Summary Report for St. Andrew Bay

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in

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Summary Report for St. Andrew Bay

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General assessment

Acreage of seagrasses in the St. Andrew Bay region is stable. In 2015, seagrasses covered 11,093 acres, a loss of 56 acres since 2010 (Table 1, Figures 1 and 2). While total acreage remained stable between 2010 and 2015, about 1,000 acres changed from continuous to patchy beds. North Bay and central St. Andrew Bay (which includes Grand Lagoon) gained 57 and 99 acres, respectively, between 2010 and 2015, while West Bay and East Bay lost 36 and 175 acres, respectively, during the same period. Based on aerial photos taken in 1953 and 1992, West Bay lost 49% of its seagrasses, or 1,850 acres, during that time. It has since regained almost 1,400 acres. Turtlegrass (*Thalassia testudinum*) and shoalgrass (*Halodule wrightii*) are the most common seagrasses in St. Andrew Bay, and manateegrass (*Syringodium filiforme*) occurs in beds at much lower densities. Stargrass (*Halophila engelmannii*) and widgeongrass (*Ruppia maritima*) occur infrequently and at very low densities. Heavy rains and resulting runoff reduce water clarity in the bay; heavy rainfall events since July 2012 continue to affect bay waters. Propeller scarring affects about 32% of seagrass beds in St. Andrew Bay (Table 2) and is particularly extensive near the inlet to the Gulf of Mexico.

Geographic extent

St. Andrew Bay is in Bay County in the Florida Panhandle and covers about 93 square miles. It consists of five segments: West Bay, North Bay, central St. Andrew Bay (which includes Grand Lagoon), East Bay, and St. Andrew Sound. St. Andrew Sound has no connection with the rest of the bay waters and is a small lagoon bordered by Tyndall Air Force Base (AFB) on the north and barrier peninsulas to the south. The watershed of the bay covers 1,150 square miles and is located mostly in Bay County (62%). The watershed also covers portions of five other counties: Gulf, Calhoun, Jackson, Washington, and Walton. Panama City, Panama City Beach, and Tyndall AFB border lower portions of the bay. Rivers and streams draining into the bay are small; the largest river is Econfina Creek, and its waters flow into Deer Point Lake (a reservoir) north of North Bay. Much of the water in Econfina Creek is supplied by springs, especially during moderate and low-flow conditions. The Gulf Intracoastal Waterway enters the region at the terminus of East Bay and exits on the western shore of West Bay. Extensive wetlands border the eastern part of East Bay and the shores of West Bay. Nearly 80% of the watershed is undeveloped and covered by forests and wetlands; about 12% of the area is urban and suburban. See the Surface Water Improvement and Management (SWIM) plan of the Northwest Florida Water Management District (NWFWMD) for more information on the bay watershed.

Mapping and monitoring recommendations

- Acquire imagery and map the region every six years.
- Continue and expand seagrass and water quality monitoring.

1. General Status of Seagrasses in St. Andrew Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass acreage	Yellow	Increasing patchiness	Acreage is stable
Water clarity	Yellow	Variable	Storm runoff, especially 2012 and 2013
Nutrients	Green	Generally low	Low levels, except West Bay
Natural events	Yellow	Episodic	Storm runoff
Propeller scarring	Orange	Extensive	Shallow areas, especially near mouth of bay

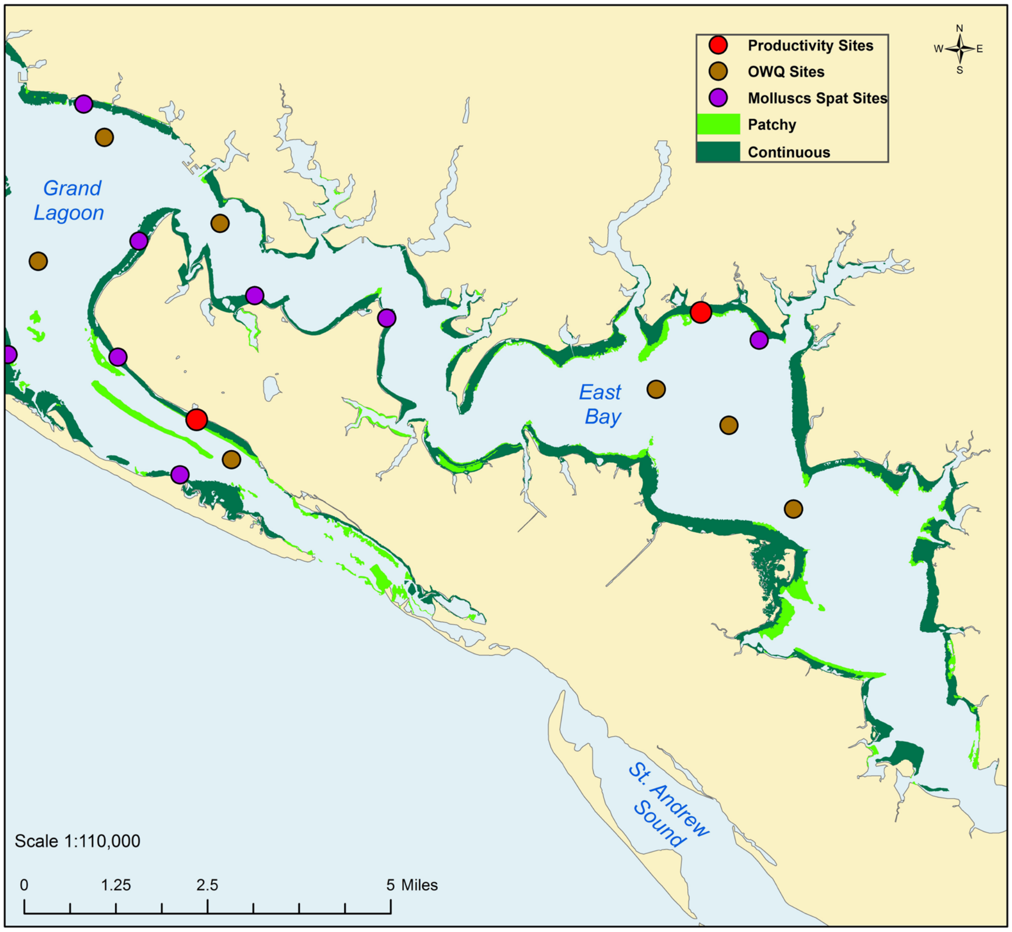

Figure 1. Seagrass cover in the eastern St. Andrew Bay region, 2015, shown as patchy and continuous beds; locations of sites for sampling optical water quality (OWQ) by scientists of the St. Andrew Bay Resource Management Association (SABMRA) in 2016 (brown circles); sites where scientists from the FWRI Molluscan group sample water monthly for optical water quality (purple circles); and locations of field measurements of the productivity of turtlegrass in 2016 (red circles).

