Summary Report for Choctawhatchee Bay

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in

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Summary Report for Choctawhatchee Bay

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General assessment

In 2015, seagrasses covered 5,735 acres in Choctawhatchee Bay, more than three times the 1,768 acres mapped in 2007. In 2003, seagrass covered 2,623 acres, a loss of 38% from the 4,261 acres mapped in 1992. Seagrasses are found only in the middle and western bay (Figure 1). Two species of seagrass are typically observed in the bay: shoalgrass (*Halodule wrightii*) and widgeongrass (*Ruppia maritima*). Both species can vary widely in cover over short periods of time and are known for their rapid colonization and growth under optimal conditions; this may account for some of the large variation in acreage observed in the mapping data. In 1992, the brackish species widgeongrass and tapegrass (*Vallisneria americana*) were the dominant submersed vegetation in the eastern bay; these species are vulnerable to fluctuations in salinity and turbidity related to rainfall and runoff. Heavy winter rainfall in early 2009 caused significant animal mortality and may have affected seagrasses. Excessive storminess in 2012–2014 elevated runoff and impacted seagrass beds in the bay.

Geographic extent

Choctawhatchee Bay is a flooded Pleistocene river valley that was enclosed by a barrier island system in recent geological history. Until 1929, the bay was a freshwater to brackish water lake because it was connected to the Gulf of Mexico only by a very shallow pass. In 1929, East Pass was created by digging out a channel, and the bay became a highly stratified estuary with freshwater flowing in from rivers atop salty, often low-oxygen, waters near the bottom. Water depths range from 3 to 13 m. The primary source of freshwater is the Choctawhatchee River, but springs contribute as well. The watershed covers about 3.3 million acres (5,200 square miles) in Alabama and Florida. Most of the watershed is covered by upland forests (56%) and wetlands (13%), while agricultural lands cover 21%. Developed areas cover about 8% of the watershed and are located primarily along the middle and western shores of the bay. The eastern half of Choctawhatchee Bay is in Walton County, and the western half is in Okaloosa County. For the purpose of this chapter, we divide the bay into three segments using the location of bridges: the western segment lies west of the U.S. 293 bridge crossing the middle of the bay; the eastern segment lies east of the SR331 bridge; and the middle segment is between the bridges. There has been extensive urbanization along the shores of the western bay in the past 30 years.

Mapping and monitoring recommendations

- Acquire imagery and map seagrasses every six years.
- Continue the annual monitoring program begun in 2009 by the Fish and Wildlife Research Institute (FWRI) of the Florida Fish and Wildlife Conservation Commission (FWC) and continued by the Choctawhatchee Basin Alliance (CBA).

Management and restoration recommendations

- Assess the effects of storm-related reductions in salinity and increases in the intensity of water color on survival of brackish-water seagrasses in the eastern bay, and

1. General status of seagrasses in Choctawhatchee Bay

Status and stressors	Status	Trend	Assessment, causes
Seagrass acreage	Green	Expanding	Large increases, 2007–2015
Water clarity	Yellow	Variable	Storm runoff, especially 2012 and 2013
Natural events	Orange	Increasing impacts	
Propeller scarring	Orange	Unknown	40% of seagrass beds

