# St. Andrew Bay: Impact of Hurricane Michael on seagrasses

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

## General assessment

Acreage of seagrasses in St. Andrew Bay was stable between 2003 and 2017. Imagery acquired in 2017 showed that seagrasses covered 10,913 acres, a gain of 126 acres since 2015 (Table 1). Seagrass beds are distributed along the shoreline throughout the bay (Figures 2–4), and West Bay had the greatest area of seagrasses in 2017. While total acreage remained stable between 2015 and 2017, about 1,000 acres changed from continuous to patchy beds. West Bay and East Bay gained 20 and 156 acres, respectively, between 2015 and 2017, while North Bay and central St. Andrew Bay (which includes Grand Lagoon) lost 33 and 17 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 about 1,300 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. Manateegrass disappeared from the central bay between 2016 and 2019. The frequency of occurrence (FO) of shoalgrass remained stable in this region between 2014 and 2019. The FO of turtlegrass increased between 2014 and 2019 (see Table 2). In West Bay, the FO of turtlegrass and shoalgrass was higher in 2019 than in 2014. Heavy rains and resulting runoff reduce water clarity in the bay; heavy rainfall events since July 2012 and runoff due to heavy rain associated with Hurricane Michael continue to affect bay waters (see Figure 2). Propeller scarring affects about 32% of seagrass beds in St. Andrew Bay and is particularly extensive near the inlet to the Gulf of Mexico (Fitzhugh et al. 2018).

Assessment of the effects of Hurricane Michael on seagrass beds in St. Andrew Bay is limited at present to in-water cover assessments. Based on cover assessment, possible effects of the hurricane due to runoff) were to continue or accelerate ongoing losses in species composition and density of seagrass beds. Physical damage due to sand overwash and scouring near the barrier islands might show up in recent imagery and will be assessed.

Changes in seagrass status between the 3rd edition of the SIMM chapter (Fitzhugh et al. 2018) and this update are observed in declines in seagrass meadow texture, frequency of occurrence, and in species composition between the two assessments. While mean cover or density of seagrass beds declined between 2009 and 2016, increasing patchiness was a greater concern in the assessment published in the 3rd edition. Since 2016, mean cover continued to decrease, some species disappeared from some locations in 2019, and the frequency of occurrence also declined. Overall recent seagrass trends are likely declining, whereas in 2016, seagrass beds were considered stable across the bay.

| Seagrass status and potential stressors in St. Andrew Bay | | | |
|---|---|---|---|
| **Status indicator** | **Status** | **Trend** | **Assessment, causes** |
| Seagrass acreage | Green | Stable | Throughout bay |
| Seagrass meadow texture | Orange | Thinning cover | Changes since 2009 |
| Seagrass occurrence | Yellow | Some species show declines | Declines in shoalgrass; losses of manateegrass |
| Seagrass species composition | Yellow | Loss of some species in 2019 | Primary species are turtlegrass and shoalgrass |
| Overall seagrass trends | Yellow | Declining? | Impacts from storm runoff, scarring |
| **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 | Orange | Episodic; Hurricane Michael | Storm runoff, tropical cyclones |
| Propeller scarring | Orange | Extensive | Shallow areas, especially near mouth of bay |

## 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), on the barrier islands that are the southern boundary of St. Andrew Bay. The eye of the storm moved northeast across Tyndall AFB and East Bay and weakened only to a Category 3 once it reached southern Georgia. Winds at landfall were estimated to be 161 mph at Mexico Beach, and the heights of storm surge inundation were 9–14 feet above ground level from southeast of Tyndall AFB to the community of Port St. Joe on the eastern shore of St. Joseph Bay (Beven et al. 2019). Rainfall totals inland varied between 4 and 11 inches. Runoff into the bay was immediate and extended well into the Gulf of Mexico (Figure 1). Devastation on land in the watershed of St. Andrew Bay was extreme, with windfall of entire pine forests, stream flooding, and losses of homes, businesses, and infrastructure. Assessment of the effects of the storm on bay ecosystems began when it was safe to put boats in the water after the storm and continued annually.

