.8	1.9	1.7	2.0	0.8	0.0	0.0	0.0	0.0
T2	1.9	1.0	2.0	1.8	2.0	0.0	1.0	2.0	0.8	2.0
T3	1.0	1.5	3.2	2.0	1.7	0.7	1.0	0.0	0.0	0.0
R2T1	1.4	1.2	2.1	2.4	nm	0.0	0.0	0.0	0.0	nm
T2	0.8	0.7	1.6	2.3	nm	0.4	2.0	1.5	2.0	nm
T3	0.7	0.8	1.4	2.0	nm	0.5	0.8	2.0	2.1	nm
R3T1	0.5	1.0	0.1	1.7	1.5	0.0	0.0	0.0	0.0	0.0

T2	0.9	1.1	1.4	0.9	0.9	0.0	0.1	0.0	0.7	0.7
T3	1.9	1.1	1.2	2.6	1.1	0.0	0.3	0.0	0.0	0.6
R4T1	2.5	1.7	1.3	0.9	1.3	0.5	0.4	1.2	0.9	1.0
T2	1.3	1.3	1.4	1.6	1.1	0.0	0.0	0.0	0.0	0.0
T3	1.9	2.0	1.7	2.2	3.1	0.6	0.3	0.5	1.3	1.6
R5T1	2.6	1.8	1.2	1.0	2.0	1.0	0.6	0.0	0.0	0.0
T2	1.3	0.8	0.5	2.1	1.4	1.8	0.7	0.6	1.3	0.8
T3	1.0	1.0	1.6	2.8	2.3	0.1	0.8	2.0	2.4	2.2
R6T1	1.6	0.0	0.0	1.7	1.4	0.0	0.0	0.0	0.0	0.0
T2	1.2	1.1	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0
T3	1.6	1.6	1.5	1.3	0.9	1.6	0.5	0.4	1.0	0.8
R7T1	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	1.4	0.0
T2	0.7	0.9	1.0	1.3	1.1	0.0	0.0	0.5	0.7	0.7
T3	0.0	0.0	0.0	1.0	0.6	0.0	0.0	0.0	1.0	0.6
MEAN	1.2	1.1	1.2	1.6	1.4	0.4	0.4	0.5	0.7	0.6
SD	0.7	0.6	0.8	0.7	0.8	0.6	0.5	0.8	0.8	0.7
T-TEST	0.0002		*nm = no measures taken							

Table 7.1. Seasonal occurrence (# sub quadrats with Halophila seagrasses).

SITE	Dec-01	Jan-02	Feb-02	Apr/May	Jun/Jul	MEANS	% in Quads
H. JOHNSONII							
R1T1	2	0	0	0	0	0.4	1.7
T2	0	2	4	4	4	2.8	11.7
T3	6	3	0	0	0	1.8	7.5
R2T1	0	0	0	0	nm	0.0	0.0
T2	10	1	5	7	nm	5.8	24.0
T3	3	11	14	16	nm	11.0	45.8
R3T1	0	0	0	0	0	0.0	0.0
T2	0	2	0	5	5	2.4	10.0
T3	0	2	0	0	2	0.8	3.3
R4T1	1	7	7	6	1	4.4	18.3
T2	0	0	0	0	0	0.0	0.0
T3	6	2	1	8	9	5.2	21.7
R5T1	2	2	0	0	0	0.8	3.3
T2	4	3	3	5	11	5.2	21.7
T3	1	2	1	8	8	4.0	16.7
R6T1	0	0	0	0	0	0.0	0.0
T2	17	0	0	0	0	3.4	14.2
T3	7	1	1	2	4	3.0	12.5
R7T1	0	0	0	4	0	0.8	3.3
T2	0	0	1	5	5	2.2	9.2
T3	0	0	0	2	7	1.8	7.5
MEANS	2.8	1.8	1.8	3.4	3.1	2.7	11.1
SD	4.4	2.7	3.4	4.1	3.7	2.7	11.1
H. DECIPIENS							
R1T1	7	6	6	7	8	6.8	28.3

T2	10	8	3	9	6	7.2	30.0
T3	11	18	8	15	8	12.0	50.0
R2T1	13	12	10	10	nm	11.3	46.9
T2	10	7	11	12	nm	10.0	41.7
T3	15	5	3	1	nm	6.0	25.0
R3T1	4	1	1	7	8	4.2	17.5
T2	8	6	7	4	3	5.6	23.3
T3	8	7	4	11	9	7.8	32.5
R4T1	15	12	11	0	10	9.6	40.0
T2	18	16	4	14	20	14.4	60.0
T3	15	15	8	15	11	12.8	53.3
R5T1	9	14	13	3	1	8.0	33.3
T2	6	7	2	12	13	8.0	33.3
T3	13	5	6	8	9	8.2	34.2
R6T1	14	0	0	15	17	9.2	38.3
T2	0	4	0	0	0	0.8	3.3
T3	0	8	9	8	5	6.0	25.0
R7T1	0	0	0	0	0	0.0	0.0
T2	15	0	3	8	7	6.6	27.5
T3	0	0	0	0	0	0.0	0.0
Means	9.1	7.2	5.2	7.6	7.5	7.4	30.6
SD	5.7	5.6	4.1	5.4	5.6	3.9	16.2

Table 8.1. Temperature Recordings of Port Everglades Source Water.

