

Summary Report for the Northern Indian River Lagoon

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cover appears to be related to increased shading by prolonged phytoplankton blooms that also led to loss of acreage.

Geographic extent

Located within the St. Johns River Water Management District, the NIRL system includes Mosquito Lagoon, Banana River Lagoon, and the northern portion of the Indian River Lagoon proper. The system extends 110 miles (177 km) from Ponce de Leon Inlet in northern Mosquito Lagoon to the southern boundary of Indian River County, and it is separated from the Atlantic Ocean by barrier islands (Figure 1). Excluding the Intracoastal Waterway, the average depth is less than 2 m. For management purposes, the NIRL is divided into 4 sublagoons and 18 segments based on similarities in water quality and hydrodynamics (Figure 1). Work in the NIRL is coordinated with work in the Southern Indian River Lagoon (SIRL) conducted by the South Florida Water Management District.

Mosquito Lagoon is the northernmost sublagoon. It connects to the Atlantic Ocean through Ponce de Leon Inlet and to the Indian River Lagoon via Haulover Canal (in ML3–4). Residential/urban land use decreases from 40% in the north (ML1 and ML2) to 3% in the south (ML3–4), with much of the southern portion in state or federal parks. Seagrasses include *Halodule wrightii*, *Syringodium filiforme*, *Ruppia maritima*, and *Halophila engelmannii* in decreasing order of occurrence.

General assessment

Seagrasses in the Northern Indian River Lagoon (NIRL) exhibit resilience when water clarity permits. Unfortunately, the cumulative effect of conditions from 2009 to early 2017 led to the loss of 39,634 acres of seagrass or 56% of the acreage mapped in 2009. Based on maps derived from digital aerial photographs, acreage in the NIRL declined between 2009 and 2011, increased by approximately 12% in both 2013 and 2015, and decreased to its lowest recorded level in 2017. Surveys of fixed transects in the years between maps indicated that losses of seagrass also occurred in the summers of 2012 and 2016. Estimates of mean percent cover within the footprint of seagrass beds have decreased since 2001. Elucidating the causes and ecological importance of changes in percent cover from 2001 to 2009 is complicated by expansion of seagrass beds into deeper water, which may have come at the expense of percent cover in shallower areas. From 2011 onward, the loss of percent

General Status of Seagrasses in the Northern Indian River Lagoon			
Indicators and stressors	Status	Trend	Assessment and causes
Seagrass acreage	Red	Losses (56%)	Phytoplankton blooms (light reduction)
Seagrass species composition	Red	Losses	<i>Halodule wrightii</i> , <i>Syringodium filiforme</i> , and <i>Thalassia testudinum</i> all affected
Seagrass cover	Red	Losses	Most beds in water >0.8 m deep lost completely and declines in cover throughout
Water clarity and light attenuation	Red	Banana River Lagoon particularly bad	Secchi depth often <0.5 m and $K_d >1.5 \text{ m}^{-1}$
Phytoplankton blooms	Orange	Moderated in some places but strong to severe in Banana River Lagoon	Chlorophyll-a concentrations often >30 $\mu\text{g/l}$ in Mosquito Lagoon and the central Indian River Lagoon
	Red		Concentrations often >30 $\mu\text{g/l}$ and at times >100 $\mu\text{g/l}$ in Banana River Lagoon and the northern portion of the Indian River Lagoon
Salinity	Yellow	Improving	Freshwater that was diverted from the watershed of the St. Johns River is being returned to that basin
Propeller scarring	Yellow	Stable	Areas being managed

Banana River Lagoon lies to the east of Merritt Island. This sublagoon is not connected to Mosquito Lagoon. It has a limited connection to the Atlantic Ocean through the navigational locks at Port Canaveral (in BR1–2), and it is connected to the Indian River Lagoon through the Canaveral Barge Canal (in BR1–2) and via a 300-m-wide opening at its southern end. Urban land use increases in the south,

with development on both Merritt Island and the barrier island. The occurrence of seagrass species follows the order observed in Mosquito Lagoon.