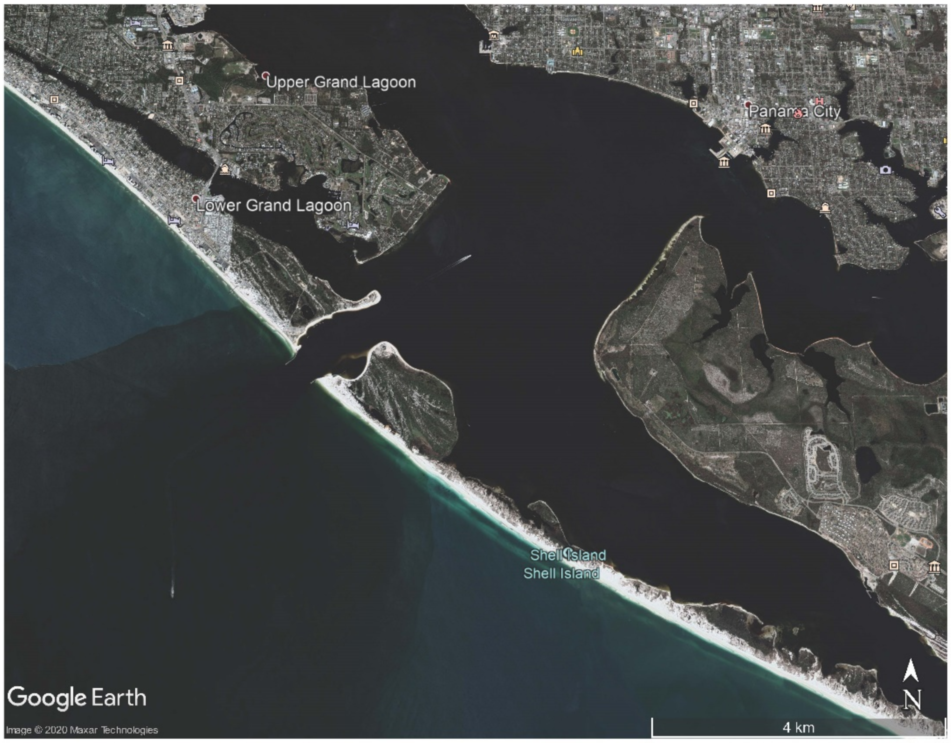


Figure 1. Aerial imagery of central St. Andrew Bay acquired on October 11, 2018. Note black color of water in the bay and the extensive plume of dark water extending into the Gulf of Mexico. Imagery collected by the National Oceanic and Atmospheric Administration and projected by Google Earth.

## 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 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, Mexico 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 (Northwest Florida Water Management District 2017).

## Seagrass mapping assessment

Seagrasses grow in all subregions of St. Andrew Bay (Figures 2–4). Seagrass acreage across the region changed by about 1% between mapping efforts in 2015 and 2017 (Table 1). Acreage has been stable, averaging 10,600 acres (standard deviation = 458) since 2003. Continuous seagrass beds covered 84% of all seagrass area in 2017, but the area of continuous seagrass beds has varied since 2003. Continuous beds increased by 564 acres, or 7%, between 2015 and 2017. Most of this increase in continuous seagrass occurred in West Bay where it is likely that 371 acres of patchy seagrass filled in to become continuous along with an expansion of 20 acres of new beds. In 2017, West Bay contained 30% of the seagrass area (3,236 acres) in the bay, but central and East bays had slightly less acreage, 27% and 24%, respectively. All subregions had high proportions of continuous-to-patchy seagrass.

Table 1. Acreage of continuous and patchy seagrass in subregions of St. Andrew Bay, 1992, 2003, 2010, 2015, 2017.

| | | Seagrass acreage | | | | | Change 2015–2017 | |
|---|---|---|---|---|---|---|---|---|
| Subregion | Bed texture | 1992 | 2003 | 2010 | 2015 | 2017 | Acres | % |
| West Bay | Continuous | 223 | 1,709 | 2,905 | 2,484 | 2,875 | 391 | 16% |
| | Patchy | 1,674 | 776 | 377 | 732 | 361 | -371 | -51% |
| | Total | 1,897 | 2,485 | 3,282 | 3,216 | 3,236 | 20 | 1% |
| North Bay | Continuous | 988 | 1,633 | 1,946 | 1,728 | 1,912 | 184 | 11% |
| | Patchy | 824 | 305 | 91 | 352 | 135 | -217 | -62% |
| | Total | 1,812 | 1,938 | 2,037 | 2,080 | 2,047 | -33 | -2% |
| Central St. Andrew Bay | Continuous | 1,249 | 1,822 | 2,455 | 2,388 | 2,357 | -31 | -1% |
| | Patchy | 1,144 | 984 | 456 | 616 | 630 | 14 | 2% |
| | Total | 2,393 | 2,806 | 2,911 | 3,004 | 2,987 | -17 | -1% |
| East Bay | Continuous | 1,598 | 935 | 2,438 | 2,000 | 2,020 | 20 | 1% |
| | Patchy | 841 | 1,651 | 233 | 487 | 623 | 136 | 28% |
| | Total | 2,439 | 2,586 | 2,671 | 2,487 | 2,643 | 156 | 6% |
| Total St. Andrew Bay | Continuous | 4,058 | 6,099 | 9,744 | 8,600 | 9,164 | 564 | 7% |
| | Patchy | 4,483 | 3,716 | 1,157 | 2,187 | 1,749 | -438 | -20% |
| | **Total** | **8,541** | **9,815** | **10,901** | **10,787** | **10,913** | **126** | **1%** |