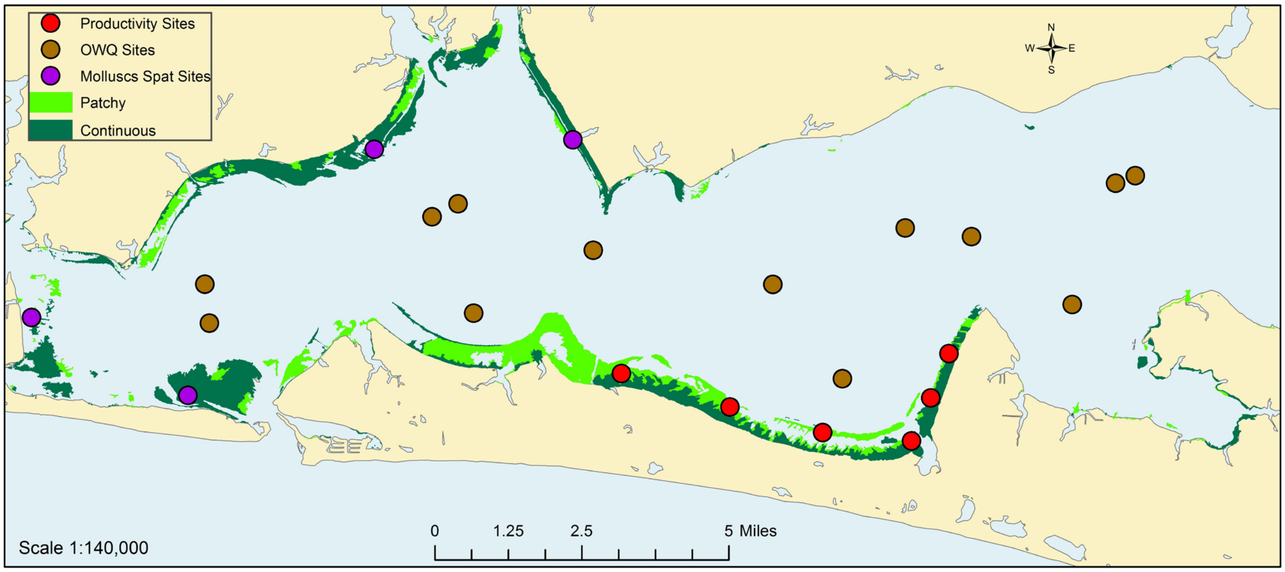

Figure 1. Seagrass cover (green) in Choctawhatchee Bay, 2015, shown as patchy and continuous beds, locations of sites for sampling of optical water quality by scientists of the Choctawhatchee Basin Alliance in 2016 (brown circles), sites where scientists from the Fish and Wildlife Research Institute (FWRI) Molluscan group sample water monthly for optical water quality (purple circles), and locations of field measurements of the productivity of shoalgrass in 2016 (red circles).

work with regional and state agencies to evaluate and institute controls of the quantity and quality of storm runoff entering the bay.

- Continue to monitor water quality in the bay and in rivers and streams contributing runoff to the bay.

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 FWRI (http://myfwc.com/research/habitat/seagrasses/projects/roadblocks/). This project is funded by the National Fish and Wildlife Federation (NFWF) Gulf Environmental Benefit Fund (GEBF), 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.

Seagrass acreage in Choctawhatchee Bay varied widely among mapping efforts in 1992, 2007, and 2015, likely due to changing environmental conditions and the rapid colonization by and growth characteristics of the dominant seagrass species, shoalgrass and widgeongrass. Based on mapping data, 58% of seagrass acreage was lost from Choctawhatchee Bay between 1992 and 2007 (Table 1). But between 2007 and 2015, acreage increased from 1,768 acres to 5,735 acres, and most of the increased area was continuous beds. Species mapped in 1992 in the eastern bay were growing in brackish regions and were sensitive to variations in salinity and to storm runoff. Field monitoring in the summers of 2009, 2011, 2014, and 2016 showed that shoalgrass was the most common species in most locations and that widgeongrass occurred sporadically (Table 3). In the eastern bay, no seagrass was observed in 2009 and 2011, and shoalgrass was present at low frequencies of occurrence (FO) in 2014 and 2016. In the middle and western portions of the bay, the FO of shoalgrass varied widely with highest values observed in 2011 and 2016. In addition, increased color due to greater colored

Table 1. Seagrass acreage in Choctawhatchee Bay, 1992, 2003, 2007, and 2015.

					Change, 2007–2015	
Bed texture	**1992**	**2003**	**2007**	**2015**	**Acres**	**%**
Continuous	781	559	5	3,685	3,680	73,600%
Patchy	3,447	2,034	1,763	2,050	287	16%
Total	**4,261**	**2,623**	**1,768**	**5,735**	**3,967**	**224%**

2. Seagrass status and potential stressors in Choctawhatchee Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Expanding	Large increases, 2007–2015
Seagrass meadow texture	Green	Recent improvements	Variable, changes in water clarity
Seagrass species composition	Yellow	Stable	Shoalgrass and widgeongrass
Overall seagrass trends	Green	Variable	Water clarity, dominant species growth patterns
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Recent improvements	Storm runoff
Nutrients	Green	Low levels	
Phytoplankton	Green	Low levels	
Natural events	Orange	Increasing impacts	Runoff from extreme storms
Propeller scarring	Orange	Unknown	40% of seagrass beds

dissolved organic matter (CDOM) in stream runoff has reduced water clarity and likely continues to contribute to seagrass losses in the eastern bay. Heavy rainfall associated with the 2009–2010 El Niño and excessive, ongoing storminess since the summer of 2012 may be contributing to the large variability in seagrass cover in this system. Assessment of propeller scarring using imagery collected in 2013 showed that scarring affected 40% of seagrass beds, but that most beds were only lightly damaged (Table 2).

