St. Joseph Bay: Impact of Hurricane Michael on seagrasses

Contacts: Laura Yarbro, Paul Carlson, Elizabeth Johnsey, and Allison Senne, Florida Fish and Wildlife Conservation Commission (mapping and monitoring); Jonathan Brucker, Central Panhandle Aquatic Preserves, Florida Department of Environmental Protection (monitoring)

General assessment

Seagrasses covered 7,121 acres in St. Joseph Bay in 2019, a loss of 609 acres since 2017 (Table 1). Mean acreage was 7,570 acres from 2003 through 2019, with no obvious trend. Most of the seagrass beds occur in the southern and southeastern parts of the bay (Figure 1). Turtlegrass (*Thalassia testudinum*) dominates beds in St. Joseph Bay, and manateegrass (*Syringodium filiforme*) and shoalgrass (*Halodule wrightii*) occur infrequently. Monitoring data from 2008 through 2019 indicated that the frequency of occurrence of turtlegrass declined in 2018 and 2019 in southern and western portions of the bay. Occurrence of manateegrass and shoalgrass varied among years, and these species occurred more frequently in eastern and northwestern parts of the bay (see Table 2). The density of all seagrass species was highest in 2008 and 2009 and has declined since that time (see Figure 4). Propeller scarring affects 30% of seagrass beds, and severe scarring occurs commonly in the southern bay (Heck et al. 2018). Generally excellent optical water quality indicates that factors other than available light are stressing seagrass beds; suggested stressors are grazing by sea urchins and turtles, heavy epiphyte levels on seagrass, which would limit the amount of light that reaches blade tissues, and propeller scarring. Large populations of sea urchins (*Lytechinus variegatus*) and swaths of mowed-down grass beds were observed in southern parts of the bay in July 2019 through June 2020.

The change in seagrass status between the 3rd edition of the SIMM chapter (Johnsey et al. 2018) and this update shows that seagrass acreage, frequency of occurrence, and thinning of beds continue to decline but that the species composition of beds has remained stable. The status of stressors has not changed but impacts from urchin grazing events in 2019 have not yet been evaluated. Overall seagrass trends continue to decline.

Seagrass status and potential stressors in St. Joseph Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Red	Decreasing	8% loss, 2017–2019
Seagrass meadow texture	Orange	Thinning	Hurricane Michael; urchin grazing, scarring
Seagrass occurrence	Yellow	Declining in some areas	
Seagrass species composition	Green	Stable	Mostly turtlegrass
Overall seagrass trends	Orange	Declining	Urchin grazing; scarring
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Impacted by storms	Storminess since 2012; development in watershed
Nutrients	Yellow	Increasing	
Phytoplankton	Yellow	Increasing?	
Natural events	Yellow	Episodic	Harmful algal blooms, sea urchins, storms
Propeller scarring	Red	Extensive	Severe in southern bay

Figure 1. Seagrass cover in St. Joseph Bay, 2019.

Hurricane Michael

Hurricane Michael made landfall as a category 5 (Saffir-Simpson scale) storm shortly after noon on October 10, 2018, near Mexico Beach and Tyndall Air Force Base (AFB), 16 km (10 miles) west northwest of the center of St. Joseph Bay. Because St. Joseph Bay was east of landfall, the beaches, shorelines, islands, and structures on the St. Joseph Bay peninsula sustained extreme damage due on onshore winds and storm surge. Winds at landfall were estimated to be 161 mph at Mexico Beach, and heights of storm surge inundation were 9–14 feet above ground level from southeast of Tyndall AFB west of the bay to the community of Port St. Joe on the eastern shore of the bay (Beven et al. 2019). Rainfall totals inland varied between 4 and 11 inches. Storm surge and currents opened an inlet or cut that was 200 feet wide and up to 10 feet deep (Florida Department of Environmental Protection 2018) at Eagle Harbor on the St. Joseph peninsula between the bay and the Gulf of Mexico (Figure 2). Longshore sediment transport carried sand into seagrass beds in the bay. By April 2019, the inlet closed on its own, leaving a low-lying sandy area. Shortly after the passage of Hurricane Michael and continuing at 6-month to annual intervals, researchers assessed the cover of seagrass in beds in the bay.

Figure 2. Aerial image of the cut at Eagle Harbor, created by the passage of Hurricane Michael on October 10, 2018, and imagery of the same location in April 2019, just after the cut closed. Note brown water flowing out of the bay through the cut on October 11, 2018.

