

# Summary Report for the Springs Coast

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in

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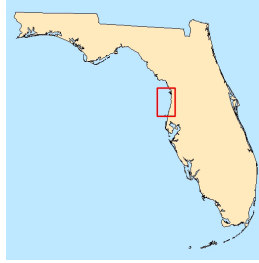
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## Summary Report for Springs Coast

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Pasco County), and near Anclote Key but is less extensive elsewhere. The seagrass beds found offshore of the mouth of the Homosassa River in the northern part of the region support large populations of scallops and the accompanying recreational fishery.

## Geographic extent

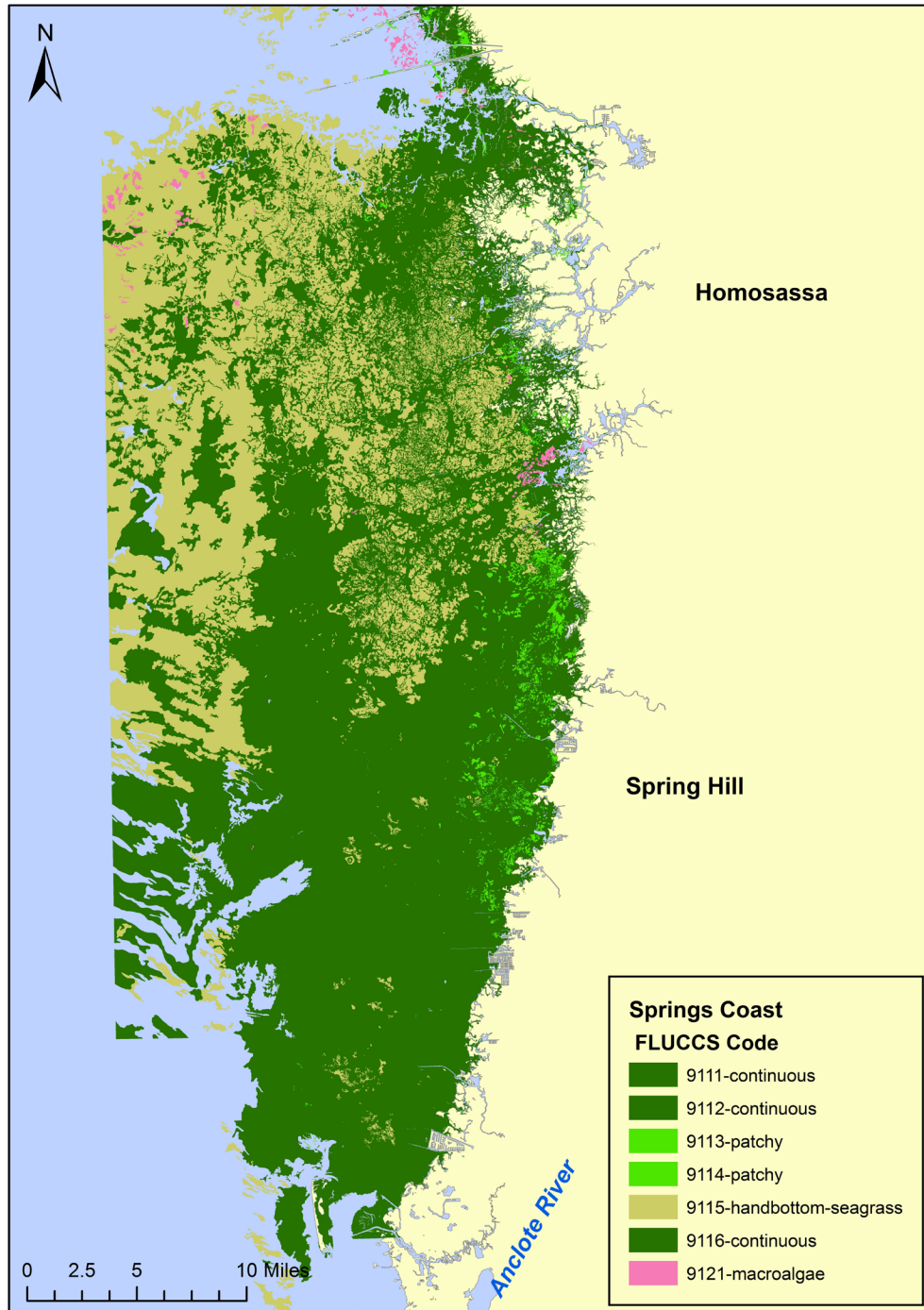
The Springs Coast extends from the mouth of the Crystal River south to Anclote Key on the Pasco/Pinellas county line, with a total nearshore area of 494,400 acres. Three counties border the coast: Citrus, Hernando, and Pasco. This region is unique because most of the freshwater runoff into coastal waters comes from springs. Four first-magnitude spring groups together contribute more than 800 million gallons a day of freshwater to the Springs Coast; these groups are Crystal River/Kings Bay, Homosassa, Chassahowitzka, and Weeki Wachee (Southwest Florida Water Management District 2015). All the rivers are short, only 6–10 miles from the headwater springs to the Gulf of Mexico. The area of land contributing freshwater to the Springs Coast includes the watershed producing surface runoff and the springsheds which feed the spring groups. Nitrogen enrichment of spring waters, primarily in the form of nitrate, is a special concern because extra nitrogen stimulates the growth of unwanted algae in springs and spring-fed rivers. The drainage area of the region varies depending on rainfall patterns and aquifer levels. At the southern border of the region, the Anclote River flows into the Gulf at the Pasco–Pinellas county line; average discharge is 180 million gallons per day at Elfers, about 2 miles from the mouth of the river (U.S. Geological Survey Waterdata). Land use among the springsheds varies. The Crystal River/Kings Bay system has experienced large-scale urbanization in the past 70 years; in other spring systems, urban and residential areas cover 24–37% of the land area. Land use along the coast is mostly wetlands, except in Pasco County, where there is considerable ur-

