Summary Report for the Pensacola Region

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in

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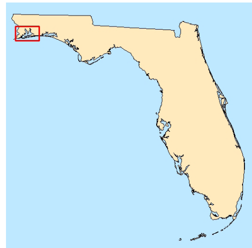
Summary Report for the Pensacola Bay Region, Including Pensacola Bay, Big Lagoon, and Santa Rosa Sound



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General assessment

Between 1950 and 1980, about 95% of seagrass habitat disappeared from the Pensacola Bay region in the western Panhandle of Florida. In 2010, mapped seagrass covered 821 acres in Pensacola Bay, Escambia Bay, and East Bay, 2,844 acres in Santa Rosa Sound, and 511 acres in Big Lagoon (Table 1). Mapped imagery acquired in fall 2015 showed that Big Lagoon had 571 acres, Santa Rosa Sound 3,080 acres, and southern Pensacola Bay 544 acres. Escambia Bay and East Bay were not mapped in 2015. Seagrass in Big Lagoon, Santa Rosa Sound, and southern Pensacola Bay increased by 202 acres between 2010 and 2015. Seagrasses in Escambia Bay and East Bay were last mapped in 2010 and increased by 230 acres between 2003 and 2010. Shoalgrass (*Halodule wrightii*) and turtlegrass (*Thalassia testudinum*) are the most common seagrass species found in the region, and turtlegrass is the dominant species found in Santa Rosa Sound and Big Lagoon. Widgeongrass (*Ruppia maritima*) can be locally abundant. Manateegrass (*Syringodium filiforme*) is observed infrequently. Seagrass beds in southern Santa Rosa Sound and Big Lagoon (along the Gulf Islands National Seashore [GINS]) are prone to burial by sediment from unconsolidated sand carried in from nearby barrier islands. In 2009, the Florida Department of Environmental Protection (FDEP) Ecosystem Restoration Program (ERS) found that as much as 9 cm of sand had been deposited (timeframe unknown) on monitored transplanted plots adjacent to Johnson's Beach (GINS). The ERS maintains a seagrass salvage program in this area that relocates seagrasses about to be destroyed by marine construction to areas in which seagrasses need restoration. Propeller scarring is generally low in intensity (#scars/ha), but scarring affects 28%, 26%, and 35% of seagrass beds in Santa Rosa Sound, Big Lagoon, and East Bay, respectively (Table 2).

During surveys of the bottom of Pensacola Bay in 2008, seasonal hypoxia was observed in up to 25% of the bottom area. Portions of Pensacola Bay, particularly areas near Pensacola Pass and Gulf Breeze, and locations in Santa Rosa Sound and Big Lagoon near the inlet to the Gulf of Mexico were repeatedly exposed to crude oil and weathered residue from the Deepwater Horizon oil spill during the summer of 2010. Restoration projects are under development.

1. General Status of Seagrasses in Pensacola Bay			
Status and stressor	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Green	Increasing	Increasing, 2010–2015
Water clarity	Yellow	Variable	Runoff, turbidity high in some locations
Natural events	Yellow	Increasing	Storm runoff
Propeller scarring	Yellow	Localized	35% of beds in East Bay
General Status of Seagrasses in Santa Rosa Sound and Big Lagoon			
Status and stressor	**Status**	**Trend**	**Assessment, causes**
Seagrass acreage	Green	Increasing	Small increases, 2010–2015
Water clarity	Yellow	Variable	Likely color, phytoplankton blooms
Natural events	Yellow	Increasing	Storm runoff
Propeller scarring	Yellow	Localized	26–28% of beds, on south shores; near development

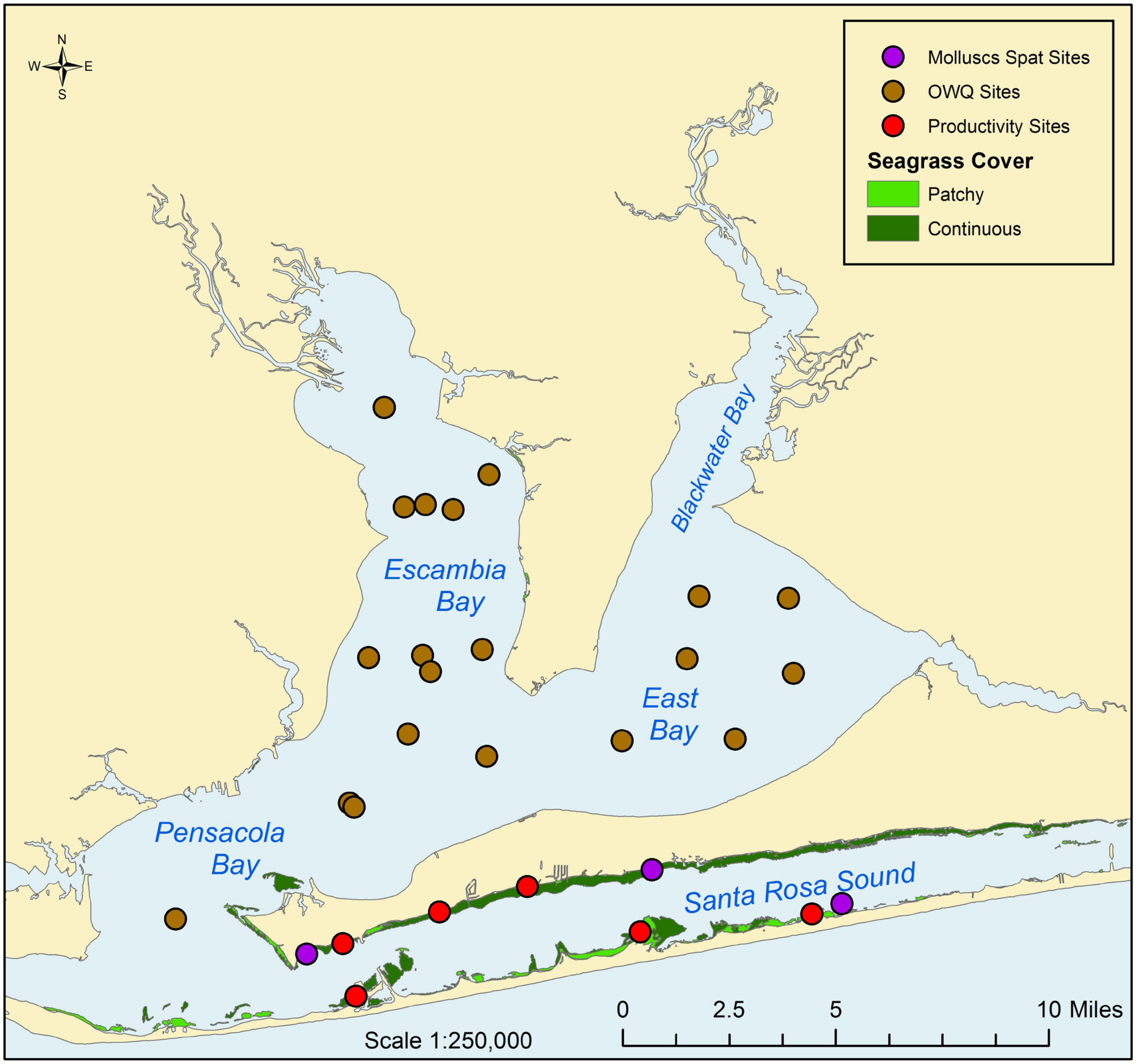

Figure 1. Seagrass mapped in 2015 and locations of sites for optical water quality (OWQ) sampling and for studies of productivity of turtlegrass in 2016 in Pensacola Bay, Escambia Bay, and East Bay. OWQ sites were visited quarterly in 2016 by scientists from the Fish and Wildlife Research Institute and the University of West Florida. The Molluscs spat sites have been visited monthly since 2014 by scientists from the Molluscan group at FWRI who also collect water samples for OWQ analyses.