Dec Date	Temp (Celsius)	Jan Date	Temp (Celsius)	Feb Date	Temp (Celsius)	Mar Date	Temp (Celsius)
2	24.3	2	23.2	3	21.3	2	24.9
4	24.7	4	20.4	4	21.7	4	25.7
6	25.2	6	20.4	5	22.1	5	27.7
10	24.1	8	19.3	6	22.3	6	26.4
12	26.2	10	20.9	7	22.7	8	26.7
15	23.3	13	22.4	8	22.8	10	26.3
17	22.4	21	19.2	10	22.3	12	27
21	21.7	23	20.4	11	23	13	26.8
25	21.9	25	18.9	12	22.6	14	26.2
27	21.3	27	19.4	13	22.3	17	25.1
29	20.5			14	22.2	19	25.2
				17	23.1	22	26.3
				20	23.4		
				22	24.8		
				24	23.2		
				25	23.7		
				26	24.3		
				27	24.1		
				28	24.3		
Mean 23.2		Mean 20.5		Mean 23.0		Mean 26.2	

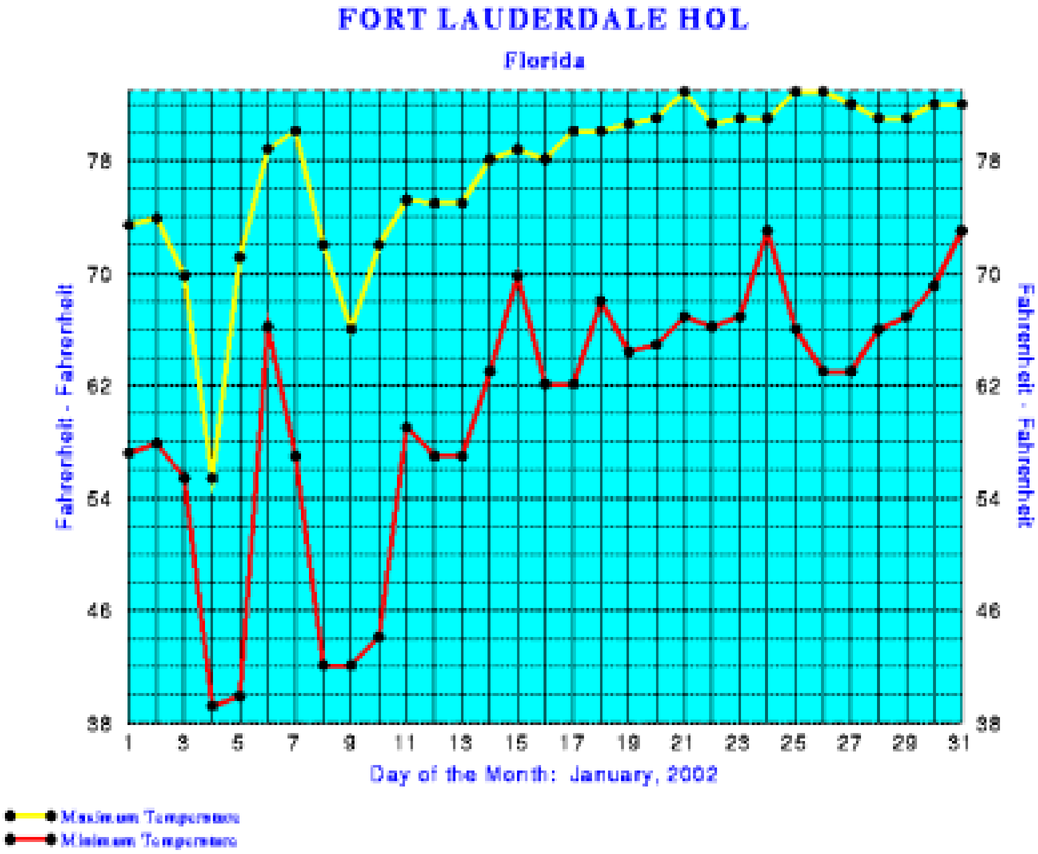
Table 9.1. Winter Light Readings (Lumens/sq ft).