The Indian River Lagoon is divided into two sublagons, Indian River Lagoon North (IR1–3 to IR8) and Central (IR9–11 to IR21). These portions of the lagoon are connected to the ocean via Sebastian Inlet (in IR14–15). Land use in the watershed is divided approximately equally between urban, agricultural, undeveloped, and water/wetlands. The watershed has been expanded by drainage canals, with the southern portion increased by a factor of 1.5. In these sublagons, *H. wrightii* and *S. filiforme* remain dominant, *R. maritima* is less common than *H. engelmannii*, and *Thalassia testudinum*, *Halophila decipiens*, and *Halophila johnsonii* occur south of Sebastian Inlet.

Assessment

From 1996 through 2009, the areal extent of the seagrass canopy increased in some segments as seagrass extended into deeper water (Figure 2). After 1999, the areal extent of seagrasses surpassed that seen in 1943, with gains of more than 100 acres in northern Banana River Lagoon (BR1–2 and BR3–5), Indian River Lagoon North (IR5), and near Sebastian Inlet (IR12–13A, IR13B, and IR14–15). These results suggest that seagrasses may have been stressed in 1943. In 2007, seagrasses covered 71,676 acres, with 55,906 acres or 78% located north of Titusville (IR5), through the southern Mosquito Lagoon and in Banana River Lagoon (Figure 2). This acreage represented 83% of lagoon bottom that could be expected to support seagrass (Steward et al. 2005).

The areal extent of the seagrass canopy has decreased since 2009 (for example, in Banana River Lagoon and Indian River Lagoon North; Figure 3). The mean distance to the offshore edge of the canopy correlates well with areal extent ($r^2 = 0.87$), and these data document offshore expansion of the seagrass canopy up to 2010, a reduction in 2011, small expansions in 2013 and 2015, and another reduction in 2017 (Figure 4). Within the canopy, the percent of the bottom covered by seagrass has decreased since 2000 (Figure 4).

Understanding the causes and importance of changes in percent cover within the seagrass canopy from 2001 through 2009 is complicated by expansion into deeper water. From 2011 onward, the decrease in percent cover appears related to increased shading by prolonged and intense phytoplankton blooms that also led to loss of acreage (Figure 5). Recovery of seagrass will depend on increasing the availability of light by reducing the intensity and