Geographic extent

St. Joseph Bay is in Gulf County in the central Panhandle. The bay is bounded on the eastern shoreline by the city of Port St. Joe and St. Joseph Bay State Buffer Preserve lands and on the west by the St. Joseph Peninsula and St. Joseph Peninsula State Park. The total surface area of the bay at mean high water is approximately 42,872 acres (Hemming et al. 2002). The watershed of the bay is small, consisting of lands immediately adjacent to the bay, and the bay does not receive much freshwater inflow (NWFWMD 2017). The bay is listed by the Florida Department of Environmental Protection (FDEP) as an impaired waterbody for bacteria and nutrients. Residences on the St. Joseph Peninsula use septic systems for domestic waste disposal, and much of the residential development around Port St. Joe also likely relies on septic systems.

More information about the St. Joseph Bay watershed is available in the St. Andrew Bay Watershed Surface Water Improvement and Management Plan (NWFWMD 2017).

Seagrass mapping assessment

Seagrasses covered 7,121 acres in 2019, based on interpretation of imagery collected in the spring (Table 1). This is a decrease of 609 acres from acreage measured in imagery acquired in fall 2017. The mean acreage of seagrasses between 2003 and 2019 was 7,570 acres (std. dev. = 433). The proportion of continuous versus patchy beds varied widely across mapping efforts, and some of the variation might represent differences in mapping resolution. The same mapping methods were used in 2010, 2015, and 2017, and for those years, patchy beds were 17%, 6%, and 10% of total acreage, respectively. The increased proportion of patchy beds in 2019 (47%) might represent changes due to hurricane damage and grazing by large populations of sea urchins.

Table 1. Mapping estimates of continuous and patchy seagrass beds in St. Joseph Bay, 1992, 2003, 2010, 2017, 2019.

	Seagrass acreage					Change, 2015–2017	
Bed texture	1992	2003	2010	2015	2017	Acres	%
Continuous	5,272	1	6,849	7,173	6,970	-203	-3.0%
Patchy	3,739	7,122	1,435	481	760	279	19%
Total	**9,011**	**7,123**	**8,284**	**7,594**	**7,730**	**136**	**1.6%**

		Change, 2017–2019	
Bed texture	2019	Acres	%
Continuous	3,748	-3,222	-46.2%
Patchy	3,373	2,613	343.8%
Total	**7,121**	**-609**	**-7.9%**

Monitoring assessment

Several agencies have conducted field monitoring of seagrasses in St. Joseph Bay. The Coastal and Managed Areas (CAMA) program of the FDEP monitored seagrasses twice a year from 2002 through 2008 and then annually in 2009 and 2010. This program resumed in the summer of 2015, and the Central Panhandle Aquatic Preserves (CPAP) continues this effort. The Fish and Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Conservation Commission conducted field assessments in late summer/fall in 2008, 2009, 2011, 2014, 2018, and 2019 using a randomly-selected spatially-distributed sample design. Staff from the Dauphin Island Sea Lab (DISL) assessed seagrasses in June 2016 but sampled only where seagrasses were present.

Seagrass cover data were used to calculate the frequency of occurrence (FO) and the mean cover of each species of seagrass present. Baywide, the FO of turtlegrass and bare areas showed little variation over the period of record (Table 2). Manateegrass and shoalgrass occurred at low and variable frequencies from 2008 through 2019. In Table 2, values from 2008 through

2019 can be compared, with the exception of data from 2016. FO of species in 2016 are shown only to indicate what species were present, because 2016 assessments were made only in seagrass beds. Turtlegrass was the dominant seagrass in all years, occurring most frequently (in 58–67% of quadrats). The FO of turtlegrass was very stable over the period of field assessment, as shown by the small coefficient of variation (4.5%) around a mean of 64.6%. The percentage of bare quadrats varied from 30% in 2008 to 37% in 2018, with a mean of nearly 33%.

Table 2. Frequency of occurrence of seagrass species and bare quadrats calculated from data collected by FWRI and collaborators throughout St. Joseph Bay, 2008, 2009, 2011, 2014, 2016, 2018, 2019. In 2016, quadrats were assessed only where seagrass was present. CoV = coefficient of variation.