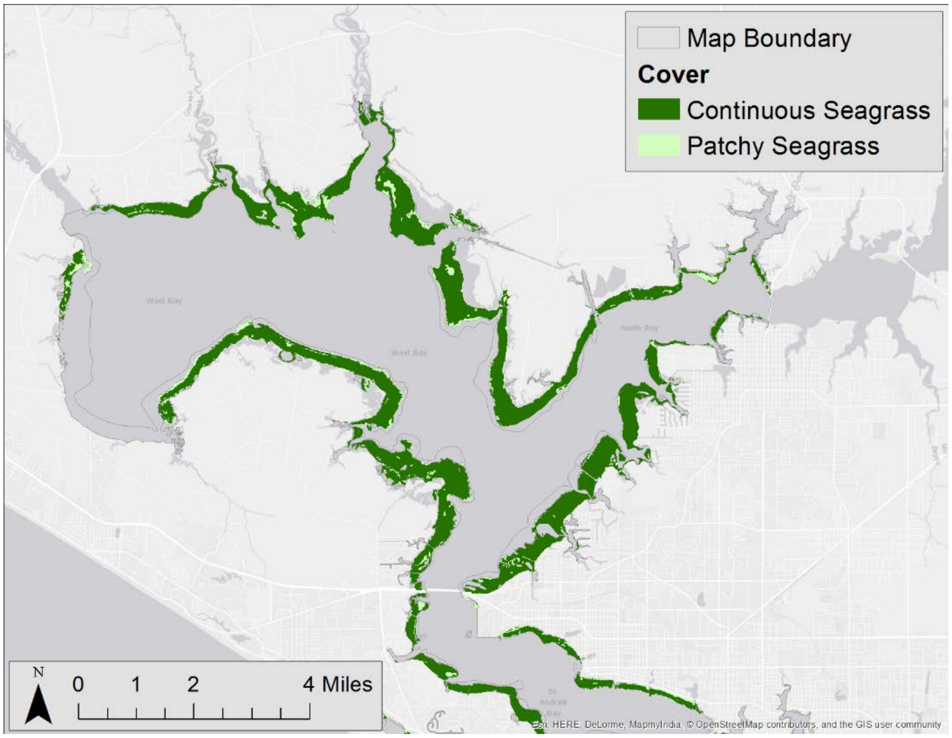


Figure 2. Continuous and patchy seagrass cover in West Bay and North Bay, St. Andrew Bay, 2017.