Table 2. Assessment of propeller scarring of seagrass beds in Choctawhatchee Bay using imagery acquired by the NAIP in 2013. Imagery was overlaid by a grid of 1-ha cells. Each cell received a scarring score.

Description	Score	Cell count	% of vegetated cells
Vegetated, no scars	0	2,852	59.9%
1–5 scars	1	1,268	26.6%
6–10 scars	2	379	8.0%
11–25 scars	3	152	3.2%
26–50 scars	4	61	1.3%
>50 scars	5	36	0.8%
Unreadable, sun glare	6	15	0.3%
Doughnut-shaped bed	7	1	0.0%
Total vegetated		4,764	100.0%
Total scarred		1,896	39.8%

Status graphics provide a quick visual assessment of the health of seagrass beds and a summary of the impact of likely stressors. The general status of seagrasses in Choctawhatchee Bay shows improvement (Status graphic 1) over the same assessment in the second edition of this chapter, primarily because of the large increase in seagrass acreage observed between 2007 and 2015. However, recent quantitative assessment of propeller scarring showed that about 40% of seagrass beds were scarred. This information was not available in earlier editions. Improvement in seagrass cover and meadow texture indicates that seagrasses are in good condition (Status graphic 2), but this assessment is tempered by large variability observed in beds dominated by shoalgrass and widgeongrass.

Seagrass mapping assessment

Seagrass acreage has varied widely since 1992 (Table 1). Mapping data were generated using the same spatial footprint for each dataset so that data could be compared among years. In 1992, 4,261 acres were mapped, of which 18% were continuous beds. Acreage declined through 2007, reaching a low of 1,768 acres, with only 0.2% being continuous beds. By the fall of 2015, acreage had more than tripled, and most (64%) was continuous seagrass. Examination of imagery collected in the fall of 2017 by the National Agricultural Imagery Program (NAIP) of the US Department of Agriculture showed significant losses since 2015 (see also Figure 2). As shown in Figure 1,

Figure 2. Imagery acquired by NAIP of the shoreline near Sandestin, Florida, in 2007, 2010, 2013, 2015, 2017. A: images at large scale along the north-facing shoreline of Sandestin; B: smaller scale images showing changes in seagrass beds just east of the shoreline show in in A.

seagrass was limited to the central and western half of Choctawhatchee Bay in 2015. This pattern of distribution could be related to a strong gradient in water clarity. Seagrass was also limited to the shallow margins of the bay. There is one large, continuous seagrass bed at the west end of the bay along the Intracoastal Waterway entrance to Santa Rosa Sound. Other beds are very patchy. Review of imagery collected by the NAIP over several years of the coastline near Sandestin shows the ephemeral nature of seagrass beds dominated by shoalgrass and widgeongrass (dark patches in Figure 2A and B). The striking view of sand ripples in these images also indicates that this area is subject to considerable wave energy which might make it difficult for seagrasses to get established and survive.

Propeller scarring

Propeller scarring of seagrass beds was quantified using aerial imagery collected in 2013 by the NAIP. Imagery was overlaid by a grid of 1-ha cells. For each cell that covered seagrass, scars were counted, and the cell was given a scarring score (Table 2). About 40% of seagrass beds had some level of scarring, but two-thirds of scarred beds were lightly scarred, with 1–5 scars per cell. The most heavily scarred location was near Destin and just inside the inlet to the Gulf of Mexico, where boaters often raft up during holidays (Figure 3).

Monitoring assessment

The FWRI began field monitoring of seagrasses in summer 2009 and monitored again in 2011, and 2014. The CBA continued monitoring in 2016 and 2017 using the same sampling methods. In 2009, shoalgrass was found in 24% of quadrats surveyed (Figure 4), widgeongrass was observed in 0.41% of quadrats and 76% of quadrats were bare. In 2011, the FO of shoalgrass was much greater than in 2009, at nearly 60%, but no widgeongrass was found in the estuary. With the higher occurrence of shoalgrass, the percentage of bare quadrats dropped to 41% in 2011. In 2014, widgeongrass and shoalgrass were each observed in about 30% of all quadrats, and in 2016 more than 70% of quadrats contained shoalgrass. The high FO of shoalgrass observed in summer 2016 supports the large increase in acreage of seagrass mapped in 2015 imagery. In Choctawhatchee Bay, shoots of shoalgrass are typically