		Frequency of occurrence (%)			
Year	# quads	Turtle-grass	Manatee-grass	Shoal-grass	Bare
2008	328	67.4	2.4	3.7	29.9
2009	424	58.7	0.71	7.3	36.6
2011	480	66.0	5.4	2.9	30.8
2014	490	66.1	6.9	5.5	29.8
2016*	120	99.2	28.3	3.3	
2018	430	63.2			36.7
2019	520	66.2	1.9	2.9	33.3

*sampled only where seagrass present

Mean**	64.6	3.5	4.5	32.8
Std. dev.**	2.91	2.32	1.72	2.92
CoV**	4.5%	67%	39%	8.9%

**2016 data not included

Seagrass cover assessed in 0.25 m^2 quadrats by CPAP generally resulted in higher values of FO for each seagrass species than those calculated from FWRI data (Table 3). This was especially true for manateegrass and shoalgrass. As observed in FWRI data, the occurrence of turtlegrass was high (69–92%), and the occurrence of manateegrass and shoalgrass was much lower. The presence of drift red algae was assessed in quadrats in all years except 2005, and the FO for these macroalgal species varied from year to year and was very high (48%) in 2008.

Table 3. Frequency of occurrence (FO) of seagrass species, drift red macroalgae, and bare quadrats calculated from data collected by CPAP in St. Joseph Bay, 2005–2009, 2015–2019. Four quadrats were assessed at each site. Cover assessment was completed twice a year, in spring and summer/fall, in 2005, 2008, 2015, 2016, and 2019. During other years, assessment was completed once in summer or fall.

Year	# quads	Turtle-grass	Manatee-grass	Shoal-grass	Drift red algae	Bare
2005	108	69.4	25.9	13.0		16.7
2006	32	87.5	25.0	9.4	9.4	
2007	16	81.3	43.8	6.3	6.3	
2008	64	92.2	21.9	15.6	48.4	
2009	88	90.9	12.5	4.5	13.6	
2015	60	88.3	11.7	11.7	21.7	1.7
2016	192	78.1	5.2	13.0	17.2	9.9
2017	100	78.0	8.0	17.0	13.0	8.0
2018	100	75.0	6.0	13.0	12.0	14.0
2019	240	73.8	10.4	10.4	17.1	15.4

To examine post-Michael changes in seagrasses at a finer spatial resolution, the bay was divided into seven sectors (Figure 3). Using FWRI and DISL data, the FO of seagrass species in each sector was determined. Turtlegrass was the most frequently occurring species in all sectors, and it was the only seagrass species found in the southeast sector for the period of record (Table 4). In the west and south sectors, shoalgrass occurred at low frequencies in some years. In the east and northwest sectors, manateegrass and shoalgrass were observed during most sampling periods at the greatest FO for those species in the bay. Seagrass disappeared from the east sector in 2019; this sector was adjacent to the town of Port St. Joe and received intense winds and storm surge from Hurricane Michael in October 2018. The FO of turtlegrass declined between 2018 and 2019 in the south and west sectors, regions where urchin grazing was observed during field sampling in the summer of 2019.

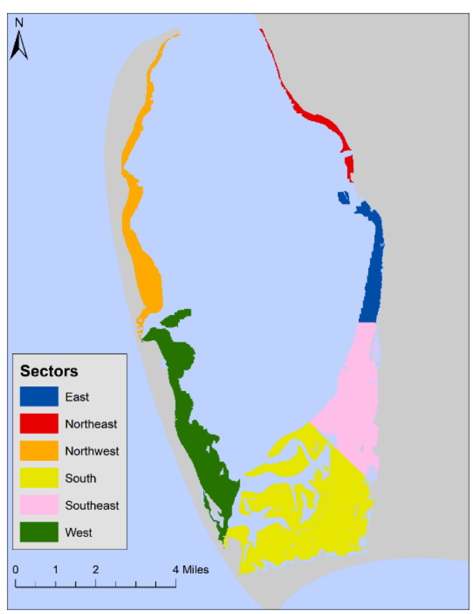

Figure 3. Subdivision of St. Joseph Bay into sectors.

Table 4. Frequency of occurrence of seagrass species and bare quadrats in sectors of St. Joseph Bay, 2008, 2009, 2011, 2014, 2016, 2018, 2019. In 2016, quadrats were assessed only where seagrass was present.