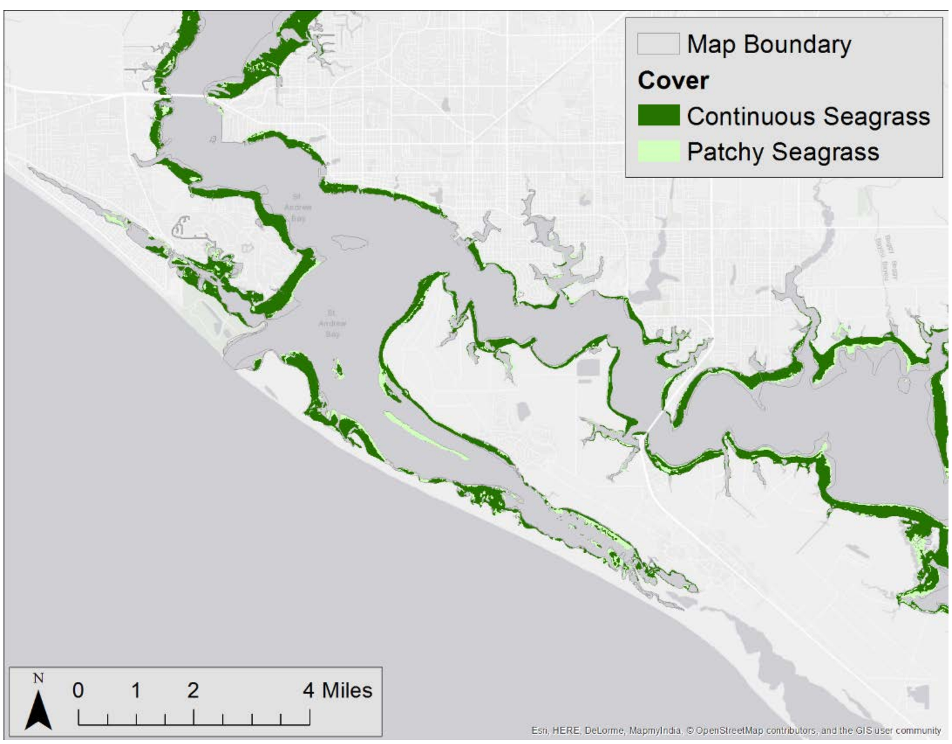


Figure 3. Continuous and patchy seagrass cover in central bay, including Grand Lagoon, St. Andrew Bay, 2017.

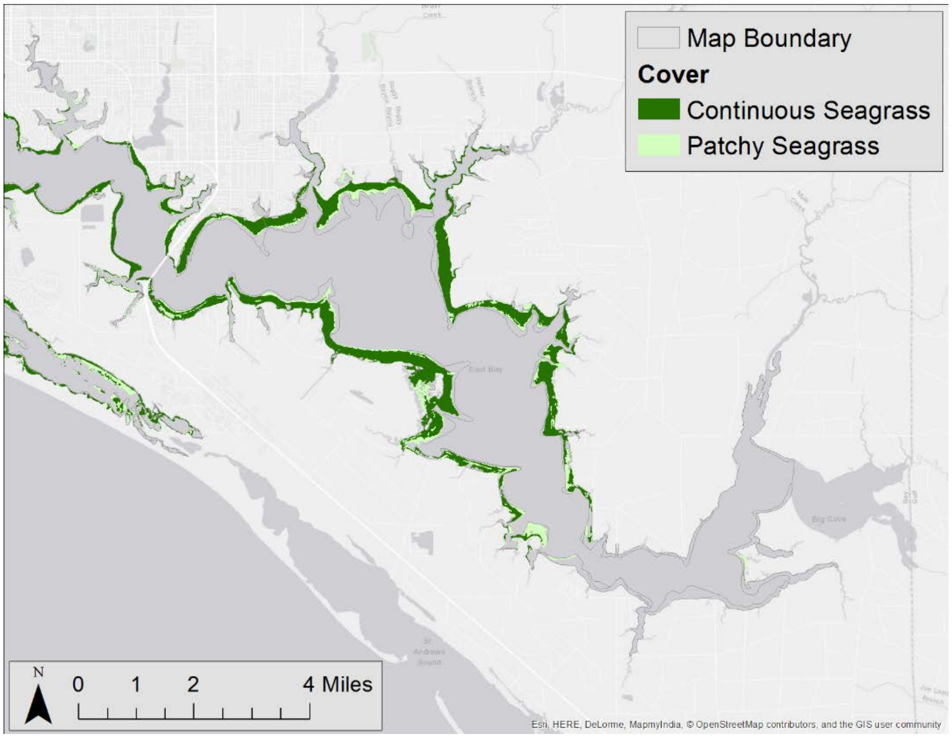


Figure 4. Continuous and patchy seagrass cover in East Bay, St. Andrew Bay, 2017.

The predominance of continuous beds in West Bay is clear in the maps from 2017 imagery (Figure 2). Seagrass has been absent along the southern shoreline of West Bay since 1980 (Roadblocks to Seagrass Recovery website); water quality in this area has been poor for a long time. Seagrass beds in North Bay were continuous to the upper reaches of the bay where more beds were patchy in 2017. There are proportionately more patchy beds in the central bay (Figure 3), and patchy beds were mapped on shoals and shorelines in eastern Grand Lagoon. In East Bay, beds have become progressively patchier in an eastward direction and disappear altogether at Murray Bayou (Figure 4). Imagery collected by the National Oceanic and Atmospheric Administration (NOAA) on October 11, 2018, the day after Hurricane Michael's passage, showed that shoals along the southern shoreline along Tyndall AFB were bare.