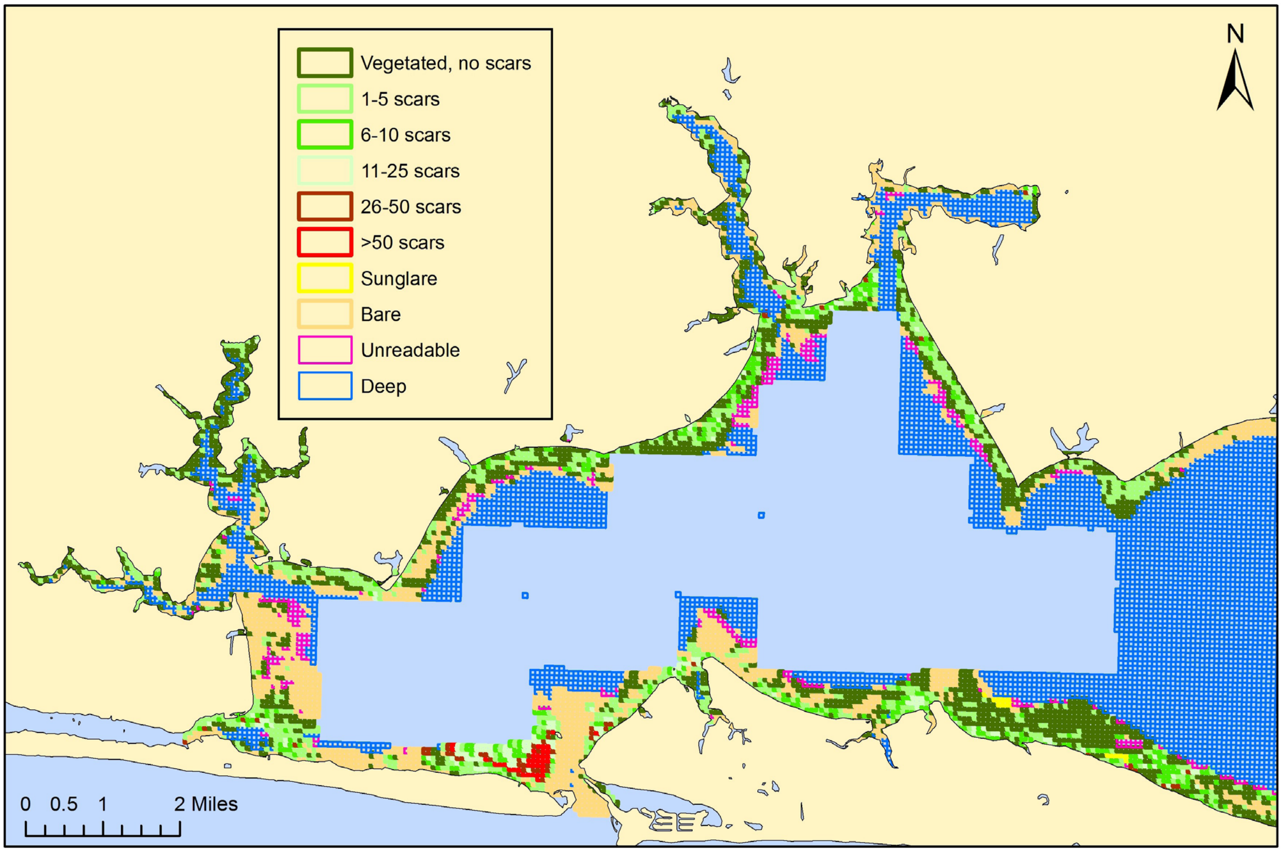

Figure 3. Propeller scarring in western Choctawhatchee Bay, from imagery collected in 2013.

very small and can look like new growth of widgeongrass, especially when viewed underwater. Therefore, the 60% occurrence of shoalgrass in 2011 may include shoots of widgeongrass. The FO of seagrasses varied among regions of the bay (Table 3). Sampling was limited in 2017 due to bad weather, so FO data from this effort cannot be compared with data from previous years. No seagrasses were observed in the eastern bay in 2009 and 2011, and shoalgrass occurred there at low levels (13–20%) in 2014 and 2016. Shoalgrass occurred more frequently in the middle and western regions in all years sampled, but variation among years was large. Widgeongrass was observed sporadically in the middle and western regions. The frequency of bare quadrats in both the middle and western regions declined from highs in 2009 to 26% and 15% in 2016, respectively. The mean percent cover of a seagrass species (an estimation of density), when it was present in a quadrat, ranged from 4 to 27% in the middle and western bays (Figure 5) during all sampling efforts, with the lowest values observed in 2014. Optical water quality, which affects the amount of light reaching seagrass beds, was poor in the summer of 2014 and may have reduced growth of seagrasses. Because assessing cover by diminutive shoots in poor visibility is somewhat subjective, confidence in cover data is less than that in species occurrence values.