Sector	Year	# Quads	Turtle-grass	Manatee-grass	Shoal-grass	Bare
Northeast						
	2011	20			35	65
	2016*	5	100	100		
East						
	2008	8				100
	2009	44	27.3	6.8	18.2	54.5
	2011	30	36.7	60	16.7	40
	2014	50	32	20	14	44
	2016*	15	93.3	93.3	20	0
	2019	10				100
Southeast						
	2008	16	25			75
	2009	76	80.3			18.4
	2011	120	75			25
	2014	80	75			25
	2016*	15	100			0
	2018	35	62.9			37.1
	2019	90	76.7			23.3
South						
	2008	196	80.1		6.1	15.8
	2009	140	63.6		2.1	35.7
	2011	170	62.9			37.1
	2014	130	60	2.3	3.8	38.5
	2016*	30	100			0
	2018	350	60			40
	2019	200	49.5			50.5
West						
	2008	56	51.8			62.5
	2009	96	58.3		9.4	34.4
	2011	90	66.7		1.1	33.3
	2014	120	62.5		11.7	36.7
	2016*	20	100			
	2018	45	88.9			11.1
	2019	130	76.2		3.8	23.8
Northwest						
	2008	44	70.5	18.2		27.3
	2009	68	45.6		16.2	50
	2011	50	98	16	2	0
	2014	110	86.4	19.1	0.9	9.1
	2016*	35	100	42.9	2.9	0
	2019	90	85.6	11.1	11.1	11.1

*sampled only where seagrass present

In addition to identifying the seagrass and macroalgal species present in a quadrat, FWRI also estimated the percentage of the quadrat covered by each species; this estimate is called percent cover, and the technique is similar to the Braun-Blanquet method. While small declines in the FO of seagrass species were observed in 2018 and 2019, estimates of mean cover have decreased sharply (Figure 4). Seagrass beds in the eastern sector of the bay contained turtlegrass, manateegrass, and shoalgrass at varying densities between 2009 and 2016. This sector was not monitored in 2018 and was devoid of seagrasses at monitoring locations in 2019 (Table 4). Turtlegrass is the sole seagrass species occurring in the southeast sector (see also Table 4) and densities show a general downward trend. Most of the acreage of seagrass in St. Joseph Bay occurs in the southeast, south, and west sectors of the bay (Figure 1), and densities in these sectors have declined since 2014. Shoalgrass and manateegrass occurred in some years in the south and west sectors with varying densities.