Management and restoration recommendations

- Assess changes in the quality of freshwater runoff and in the quality and clarity of bay waters resulting from the conversion of forest and wetlands to residential, commercial, and industrial land uses.
- Continue to assess changes in water quality and seagrass beds after diversion of wastewater effluent from the western portion of West Bay (WB-BOWL), which began in April 2011. Comparison of water quality data in the St. Andrew region between 1992 and 2013 showed that nutrient levels in West Bay improved dramatically after inputs of wastewater effluent were eliminated; however, nutrient levels increased in Grand Lagoon (St. Andrew Bay Resource Management Association Inc. 2014).
- Assess changes in bay water quality and seagrass coverage in West Bay, especially the eastern part of West Bay (WB-ARM), resulting from stormwater runoff from the Northwest Florida Beaches International Airport. The drainage system of the airport feeds into Crooked and Burnt Mill creeks, which in turn discharge into West Bay.
- Assess changes in bay water quality and seagrass cover in Grand Lagoon.
- Restore badly scarred seagrass beds, and monitor their condition. An early restoration project funded by the Deepwater Horizon oil spill Natural Resources Damage Assessment (NRDA) is investigating whether nutrients in bird guano will improve seagrass productivity. Bird-roosting stakes were placed behind Shell Island in the southern bay to provide guano to seagrass beds in the area.

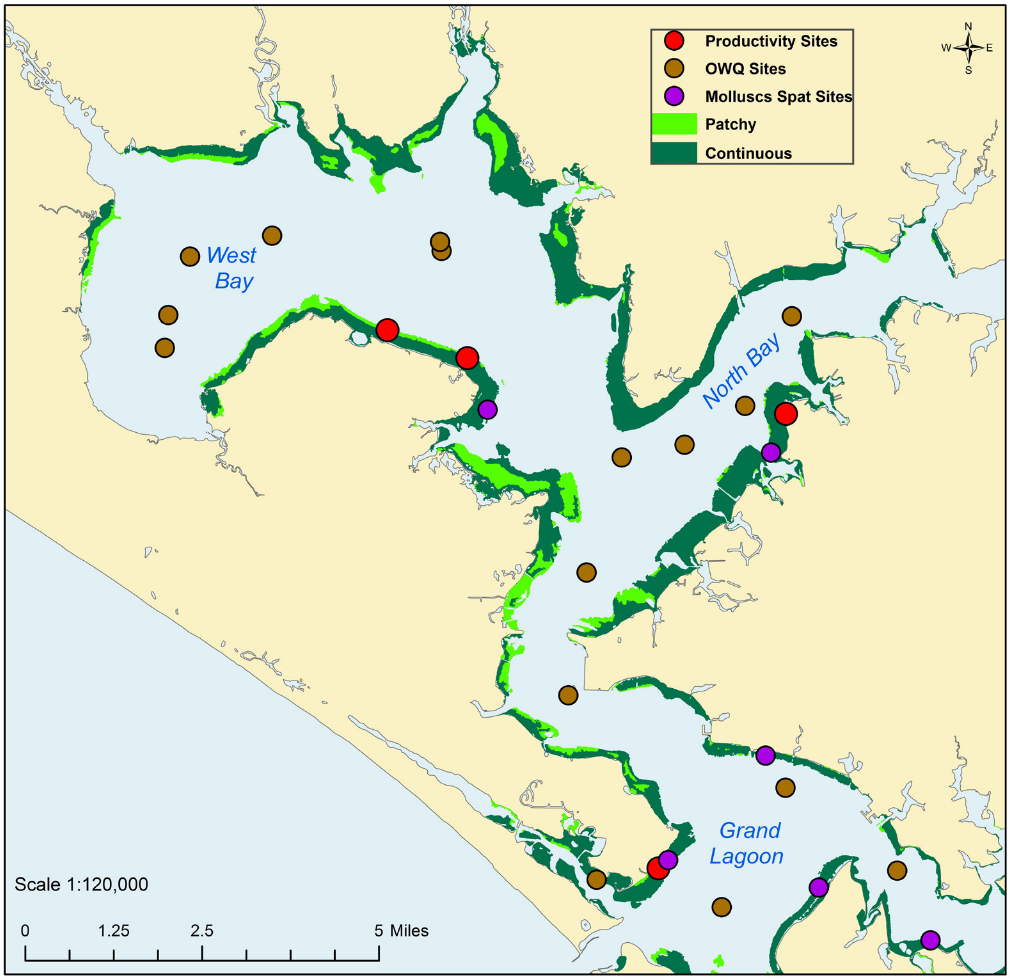

Figure 2. Seagrass cover in central and western St. Andrew Bay, 2015, shown as patchy and continuous beds; locations of sites for sampling optical water quality (OWQ) by scientists of the St. Andrew Bay Resource Management Association (SABMRA) in 2016 (brown circles); sites where scientists from the FWRI Molluscan group sample water monthly for optical water quality (purple circles); and locations of field measurements of the productivity of turtlegrass in 2016 (red circles).

- Facilitate a joint project between SABMRA and the Florida Department of Environmental Protection (FDEP), Pensacola office, to study transplantation into WB-BOWL of seagrasses salvaged from dock construction sites.
- Use the boating and angling guide for waters in the region to improve boater education on and awareness of seagrass beds and to reduce propeller scarring.

Summary assessment

In the Florida Panhandle, the status of seagrasses and the potential for recovery of seagrass where beds have been lost are being assessed by the Roadblocks to Seagrass Recovery project of the Fish and Wildlife Research Institute of the Florida Fish and Wildlife Conservation Commission (http://myfwc.com/research/habitat/seagrasses/projects/roadblocks/). This project is funded by the National Fish and Wildlife Federation's Gulf Environmental Benefit Fund, and activities include mapping of seagrasses from the Alabama state line to the mouth of the Suwannee River, field assessments of seagrass cover and species composition, and quantitative estimation of factors affecting recovery and restoration of seagrasses. These factors include current and historical seagrass extent, optical water quality and light attenuation, sediment quality and toxicity, bathymetry, propeller scarring, and physical stressors such as wind energy. Data and results are part of a seagrass recovery potential (SRP) model that will be served on the Web.