Geographic extent

The Pensacola region is in the western Florida Panhandle and includes three subregions: the Pensacola Bay system, Santa Rosa Sound, and Big Lagoon. The Pensacola Bay system includes Escambia Bay, East Bay, Blackwater Bay, and Pensacola Bay. The Escambia River is the largest river in the region and carries sediment to Escambia Bay. It originates in Alabama and drains 4,200 square miles. The Yellow, Blackwater, and East rivers flow into northern portions of Pensacola Bay. Santa Rosa Sound is a lagoon located behind a barrier island and is south of Pensacola Bay. It connects with Choctawhatchee Bay to the east and with Pensacola Bay to the west. Big Lagoon is located west of Pensacola Bay, behind a barrier island, and connects Perdido Bay and Pensacola Bay. Big Lagoon and Santa Rosa Sound are separated by Pensacola Pass, which is open to the Gulf of Mexico. County boundaries separate Big Lagoon in Escambia County and Santa Rosa Sound in Santa Rosa and Okaloosa counties.

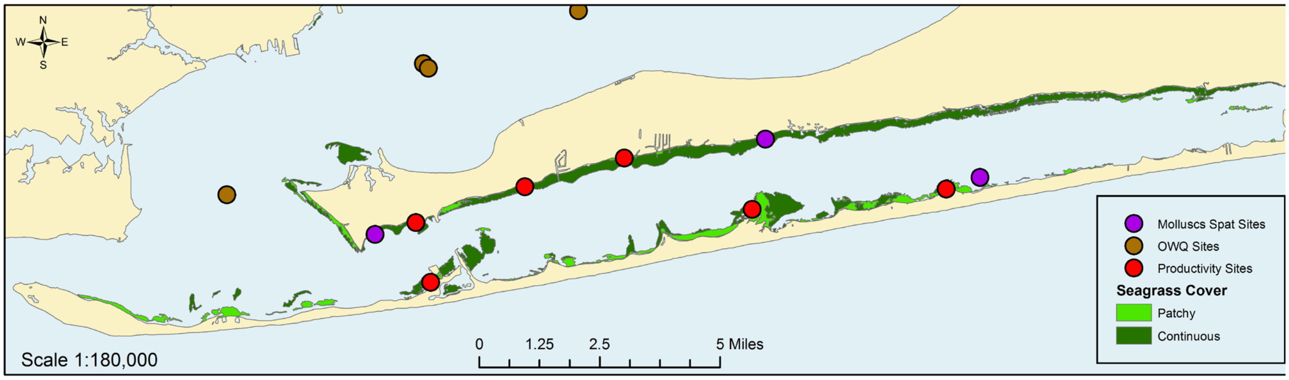

Figure 2. Seagrass mapped in 2015 and locations for optical water quality (OWQ) sampling and studies of the productivity of turtlegrass in 2016 in western Santa Rosa Sound. OWQ sites were visited quarterly in 2016 by scientists from FWRI and the University of West Florida; the molluscs spat sites have been visited monthly since 2014 by scientists from the Molluscan group at FWRI who also collect water samples for OWQ analyses.

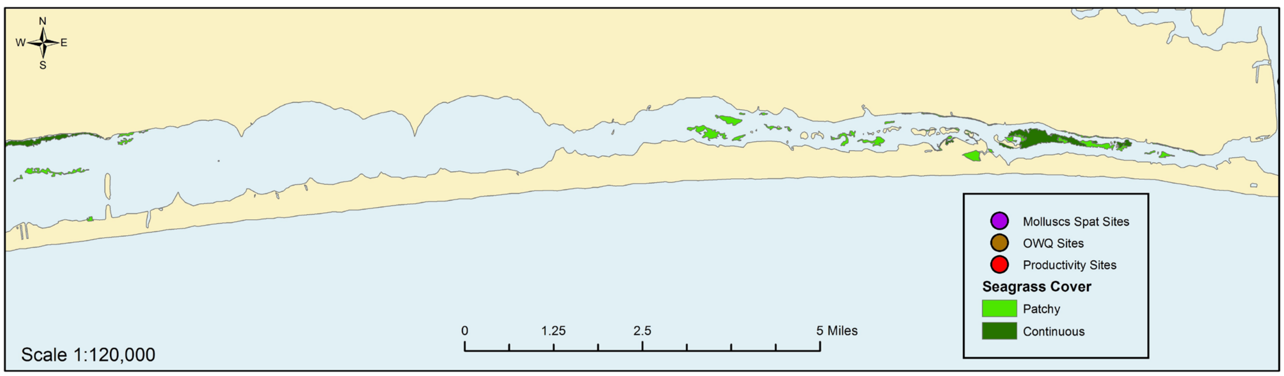

Figure 3. Seagrass mapped in 2015 in eastern Santa Rosa Sound. There are no locations for optical water quality sampling and studies of productivity of turtlegrass in this subregion.