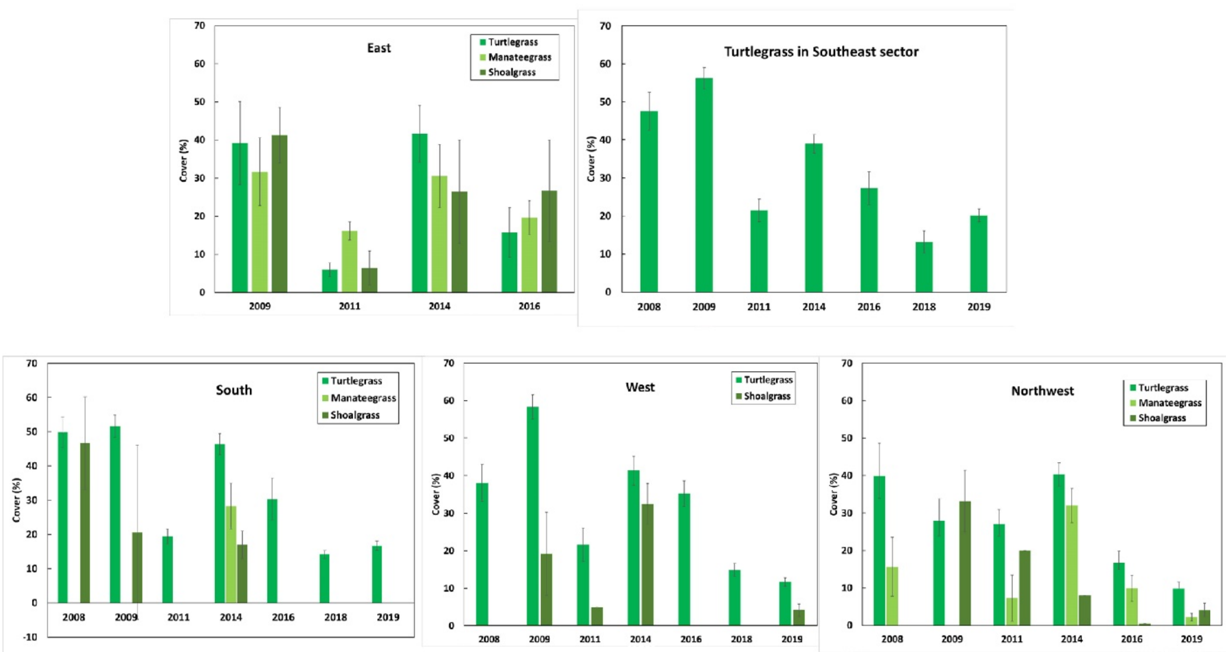

Figure 4. Mean cover (± 2 standard error) of seagrasses in sectors of St. Joseph Bay, from data gathered by FWRI and DISL. The northeast sector is not shown because seagrasses were assessed there only in 2011 and 2016.

Since 2014, sharp declines in the mean cover of turtlegrass, the dominant species in the bay, occurred in similar fashion in the southeast, south, and west sectors (Figure 5). Highest densities (52–58%) were observed in 2009; densities declined by more than half in 2011 and then increased in 2014, to 39–46%. Since 2014, the mean cover of turtlegrass in all three sectors has declined about 5% per year, with the greatest change observed between 2016 and 2018.

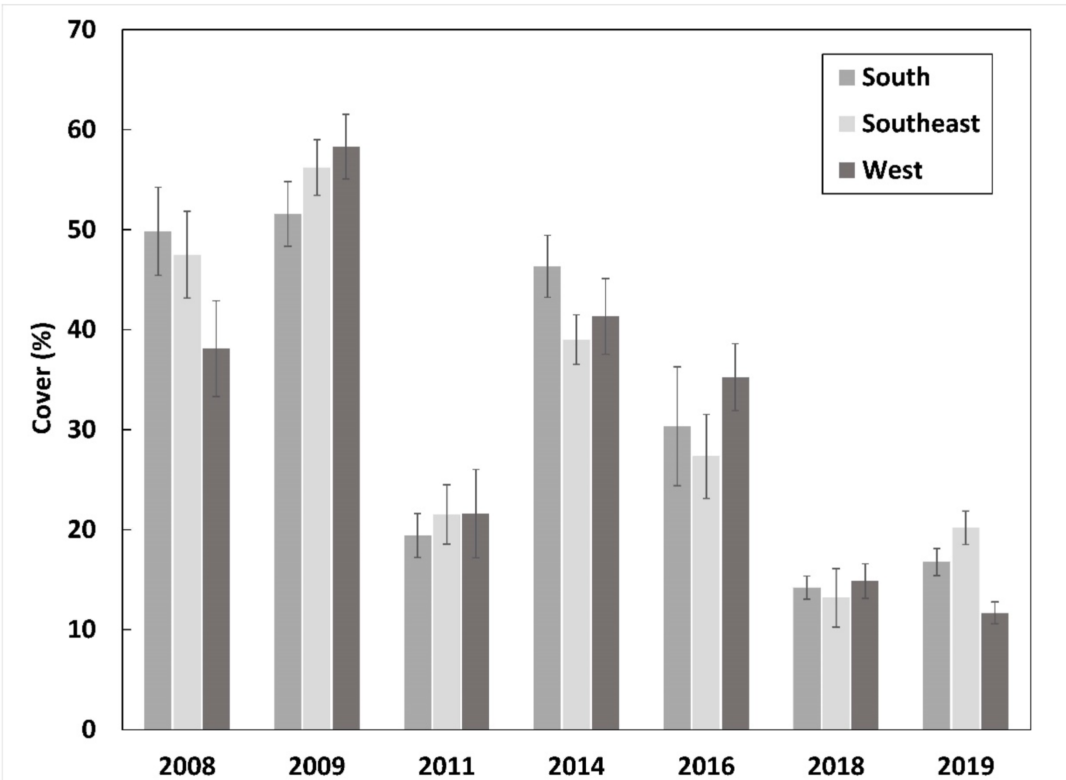

Figure 5. Mean cover (± 2 standard error) of turtlegrass in the south, southeast, and west sectors of St. Joseph Bay, from data gathered by FWRI and DISL, 2008, 2009, 2011, 2016, 2018, 2019.