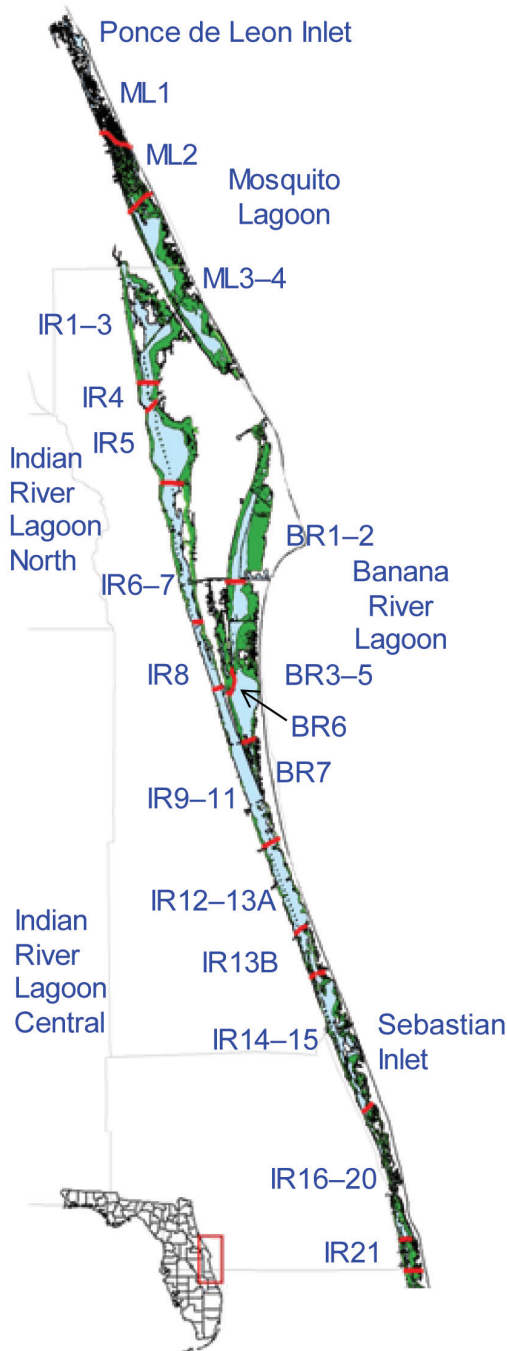
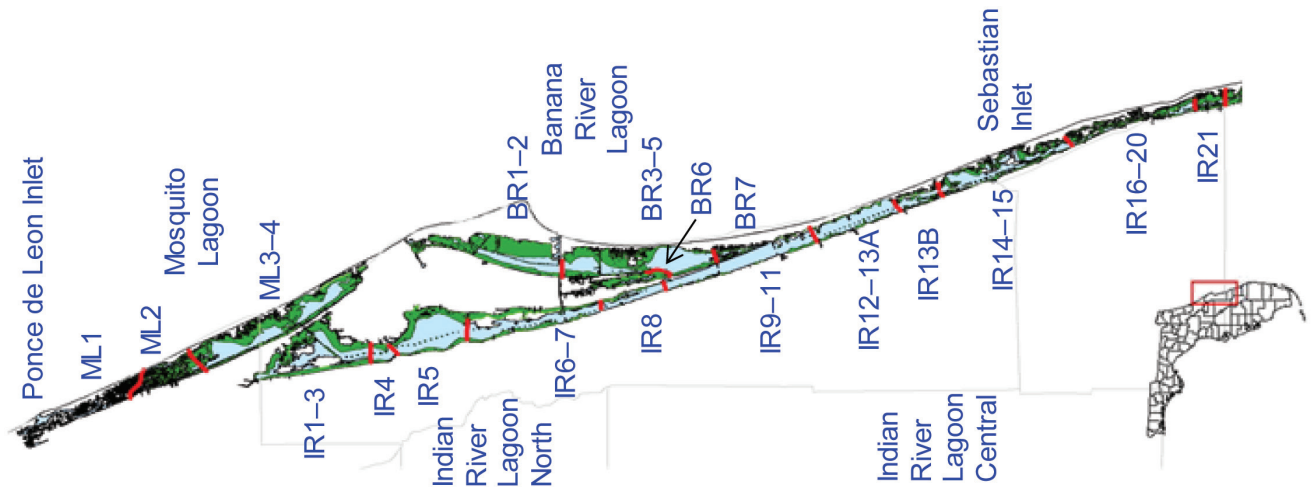


Figure 1. Northern Indian River Lagoon (NIRL) system, showing sublagons and segments. Green areas depict the extent of seagrass in 2009.



Sublagoon	Segment	1943	1992	1994	1996	1999	2003	2005	2007	2009	2011	2013	2015	2017
Mosquito Lagoon	ML1	822	330	192	19	59	67	72	94	73	78	64	67	54
	ML2	2,975	2,669	2,400	2,351	2,811	2,737	2,761	2,767	2,690	2,655	2,722	2,792	2,462
	ML3-4	14,517	13,332	12,823	13,465	13,345	13,466	13,368	13,970	13,748	14,155	14,125	13,900	12,089
Banana River Lagoon	BR1-2	6,722	9,828	8,484	9,966	10,483	11,866	11,848	12,187	12,286	2,127	3,390	5,440	2,129
	BR3-5	6,476	6,417	5,337	5,317	6,905	6,646	6,651	8,449	8,210	733	1,681	3,422	943
	BR6	2,796	1,375	1,142	1,288	2,281	2,531	2,440	2,927	2,863	223	359	400	245
	BR7	406	173	78	159	210	221	219	459	443	73	10	5	3
Indian River Lagoon North	IR1-3	8,732	9,336	9,909	9,467	8,152	8,437	8,426	8,960	8,555	9,238	8,489	9,270	6,344
	IR4	690	790	581	527	753	757	757	734	717	612	597	628	145
	IR5	4,620	4,841	3,859	4,411	5,039	5,329	5,379	5,384	5,333	3,301	3,563	4,525	2,313
	IR6-7	4,979	1,955	1,521	2,986	4,301	4,397	4,384	4,531	4,632	2,086	3,573	3,298	518
Indian River Lagoon Central	IR8	427	213	214	101	517	520	473	487	501	3	17	1	1
	IR9-11	2,265	197	89	175	722	769	786	832	834	185	236	7	4
	IR12-13A	1,017	161	466	831	1,009	1,146	1,128	1,270	1,245	71	181	114	31
	IR13B	352	347	444	908	834	859	845	1,033	979	157	671	600	341
	IR14-15	1,325	2,673	3,267	3,502	3,167	3,307	3,411	3,785	3,644	1,249	1,498	1,886	1,239
	IR16-20	1,727	734	501	910	1,154	1,305	1,331	2,422	2,114	500	791	955	669
	IR21	1,322	824	718	1,041	1,370	1,282	1,270	1,386	1,371	877	1,117	1,199	1,074
	Total	62,169	56,196	52,025	57,422	63,111	65,642	65,548	71,676	70,238	38,322	43,084	48,509	30,604