## Monitoring assessment

Personnel from the Fish and Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Conservation Commission visited 50–100 randomly distributed sites in the falls of 2009 and 2011 and in late summer of 2014 and 2019 to assess seagrass cover, seagrass and macroalgal species distribution, and water quality and clarity. Sites in East Bay and North Bay were not visited in 2019. In summer 2016, staff from the St. Andrew Bay Resource Monitoring Association (SABRMA) assessed cover at 71 sites where seagrass was present. Between 2014 and 2019, only shoalgrass had a large increase in FO in West Bay (to 65%; Table 2). The FO of turtlegrass and bare quadrats in West Bay varied among sampling years without trend. In Central Bay, turtlegrass was the dominant seagrass species with a mean FO of 61% for all sampling years. Shoalgrass and manateegrass were also present in Central Bay at lower and variable frequencies of occurrence. These assessments suggest little effects of Hurricane Michael.

Table 2. Frequency of occurrence (FO; %) of seagrass species in subregions of St. Andrew Bay, 2009, 2011, 2016, 2019, calculated from assessments by FWRI and SABRMA (2016 only).

| Subregion | Year | # quadrats | Turtle-grass | Manatee-grass | Shoal-grass | Star-grass | Widgeon-grass | Bare |
|---|---|---|---|---|---|---|---|---|
| Central Bay | | | | | | | | |
| | 2009 | 190 | 38.9 | 5.26 | 23.2 | | | 45.3 |
| | 2011 | 172 | 55.8 | 9.30 | 22.1 | | | 29.7 |
| | 2014 | 320 | 61.6 | 12.5 | 14.4 | | 2.19 | 23.1 |
| | 2016* | 230 | 75.7 | 3.91 | 20.4 | | | 13.5 |
| | 2019 | 180 | 74.4 | | 13.9 | | | 13.9 |
| East Bay | | | | | | | | |
| | 2009 | 152 | 41.4 | 19.1 | 31.6 | | | 35.5 |
| | 2011 | 200 | 34.0 | 8.50 | 27.0 | 0.50 | | 52.0 |
| | 2014 | 300 | 53.3 | 3.67 | 25.7 | | 12.3 | 28.3 |
| | 2016* | 220 | 41.4 | 5.00 | 62.7 | | 1.82 | 15.0 |
| West Bay | | | | | | | | |
| | 2009 | 128 | 39.1 | | 32.8 | 3.91 | 2.34 | 46.1 |
| | 2011 | 52 | 48.1 | 15.4 | 30.8 | 9.62 | | 17.3 |
| | 2014 | 250 | 21.6 | | 30.4 | | 17.2 | 50.4 |
| | 2016* | 130 | 30.8 | | 79.2 | 0.77 | 3.85 | 10.0 |
| | 2019 | 270 | 36.3 | | 65.2 | | 3.70 | 29.3 |
| North Bay | | | | | | | | |
| | 2014 | 60 | 31.7 | . | 60.0 | | 10.0 | 18.3 |
| | 2016* | 130 | 20.0 | . | 63.1 | | 0.77 | 30.8 |

*sampled only where seagrass was present

Seagrass cover data collected by Central Panhandle Aquatic Preserves (CPAP) in 2016, 2017, and 2019 in Central St. Andrew Bay showed similar frequencies of occurrence for seagrass species and bare quadrats as values from the assessments by FWRI (Table 3). Turtlegrass was dominant (mean FO = 64%), and manateegrass and shoalgrass occurred at much lower frequencies. Assessments of the occurrence of drift red algae showed that its FO more than doubled between 2017 and 2019.

Table 3. Frequency of occurrence (FO; %) of seagrass species in central St. Andrew Bay, 2016, 2017, 2019, calculated from assessments by CPAP.

| Year | # Quadrats | Turtle-grass | Manatee-grass | Shoal-grass | Star-grass | Bare | Drift red algae |
|---|---|---|---|---|---|---|---|
| 2016 | 204 | 61.8 | 8.8 | 15.7 | 0.49 | 18.1 | 10.3 |
| 2017 | 100 | 66.0 | 10.0 | 17.0 | 2.00 | 16.0 | 32.0 |
| 2019 | 100 | 63.0 | 7.0 | 17.0 | | 21.0 | 74.0 |

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 5). In West Bay and Central Bay, where assessments were done in 2019, some differences were observed between mean cover in 2016 and 2019. In Central Bay, manateegrass was absent in 2019 but had been present at very low densities in 2016. The density of turtlegrass was stable and the density of shoalgrass decreased by more than half between 2016 and 2019. In West Bay, stargrass was present at very low densities in 2016 but was absent in 2019. Densities of turtlegrass and shoalgrass in West Bay were similar in 2016 and 2019.