## General assessment

In 2016, the Springs Coast region contained 396,100 acres of seagrass within 14 miles of shore (Figure 1). Extensive, unmapped areas of sparse seagrass occur farther offshore, on the continental shelf. Seagrass cover has increased by 17,290 acres since 2007, or 0.5%/yr (Table 1). Seagrass species composition shows small variations from one monitoring period to another and is dominated by turtlegrass (*Thalassia testudinum*). Manatee grass (*Syringodium filiforme*), shoalgrass (*Halodule wrightii*), and stargrass (*Halophila engelmannii*) are less common but occur throughout the region. Widgeongrass (*Ruppia maritima*) occurs sporadically. Macroalgae are diverse in this region where the bottom is a mix of seagrass, hardbottom, and corals. Stressors include nutrients, phytoplankton, and turbidity which affect light available to seagrasses. These were elevated after the 2004 and 2005 hurricane seasons, but they returned to background levels in 2014. In the falls of 2012, 2013, and 2014, optical water quality and clarity were exceptionally good in the region. Heavy propeller scarring is evident around the mouth of Pithlachascotee River, the St. Martins marker shoal (10 nmi off

**1. General Status of Seagrasses in the Springs Coast Region**

| Status and stressors | Status | Trend                          | Assessment, causes                                                    |
|----------------------|--------|--------------------------------|-----------------------------------------------------------------------|
| Seagrass acreage     | Green  | Increasing                     | Excellent water quality                                               |
| Seagrass density     | Yellow | Some losses of continuous beds |                                                                       |
| Water clarity        | Green  | Stable                         |                                                                       |
| Natural events       | Green  | None since 2005                |                                                                       |
| Propeller scarring   | Yellow | Localized                      | Mouth of Pithlachascotee River, St. Martins marker shoal, Anclote Key |