Mapping data show very little difference in total seagrass cover in St. Andrew Bay between imagery collected in 2010 and in 2015 (Table 1). Total cover in 2015 was 11,093 acres, of which 80% was continuous seagrass beds (Figures 1 and 2). While seagrass acreage was stable between 2010 and 2015, a little more than 1,000 acres of continuous seagrass changed to patchy seagrass. Small changes in acreage occurred in all subregions of the bay between 2010 and 2015, but East Bay had the greatest change, a loss of 175 acres. The distribution and frequency of occurrence (FO) of seagrass species show some variations among sampling years (Table 3). Turtlegrass is the most common seagrass species in central St. Andrew Bay (including Grand Lagoon) and, most likely, East Bay (Table 4). Shoalgrass is the most common seagrass species in North Bay and is second in FO in all other subregions. Manateegrass occurs at low levels in East Bay and central St. Andrew Bay, while stargrass and widgeongrass occur sporadically in the region. In 2016, optical water quality was poor throughout the region in spring, as indicated by increased light attenuation, but moderate during other seasons (see Figure 5). Water color showed large increases in spring indicating that it was likely the primary factor affecting light attenuation in the water column at that time. Propeller scarring affects nearly 32% of seagrass beds, but most scarring is low in intensity (Table 2).

The general status of seagrasses (Status graphic 1) has changed slightly since the second edition of this chapter: the status of seagrass cover shifted from green in the second edition to yellow in this chapter, because acreage is stable, and beds are likely thinning. A detailed assessment of seagrass status (Status graphic 2) shows few differences between chapter editions, although thinning of beds has likely increased since the second edition of the chapter was released.

Seagrass mapping assessment

Seagrass acreage across the region changed by <1% between mapping efforts in 2010 and 2015 (Table 1). The acreage mapped in 2010 and 2015 covered the largest area since mapping efforts in 1992. But the area of continuous seagrass beds decreased during the period by 1,067 acres, or 11%, while the extent of patchy beds nearly doubled, increasing from 1,224 acres to 2,235 acres. Loss of continuous beds occurred in all subregions, but East Bay had the greatest loss, at 422 acres, or 17%. Patchy beds increased in all subregions, often by large percentages because patchy beds were a small proportion of seagrass acreage in 2010. Overall, between 2010 and 2015, seagrasses increased in acreage in North Bay and the central bay and decreased in acreage in West Bay and East Bay.

Propeller scarring

Propeller scarring of seagrass beds was quantified using aerial imagery collected in 2013 by the U.S. Department of Agriculture National Agricultural Imagery Program (NAIP). The imagery was overlaid by a grid of cells, each with an area of 1 ha. In each cell that covered seagrass, the scars were counted, and the cell was given

2. Seagrass Status and Potential Stressors in St. Andrew Bay

Status indicator	**Status**	**Trends**	**Assessment, causes**
Seagrass cover	Green	Stable	Throughout bay
Seagrass meadow texture	Yellow	Increasing patchiness	Changes since 2009
Seagrass species composition	Green	Stable	Primarily turtlegrass and shoalgrass
Overall seagrass trends	Green	Stable	Possible impacts from storm runoff
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Impacted by storms	Storm runoff; development in watershed
Nutrients	Green	Low, variable	
Phytoplankton	Green	Low, variable	
Natural events	Yellow	Episodic	Storm runoff, tropical cyclones
Propeller scarring	Orange	Extensive	Shallow areas, especially near mouth of bay

a score (see methods; Table 2). Nearly 32% of seagrass beds had some scarring, but almost 80% of scarred beds were lightly scarred, with 1–5 scars per cell. The most heavily scarred locations were in the central bay and often on shoals adjacent to points of land.

Monitoring assessment

Several agencies have carried out field monitoring since 2000. SABMRA volunteers monitored seagrasses in the fall in 2000–2009 in two areas of the bay: St. Andrew Bay (SAB) behind Shell Island, and West Bay. Personnel from FWRI visited 50–100 randomly distributed sites in the falls of 2009 and 2011 and in late summer of 2014 and assessed seagrass cover, seagrass and macroalgal species distribution, and water quality and clarity. In summer 2016, SABMRA staff assessed cover at 71 sites where seagrass was present. Turtlegrass was the most commonly found seagrass during all sampling efforts, occurring in 40–47% of all quadrats surveyed (Table 3). Shoalgrass was second most abundant, occurring in 25–28% of all quadrats in 2009–2014 and in 52% of quadrats in 2016. Occurrence of manateegrass, stargrass, and widgeongrass was much lower than occurrence of turtlegrass and shoalgrass in all sampling periods. In 2009, no seagrass was observed in 42% of quadrats but the percentage of bare quadrats had dropped to 31% by 2014.

The FO of seagrasses varied among subregions of the bay (Table 4). Turtlegrass was the most common seagrass in East Bay and the central bay during all sampling efforts. In North Bay, in 2014 and 2016, shoalgrass was the most common species, followed by turtlegrass. In West Bay, turtlegrass was the most common seagrass in 2009 and 2011, but shoalgrass was most common in 2014 and 2016. The number of bare quadrats decreased from 2011 to 2014 in East Bay and the central bay but was variable in West Bay.

While FO is a measure of the abundance of each seagrass species in a specific area, quadrat cover (similar to the assessment using the Braun-Blanquet method; see methods below) provides an assessment of plant density in each quadrat. Mean cover of turtlegrass and shoalgrass, the two most common species in St. Andrew Bay, was greatest in all subregions in 2009 and was much lower during all subsequent sampling assessments (Figure 3). Mean cover of turtlegrass was lowest in West Bay of all subregions during all sampling years. After 2009, mean cover of both species dropped to <20% in 2011 and remained at these levels in 2014 and 2016.

Productivity of turtlegrass

Field measurements of the productivity of turtlegrass were made in June and July 2016 at six sites (see Figures 1 and 2) by scientists from SABMRA, using the punch–

Table 1. Seagrass acreage in subregions of St. Andrew Bay, 1992, 2003, 2010, 2015.