Optical water quality

As part of the Hurricane Michael assessment of the Roadblocks to Seagrass Recovery project, scientists from FWRI and CPAP collected water samples and field data monthly in 2019 throughout the bay to measure the optical water quality parameters chlorophyll-a, color, turbidity as well as salinity and water temperature. In addition, FWRI staff collected water samples in March and July 2019 from streams discharging into the bay. Analyses of stream water samples included conductivity, water temperature, chlorophyll-a, color, and turbidity. Generally, optical water quality is excellent in St. Joseph Bay, resulting low light attenuation in the water column and sufficient light available for seagrass growth (Johnsey et al. 2018). Seasonal mean color, in particular, was low in bay waters during 2014–2017. Mean turbidity was greater when chlorophyll-a concentrations were elevated. In 2019, monthly mean color values were slightly higher in the winter and spring when salinities were lower (Table 5). Overall, mean values measured in 2019 were not different from values measured in previous years. The tributary stream, however, had much higher levels of chlorophyll-a, turbidity, and color in March and July 2019 than mean values measured in bay waters during those months. The watershed of St Joseph Bay is very small compared with other estuarine systems in the Panhandle (Northwest Florida Water Management District 2017), and runoff effects on bay optical water quality are sporadic and associated with incoming freshwater after large amounts of rain in the watershed.

Table 5. Monthly means of salinity, turbidity, color, and chlorophyll-a in St. Joseph Bay in 2019, and monthly means of conductivity, turbidity, color, and chlorophyll-a in the stream discharging into bay waters in March and July 2019.

St. Joseph Bay

Month	Salinity (psu)	Turbidity (ntu)	Color (pcu)	Chlorophyll-a (µg/l)
February	24.55	1.45	15.38	3.834
March	28.42	1.03	10.02	3.715
April	29.05	1.40	9.04	2.147
May	29.21	1.02	9.23	1.896
June	31.93	1.59	5.67	3.560
July	31.89	1.31	6.43	2.961
August	29.95	1.41	13.64	3.657
September	32.01	2.31	11.99	4.055
October	31.80	1.52	9.54	3.344
November	30.99	0.76	6.58	1.484

Tributary stream

Month	Conductivity (µS)	Turbidity (ntu)	Color (pcu)	Chlorophyll-a (µg/l)
March	522	6.84	68.37	15.81
July	10,500	4.86	55.70	8.730

Mapping methods, data, and imagery

Natural color aerial imagery collected by the Florida Department of Regulation in the spring of 2019 was interpreted and mapped by estimating percent cover of seagrass inside cells 20 m by 20 m (0.1 acre). In mapping software, a 20m x 20m grid was superimposed on georectified imagery, and the percent cover of continuous or patchy seagrass in each cell was estimated.

Mapping data for 2017 were acquired from natural color imagery collected by the National Agricultural Imagery Program (NAIP) during the fall. Quantum Spatial Inc. (St.

Petersburg) interpreted and mapped the imagery with a minimum mapping unit of 0.25 acres. The Florida Land Use Cover Classification System (FLUCCS; Florida Department of Transportation 1999) was used to classify bottom features.

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 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 a USGS NWRC-derived classification scheme based on the Coastwatch Change Analysis Project Coastal Land Cover Classification system of the National Oceanic and Atmospheric Administration (NOAA).

In 1992, seagrass distribution along the Gulf coast of Florida from Anclote Key to the Alabama-Florida line was interpreted from natural color photographs (1: 24,000 scale). The joint NWRC/NOAA seagrass mapping protocol was used, and the abundance of seagrasses in St. Joseph Bay was estimated at 9,740 acres. Sargent et al. (1995) used the 1992 and 1993 aerial photography of St. Joseph Bay to estimate the total area of seagrass beds and the area damaged by propeller scarring.

Monitoring methods and data

Seagrasses were monitored in St. Joseph Bay each year from 2002 through 2010 by personnel from the Aquatic Preserve Program of the FDEP. Seagrass and macroalgal cover were estimated by species in four quadrats at each of 25 sites throughout the bay. Other data collected included canopy height, epiphyte coverage and type, sediment type, animals observed in quadrats, and depth; underwater photographs or video were also taken. Additional samples included biomass cores (taken occasionally) and seagrass blades, collected for quantitative estimates of epiphyte loads. Water quality measurements included dissolved oxygen concentration, temperature, salinity, pH, turbidity, Secchi depth, and light attenuation.