Figure 2. Acres of seagrass mapped in the sublagosons and segments of the Northern Indian River Lagoon. Green areas on the map depict the extent of seagrass in 2009.

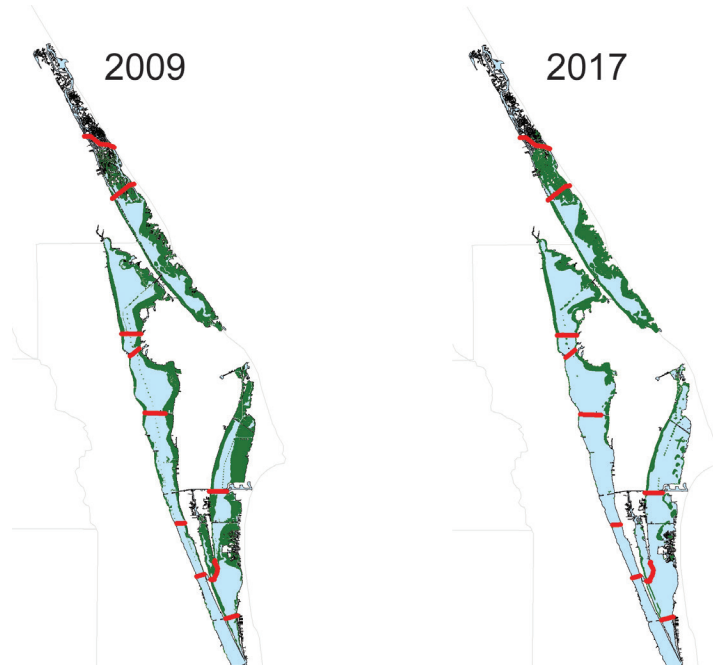


Figure 3. Maps of seagrasses in a portion of the Northern Indian River Lagoon illustrating the decrease in areal extent of the canopy, 2009–2017.