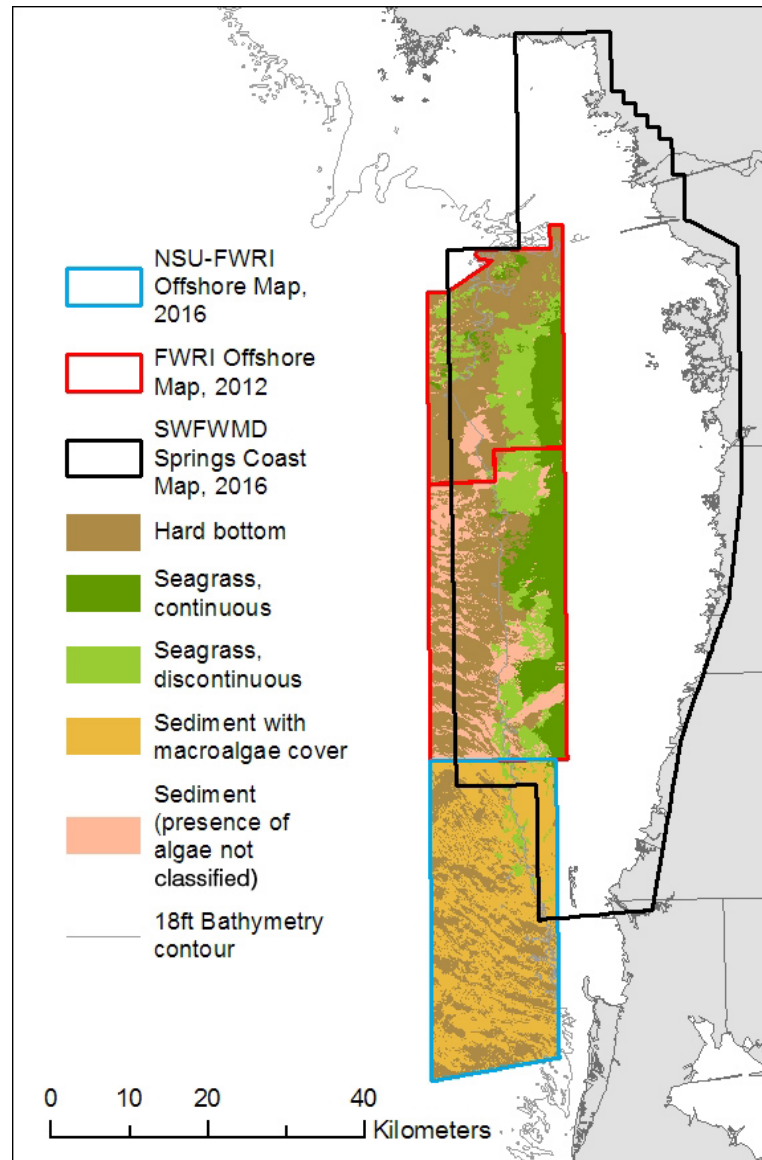


**Figure 1.** Map of Springs Coast seagrasses, 2016. Florida Land Use Cover Classification System (FLUCCS) codes delineate bed characteristics. Mapping data are from the Southwest Florida Water Management District.

ban development near and along the shore. Seagrass beds extend a considerable distance beyond the mapped area shown in Figure 1 and grow to water depths of 5 m. These beds grow where adequate sediments overlie carbonate strata. Calcareous macroalgae grow where carbonate rock is exposed on the bottom.

### Mapping and monitoring recommendations

- Acquire and photo-interpret aerial or satellite imagery every six years.
- Continue to map and monitor seagrasses in waters too deep for conventional aerial photography.



**Figure 2.** Map of offshore benthic habitats, interpreted from satellite imagery collected in 2012 and 2016. Data from FWRI and Nova Southeastern University.

- Continue the monitoring program in the St. Martins Keys area (south of the mouth of the Crystal River through Homosassa Bay) conducted by the Florida Department of Environmental Protection's (FDEP) Big Bend Seagrasses Aquatic Preserves, and resume the region-wide fall monitoring program conducted by the Florida Fish and Wildlife Conservation Commission's (FWC) Fish and Wildlife Research Institute (FWRI).
- Continue water-quality monitoring of the Homosassa, Pithlachascotee, Crystal, Weeki Wachee, and Withlacoochee rivers, their associated estuaries, and adjacent coastal marine waters. Water quality monitoring programs such as Project Coast (SWFWMD and the University of Florida) assess changes in nutrient loads.
- Investigate and develop mapping techniques for monitoring trends of expanding drift macroalgae and its impacts on seagrass communities.

### Management and restoration recommendations

- Monitor impacts of propeller scarring on the St. Martins marker shoal to develop a strategy for reducing further impacts.
- Use the boating and angling guides for the region to improve boater education and awareness of seagrass beds.

| <b>2. Seagrass status and potential stressors in the Springs Coast region</b> |                  |                                |                                                                       |
|-------------------------------------------------------------------------------|------------------|--------------------------------|-----------------------------------------------------------------------|
| <b>Status indicator</b>                                                       | <b>Status</b>    | <b>Trend</b>                   | <b>Assessment, causes</b>                                             |
| Seagrass cover                                                                | Green            | Increasing                     | Expanded 4.5%, 2007–2016                                              |
| Seagrass meadow texture                                                       | Yellow           | Some losses of continuous beds |                                                                       |
| Seagrass species composition                                                  | Green            | Stable, diverse                | Turtlegrass is most common                                            |
| Overall seagrass trends                                                       | Green            | Stable                         | Excellent water quality                                               |
| <b>Seagrass stressor</b>                                                      | <b>Intensity</b> | <b>Impact</b>                  | <b>Explanation</b>                                                    |
| Water clarity                                                                 | Green            | Excellent in 2012, 2013, 2014  | Low levels of freshwater runoff, mostly from springs                  |
| Nutrients                                                                     | Green            | Low impact near Anclote?       |                                                                       |
| Phytoplankton                                                                 | Green            | Very low levels                |                                                                       |
| Natural events                                                                | Green            | No impacts since 2005          |                                                                       |
| Propeller scarring                                                            | Yellow           | Localized                      | Mouth of Pithlachascotee River, St. Martins marker shoal, Anclote Key |