		Seagrass acreage				Change 2010–2015	
Subregion	**Bed texture**	**1992**	**2003**	**2010**	**2015**	**Acres**	**%**
West Bay	Continuous	215	1,704	2,927	2,539	−388	−13%
	Patchy	1,675	780	384	736	352	91%
	Total	1,890	2,484	3,312	3,275	−36	−1.1%
North Bay	Continuous	996	1,654	1,976	1,772	−204	−10%
	Patchy	834	318	100	361	261	262%
	Total	1,830	1,972	2,076	2,132	57	2.7%
Central St. Andrew Bay	Continuous	1,266	1,838	2,557	2,504	−53	−2.1%
	Patchy	1,208	1,092	490	642	152	31%
	Total	2,474	2,930	3,047	3,146	99	3.2%
East Bay	Continuous	1,608	944	2,464	2,043	−422	−17%
	Patchy	850	1,684	250	497	247	99%
	Total	2,458	2,628	2,714	2,540	−175	−6.4%
Total St. Andrew Bay	Continuous	4,086	6,139	9,925	8,858	−1,067	−11%
	Patchy	4,566	3,875	1,224	2,235	1,012	83%
	Total	8,652	10,014	11,149	11,093	−56	−0.5%

Table 2. Assessment of propeller scarring of seagrass beds in St. Andrew Bay using imagery acquired by the NAIP in 2013. Imagery was overlaid by a grid with each cell having an area of 1 ha. Each cell received a scarring score.

Description	Score	Cell count	% of vegetated cells
Vegetated, no scars	0	6,068	64.4%
1–5 scars	1	2,325	24.7%
5–10 scars	2	396	4.2%
11–25 scars	3	177	1.9%
26–50 scars	4	60	0.6%
>50 scars	5	37	0.4%
Unreadable, turbid water	10	365	3.9%
Total vegetated		9,428	
Total scarred		2,995	31.8%

and harvest– method developed by Zieman and Zieman (1989). Live biomass ranged from 329 to 1,805 g/m^2, with highest values measured in the central bay (Table 5). Dead biomass was 3–30% of live biomass. Live biomass above the sediment surface (short shoots and blades) was generally >75% of below-sediment biomass (roots and rhizomes), except in the middle bay where it was 20–60% of below-sediment live biomass. Because these experiments were a done month apart during summer, no temporal trends were expected.

A variety of measures of productivity can be reported using the data collected from these experiments. We have chosen to report counts of turtlegrass shoots, 1-sided leaf area index (LAI), and average shoot specific growth. Shoot counts, reported per m^2, are a common metric for seagrass ecosystems, and counts can vary widely over short distances. Because turtlegrass is a long-lived species, the variation in shoot counts over short periods of time is likely to be less than variation from one place to another. In these experiments, scientists conducted measurements at the same site at two times, but the locations of the quadrats by necessity were slightly different from one sampling period to another. Shoot counts ranged from 800–1,587/m^2 (Figure 4), with an average of 1,205 for all sites during both months. Variation in shoot counts among quadrats at a site was frequently high, and there were no consistent differences between sampling periods or among sites.

The 1-sided LAI is a unitless metric calculated by dividing the total blade area in cm^2 covering 1 m^2 of sediment surface by 10,000 (i.e., the number of cm^2 in 1 m^2). The 2-sided LAI (2 × 1-sided LAI) estimates total blade surface area compared to the sediment surface. 1-sided LAI ranged from 1.2 to 3.5 with both the highest and lowest values measured at site S7 in the central bay (Figure 4). This does not indicate simply high growth rates between sampling efforts but also differences in the seagrass bed among quadrat locations. Shoot counts at the July S7 location were 50% greater than shoot counts at the S7 location in June.

Shoot-specific blade growth (SSBG) is a measure of the increase in blade area of each punched shoot during the experiment and is reported in cm^2/day. We report means of SSBG because the data provide information on shoot performance at each site; multiplying SSBG by shoot counts estimates productivity in cm^2/m^2/day. SSBG ranged from 0.14 to 0.32 cm^2/day across all sites and during both sampling efforts (Figure 4). For both sampling periods, the lowest SSBG was measured in North Bay and the highest SSBG was measured in East Bay.

Water quality and clarity

As part of the Roadblocks to Seagrass Recovery project, scientists from SABRMA collected water samples and data quarterly in 2016 in subregions of the bay to measure the optical water quality parameters chlorophyll-a, color, turbidity, and light attenuation or k_{par} (Figure 5). Average concentrations of chlorophyll-a

Table 3. Frequency of occurrence (percent of quadrats having a seagrass species present) of seagrasses in St. Andrew Bay, 2009, 2011, 2014, and 2016. Most of the time, 10 quadrats were evaluated at each site.

Year	# quadrats sampled	Shoal-grass	Manatee-grass	Turtle-grass	Stargrass	Widgeon-grass	No grass
2009	470	28.5	8.30	39.8	1.06	0.64	42.3
2011	429	26.3	9.56	45.5	1.40		38.5
2014	920	25.5	5.54	46.7		10.1	31.1
2016*	710	52.1	2.82	46.6	0.14	1.41	16.5

*Sampling locations were different from those of previous years and were primarily in seagrass beds.

were <8 µg/l during all seasons and in all subregions, but variation around the means was large in the spring and summer. Lowest values were measured in the fall in East Bay, St. Andrew Bay (central bay), and West Bay. Color, however, was very high in all subregions in the spring and likely contributed to the high values of k_{par} measured in the spring in all subregions. Turbidity was moderate to low in subregions of the bay, except in the summer (but with large variation) in West Bay. The high values of k_{par} measured in the spring likely caused light stress in seagrasses just at the time that they were beginning growth and flowering.

Watershed management

The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, provides a framework for resource management, protection, and restoration using a watershed approach. An updated SWIM plan for the St. Andrew Bay Watershed was released in fall 2017: https://www.nwfwater.com/Water-Resources/Surface-Water-Improvement-and-Management/St.-Andrew-Bay. The plan describes the watershed's physical characteristics and natural resources, provides an assessment of current conditions, and identifies priority challenges affecting watershed resources and functions. Priority projects are:

- Stormwater planning and retrofit
- Septic tank abatement
- Advanced onsite treatment systems
- Agriculture and silviculture best management practices
- Basinwide sedimentation abatement
- Riparian buffer zones
- Aquatic, hydrologic, and wetland restoration
- Estuarine habitat restoration
- Strategic land conservation
- Watershed stewardship initiative
- Subbasin restoration plans
- Wastewater treatment and management improvements
- Analytical program support
- Comprehensive monitoring program

Table 4. Frequency of occurrence (percent of quadrats having a seagrass species present) of seagrasses in subregions of St. Andrew Bay, 2009, 2011, 2014, and 2016. Note that sampling locations in 2016 were different from those in other years, and almost all sites visited in 2016 were over seagrass beds. Most of the time, 10 quadrats were evaluated at each site.