Productivity of shoalgrass

Field estimates of shoalgrass productivity were made at six sites in the middle bay in October 2016 using the blade clip/reclip method (Dunton 1990). CBA staff completed the field work, and FWRI staff measured the harvested tissues. For all sites, the mean number of live shoots of shoalgrass per m^2 was 16,800 while the number of dead shoots averaged 10,300 per m^2 (Table 4). One-sided leaf area index for shoalgrass was much lower than values found for turtlegrass in studies in other Panhandle estuaries (see Pensacola, St. Andrew Bay, St. Joseph Bay, Franklin County chapters), with a mean of 0.38. Because shoalgrass has substantially smaller blades than turtlegrass, this difference is not surprising. Turnover, however, was greater than values found for turtlegrass in other Panhandle estuaries. Blade productivity averaged 200 cm^2/m^2/day and is probably an underestimate by as much as 50% (Kowalski et al. 2001).

Productivity, based on the weights of reclipped blades, averaged 0.79 g/m^2/day, and the weight of reclipped blades was 17% of the clipped blades present at the start of the experiment (Table 5A). The amounts of live and dead biomass in each pipe section were approximately equal, as were the amounts of live biomass above and below the sediment surface (Table 5B).

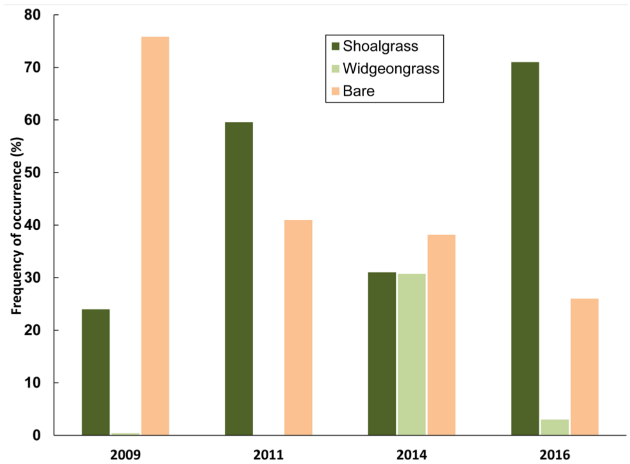

Figure 4. Frequency of occurrence (%) of seagrass species in Choctawhatchee Bay, 2009, 2011, 2014, 2016.

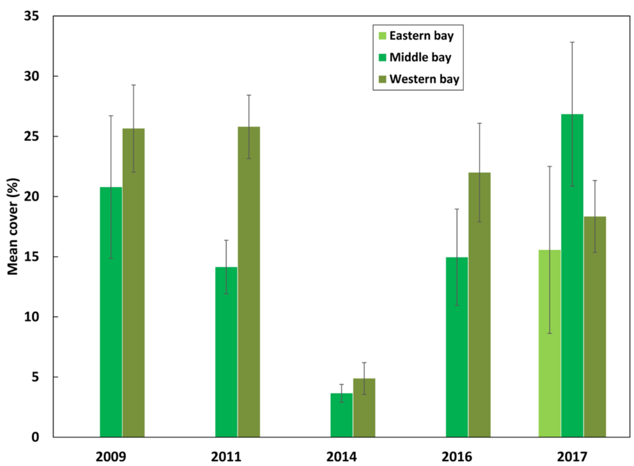

Figure 5. Mean cover (%) of shoalgrass in quadrats, 2009, 2011, 2014, 2016, 2017. Only quadrats having seagrass were included in the estimates. Shoalgrass was found in the eastern bay only in 2017.

Water quality and clarity

In August 2009, October 2011, August 2014, and quarterly in 2016, staff from FWRI and CBA measured water quality and clarity parameters. They measured the standard field water-quality parameters salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentration, as well as optical water quality (OWQ) parameters—light attenuation, chlorophyll-a concentration, turbidity, total suspended solids (TSS), and water color. Light attenuation, expressed as an extinction coefficient, k_{par} (m^{-1}), and the resultant light available to seagrasses on the bottom are a function of the levels of the other OWQ parameters, turbidity, TSS, chlorophyll-a concentration (a proxy for phytoplankton levels) and water color. The contribution of each component to light attenuation varies by location, season, and from one year to the next. Figure 6 shows seasonal means of OWQ parameters in regions of Choctawhatchee Bay in winter 2015 through fall 2016. Light attenuation, presented as k_{par} using a spherical sensor, was greatest in the eastern bay during all seasons, as were chlorophyll-a concentrations and color. Since field monitoring began, seagrasses have been absent or observed at very low levels in the eastern bay, and the high k_{par} levels (>1) indicate that light conditions are poor for seagrasses in this region. The extremely high levels of turbidity in the eastern bay in spring might be the result of spring runoff from the watershed; color was also greatest in the spring in the eastern bay. In contrast, light attenuation and the levels of other OWQ parameters were moderate to low in value in the middle and western regions where seagrasses are most common. However, there are extensive shallow bare areas nearshore in the middle and western bays that are visible in aerial photographs. Factors preventing seagrass colonization and recovery in these areas might include high wave energy and salinity fluctuations and are under investigation.