## Summary assessment

The Springs Coast region contained 396,100 acres of seagrass in 2016 in waters within 14 miles of shore. Extensive, unmapped areas of sparse seagrass occur farther offshore on the continental shelf. Seagrass cover in the near-shore region is stable or increasing slightly in area, based on a comparison between mapping data from 2007 and 2016 (Table 1). Seagrass species composition is diverse and stable, with turtlegrass most frequently observed. Manatee grass, shoalgrass and stargrass are less common but occur throughout the region, along with a diverse mixture of macroalgae. Seagrass beds are often intermixed with hardbottom where corals are common. Offshore mapping in 2012 and 2016 (Figure 2) found large areas of hardbottom, sediments covered by macroalgae, and sediments with unidentified submersed aquatic vegetation. Many of those areas had been expected to be seagrass, based on aerial signatures or previous mapping efforts.

Stressors include nutrients, phytoplankton, and turbidity, which in turn affect light available to seagrasses. These were elevated after the 2004 and 2005 hurricane seasons, but they have returned to background levels.

In the falls of 2012, 2013, and 2014, optical water quality and clarity were exceptionally good throughout the Springs Coast region. Heavy propeller scarring is evident around the mouth of the Pithlachascotee River, the St. Martins marker shoal, and near Anclote Key but is less extensive elsewhere. The seagrass beds found offshore of the mouth of the Homosassa River support large populations of scallops.

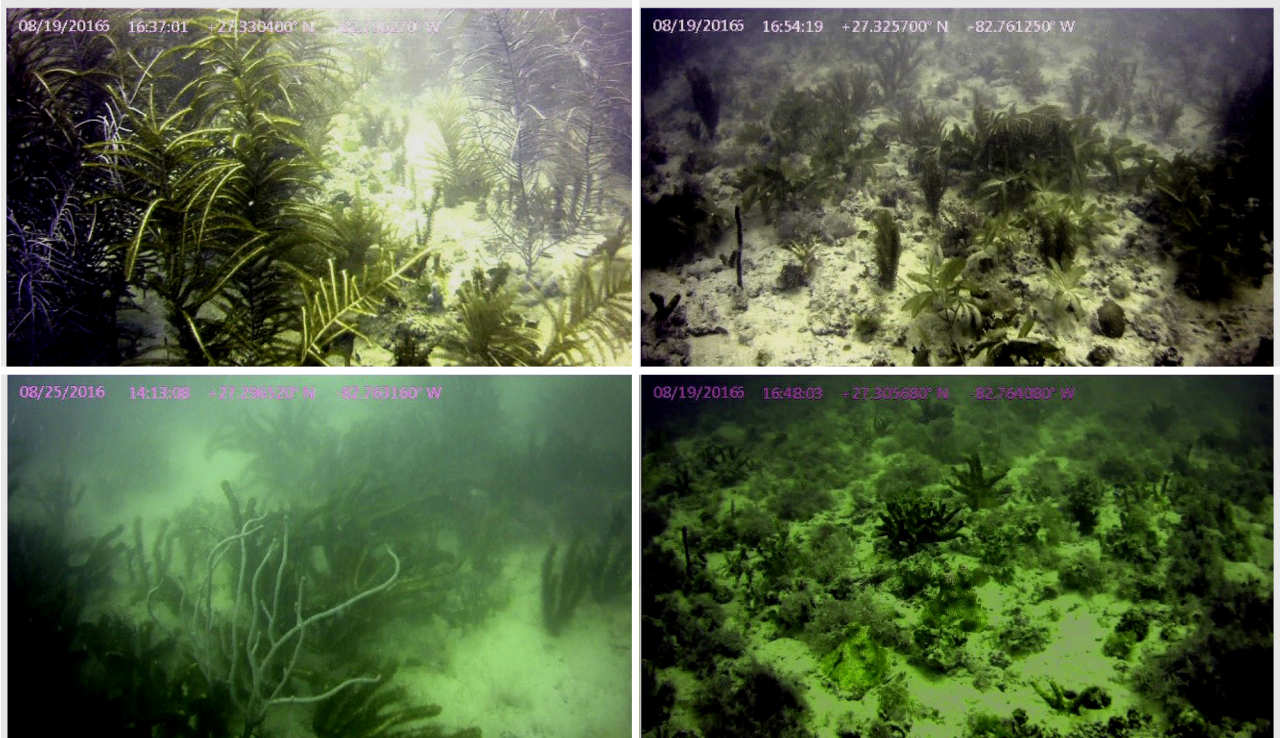
The general status of seagrasses (Status graphic 1) has changed slightly since the second edition of this chapter: the status of seagrass cover remains good (green), because acreage is stable or slightly increasing. Seagrass beds, though, are likely thinning, and status has changed from good to declining.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