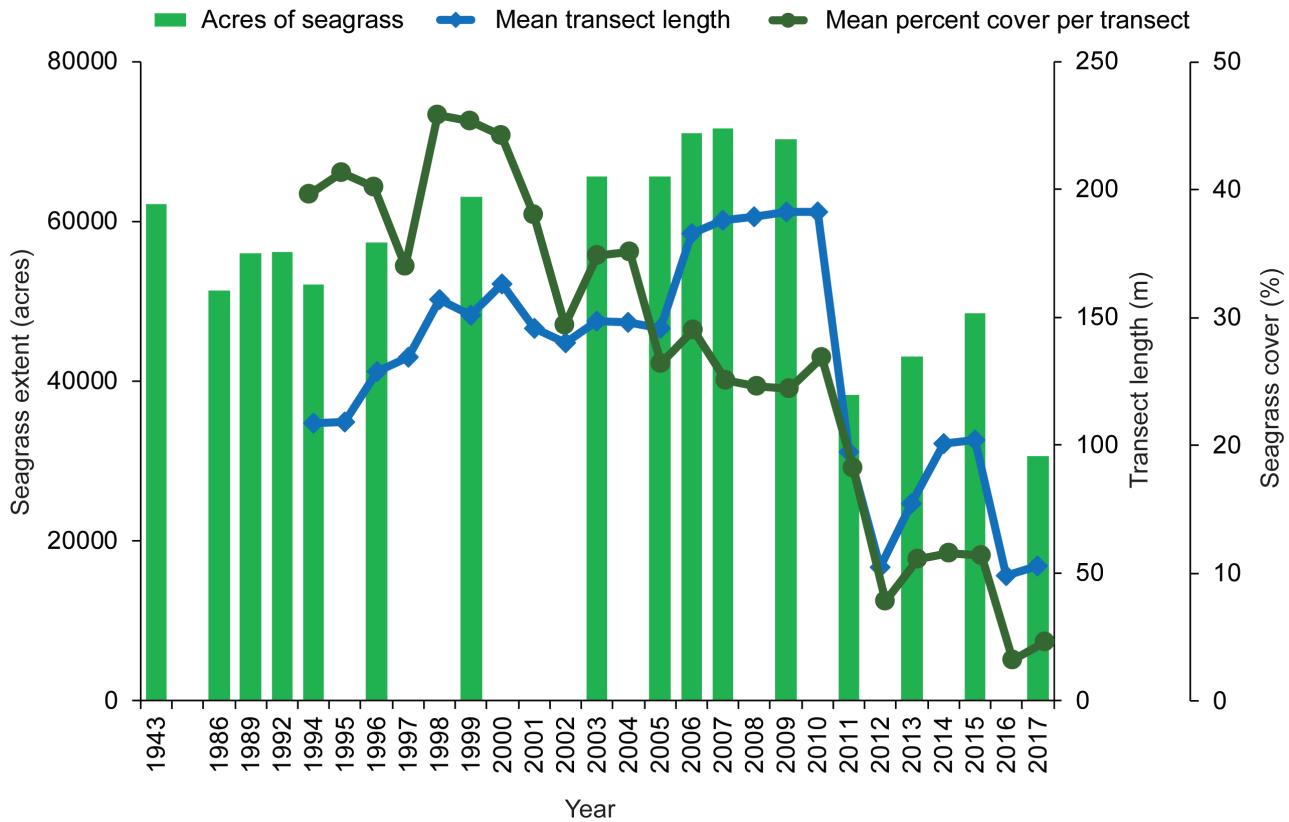


Figure 4. Acres of seagrass, mean lengths of transects to the edge of the seagrass canopy, and mean percent cover values for the Northern Indian River Lagoon.

duration of phytoplankton blooms. Achieving this goal depends on successfully implementing the many projects designed to reduce loads of nutrients to the lagoon.

METHODS

Mapping

The Surface Water Improvement and Management (SWIM) Plan for the entire Indian River Lagoon directs the St. Johns River Water Management District (SJRWMD) and the South Florida Water Management District (SFWMD) to map seagrasses every 2–3 years (Steward et al. 1994). Accordingly, maps have been prepared for 1986, 1989, 1992, 1994, 1996, 1999, 2003, 2005, 2007, 2009, 2011, 2013, 2015, and 2017, as well as 1943 (Figures 2 and 4). Mapping has been based on visual interpretation of aerial photographs, primarily at a 1:24,000 scale but in some cases at a 1:10,000 scale. Features on the aerial photographs were identified with the aid of stereoscopic analysis, photo-interpretation keys, and ground truthing. Features were classified according to Florida Land Use, Cover and Forms Classification Sys-

tem codes (Florida Department of Transportation 1999) as modified by the SJRWMD and SFWMD. Features were delineated, and the resulting polygons were connected to create a GIS data layer for the areal extent of seagrass. The accuracy of classifications has been evaluated since 1999. Further information and the data may be found at http://data-floridaswater.opendata.arcgis.com/datasets?group_id=adb3f173bb1b44c181def265bdf2526f

Seagrass surveys

Seagrasses in the NIRL have been surveyed along fixed transects twice a year (summer and winter) in most years since 1994. Surveys conducted by a group of collaborators have been coordinated by the SJRWMD. Each transect was delineated by a graduated line laid perpendicular to the shoreline from the shore out to the deep edge of the seagrass canopy. Every 10 m along the transect, standardized, non-destructive measurements were made within a 1-m² quadrat divided into 100 cells by strings. Measurements included: 1) species composition documented as the number of cells occupied by at least