Other agencies monitor seagrasses in St. Joseph Bay (Figure 6). FWRI included St. Joseph Bay in its summer monitoring program in 2008, 2009, 2011, 2014, 2018, and 2019. Forty to 60 spatially-distributed, randomly-located sites were chosen using a design developed by the U.S. Environmental Protection Agency Environmental Monitoring and Assessment Program (EPA EMAP). Using ArcMap, a spatial layer composed of a hexagonal grid was superimposed over the area where water depth was <3 m; the grids to be sampled and the location of a site within each grid were chosen randomly. The design ensured full spatial coverage of the potential seagrass habitat, but the randomized selection of a point within each delineated hexagon permitted the use of parametric statistics. At each sampling site, seagrass and macroalgal cover were estimated in ten 0.25-m^2 quadrats using a modification of the Braun-Blanquet technique. The presence and numbers of scallops and sea urchins in each quadrat were also recorded. In addition to seagrass field assessment, personnel measured standard field water quality parameters of salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentration, as well as the OWQ parameters light attenuation, chlorophyll-a concentration, turbidity, total suspended solids, and water color.

Beginning in May 2015, personnel from the Central Panhandle Aquatic Preserves (CPAP) of the FDEP resumed monitoring of seagrass beds at 27 locations in St. Joseph Bay (Figure 6). Since that time, field monitoring has been done twice a year most years, in late spring/early summer and in fall. At each site, 4 quadrats are assessed for cover of seagrasses and macroalgae using the Braun-Blanquet technique; in addition, scientists measure the length and width of a subset of turtlegrass blades, determine the water depth, and count scallops and sea urchins. Dissolved oxygen concentration, pH, salinity, water temperature, and Secchi depth are measured at each site.

In June 2016, scientists from DISL conducted field monitoring at 24 sites, all in seagrass beds. Seagrass cover was estimated in 5 quadrats at each site.

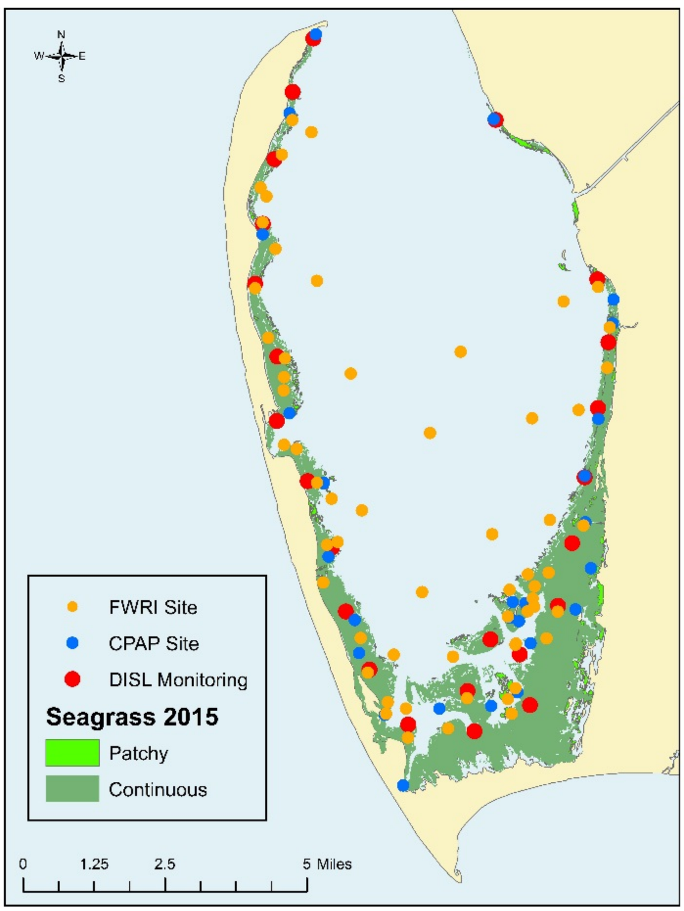

Figure 6**.** Distribution of patchy and continuous seagrass in 2015 and locations of sites monitored by FWRI, the Central Panhandle Aquatic Preserves (CPAP) and DISL in St. Joseph Bay.

Optical water quality measurements

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 the measurement of total suspended solids (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.

During 2019, staff from the FWRI Eastpoint laboratory and the CPAP collected water samples monthly from 19 sites distributed throughout the bay. The water samples were chilled on ice and shipped overnight for processing and analysis at FWRI in St. Petersburg. In March and July 2019, water samples were collected by FWRI from the mouth of the St. Joe Canal.

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-2910 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.