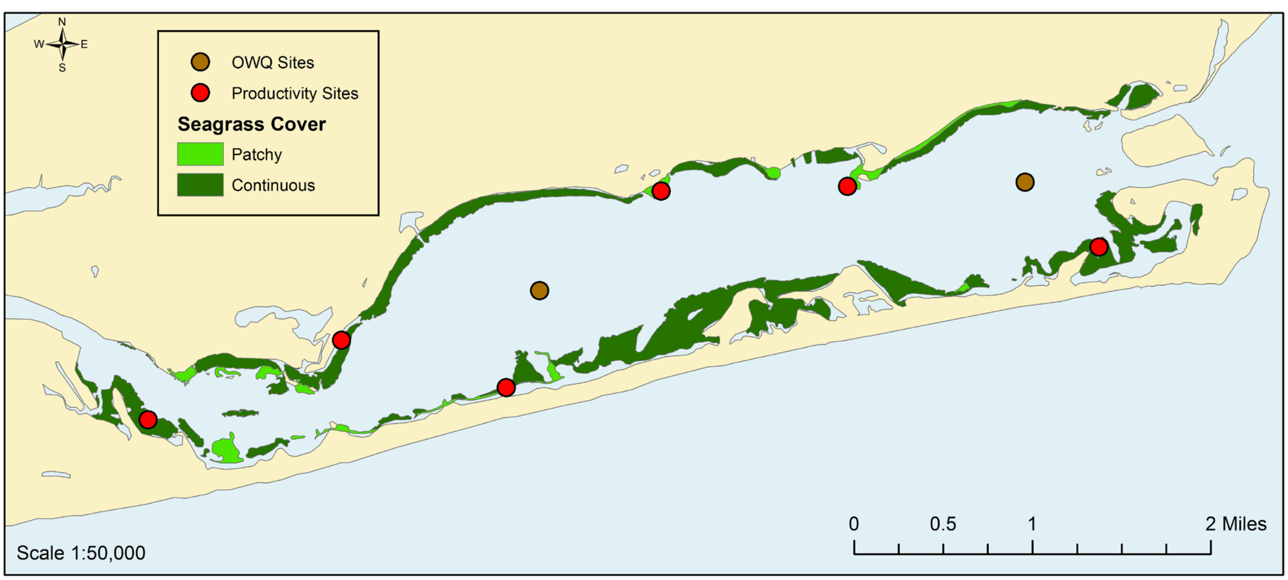

Figure 4. Seagrass mapped in 2015 and locations for optical water quality (OWQ) sampling and studies of the productivity of turtlegrass in 2016 in Big Lagoon. OWQ sites were visited quarterly in 2016 by scientists from FWRI and the Dauphin Island Sea Lab; the Molluscs spat sites have been visited monthly since 2014 by scientists from the Molluscan group at FWRI who also collect water samples for OWQ analyses.

The watershed drained by rivers flowing into the bay region covers 6,830 square miles, two-thirds of them in Alabama. Floodplains line the shores of the region's rivers, and wetlands are found extensively along the shoreline of the upper reaches of Escambia Bay, Blackwater Bay, and East Bay. Land use in the watershed is nearly two-thirds upland forest, 16% agriculture, 12% wetlands, and about 7% developed areas (see Northwest Florida Water Management District Surface Water Improvement and Management Plan for more information). See Lewis et al. (2016) for detailed information on environmental quality and sediment chemistry and toxicology.

Mapping and monitoring recommendations

- Implement regular, at least biennial, field seagrass monitoring throughout the region.
- Acquire high-resolution imagery of seagrass beds at least every six years, and complete mapping of same.

Management and restoration recommendations

- Determine the roadblocks to seagrass recovery for locations where sufficient light reaches the bottom but no seagrass has returned. As part of the effort to identify conditions preventing seagrass recovery, the FWRI Gulf Environmental Benefit Fund project has created spatial layers to populate the Seagrass Recovery Potential (SRP) model. These layers are bathymetry, wave exposure, sediment toxicity, optical water quality, propeller scarring, present and historical seagrass coverage, and the reproductive capacity of turtlegrass.
- Assess the relationship between development pressures and storm runoff, propeller scarring, sedimentation, and construction activities.
- Assess the extent and effects of seasonal hypoxia and the long-term effects of salinity change on submerged aquatic vegetation in the upper portions of the Pensacola Bay system.

Table 1. Acreage of seagrass in subregions of the Pensacola region, 1992, 2003, 2010, 2015. Escambia Bay and East Bay were not mapped in 2015.

		Acres of seagrass				Change, 2010–2015	
Subregion	**Bed texture**	**1992**	**2003**	**2010**	**2015**	**Acres**	**%**
Big Lagoon	Continuous	343	383	465	510	46	9.9%
	Patchy	146	125	46	60	14	30%
	Total	**489**	**508**	**511**	**571**	**60**	**12%**
Santa Rosa Sound	Continuous	1,947	1,687	2,339	2,407	68	2.9%
	Patchy	727	1,276	505	674	169	33%
	Total	**2,674**	**2,963**	**2,844**	**3,080**	**236**	**8.3%**
Southern Pensacola Bay	Continuous	33	0	77	275	197	256%
	Patchy	222	337	265	270	5	1.8%
	Total	**254**	**337**	**342**	**544**	**202**	**59%**
Total	Continuous	2,323	2,070	2,881	3,192	311	11%
	Patchy	1,095	1,738	816	1,004	188	23%
	Total	**3,418**	**3,808**	**3,697**	**4,196**	**499**	**13%**

	Acres of seagrass			Change, 2003–2010	
Subregion	**1992**	**2003**	**2010**	**Acres**	**%**
Escambia Bay	440	111	196	85	77%
East Bay	170	27.2	283	256	940%
Pensacola Region Total	**4,028**	**3,946**	**4,176**	**230**	**0.1**

- Restore areas along the southern shore of Santa Rosa Sound, near Pensacola Beach, where seagrass beds were covered with sediment deposited by storm surge during hurricanes.
- Restore vegetation on adjoining non-vegetated dune areas on the barrier islands.
- Continue restoration projects and planning to mitigate damage to seagrasses from the 2010 Deepwater Horizon oil spill.

The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, uses a watershed framework for resource management, protection, and restoration. An updated SWIM plan for the Pensacola Bay System was released in fall 2017: https://www.nwfwater.com/Water-Resources/Surface-Water-Improvement-and-Management/Pensacola-Bay-System . The plan describes the watershed's physical characteristics and natural resources, provides an assessment of current conditions, and identifies priority challenges affecting watershed resources and functions. This plan lists the following activities as having the highest priority:

- Stormwater planning and retrofit of existing systems
- Abatement of septic tanks
- Establishment of advanced onsite treatment systems
- Establishment or improvement of best management plans (BMPs) for agriculture and silviculture
- Abatement of sedimentation basin-wide
- Establishment of riparian buffer zones
- Restoration of aquatic, estuarine, and wetland habitats
- Conservation of strategic lands

2a. Seagrass Status and Potential Stressors in Pensacola Bay			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Improving	59% increase, 2010–2015
Seagrass meadow texture	Yellow	Variable	Impacts from runoff, wave energy
Seagrass species composition	Green	Variable	
Overall seagrass trends	Green	Increasing	Far southern bay only
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Some improvement	Poor in some areas
Nutrients	Green	Low levels	Episodic runoff
Phytoplankton	Green	Low levels	
Natural events	Yellow	Increasing	Runoff from rain events
Propeller scarring	Yellow	Localized	35% of beds in East Bay
Seasonal hypoxia	Red	Continuing	High sulfide levels

2b. Seagrass Status and Potential Stressors in Santa Rosa Sound and Big Lagoon			
Status indicator	**Status**	**Trend**	**Assessment, causes**
Seagrass cover	Green	Increasing	8% increase, 2010–2015
Seagrass meadow texture	Yellow	Stunted	
Seagrass species composition	Green	Little change	
Overall seagrass trends	Green	Increasing	Improved water quality
Seagrass stressor	**Intensity**	**Impact**	**Explanation**
Water clarity	Yellow	Variable	Turbidity, phytoplankton
Nutrients	Green	Low levels	Episodic runoff; septic tanks non-point inputs
Phytoplankton	Yellow	Variable	
Natural events	Green	Infrequent	Storms
Propeller scarring	Yellow	Localized	26–28% of beds, on south shores; near development

- Creation of watershed stewardship initiatives
- Establishment of subbasin restoration plans
- Improvements in wastewater treatment and management
- Interstate coordination
- Support of analytical programs
- Creation and support of comprehensive monitoring programs

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 FWRI's Roadblocks to Seagrass Recovery project (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.