Table 3. Percentage frequency of occurrence of seagrass species in quadrats assessed during annual monitoring in Choctawhatchee Bay, 2009, 2011, 2014, 2016, 2017.

		Frequency of occurrence (%)			
Region	Year	# quadrats	Shoal-grass	Widgeon-grass	Bare
East					
	2009	88			100
	2011	53			100
	2014	80	13		88
	2016	30	20		80
	2017*	30	53		46.7
Middle					
	2009	200	18	1	82
	2011	163	58		42
	2014	270	24	37	38
	2016	120	67	7.5	26
	2017*	70	90		8.6
West					
	2009	204	40		60
	2011	155	82		19
	2014	295	42	33	25
	2016	150	85		15
	2017*	100	83		17

*sampled only where seagrass present

Table 4. Estimates of counts of live and dead shoots, one-sided leaf area index (LAI), productivity of blades, and turnover of shoalgrass at six locations in middle Choctawhatchee Bay, 2016.

	Mean # shoots/m²		LAI 1-sided		Productivity (cm²/m²/day)		Turnover	
Site	**Live**	**Dead**	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**	**Mean**	**Std. dev.**
CHN005	27,300	5,420	0.311	0.048	202	80.9	6.4%	1.9%
CHN013	19,400	9,790	0.284	0.026	141	74.9	5.0%	2.7%
CHN015	12,900	13,100	0.244	0.048	197	48.8	8.1%	1.5%
CHN038	12,300	9,170	0.315	0.013	163	42.6	5.2%	1.4%
CHN054	18,100	10,000	0.677	0.827	375	308	13%	14%
CHR014	11,000	14,600	0.450	0.381	121	56.5	3.8%	3.0%
Average	16,800	10,300	0.380		200		7.0%	
Std. dev.	5,580	2,940	0.147		83.3		3.2%	

Table 5. A) Productivity of shoalgrass blades (g/m²/day) and the ratio of the weights of reclipped blades to clipped blades; B) live and dead biomass of shoalgrass in PVC pipe sections. Above = above sediment surface; below = below sediment surface.

A

Site	**Mean (g/m²/day)**	**Std. dev. (g/m²/day)**	**N**	**Ratio reclips/clips g/m²**	**Ratio reclips/clips g/m²/day**
CHN005	0.78	0.25	4	11%	1.3%
CHN013	0.46	0.20	4	6.7%	0.7%
CHN015	0.89	0.12	3	16%	1.8%
CHN038	0.52	0.11	4	11%	1.3%
CHN054	1.2	0.75	4	22%	2.5%
CHR014	0.91	0.60	4	33%	3.7%
Average	0.79			17%	1.9%
Std. dev.	**0.24**			**8.7%**	**1.0%**

B

	Live (g/m²)			Dead (g/m²)			
Site	**Above**	**Below**	**Total**	**Above**	**Below**	**Total**	**Live above/ live below**
CHN005	163	87.7	250	37.2	57.7	94.9	1.9
CHN013	76.5	145	222	40.2	242	282	0.53
CHN015	97.0	111	208	45.7	267	313	0.87
CHN038	61.4	50.7	112	39.2	69.8	109	1.2
CHN054	77.2	88.9	144	36.7	183	219	0.87
CHR014	95.2	117	213	60.3	125	185	0.81
Average	95	100	191	43	157	200	1.02
Std. dev.	33	29	48	8	80	81	0.42