## Seagrass mapping assessment

In 2016, the total seagrass cover for the area within 14 miles of the coastline was 396,100 acres, and 80% of the beds were continuous seagrass (Table 1). Between 2007 and

**Table 1.** Seagrass acreage in the Springs Coast region, 2007, 2016. Data are from the Southwest Florida Water Management District.

| Bed texture  | Seagrass Acreage |                | Change        |             |
|--------------|------------------|----------------|---------------|-------------|
|              | 2007             | 2016           | Acres         | %           |
| Continuous   | 360,084          | 317,601        | −42,483       | −11.8%      |
| Patchy       | 18,728           | 78,499         | 59,771        | 319.2%      |
| <b>Total</b> | <b>378,813</b>   | <b>396,100</b> | <b>17,287</b> | <b>4.6%</b> |



**Figure 3.** Examples of hard-bottom habitats located offshore of the Springs Coast. Images were acquired using underwater video by staff from FWRI and Nova Southeastern University.

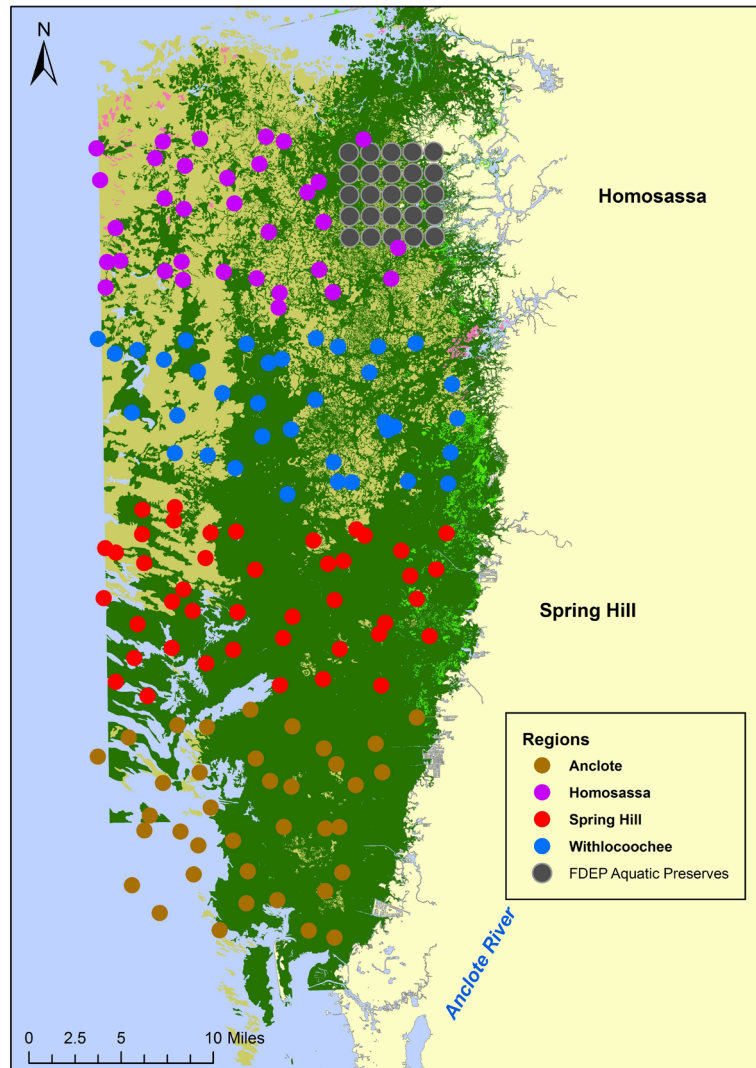
2016, the region lost almost 42,500 acres of continuous beds but gained 59,771 acres of patchy seagrass, resulting in a small (4.6%) percentage gain in seagrass area of nearly 17,300 acres. While the gain in area appears substantial, it is a very low percentage of the total area of seagrass in the region and might be within the error of the two mapping efforts. While inshore seagrass habitats in the Springs Coast are regularly mapped and monitored by the Southwest Florida Water Management District (SWFWMD), offshore areas have not been mapped since 1986. The offshore extent of seagrass habitat along the Springs Coast region represents an important corridor for inshore-offshore migration of economically important fish and shellfish. Along the nearshore-to-offshore gradient, the dominant biological bottom cover transitions from seagrass to hard bottom colonized by soft coral, sponges, and macroalgae (Figure 2). The seagrass–hard bottom transition occurs at depths approaching seagrass light requirements (4.5–7.5 m) and typically more than 15 miles from shore. These offshore areas have been difficult to map using traditional airborne mapping methods. To address this data gap, FWRI initiated offshore mapping in 2012 using new remote-sensing techniques and high-resolution satellite imagery. The first mapping effort covered more than 1,100 km<sup>2</sup> using a combination of photo-interpretation and automated machine-based classification. In 2016, a collaborative effort between FWRI and Nova Southeastern University (NSU)