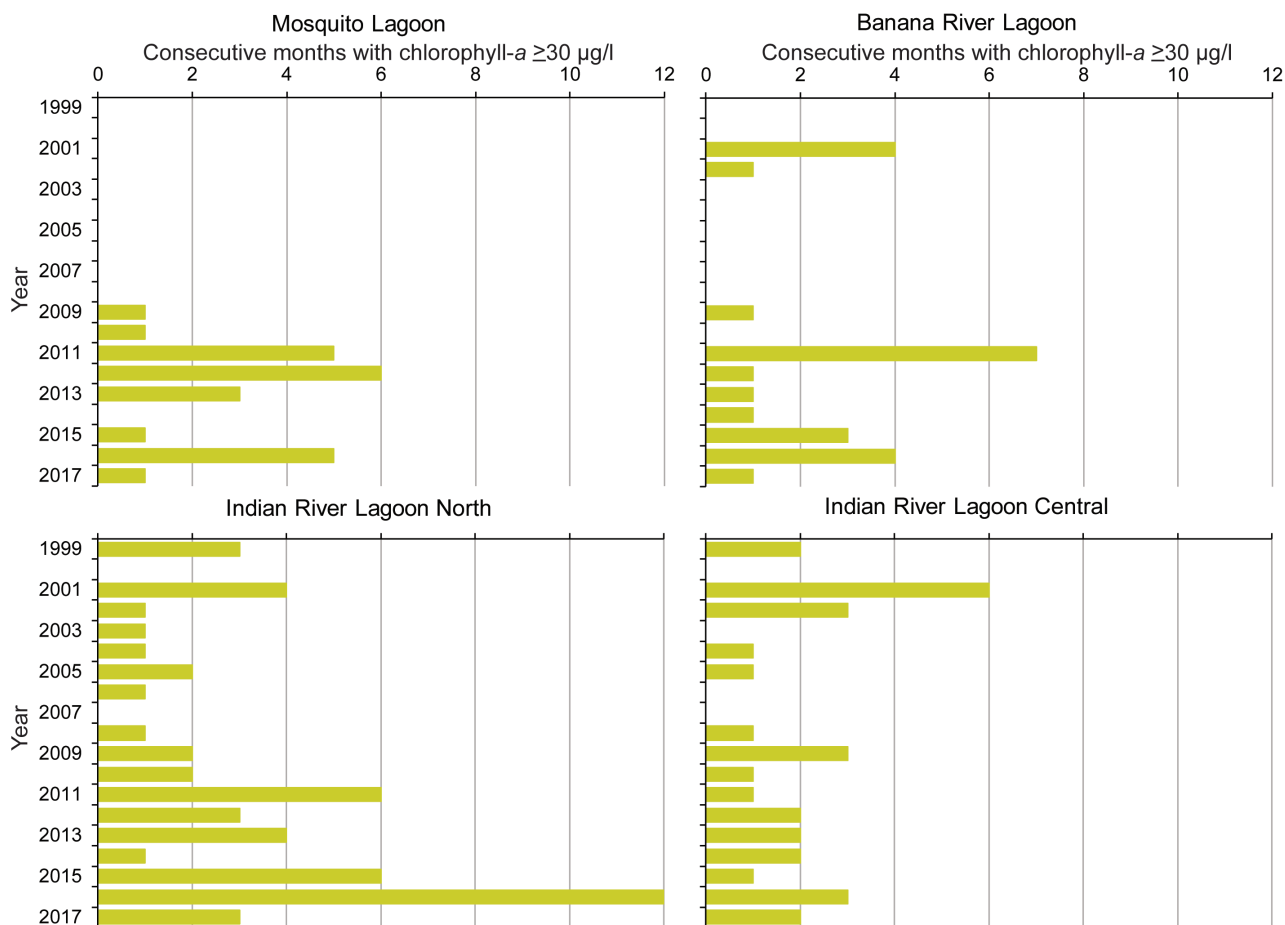


Figure 5. Number of consecutive months with chlorophyll-a concentrations $\geq 30 \mu\text{g/l}$ in sublagoons of the NIRL.