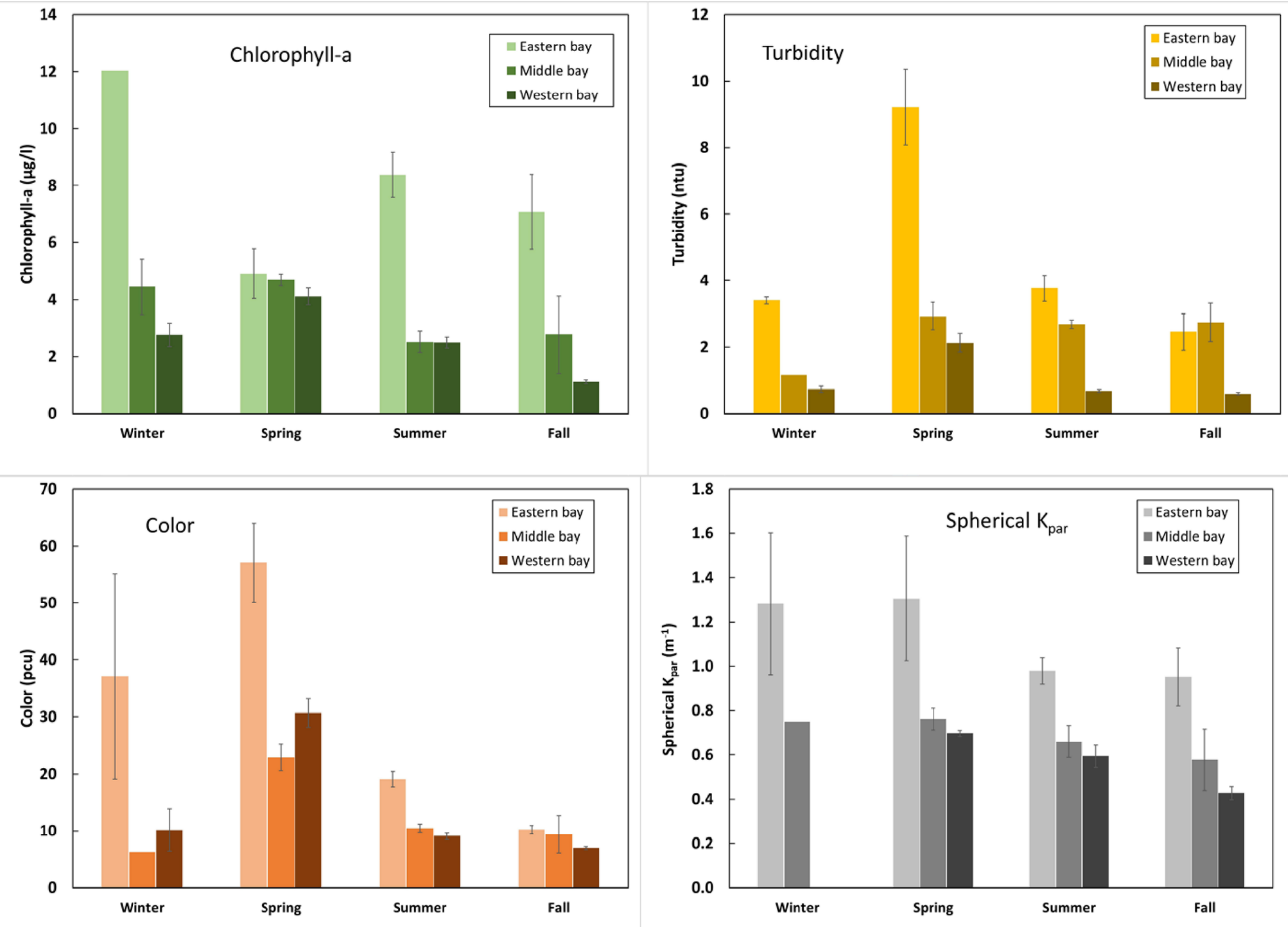

Figure 6. Means (±2 standard error) of chlorophyll-a, turbidity, color, and spherical k_{par} in regions of Choctawhatchee Bay in winter 2015 and in spring, summer, and fall 2016.

Watershed management

The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, identifies and addresses water resources issues of concern within the SWIM planning basins. An updated SWIM plan for the Choctawhatchee Bay region was released in fall 2017: https://www.nwfwater.com/Water-Resources/Surface-Water-Improvement-and-Management/Choctawhatchee-River-and-Bay. This plan lists several priorities, including:

- Stormwater planning and retrofit
- Septic tank abatement
- Advanced onsite treatment systems
- Agriculture and silviculture best management plans
- 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
- Interstate coordination
- Analytical program support
- Comprehensive monitoring program

To protect water quality, habitat quality, and groundwater recharge, as well as to maintain compatible public access and use, the district protects more than 67,000 acres in the Choctawhatchee River and Bay Basin. This includes approximately 53% of the Choctawhatchee River floodplain in Florida. District staff continue to help local governments develop and implement cooperative habitat restoration, spring protection, and 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, Florida). 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.