Significant losses in seagrass acreage occurred in the Pensacola Bay region between 1950 and 1992 (Lewis et al. 2016). Since 1992, however, seagrass cover has been stable or increasing. Seagrass for most of the region was most recently mapped from imagery acquired in 2015 as part of the Roadblocks to Seagrass Recovery project (Table 1). Seagrass acreage increased 13% between 2010 and 2015 in Big Lagoon, Santa Rosa Sound, and southern Pensacola Bay, from about 3,700 acres to 4,200 acres. Most (76%) of the mapped seagrass were continuous beds, and 62% of the increased acreage was also continuous seagrass. In East Bay (including Blackwater Bay) and Escambia Bay, seagrasses covered 479 acres in 2010, an increase of 341 acres from 2003. Since 2000, significant changes in species composition occurred in Escambia Bay because higher salinities eliminated beds of tapegrass (*Vallisneria americana*) and widgeongrass (*Ruppia maritima*). Five species of seagrass have been observed in the region, but turtlegrass and shoalgrass are the most common (Table 3). Turtlegrass had the greatest frequency of occurrence (FO) in Santa Rosa Sound, in Big Lagoon, and at Fort McRae in 2011 and 2014. The FO of shoalgrass dropped sharply from 2011 to 2014 in all subregions. Rains and storm runoff were unusually high throughout the Panhandle in 2014 and may have contributed to declines in the FO of shoalgrass. Widgeongrass is the third most common species in the region, and its FO exceeded that of shoalgrass at most locations where both occurred in 2014. Manateegrass and stargrass (*Halophila engelmannii*) are found infrequently.

The extent of propeller scarring was evaluated using imagery acquired in 2013 by the U.S. Department of Agriculture National Agricultural Imagery Program (NAIP). In Big Lagoon, scarring was common along the south shore, near points of land, and in Sherman Cove. In Santa Rosa

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

		East Bay		Escambia Bay		Santa Rosa Sound		Big Lagoon	
Description	**Score**	**Cell count**	**% of vegetated cells**	**Cell count**	**% of vegetated cells**	**Cell count**	**% of vegetated cells**	**Cell count**	**% of vegetated cells**
Vegetated, no scars	0	625	65%	282	92%	1,799	69%	448	73%
< 5 scars	1	264	28%	22	7.2%	568	22%	135	22%
5–10 scars	2	54	5.6%	3	1.0%	98	3.7%	15	2.4%
11–25 scars	3	12	1.3%			41	1.6%	11	1.8%
26–50 scars	4	5	0.5%			10	0.4%	1	0.2%
>50 scars	5					6	0.2%		
Doughnut-shaped beds	7					74	2.8%	3	0.5%
Unreadable, grass	10					24	0.9%		
Total vegetated		960		307		2,620		613	
Total scarred		335	35%	25	8.1%	723	28%	162	26%

Sound, scarring was evident near developed areas, especially on the east side of the Gulf Breeze causeway. Generally, the intensity of propeller scarring was low, but scarring affected 28%, 26%, and 35% of seagrass beds in Santa Rosa Sound, Big Lagoon, and East Bay, respectively (Table 2).

The 95% decline in seagrass acreage between 1950 and 1980 has been attributed to poor water quality due to industrial and sewage pollution and perhaps harbor dredging (Olinger et al. 1975). But since 2000, water clarity has been relatively high, and nutrient concentrations and chlorophyll-a levels have been low. Koch (2001) reported that seagrasses were absent from many locations where light was sufficient for their growth, which is of special concern to regional management agencies.

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 Pensacola Bay appears stable while status in Santa Rosa Sound and Big Lagoon show improvement (status graphic 1) over the same assessment in the second edition of this chapter, due primarily to increases in seagrass acreage observed between 2010 and 2015. However, recent quantitative assessment of propeller scarring showed that 35% of seagrass beds in East Bay were scarred and that 26–28% of beds in Santa Rosa Sound and Big Lagoon had some scarring damage. 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).

Seagrass mapping assessment

In 2010, 4,176 acres of seagrass were mapped in the Pensacola region, a 6% (230 acres) increase over the 2003 mapping effort (Table 1). Mapping of imagery collected in fall 2015 for all areas except Escambia Bay and East Bay showed an increase of 499 acres from 2010. Most of the increase occurred as continuous beds. But between 2003 and 2010, Santa Rosa Sound lost 119 acres and Big Lagoon lost 3 acres of seagrass. Between 1992 and 2003, total cover of submersed aquatic vegetation (SAV) in the Pensacola region declined only 2%, but larger changes occurred in each subregion (Table 1). Santa Rosa Sound, Big Lagoon, and Pensacola Bay gained 390 acres (111% increase since 1992), while Escambia Bay and East Bay lost 472 acres (77% of acreage in 1992). The declines in Escambia Bay and East Bay occurred in upper portions of these bays and resulted from losses of brackish-water SAV due to increased salinity. Mapping data from 2010 and 2015 distinguished between patchy and continuous seagrass beds, and for both mapping efforts about 75% of all seagrass occurred as continuous beds. In 2015, 89% and 78% of seagrass beds were continuous in Big Lagoon and Santa Rosa Sound, respectively. In the southern portion of Pensacola Bay, 50% of beds were continuous in 2015.

Table 3. Percentage occurrence of seagrass species in subregions of the Pensacola region in 2011, 2014, and 2016. Fort McRae is located just west of the Pensacola inlet and Fort Pickens is located just east of the Pensacola inlet.

Subregion	Year	# quadrats	Manatee-grass	Turtle-grass	Shoal-grass	Widgeon-grass	Star-grass	Bare
Pensacola Bay	2011	110		40	58	3.6		16
	2014	100	3.0	32	16	36		39
Fort McRae	2011	100		78	72			
	2014	100		73	15	32		15
Fort Pickens	2011	130		6.2	83			17
	2014	125		14	20	44		32
East Bay	2016	23				13		70
Santa Rosa Sound	2011	800	5.1	52	28		0.13	31
	2014	100	45	67	7.0	18		17
	2016	68		78	40			
Big Lagoon*	2011	270	3.3	62	53			17
	2014	245		50	15	30		28
	2016	90		82	84			1.1

*Only sites with seagrass were visited in 2016.

Propeller scarring

Propeller scarring of seagrass beds was quantified using aerial imagery collected in 2013 by the NAIP. The imagery was overlaid by a grid of cells, each with an area of 1 ha. Inside each cell that covered seagrass, scars were counted, and the cell was given a score (Table 2). Most cells in each subregion had no scarring, and where scarring was observed, intensity (number of scars per cell) was usually low. Seagrass beds in Escambia Bay had the lowest percentage of scarring (8.1%), but the amount of seagrass in this subregion is also very low. East Bay had the highest percentage of scarring (35%), while about one-fourth of seagrass beds in Santa Rosa Sound and Big Lagoon were scarred. In Santa Rosa Sound and Big Lagoon, scarring was most frequent on shoals and near points of land.