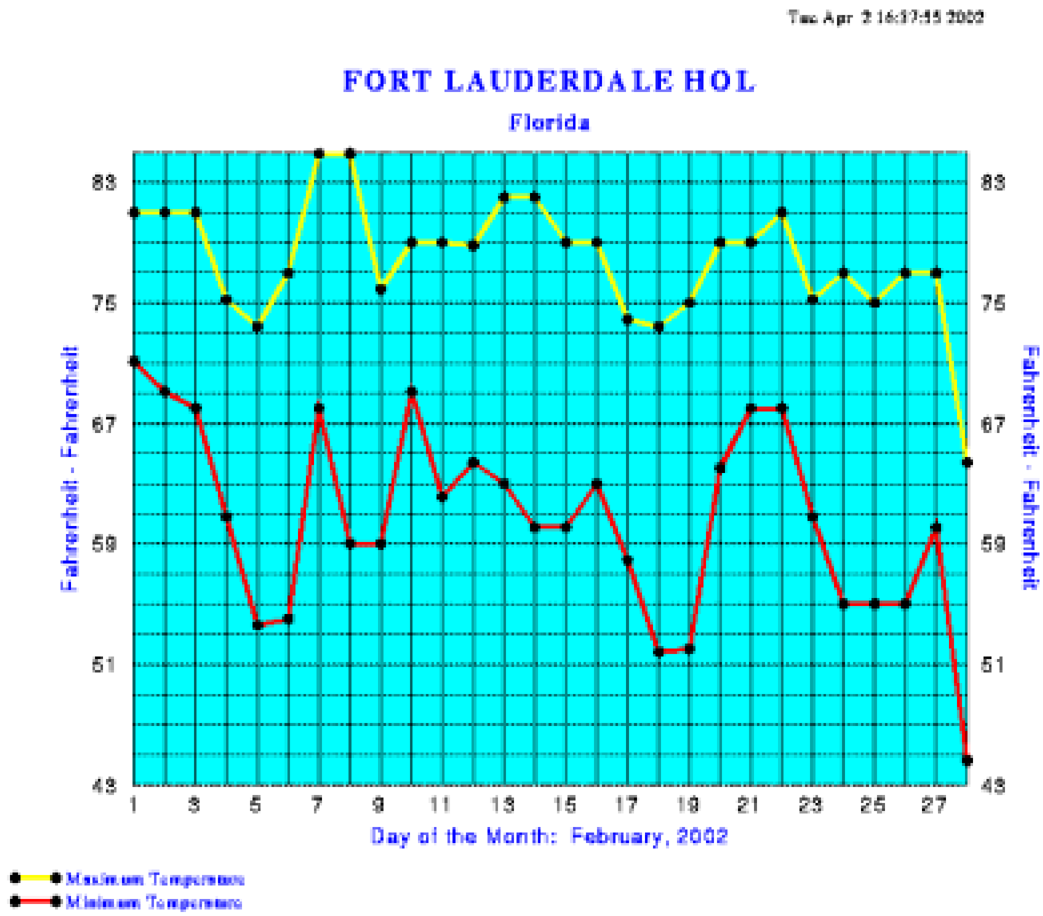
Aquarium #	Location	January	February	March
1	Upper east	20	95±60	233±204
2	Upper east	20	95±60	233±204
3	Upper east	20	95±60	233±204
4	Upper east	20	95±60	233±204
5	Upper east	20	95±60	233±204
6	Upper east	20	95±60	233±204
7	Upper east	20	95±60	233±204
8	Upper east	20	95±60	233±204
9	Upper east	20	95±60	233±204
10	Upper east	20	95±60	233±204
11	Upper east	20	95±60	233±204
12	Upper east	20	95±60	233±204
13	Upper east	20	95±60	233±204
14	Upper east	20	95±60	233±204
15	Upper east	20	95±60	233±204
16	Upper west	25	96±61	141±29
17	Upper west	25	96±61	141±29
18	Upper west	25	96±61	141±29
19	Upper west	25	96±61	141±29
20	Upper west	25	96±61	141±29
21	Upper west	25	96±61	141±29
22	Upper west	25	96±61	141±29
23	Upper west	25	96±61	141±29
24	Upper west	25	96±61	141±29
25	Upper west	25	96±61	141±29
26	Upper west	25	96±61	141±29
27	Upper west	25	96±61	141±29
28	Upper west	25	96±61	141±29
29	Upper west	25	96±61	141±29
30	Upper west	25	96±61	141±29
31	Lower east	<2	23±26	83±67
32	Lower east	<2	23±26	83±67
33	Lower east	<2	23±26	83±67
34	Lower east	<2	23±26	83±67
35	Lower east	<2	23±26	83±67
36	Lower east	<2	23±26	83±67
37	Lower east	<2	23±26	83±67
38	Lower east	<2	23±26	83±67
39	Lower east	<2	23±26	83±67
40	Lower east	<2	23±26	83±67