Subregion	Year	# quadrats	Shoal-grass	Turtle-grass	Manatee-grass	Star-grass	Widgeon-grass	Bare
East Bay	2009	152	31.6	41.4	19.1			35.5
	2011	200	27.0	34.0	8.5	0.5		52.0
	2014	300	25.7	53.3	3.7		12.3	28.3
	2016*	220	62.7	41.4	5.0		1.8	15.0
North Bay	2009				No data			
	2011				No data			
	2014	60	60.0	31.7			10.0	18.3
	2016*	130	63.1	20.0			0.8	30.8
Central Bay	2009	190	23.2	38.9	5.3			45.3
	2011	172		55.8	9.3			29.7
	2014	310	14.8	63.5	12.9		2.3	20.6
	2016*	230	20.4	75.7	3.9			13.5
West Bay	2009	128	32.8	39.1		3.9	2.3	46.1
	2011	52	30.8	48.1	15.4	9.6		17.3
	2014	250	30.4	21.6			17.2	50.4
	2016*	130	79.2	30.8		0.8	3.8	10.0

*sampling locations were different from previous years and were primarily in seagrass beds

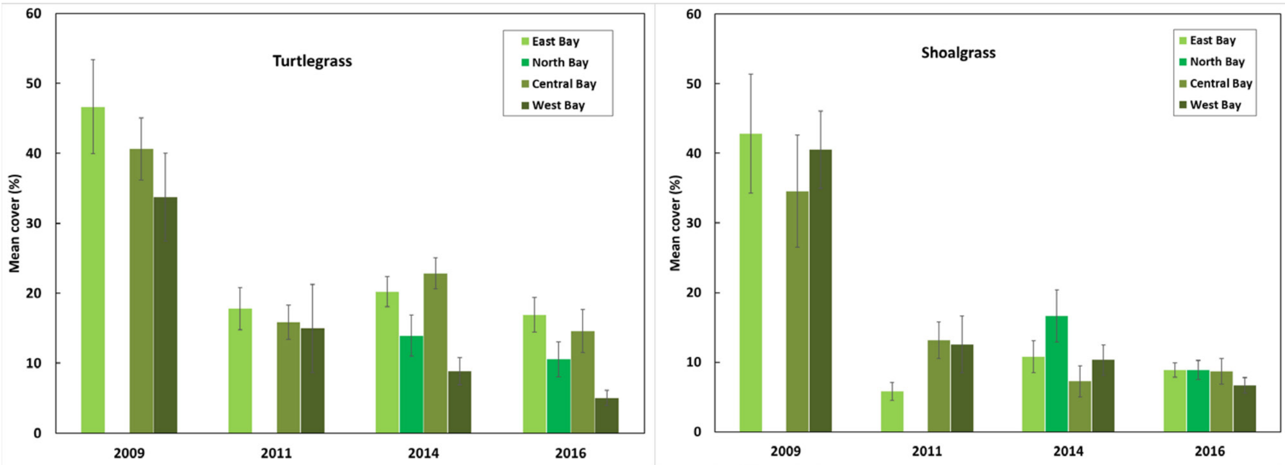

Figure 3. Mean cover (±2 standard error) of turtlegrass and shoalgrass in subregions of St. Andrew Bay, 2009, 2011, 2014, 2016. Only quadrats having the species of seagrass were included in the estimates of mean cover by species. No data were available for North Bay in 2009 and 2011.

To protect water quality, habitat quality, and groundwater recharge, and to maintain compatible public access and use, NWFWMD protects more than 45,500 acres in Bay and Washington counties as the Econfina Creek Water Management Area (WMA). The WMA comprises much of the recharge area for springs contributing to Econfina Creek and Deer Point Lake reservoir, as well as the Sand Hill Lakes.

District staff continue to help local governments develop and implement cooperative stormwater retrofit projects. Implementation of these projects will provide substantial benefits to the public, including improved estuarine water quality, aquatic habitats, and flood protection.

Mapping methods, data and imagery

In fall of 2015, the NAIP collected imagery for Panhandle estuaries as part of a collaborative arrangement with FWRI. The imagery was photo-interpreted for benthic habitats by Dewberry Inc. (Tampa). The Florida Land Use, Cover, and Forms Classification System (FLUCCS; Florida Department of Transportation 1999) was used to classify bottom features as continuous seagrass, patchy seagrass, oyster bed, bare intertidal, shallow bare bottom, or deep bare bottom. Bottom features were delineated by polygonal shapefiles, with a minimum mapping unit of 0.1 ha.

High-resolution (1 m) four-band aerial imagery was collected for the entire northern Gulf coast in October 2010, and photo-interpretation was completed by PhotoScience Inc. (St. Petersburg). The FLUCCS (Florida Department of Transportation 1999) was used to classify bottom features. Mapping data for 2003 were derived from the interpretation of color infrared photography. These images were mapped at 1:12,000 scale as hard copies rectified to U.S. Geological Survey (USGS) digital orthophoto quarter-quadrangle base maps and were digitized at the USGS National Wetlands Research Center (NWRC). The seagrass beds were classified according to an NWRC-derived classification scheme based on the Coastwatch Change Analysis Project Coastal Land Cover Classification system of the National Oceanic and Atmospheric Administration.

Mapping data from 1992 are part of a northwest Florida seagrass mapping data set collected in December 1992 and early 1993. The data set was created by the USGS Biological Resources Division at the NWRC. The study area covered Anclote Key to Perdido Bay on the Alabama–Florida state line. Imagery was natural color at 1:24,000 scale. Aerial photographs were interpreted and delineated by USGS and then transferred to a base map using a zoom transfer scope. Maps were digitized into ArcInfo software.

To compare mapped seagrass areas among years, a polygon was defined for the bay and its subregions and used for each set of mapping data. Change in area was estimated in ArcMap.

Propeller scarring assessment

As part of the Roadblocks to Seagrass Recovery project, scientists at FWRI assessed the extent and severity of propeller scarring of seagrass beds in the St. Andrew Bay region using imagery acquired in 2013 by the NAIP. ArcMap was used to overlay water areas <4 m deep with a grid

Table 5. Biomass of live and dead turtlegrass, above and below the sediment surface, in subregions of St. Andrew Bay, June and July 2016.