Monitoring assessment

Seagrass field monitoring in the Pensacola region is conducted by several agencies. Seagrasses have been assessed in association with restoration plantings by FDEP Northwest District staff. Staff from the Dauphin Island Sea Lab (DISL) have monitored seagrass beds located within the boundaries of the Gulf Islands National Seashore, i.e., Big Lagoon and Santa Rosa Sound, each fall since 2011. In June 2010, October 2011, and August 2014, personnel from FWRI monitored seagrasses throughout the region. Field sampling was completed in early June 2010 so that baseline information could be gathered before spilled Deepwater Horizon oil reached the Pensacola region. Therefore, the sampling design was targeted to assess existing beds, not to evaluate the cover and species distributions across all bottom areas in the region. In 2011 and 2014, FWRI expanded its sampling effort and used a spatially distributed random-sampling design to assess bottom habitats in water <3m deep. Sampling in 2011 and 2014 did not extend into the upper reaches of Escambia and East bays, and many fewer sites were sampled in Santa Rosa Sound in 2014 than in 2011. Because sampling designs differ among the monitoring efforts, data cannot be compared. Seagrass cover assessment in 2011, 2014, and 2016 showed that turtlegrass and shoalgrass were most common in the region and that manateegrass occurred much less frequently (Table 3). In 2011, following a drought, widgeongrass was observed only in Pensacola Bay, but in 2014, after two years of storminess and above–average rainfall and runoff, it occurred in all subregions in 18–44% of quadrats. Note, however, that only four sites were visited in Santa Rosa Sound in 2014. Monitoring in 2016 was done only at sites where seagrass was present which is the reason that occurrence values for turtlegrass and shoalgrass are so high.

While frequency of occurrence is a measure of the abundance of each seagrass species in a specific area,

Table 4. Mean (2× standard error in parentheses) percent cover of seagrass species in subregions of the Pensacola region, 2011, 2014, and 2016. Analysis included, for each species, only those quadrats where that species was present; therefore, the number of quadrats used for the means was variable. The method of assessment in the field used in 2016 was different from that used in 2011 and 2014 (see methods for explanation).

Year	Subregion	Shoal-grass	Turtle-grass	Manatee-grass	Widgeon-grass
2011	Pensacola Bay	29 (5.8)	37 (5.4)		
	Fort Pickens	26 (3.0)	4.6 (0.65)		
	Fort McRae	16 (3.9)	22 (3.2)		
	Santa Rosa Sound	13 (1.6)	23 (1.4)	7.8 (2.1)	
	Big Lagoon	23 (3.0)	19 (2.3)	4.6 (2.5)	
2014	Pensacola Bay	1.2 (.37)	3.6 (0.85)	2.4 (0.86)	1.4 (0.29)
	Fort Pickens	4.5 (2.1)	13 (6.7)		4.6 (1.8)
	Fort McRae	3.7 (1.8)	4.9 (0.84)		5.3 (1.4)
	Santa Rosa Sound		5.8 (2.5)	2.3 (0.62)	
	Big Lagoon	3.2 (0.57)	4.1 (0.64)		4.3 (0.64)
2016	Santa Rosa Sound	44 (8.7)	57 (6.5)		
	Big Lagoon	43 (7.3)	34 (6.5		

quadrat cover (similar to the Braun-Blanquet method; see methods below) provides an assessment of plant density at each site. Mean percentage cover of seagrass species in quadrats assessed in 2011, 2014, and 2016 (Table 4) provides strong evidence for the effects of storminess and excessive rainfall and runoff in 2014 on the condition of seagrass beds. Except for turtlegrass in the Fort Pickens segment, located near Pensacola Pass and the Gulf of Mexico, mean cover of seagrass was lower in all segments in 2014 than in 2011. Widgeongrass was not observed in the region in 2011, and in 2014 its mean cover was low. In 2016, field assessment of seagrass cover was conducted in Santa Rosa Sound (4 sites) and Big Lagoon (30 sites), and assessment occurred only where seagrasses were known to be present. In 2016, mean densities of shoalgrass and turtlegrass were high in Santa Rosa Sound and Big Lagoon, and other species of seagrasses were not observed.

Productivity of turtlegrass

Field measurements of the productivity of turtlegrass were made twice in summer 2016 at six sites each in Big Lagoon and Santa Rosa Sound (see Figures 2 and 4) by scientists from DISL and the University of West Florida (UWF), respectively, using the punch and harvest method developed by Zieman and Zieman (1989). Live biomass averaged 366–453 g/m^2 in Big Lagoon, and 70% was above the sediments in June and 54% was above the sediments in August (Table 5). Dead biomass was 10-14% of all biomass collected in Big Lagoon. More than twice as much biomass (625 g/m^2) was present at Santa Rosa Sound (SRS) sites in September than was measured in June (308 g/m^2). About two-thirds of live biomass was above the sediment surface in SRS, and 13-29% of all biomass was dead.

A variety of measures of productivity can be reported using the data collected from these experiments. We have chosen to report counts of turtlegrass shoots, 1-sided leaf area index (LAI), and average shoot specific blade growth (SSBG). Shoot counts, reported per m^2, are a common metric for seagrass ecosystems, and counts can vary widely over short distances. Because turtlegrass is a long-lived species, the variation in shoot counts over short periods of time is likely to be less than variation from one place to another. In these experiments, scientists conducted measurements at the same site at two times, but the locations of the quadrats by necessity were slightly different from one sampling period to another. Shoot counts ranged from 460 to 1,950/m^2, with considerable variability, for sites in Big Lagoon during both sampling periods (Figure 5). Sites listed along the x-axis in Figure 5 are from east to west along the lagoon shores. Lowest counts were measured at sites BLP5 and OBL01 located in the western part of the lagoon, and counts were greater in August than in June at all sites except BLP5.

The 1-sided LAI is a unitless metric calculated by dividing the total blade area in cm^2 covering a m^2 of sediment surface by the number of cm^2 (10,000) in a m^2. The 2-sided LAI (2× 1-sided LAI) is another reported metric that estimates total blade surface area compared to 1 m^2 of sediment surface. Means of 1-sided LAI were also lowest at sites BLP5 and OBL01 in western Big Lagoon, where shoots were sparse, small and short, and were very

Table 5. Biomass of live and dead turtlegrass, above and below the sediment surface, in Big Lagoon and Santa Rosa Sound, during two sampling periods in summer 2016.