41	Lower east	<2	23±26	83±67
42	Lower east	<2	23±26	83±67
43	Lower east	<2	23±26	83±67
44	Lower east	<2	23±26	83±67
45	Lower east	<2	23±26	83±67
46	Lower west	<4	8±12	96±10
47	Lower west	<4	8±12	96±10
48	Lower west	<4	8±12	96±10
49	Lower west	<4	8±12	96±10
50	Lower west	<4	8±12	96±10
51	Lower west	<4	8±12	96±10
52	Lower west	<4	8±12	96±10
53	Lower west	<4	8±12	96±10
54	Lower west	<4	8±12	96±10
55	Lower west	<4	8±12	96±10
56	Lower west	<4	8±12	96±10
57	Lower west	<4	8±12	96±10
58	Lower west	<4	8±12	96±10
59	Lower west	<4	8±12	96±10
60	Lower west	<4	8±12	96±10
Basin		43	85±66	Not taken
Open sky		3307±375	2036±365	1805±519

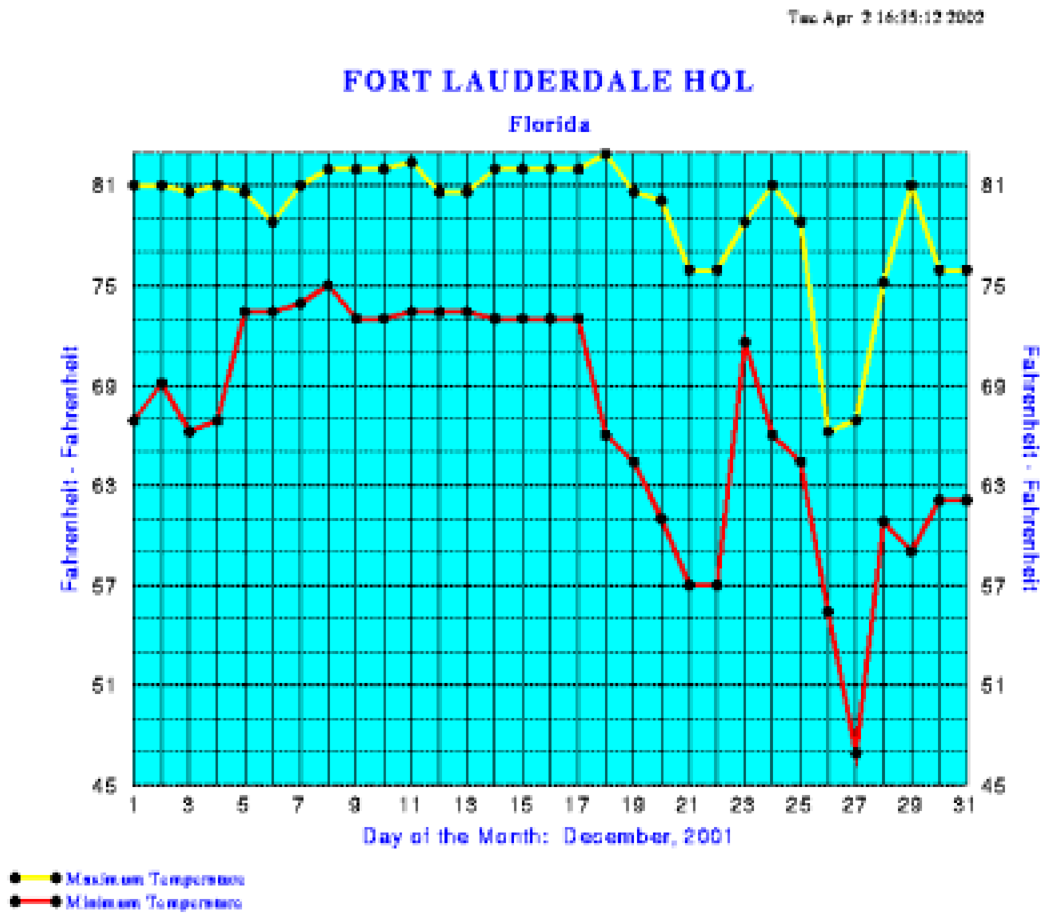
APPENDIX C. WINTER WATER TEMPERATURES

Tue Apr 2 16:57:21 2002





FORT LAUDERDALE HOL
Florida
83
75
67
59
51
43
Fahrenheit - Fahrenheit
1
3
5
7
9
11
13
15
17
19
21
23
25
27
Day of the Month: February, 2002
Maximum Temperature
Minimum Temperature



Tue Apr 2 16:35:12 2002
FORT LAUDERDALE HOL
Florida
Fahrenheit - Fahrenheit
Day of the Month: December, 2001
Maximum Temperature
Minimum Temperature