				Turtlegrass biomass (g/m^2)					
				Live			Dead		
Subregion	**Site**	**Month**	**Fraction**	**Mean**	**Std. dev.**	**N**	**Mean**	**Std. dev.**	**N**
East Bay	E1	June	Above	249	62.8	4	37.9	31.6	4
			Below	304	63.1	4	8.9	2.0	3
			Total	**553**			**46.8**		
		July	Above	330	131	4	22.9	12.2	4
			Below	439	208	4			
			Total	**769**			**22.9**		
North Bay	NB	June	Above	207	31.2	4	16.8	17.6	4
			Below	233	57.1	4	30.6	20.2	3
			Total	**440**			**47.4**		
		July	Above	348	87.3	4	30.4	5.7	4
			Below	435	282	4			
			Total	**783**			**30.4**		
Central bay	S7	June	Above	309	33.6	4	354	271	4
			Below	1,496	349	4	201	327	4
			Total	**1,805**			**555**		
		July	Above	562	91.2	4	39.1	11.4	4
			Below	991	142	4			
			Total	**1,553**			**39.1**		
	SAB	June	Above	316	58.0	4	159	133	4
			Below	1,252	535	4	17.5	13.2	3
			Total	**1,568**			**176**		
		July	Above	390	110	4	50.6	53.7	4
			Below	632	81.9	4			
			Total	**1,022**			**50.6**		
West Bay	W8	June	Above	272	73.0	4	16.8	6.5	4
			Below	233	99.0	4	17.7	10.4	4
			Total	**505**			**34.5**		
		July	Above	275	44.0	4	43.6	19.3	4
			Below	284	91.6	4			
			Total	**559**			**43.6**		
	W9	June	Above	189	61.1	4	13.3	13.9	4
			Below	140	29.3	4	65.0	60.2	2
			Total	**329**			**78.2**		
		July	Above	245	98.1	4	48.4	35.9	4
			Below	303	48.8	4			
			Total	**548**			**48.4**		

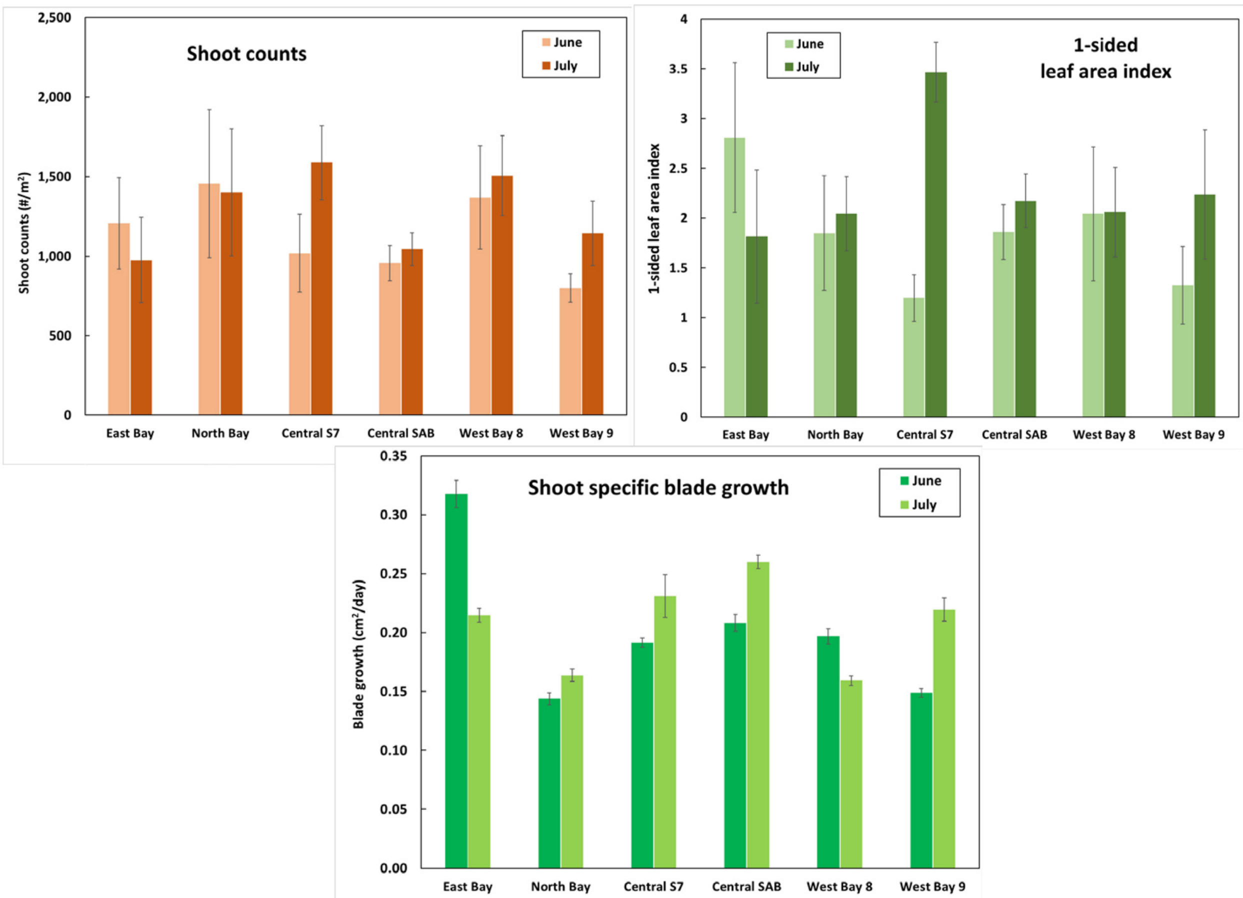

Figure 4. Mean (±2 standard error) shoot counts (#/m^2), 1-sided leaf area index (LAI), and shoot-specific blade growth (cm^2/day) of turtlegrass in subregions of St. Andrew Bay, June and July 2016.

constructed of square cells 100 m on a side, thus covering 1 ha each. For each cell that was over seagrass, scars were counted, and the cell was scored in the following manner:

Description	Score
Vegetated, no scars	0
<5 scars	1
5–10 scars	2
11–25 scars	3
26–50 scars	4
>50 scars	5
Doughnut-shaped beds	7
Unreadable, vegetated	10

For each subregion, the number of cells having each score was summed and compared with the total number of vegetated cells to calculate the percentage for each scarring score and the overall scarring percentage. In addition, maps were created showing the distribution of scarring intensity, and these maps constitute a layer of the Seagrass Recovery Potential model of the Roadblocks project.

Monitoring methods and data

Field monitoring of seagrass beds has been carried out by several agencies since 2000. Monitoring was done by SABMRA volunteers every fall in central St. Andrew Bay and West Bay from 2000 through 2009. Five permanent transects were sampled in the central bay, and four permanent transects were sampled in West Bay. SABMRA also had three permanent transects in WB-ARM, two transects between Crooked and Burnt Mill creeks, and another transect on the opposite side of the bay. The two transects between Crooked and Burnt Mill creeks were monitored for several years. Monitoring data may be obtained from the 2010 St. Andrew Bay Monitoring Report by contacting Linda Fitzhugh.