Subregion	Month	Fraction	Biomass (g/m^2) Live Mean	Live Std. dev.	Live N	Dead Mean	Dead Std. dev.	Dead N
Big Lagoon	June	Above	257	191	23	27.0	31.2	21
		Below	109	78.4	23	14.5	11.0	18
		Total	**366**			**41.6**		
	August	Above	247	166	24	49.1	51.5	20
		Below	206	156	24	25.2	27.4	20
		Total	**453**			**74.3**		
Santa Rosa Sound	June	Above	214	137	28	39.2	31.3	26
		Below	94.2	51.2	25	84.6	69.3	26
		Total	**308**			**124**		
	September	Above	390	85.6	24	24.9	10.4	24
		Below	236	94.4	24	65.7	32.7	24
		Total	**625**			**90.6**		

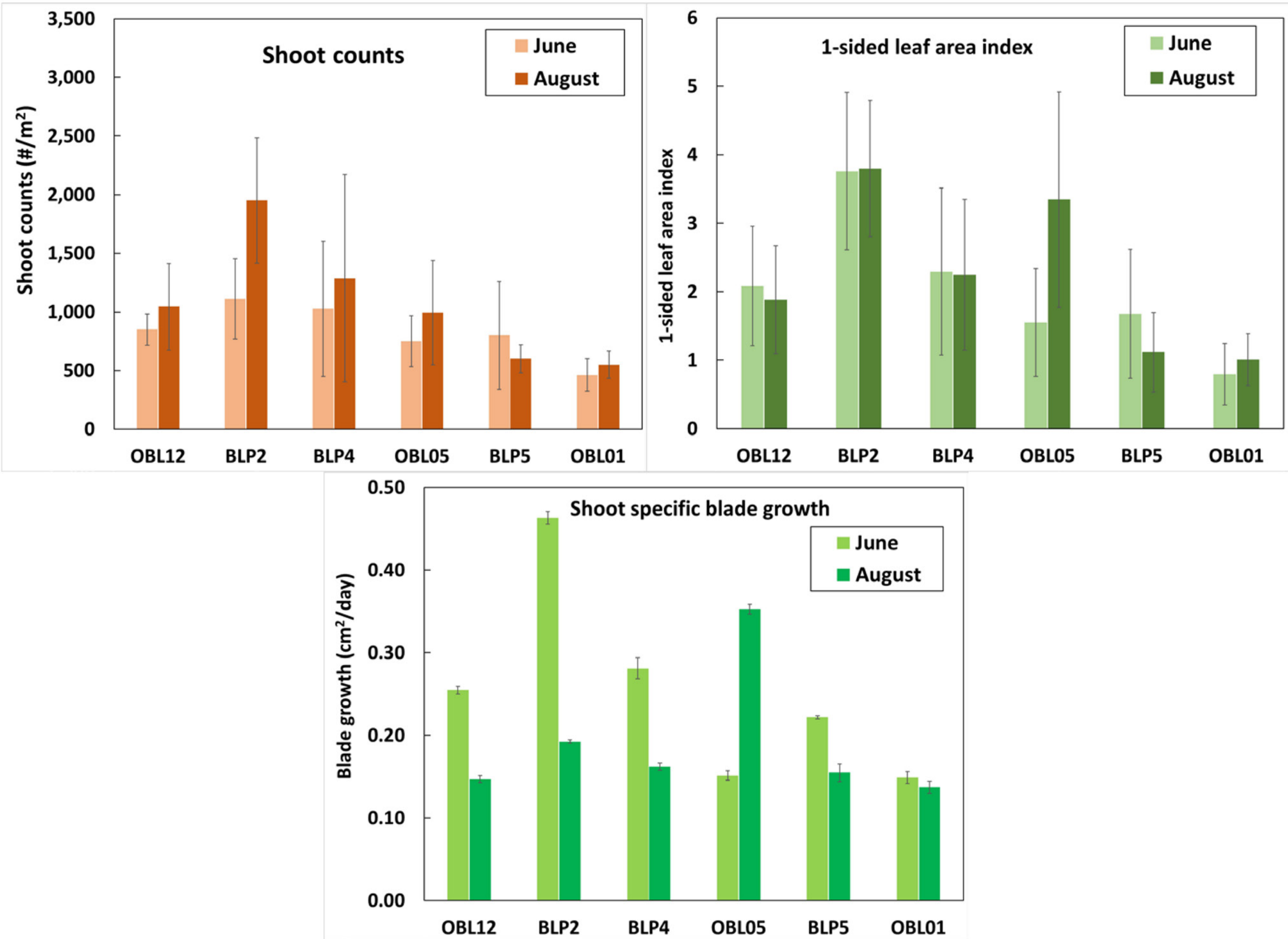

Figure 5. Mean (± 2 standard error) shoot counts (#/m^2), one-sided leaf area index (LAI), and shoot specific blade growth (cm^2/day) of turtlegrass in Big Lagoon in June and August 2016.

high at BLP2, a site in the middle of the lagoon (Figure 5), where shoot counts were high as well. Shoot-specific blade growth (SSBG) is a measure of the increase in blade area during the experiment and is reported as cm^2/day for each punched shoot. We report mean SSBG because it provides information on shoot performance at each site; multiplying SSBG by shoot counts estimates productivity in cm^2/m^2/day. SSBG was also lowest at western Big Lagoon sites BLP5 and OBL01 and generally was lower in August than in June. Very high blade growth was measured at BLP2, in the middle of the lagoon in June, and in August, at OBL05, also in the middle portion of the lagoon.

Shoot counts, 1-sided LAI, and SSBG were more variable among sites and between sampling periods in Santa Rosa Sound (SRS) than in Big Lagoon (Figure 6). Overall mean shoot counts for all sites and sampling periods were greater in SRS (1,330/m^2) than in Big Lagoon (950/m^2). No spatial patterns in shoot counts were evident in SRS. Generally, 1-sided LAI was lower at sites in SRS than sites in Big Lagoon, and variation in the means between June and September showed no pattern. SSBG was very high at EPA and Shoreline Park in June in western SRS and during both sampling periods at Oriole Beach, located in the middle of SRS. These values were nearly four times those measured in Big Lagoon. Naval Live Oaks, in middle SRS, and Opal Beach, in the eastern sound, had SSBG closer to values measured in Big Lagoon.

Water quality and clarity

In 2016, personnel from FWRI and UWF measured water clarity parameters as part of the Roadblocks to Seagrass Recovery project. Chlorophyll-a concentration (a proxy for phytoplankton levels), turbidity, and water color were measured quarterly at locations in Pensacola Bay, Escambia Bay, East Bay, and Santa Rosa Sound (see Figures 1, 2, and 4). Means (±2 standard error) of these parameters are shown in Figure 7. Mean values of all parameters were greatest in Escambia Bay during all seasons, and all means were lowest in the fall. Escambia Bay receives large volumes of freshwater runoff from the Escambia River, which drains a large area in Flor-