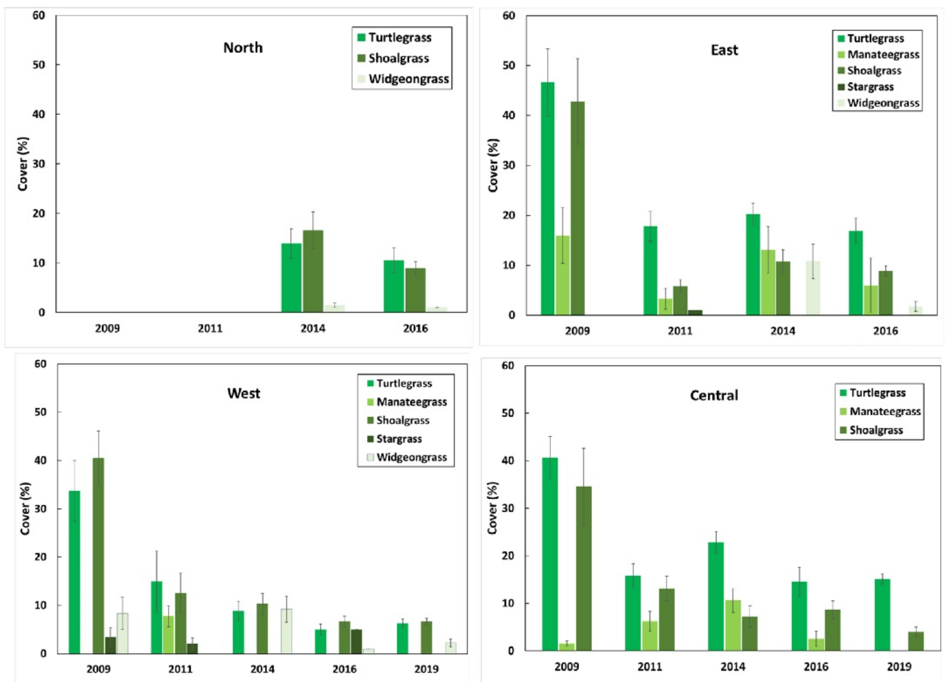


Figure 5. Mean (± 2 standard error) cover of seagrass species in subregions of St. Andrew Bay. No assessments were completed in North Bay and East Bay in 2019; note differences in years on the x-axes.

## 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, and 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 these stream water samples included conductivity, water temperature, chlorophyll-a, color, and turbidity. Three months after the passage of Hurricane Michael, in January 2019, mean salinity was low and mean color values were extremely high in bay waters (Table 4). Mean color values decreased, and salinity increased from January through July 2019. Turbidity was elevated in

January 2019 but declined until August 2019. Monthly measurements of optical water quality in 2016, a period of more “normal” weather and runoff showed that color values were low in winter months and peaked in spring throughout the bay (Fitzhugh et al. 2018--see Figure 5). On average chlorophyll-a concentrations were greater throughout the year in 2016 than values measured in 2019, and turbidity values fluctuated between 1-2 ntu with no pattern. Mean values of optical water quality parameters measured in tributary waters in March and July 2019 (Table 4) showed that color was elevated in these low-lying streams that drain pine plantations. Mean turbidity was higher in streams, and mean chlorophyll-a was especially high in streams in July.

Table 4. Monthly means of salinity, turbidity, color, and chlorophyll-a in St. Andrew Bay in 2019, and monthly means of conductivity, turbidity, color, and chlorophyll-a in streams discharging into bay waters in March and July 2019.