References

Arar EJ. 1997. Method 446.0: In vitro determination of chlorophyll a, b, c, and pheopigments in marine and freshwater algae by visible spectrophotometry. Publication EPA/600/R-15/005, U.S. Environmental Protection Agency, Washington, DC. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=309415. Accessed June 2020.

Beven II JL, Berg R, Hagen A. 2019. Hurricane Michael (AL 142018). National Hurricane Center Tropical Cyclone Report. Miami, 86 p. https://www.nhc.noaa.gov/data/tcr/AL142018_Michael.pdf. Accessed April 2020.

Florida Department of Environmental Protection. 2018. Preliminary Hurricane Michael post-storm beach conditions and coastal impact report. Division of Water Resource Management, Florida Department of Environmental Protection, Tallahassee, 81 p. https://floridadep.gov/sites/default/files/MichaelPreliminaryReport.pdf. Accessed April 2020.

Florida Department of Transportation. 1999. Florida Land Use, Cover and Forms Classification System, A Handbook. Division of Surveying and Mapping, Geographic Mapping Section, Tallahassee.

Gallegos CL, Correll DL, Pierce JW. 1990. Modelling spectral diffuse attenuation, absorption, and scattering coefficients in a turbid estuary. Limnology and Oceanography 35:1486–1502.

Hemming JM, Brim M, Jarvis RB. 2002. Survey of dioxin and furan compounds in sediments of Florida Panhandle bay systems. Publication Number PCFO-EC 02-01, U.S. Fish and Wildlife Service Panama City, Florida.

Hill VJ, Zimmerman RC, Bissett WP, Dierssen H, Kohler DDR. 2014. Evaluating light availability, seagrass biomass and productivity using hyperspectral airborne remote sensing in Saint Joseph's Bay, Florida. Estuaries and Coasts 37:1467–1489. DOI 10.1007/s12237-013-9764-3.

Johnsey E, Carlson PR, Byron D, Heck, K, Brucker J, Kebart K. 2018. Summary report for St. Joseph Bay. pp. xx–xx, Yarbro L, Carlson PR, (eds.). Seagrass Integrated Mapping and Monitoring Report No. 3. Fish and Wildlife Research Institute Technical Report TR-17 version 3, Florida Fish and Wildlife Conservation Commission, St. Petersburg.

Kirk JTO. 1976. Yellow substance (gelbstoff) and its contribution to the attenuation of photosynthetically active radiation in some inland and coastal south-eastern Australia waters. Australian Journal of Marine and Freshwater Research 27:61–71.

Northwest Florida Water Management District. 2017. St. Andrew Bay Watershed Surface Water Improvement and Management Plan. Northwest Florida Water Management District. Havana, Florida. https://www.nwfwater.com/Water-Resources/Surface-Water-Improvement-and-Management/St.-Andrew-Bay. Accessed April 2020.

Sargent, FJ, Leary TJ, Crewz DW, Kruer CR. 1995. Scarring of Florida's seagrasses: assessment and management options. Florida Marine Research Institute Technical Report TR-1, Florida Department of Environmental Protection, St. Petersburg.

Standard Methods for the Examination of Water and Wastewater. 1985. 16th edition. American Public Health Association, Washington, D.C.

Welshmeyer NA. 1994. Fluorometric analysis of chlorophyll a in the presence of chlorophyll b and phaeopigments. Limnology and Oceanography 39:1985–1992.

Acknowledgments

This report results from a collaborative effort among several groups. Assessment of seagrass cover, status, and stressors resulted from the contribution of many field and laboratory staff. Hard workers in the seagrass group at FWRI included Sheila Scolaro, Mike Poniatowski, Allison Patranella, Michael Mosser, and Grayson Austin. Crystal York kept our budgets in working order, and Jim Kozlowski and Jeanne Halma provided excellent administrative support. Staff from the FWRI Eastpoint Laboratory who collected monthly water samples included Kelly Williams, Cameron Baxley, Zoe Cross, Sarah Cole, Matthew LaGanke, Elizabeth Pudlak, and Sarah Sharkey. At CPAP, field assistance was provided by Megan Christopher, Nikkie Cox, Katie Davis, Jessica Stuczynski, Lauren Christensen, and Jordan Williams. Data collection and mapping by FWRI was supported by a grant from the Gulf Environmental Benefits Fund of the National Fish and Wildlife Federation (FN003), and data analysis and report preparation was supported by a grant from the State Wildlife Grants Program (F19AF00401).