Since 2009, three agencies have carried out field monitoring. Locations of monitoring sites are shown in Figure 6. FWRI staff conducted monitoring in late summer or fall of 2009, 2011, and 2014. They used a spatially distributed random-sampling design to assess bottom habitats where water depth was <3 m. Field sampling included assessment of ten 0.25-m^2 quadrats randomly located at

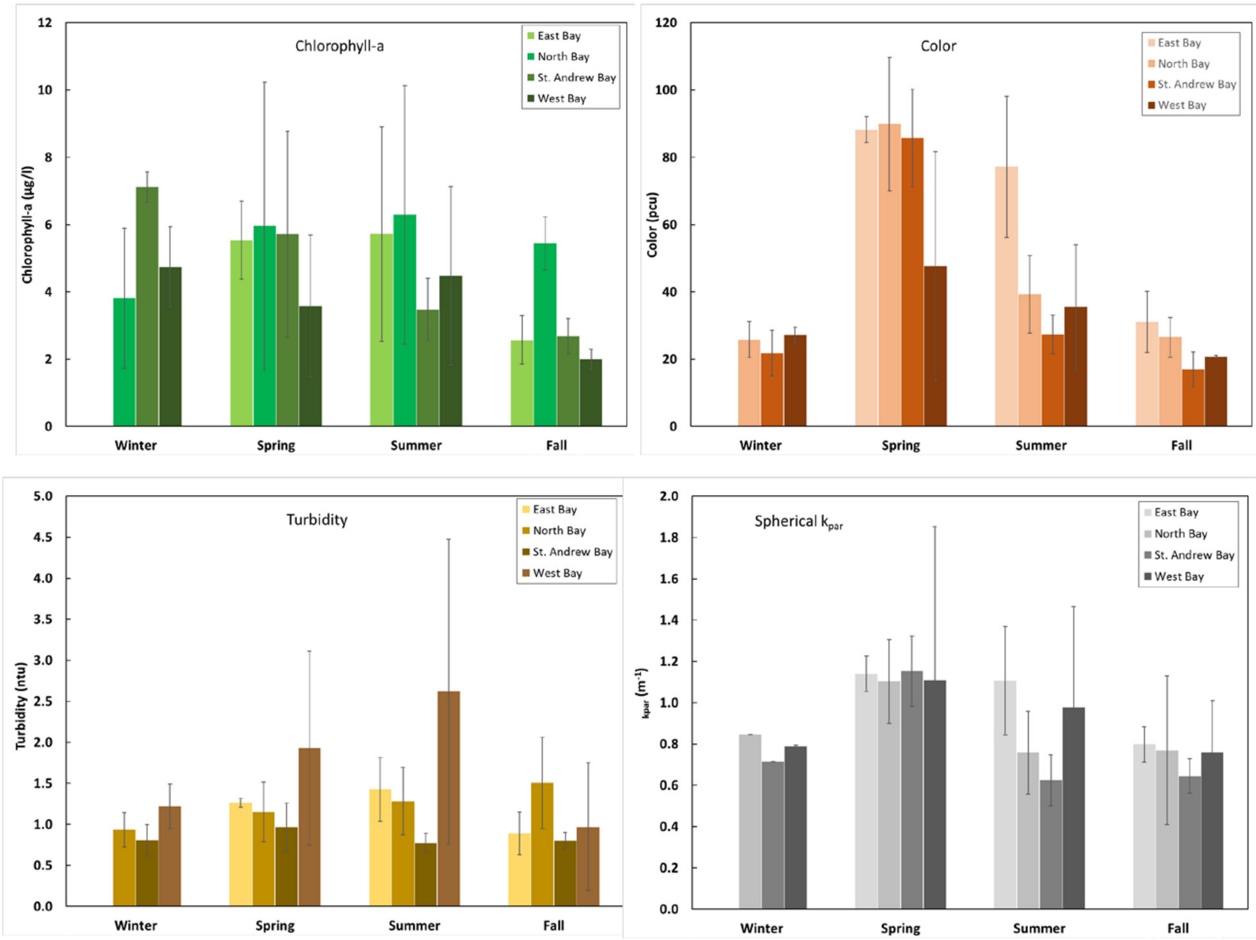

Figure 5. Mean (±2 standard error) values of chlorophyll-a, color, turbidity, and spherical kpar in subregions of St. Andrew Bay, in winter, spring, summer, and fall, 2016.

each sampling site. In each quadrat, seagrass and macroalgal species were identified, and bottom cover was estimated using a modification of the Braun-Blanquet technique. FWRI also measured water quality and clarity parameters, including salinity, water temperature, water depth, Secchi depth, pH, dissolved oxygen concentration, and light attenuation. Samples were collected for measurement of chlorophyll-a concentration, turbidity, total suspended solids, and water color.

Personnel from the FDEP Central Panhandle Aquatic Preserves (CPAP) resumed monitoring in the summer of 2015 and fall of 2016. This program will continue in spring and fall as conditions permit. In summer 2015, volunteers for the SABMRA determined the feasibility of using low-cost side-scan sonar to map seagrass beds in St. Andrew Bay.

As part of the Roadblocks to Seagrass Recovery project, the SABMRA conducted field monitoring at 71 locations in 2016 (Figure 6). Sites were not randomly chosen because all locations had some seagrass present and were, on average, in 1.2 m of water. At each site, ten 50-cm × 50-cm (0.25 m^2) quadrats were assessed for seagrass basal area, and an underwater photograph was taken of each quadrat.

Water quality has been monitored in the St. Andrew Bay system since 1990, and data analysis comparing the water quality of WB-BOWL, WB-ARM, and St. Andrew Bay has been completed.