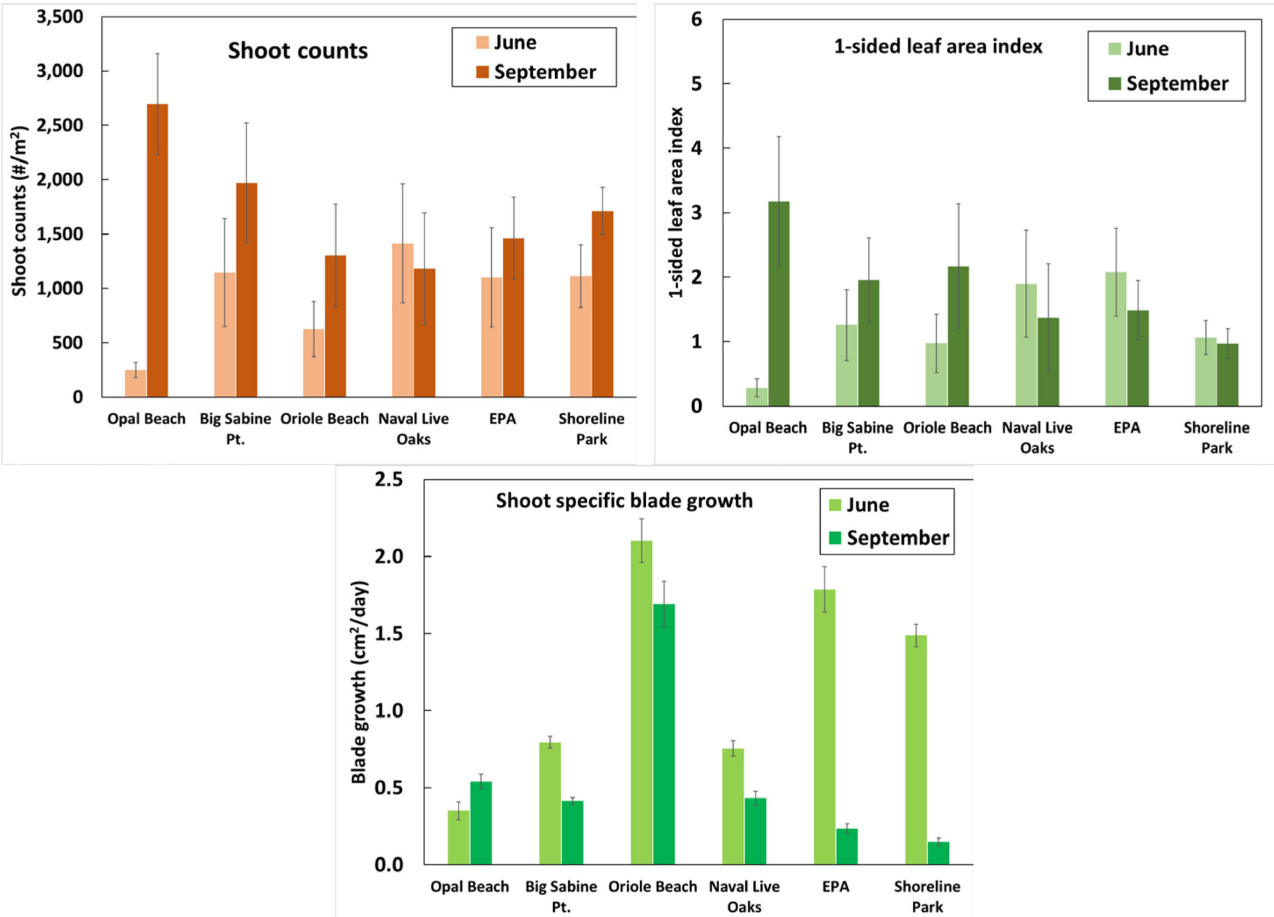

Figure 6. Mean (± 2 standard error) shoot counts (#/m^2), one-sided leaf area index (LAI), and shoot specific blade growth (cm^2/day) of turtlegrass in Santa Rosa Sound in June and September 2016.

ida and Alabama; the runoff, especially after storms, is turbid enough to be visible in satellite images. It is likely that nutrients in runoff contribute to high chlorophyll-a concentrations, that turbidity in the runoff contributes to elevated turbidities in the bay, and that drainage from marshes and swamps in the floodplain of the Escambia River contribute water color to runoff. Values from 2016 are comparable to those from previous years (see Seagrass Integrated Mapping and Monitoring Report 2, 2013).

Watershed management

The Northwest Florida Water Management District, http://nwfwater.com/, through the Surface Water Improvement and Management (SWIM) program, identifies and addresses issues of water resource concern within the SWIM planning basins. The Pensacola Bay System SWIM plan released in the fall of 2017 (https://www.nwfwater.com/Water-Resources/Surface-Water-Improvement-and-Management/Pensacola-Bay-System) lists several priorities, including:

- Minimization of undesirable impacts on the riverine and estuarine system from adjacent uplands.
- Improvement of water and sediment quality for perpetuation of a healthy riverine and estuarine system.
- Acquisition and support of environmentally sensitive lands to protect the water quality and habitats of the Pensacola Bay system.
- Increased public awareness and coordinated cooperative management of the system.

The Pensacola Bay system watershed includes a major alluvial river, blackwater streams, and five interconnected bays. Significant habitats include seagrass beds, tidal marshes, and bottomland hardwood forests, among others. The district owns and manages more than 57,000 acres in the watershed, including lands along the Escambia, Blackwater, and Yellow rivers and on Garcon Point.

District personnel continue to help local governments develop and implement cooperative habitat restoration and stormwater retrofit projects. Implementation of these