In 2007, color imagery was collected and digitized manually by Brian Schoonard of FWRI using a classification scheme of the U.S. Geological Survey (USGS) National Wetlands Research Center (NWRC) based on the Coastwatch Change Analysis Project Coastal Land Cover Classification system of the National Oceanic and Atmospheric Administration. Seagrass mapping data for 2003 were derived from interpretation of color infrared photography. These images were acquired at 1:12,000 scale, rectified to USGS digital orthophoto quarter quadrangle base maps, and digitized at the USGS NWRC. The seagrass beds were classified according to the same NWRC-derived classification scheme used in 2007.

Imagery collected in 1992 is part of the northwest Florida seagrass mapping data set and was collected in December 1992 and early 1993. The data set was created by the USGS Biological Resources Division at the NWRC in Lafayette, Louisiana. The study area was from 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 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 on seagrass beds in Choctawhatchee Bay using imagery acquired in 2013 by the NAIP. Using ArcMap, water areas <4 m deep were overlaid by a grid constructed of square cells 100 m on a side, thus covering 1 ha each. For each cell that was over seagrass, the 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

When scoring was complete for each region, 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 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

Seagrass beds were assessed in the fall of 2009, 2011, and 2014 by scientists from FWRI and in 2016 and 2017 by scientists from CBA. For every year except 2017, a spatially distributed random-sampling design was used to select sites, and 50–60 sites were visited by FWRI and 30 sites by CBA in 2016. In 2017, a limited number of sites was visited due to bad weather and poor water visibility, and all sites had seagrass present. At each site, seagrass and macroalgal cover was estimated in ten 0.25-m^2 quadrats using a modification of the Braun-Blanquet technique. In addition to seagrass field assessment, scientists measured standard field water-quality parameters of salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentration, as well as OWQ parameters light attenuation, chlorophyll-a concentration, turbidity, total suspended solids, and water color. For more information, contact Paul Carlson at FWRI.

Productivity of shoalgrass was estimated in the fall of 2016 by CBA scientists working at six sites in the middle bay. Productivity on both a blade-area and biomass basis was measured by a clip/reclip method (Virnstein 1982; Dunton 1990; Tomasko and Dunton 1995). At each site, 2-inch-long sections of thin-walled PVC pipe of 3-inch diameter (0.0012 m^2) were pressed into the sediment at 4 locations in a bed of shoalgrass. The top of the pipe section protruded just a few cm above the sediment surface. Once the pipe section was in place, divers very carefully cut off all the blades of shoalgrass shoots at the level of the top of the pipe section. These "clips" were placed in bags and put on ice. After 9 days, the shoalgrass blades were cut off once again at the level of the top of the pipe section, and these "reclips" were placed in bags and refrigerated. After removing all the reclips, divers harvested all above and below ground biomass inside each pipe section.

In the laboratory at FWRI, the length of each clip and reclip blade was measured, and the width of 10 blades from each sample was measured using a dissecting microscope and a calibrated micrometer. A mean of the blade widths for each sample was used along with the sum of measured blade lengths to calculate total blade area of clip and reclip samples. After measurements, the blades were dried at 50°C and weighed after 5–6 days. The number of live and dead shoots were counted in the remaining biomass, and the biomass was separated into aboveground fractions by live and dead categories: blades, short shoots, and loose blades. The belowground material, roots and rhizomes, was separated into live and dead fractions. After rinsing with tap water, biomass fractions were dried at 50°C and weighed after 5–6 days.

Leaf area index was calculated from the total blade area of the clipped blades for each replicate at each site. The total area of the reclipped blades in each replicate allowed calculation of productivity in cm^2/m^2/day. Dividing the blade productivity by the clipped blade area produced an estimate of blade turnover per day. The dry weight of the reclipped blades was used to calculate blade growth in g/m^2/day.

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 critical to the survival of seagrass communities, and the attenuation of light in the water column results from reflection, diffraction, and absorption 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, indicating the level of 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 column can be measured by light absorption of a filtered water sample at 440 nm (color; see below) 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 in liquid nitrogen. In the laboratory, filters were transferred to an ultralow 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 the Environmental Protection Agency (EPA) method 446.0.

Water samples for the measurement of color, turbidity, and TSS were collected by triple rinsing each sample bottle and then filling each 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 with a Hach 2100Q turbidimeter and calibrated standards following method 214 A of *the 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* by filtering water samples through combusted, tared GFC glass fiber filters. Filters were then dried at 50°C for at least five days and reweighed using a 5-place Mettler balance.

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