Productivity of turtlegrass

Field measurements of the productivity of turtlegrass were carried out at six locations in St. Andrew Bay by scientists from SABMRA once in June 2016 and once in July 2016 (see Figures 1, 2). At each location, 4 quadrats, 20 cm on a side (0.04 m^2), were anchored into a turtlegrass bed within 1 m of each other using 6-inch sod staples. Each shoot of turtlegrass in a quadrat was punched just above the end of the short shoot at the basal meristem with a 20-gauge hypodermic needle, following the method of Zieman and Zieman (1989). After about 10 days, all the seagrass material, both above and below the sediment

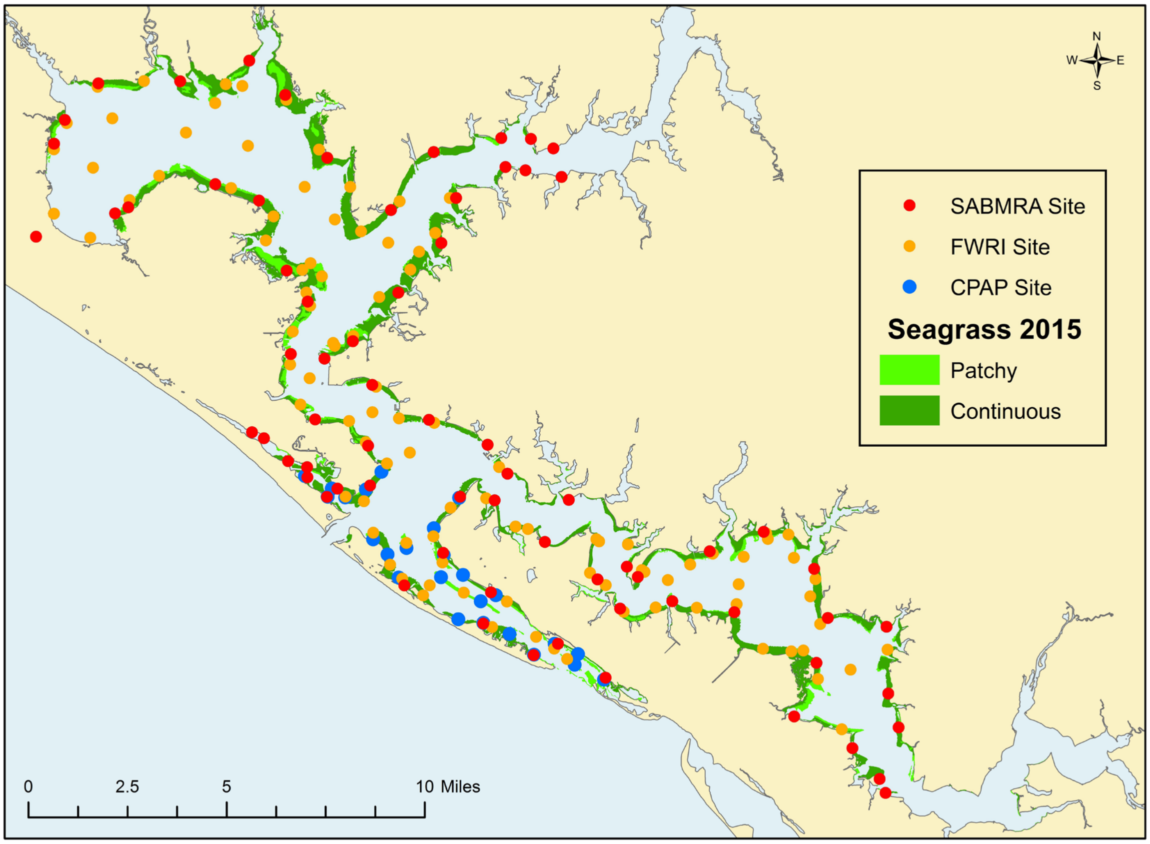

Figure 6. Seagrass cover and sites of field monitoring by SABMRA in summer 2016; FWRI in 2009, 2011 and 2014; and Central Panhandle Aquatic Preserves (CPAP) in 2015 and 2016.

surface in each quadrat, was carefully harvested, chilled, and transported to the laboratory for processing.

In the laboratory, punched turtlegrass shoots were separated from the rest of the seagrass material, and the length, width, and punch translocation distance were measured for each blade in each shoot, with up to 20 punched shoots assessed for each quadrat. The location of the punch hole in the oldest blade was used as the zero or reference position for measuring extension of the remaining younger blades. The remaining seagrass tissues were separated into blade, short shoot, root and rhizome fractions and into live and dead fractions. Blades and short shoots were designated as above-sediment and roots and rhizomes as below-sediment. Biomass was gently rinsed with tap water and dried for 5–7 days at 50°C and then weighed. The total number of shoots, both live and dead, of each species of seagrass in each quadrat was also recorded, as was the presence of macroalgae.

Optical water quality measurements

Measurements of optical water quality parameters—chlorophyll-a, color, turbidity, total suspended solids (TSS), and light attenuation—have been part of the field assessments of seagrasses in the SIMM program since 2004. The amount of sunlight reaching the bottom is often the most important factor determining the survival of seagrass communities, and the attenuation of light in the water column results from reflection, diffraction, and absorption of light by water itself, by the amount, quality, and size of particles in the water, and the amount of color added to the water column by the presence of colored dissolved organic matter (CDOM). The quantity and character of particles in the water are estimated by the measurement of chlorophyll-a as a proxy for phytoplankton, by measurement of TSS as a gravimetric estimate of the number of particles in the water, and by the measurement of turbidity, which estimates light scattering by particles as well as the quantity of particles present. The color of the water can be measured by light absorption of a filtered water sample at 440 nm (color) or, for CDOM, by light absorption over 300–600 nm.

Chlorophyll-a concentrations were determined by filtering triplicate 60-ml aliquots of surface water through 25-mm-diameter GFF glass fiber filters in the field. Each filter was stored in a microcentrifuge vial and immediately frozen on liquid nitrogen. In the laboratory, filters were transferred to an ultra-low-temperature freezer and held at -60°C until analysis. To measure the amount of chlorophyll-a, filters were extracted in 10 ml of methanol in the dark for 40 hours at 4°C. On the day of analysis, methanol extracts were centrifuged at 3,500 rpm for 20 minutes to remove filter fibers from the extract. Fluorescence of each extract was measured using a Turner Designs model 10-AU-005 fluorometer following the methods of Welshmeyer (1994). Calibration of the fluorometer used fresh spinach extracts and the trichromatic equations of EPA method 446.0 (Arar 1997).

Water samples for the measurement of color, turbidity, and TSS were collected by triple rinsing each sample bottle with site water and then filling each bottle nearly full. Samples were kept on ice or refrigerated until analysis. To measure color, water was filtered through a 0.22-μm membrane filter. Light absorbance at 440 nm of the filtered sample was determined using a 10-cm cell path in a Hitachi U-2900 spectrophotometer after Kirk (1976) and Gallegos et al. (1990). Absorbance of certified color standards was used to estimate color in platinum cobalt units (pcu). Turbidity was measured nephelometrically on a Hach 2100Q turbidimeter using calibrated standards following method 214 A of *Standard Methods for the Examination of Water and Wastewater* (1985), and units were nephelometric turbidity units (ntu). TSS was measured gravimetrically following method 2540 D of *Standard Methods* (1985) by filtering water samples through combusted, tared GFC glass fiber filters. Filters were then dried at 50°C for at least five days and re-weighed using a 5-place Mettler balance.

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