St. Andrew Bay

| Month | Salinity (psu) | Turbidity (ntu) | Color (pcu) | Chlorophyll-a (µg/l) |
|---|---|---|---|---|
| January | 14.86 | 2.24 | 103.3 | 2.270 |
| February | 17.94 | 1.58 | 40.35 | 2.846 |
| March | 23.21 | 0.80 | 34.19 | 1.794 |
| April | 24.91 | 1.09 | 20.11 | 1.733 |
| May | 24.86 | 0.70 | 19.53 | 1.397 |
| June | 26.65 | 1.03 | 16.20 | 2.498 |
| July | 25.04 | 0.89 | 18.74 | 2.429 |
| August | 18.53 | 2.33 | 69.18 | 3.354 |
| September | 29.78 | 1.21 | 16.87 | 3.150 |
| October | 30.90 | 1.18 | 10.26 | 3.089 |
| November | 28.71 | 1.44 | 13.74 | 1.869 |

Tributary Streams

| Month | Conductivity (µS) | Turbidity (ntu) | Color (pcu) | Chlorophyll-a (µg/l) |
|---|---|---|---|---|
| March | 4,710 | 3.98 | 178.3 | 1.199 |
| July | 6,339 | 5.52 | 74.79 | 15.46 |

## Mapping methods, data and imagery

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 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.

## Monitoring methods and data

Field monitoring of seagrass beds has been carried out by several agencies since 2000. Monitoring was done by SABRMA 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. SABRMA also had three permanent transects in the arm of West Bay (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, 2014, and 2019. 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 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. Water 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. This program continues in spring and fall as conditions permit. Four quadrats are assessed at each site.

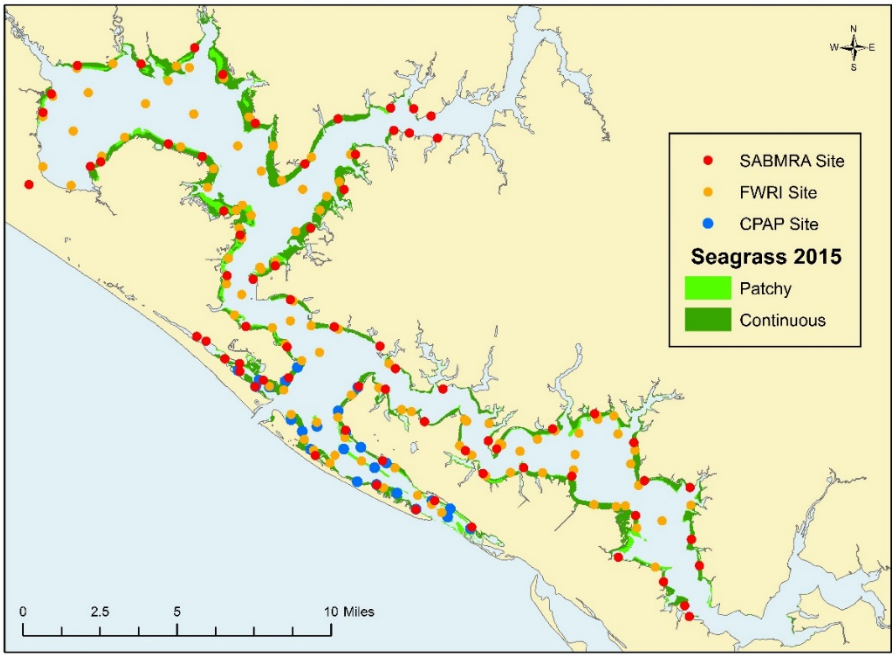


Figure 6. Sites of field monitoring by St. Andrew Bay Resource Monitoring Association (SABRMA) in summer 2016, FWRI in 2009, 2011, 2014, and 2019, and Central Panhandle Aquatic Preserves (CPAP) beginning in 2015.

As part of the Roadblocks to Seagrass Recovery project, the St. Andrew Bay Resource Management Association (SABRMA) 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.

## 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 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 37 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 staff from ten streams discharging into West Bay, North Bay, and East Bay.

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.

Fitzhugh L, Kebart K, Brucker J, Carlson PR Jr, Johnsey E, Yarbro L. 2018. Summary report for St. Andrew Bay, Pp. xx-xx, in Yarbro L, Carlson PR. (eds.) Seagrass Integrated Mapping and Monitoring report No. 3. Technical Report TR-17 version 3. Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg. https://myfwc.com/media/17704/simm3-standrewbay.pdf. Accessed May 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.

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 May 2020.

Roadblocks to Seagrass Recovery, Florida Fish and Wildlife Conservation Commission: https://myfwc.com/research/habitat/seagrasses/projects/roadblocks/. Accessed May 2020.

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 by 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).