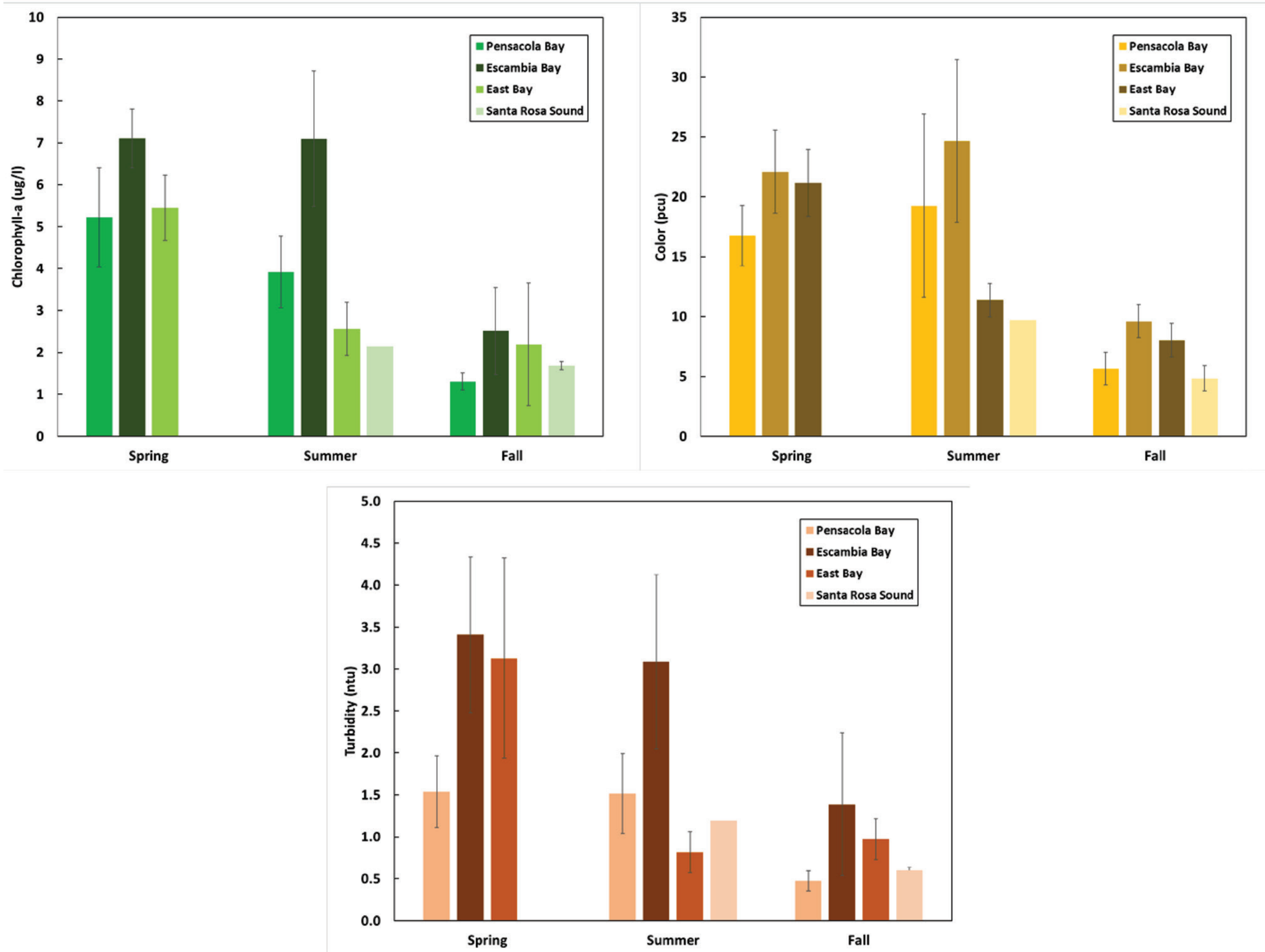

Figure 7. Seasonal means (±2 standard error) of chlorophyll-a concentration, color, and turbidity in subregions of the Pensacola region, 2016.

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 habitat by Dewberry Inc. (Tampa). The Florida Land Use, Cover, and Forms Classification System (FLUCCS; Florida Department of Transportation 1999) was used to classify bottom features as continuous seagrass, patchy seagrass, oyster bed, bare intertidal, shallow bare bottom, or deep bare bottom. Bottom features were delineated with polygonal shapefiles, with a minimum mapping unit of 0.1 ha. To compare acreage among mapping years, a polygon was created for each subregion, and the mapping shapefile for each year was clipped to the polygons. This ensured that the same spatial footprint was used to measure acreage for each set of data.

High-resolution (1 m), 4-band aerial imagery was collected for the entire northern Gulf coast in October 2010, and photo-interpretation of the Pensacola region was completed by PhotoScience Inc. (St. Petersburg). The FLUCCS (Florida Department of Transportation 1999) was used to classify bottom features. In 2003, seagrass data were derived from interpretation of color infrared photography. These images were mapped at 1:12,000 scale on hard copies that had been rectified to U.S. Geological Survey (USGS) digital orthophoto quarter-quadrangle base maps and digitized at the USGS National Wetlands Research Center (NWRC). The seagrass beds were classified according to an NWRC-derived classification scheme based on the Coastal Change Analysis Project (C-CAP) 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 that was 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 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.

Propeller scarring assessment

As part of the Roadblocks to Seagrass Recovery project, scientists at FWRI assessed the extent and severity of propeller scarring in seagrass beds in Big Lagoon, Santa Rosa Sound, Escambia Bay, and East 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, covering 1 ha each. For each cell located 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 completed for each subregion, the number of cells having each score was summed and compared with the total number of vegetated cells to calculate the percentage for each scarring score and 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.

Monitoring methods and data

Field monitoring of seagrasses in the Pensacola region is conducted by several agencies, but no program covers the entire region. Most recently, field monitoring was carried out in the summer of 2016 in Big Lagoon (19 sites) and Santa Rosa Sound (4 sites) by scientists from DISL and the UWF, respectively. In Big Lagoon, sites were selected because each had seagrass present, based on information from earlier assessments. Fifteen sites were located along the south side of the lagoon near locations where monitoring is conducted for the GINS, and 4 sites were located randomly along the north shore. At each site, five 0.25-m^2 quadrats, located randomly around the vessel, were assessed for seagrass and macroalgal basal cover to the nearest 5%. In addition, scientists from DISL have used quadrat cover assessments to monitor seagrass beds within the boundaries of GINS, i.e., Big Lagoon and Santa Rosa Sound, each fall since 2011. The 4 sites assessed for seagrass cover in Santa Rosa Sound in summer 2016 were located along the shores of the central portion of the sound, and assessment methods were the same as those used by DISL staff.

In the fall of 2016, scientists from the Northwest District of the FDEP resumed a field monitoring program in the Fort Pickens Aquatic Preserve; seagrass cover was assessed at 25 sites near Fort Pickens and in Big Lagoon. This program will monitor seagrasses each fall and spring. Seagrasses have been assessed in association with restoration plantings by FDEP Northwest District personnel.

In June 2010, October 2011, and August 2014, FWRI personnel also carried out field monitoring of seagrasses throughout the region. Field sampling in early June 2010 was completed to provide baseline information before the arrival in the Pensacola region of oil from the Deepwater Horizon spill. Therefore, the sampling design was targeted to assess existing beds and not to evaluate the cover and species distributions across all shallow-water areas. In 2011 and 2014, FWRI expanded its sampling effort and used a spatially distributed random-sampling design to assess bottom habitats where water depth was <3 m. Sampling did not extend into the upper reaches of Escambia and East bays, and many fewer sites were sampled in Santa Rosa Sound in 2014 than in 2011. Field sampling included assessment of 10 0.25-m^2 quadrats randomly located at each site. Divers identified seagrass and macroalgal species and estimated bottom cover using a modification of the Braun-Blanquet technique. Personnel also measured water quality and clarity parameters including salinity, water temperature, water depth, Secchi depth, pH, dissolved oxygen concentration, and light attenuation, and they collected water samples for measurement of chlorophyll-a concentration, turbidity, total suspended solids, and water color in the laboratory.

Productivity of turtlegrass

Turtlegrass productivity in Big Lagoon was measured at 6 locations by scientists from DISL in June and August 2016 (Figure 4) and at 6 locations in Santa Rosa Sound (Figure 2) in June and September by scientists from the UWF. At each location, 4 quadrats, 20 cm on a side (0.04 m^2), were anchored in a turtlegrass bed within 1 m of each other using 6-inch sod staples. Each shoot of turtlegrass in a quadrat was punched just above the end of the short shoot at the basal meristem with a 20-gauge hypodermic needle, following the method of Zieman and Zieman (1989). After about 10 days, all the seagrass material, both above and below the sediment surface in each quadrat, was carefully harvested, chilled, and transported back to the laboratory for processing.

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

Optical water quality measurements

Measurements of OWQ 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 light 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 of light by the water itself, by the amount, quality, and size of particles in the water, and the amount of color added to the water column by the presence of colored dissolved organic matter (CDOM). The quantity and character of particles in the water are estimated by the measurement of chlorophyll-a as a proxy for phytoplankton, by measurement of TSS as a gravimetric estimate of the number of particles in the water, and by the measurement of turbidity, which estimates light scattering by particles as well as the number of particles present. Color of the water column can be measured by light absorption of a filtered water sample at 440 nm (for color) or over 300–600 nm (for CDOM).

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 uses fresh spinach extracts and the trichromatic equations of the 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 sample water 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 on a Hach 2100Q turbidimeter using 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* (1985) by filtering water samples through combusted, tared GFC glass fiber filters. Filters were dried at 50°C for at least five days and then re-weighed using a 5-place Mettler balance.

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