one shoot of a species; 2) canopy height for each species; 3) percent cover for each species and for all species combined, which correlated strongly with density estimated by shoot counts; 4) percent cover of drift macroalgae and an index characterizing its biomass (Morris et al. 2001); 5) a visual estimate of epiphyte biomass (Miller-Myers and Virnstein 2000); 6) water depth; and 7) total transect length (measured from shore to the deep edge of the seagrass canopy). In addition, seagrass shoots were counted in a predetermined set of quadrats as a direct measure of density used to generate a relationship between percent cover and density (Morris et al. 2001). To date, 96 transects (69 in the NIRL and 27 in the SIRL) have been surveyed in the summer and winter to target maximum and minimum levels of biomass in seagrass beds (Virnstein and Morris 1996). In addition, patterns between these times were evaluated via monthly or bi-monthly monitoring of 20 transects in the NIRL from 2005 through 2017.

Water quality

Water quality has been monitored by a multi-agency team since 1989. The program was modified in 1996 to improve the precision and accuracy of the data. Since then, fieldwork has followed a standard protocol, and samples have been processed and analyzed by one laboratory. Please visit <https://www.sjrwmd.com/> for additional information or obtain data at <http://webapub.sjrwmd.com/agws10/edqqt/>.

Mapping and monitoring recommendations

- Continue to map seagrasses. Mapping is completed approximately every two years.
- Continue to survey seagrass transects. Monitoring has been conducted by the SJRWMD and its partners each winter and summer since 1994.
- Continue to evaluate propeller scarring. Field observations and aerial photography can be combined into an evaluation using the strategy of Schaub et al. (2009), and photo-interpretation tools can be applied to assess the severity of scarring. These data can be used to evaluate the effectiveness of troll and no-motor zones and to select additional areas to be managed.
- Continue to monitor water quality. Water quality monitoring has assessed potential stressors, including attenuators of light (turbidity, total suspended solids [TSS] or both), monthly since 1989. In combination, the seagrass and water quality monitoring programs provide

a rich data set of historical importance that has helped managers establish targets for seagrass depth limits and the total maximum daily load (TMDL) of nitrogen and phosphorus that the lagoon can assimilate.

- Optimize the spatial and temporal extent of all monitoring to meet changing goals for management of the resource. The relevant reviews should evaluate the ability to detect change at appropriate spatial and temporal resolutions.

Management and restoration recommendations

- Continue responses to events. Short-term changes, such as phytoplankton blooms, seagrass die-offs, fish kills, and mortalities of manatees and birds, can have longer-term consequences, and understanding such links relies on documentation of events.
- Continue to coordinate state and federal programs. Seagrass represents a critical habitat for Florida's SWIM Program, the U.S. Environmental Protection Agency's National Estuary Program, the U.S. Army Corps of Engineers' North Indian River Lagoon Feasibility Study, and the Florida Department of Environmental Protection's Basin Management Action Plans for the NIRL.
- Incorporate cycling of nutrients into targets and actions for management, including setting priorities for reducing loads of nutrients and making plans to extract nutrients by collecting and removing dead fish or harvesting drift algae.
- Determine benchmarks for key water quality parameters. The ability of seagrasses to extend to the depths codified in management plans depends on restoring supportive nutrient concentrations, TSS concentrations, turbidities, water transparency, salinities, and other characteristics of water quality. These targets provide the basis for identifying specific goals for reducing pollutant loads, which, in turn, supply details required for the design of effective projects that rehabilitate the system (U.S. Army Corps of Engineers and SJRWMD 2002; Steward et al. 2003).
- Develop targets for the quality of seagrass beds that complement existing targets for their extent. Targets for percent cover, diversity of species, or other metrics of quality will support a more complete evaluation of the health and ecological contributions of seagrass beds and an improved ability to identify times and places for implementing management actions.

- Identify conditions hampering recovery of seagrasses. Evaluation of spatial variation in key drivers of seagrass recovery will guide strategies for restoration.
- Initiate groundwork for replanting or rehabilitating seagrasses. Even after water quality can support seagrasses, they may not recover rapidly due to the extent of losses; therefore, developing nurseries that can supply the necessary plants, evaluating techniques for planting, establishing criteria for assessing sites for rehabilitation, and exploring other techniques designed to promote regrowth of seagrasses should begin as soon as possible to ensure that answers to relevant questions are available when water quality improves.

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