was funded to expand the offshore map and characterize offshore benthic communities. The NSU-FWRI map identified large areas of sand covered with algae, areas that had been expected to be seagrass based on aerial signatures or previous mapping efforts (Figure 2). Collectively, these efforts have mapped 1,750 km<sup>2</sup> along the Springs Coast. Figure 3 shows photographs of hardbottom benthic habitats in the areas offshore.

A smaller area of the Springs Coast was mapped in 1999, including only the nearshore region. Although different sets of habitat categories and techniques were used between the 2007 and 1999 projects, a similar area of seagrass coverage was found, 229,000 acres in 1999 and 226,500 acres in 2007. None of these mapping efforts extended far enough offshore to capture the deep edge of seagrass beds. Furthermore, there are extensive, but sparse, beds of paddlegrass (*Halophila decipiens*) offshore that cannot be mapped with conventional aerial photography. These beds probably serve as a bridge for grouper and other important fish and shellfish species during migration inshore or offshore.

## Monitoring assessment

Two agencies, FWRI and the FDEP St. Martins Marsh and Big Bend Seagrasses Aquatic Preserves, have monitored seagrasses using different methods. FDEP moni-



**Figure 4.** Sampling locations at which FWRI monitored seagrasses, 2012–2014, and location of sampling sites in St. Martin's Marsh where FDEP monitors seagrasses during the summer. Seagrass mapping data are from 2016 and were collected by the SWFWMD.

tored 25 sites twice a year nearshore in the St. Martin's Keys west of Homosassa from 1997 through 2006 (Figure 4); beginning in 2007, these sites have been monitored once each summer. The frequency of occurrence (FO) of seagrasses in the FDEP sampling grid has been remarkably stable during the 20-year monitoring program (Figure 5). Turtlegrass occurred in about 40–50% of quadrats surveyed, and the FO has increased since 2013 to nearly 60%. Manatee grass has been less abundant but stable, in 25–30% of quadrats. Shoalgrass has shown more variation over time: it occurred more frequently during 1999–2003 and declined in abundance in 2014–2016. Stargrass and widgeongrass had very low occurrence. The occurrence of bare quadrats was also very low. A diverse community of attached macroalgae has also been found

in the FDEP sampling grid (Figure 6). The green alga *Caulerpa prolifera* and the calcareous green algae *Peniculus* spp. were the most common macroalgae observed. For more information and up-to-date data, please visit <http://publicfiles.dep.state.fl.us/CAMA/BigBend/Seagrass%20Data/B&B%20Data/>.

FWRI monitored seagrass beds in September of 2012–2014, assessing 150 sites from Homosassa to Anclote Key and out to 20 miles offshore (Figure 4). Sites were chosen using a spatially-distributed, random-sampling design developed by the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (EPA-EMAP). For this study, the Springs Coast region was divided into four subregions, from south to north, Anclote, Spring Hill, Chassahowitzka, and Homosassa.

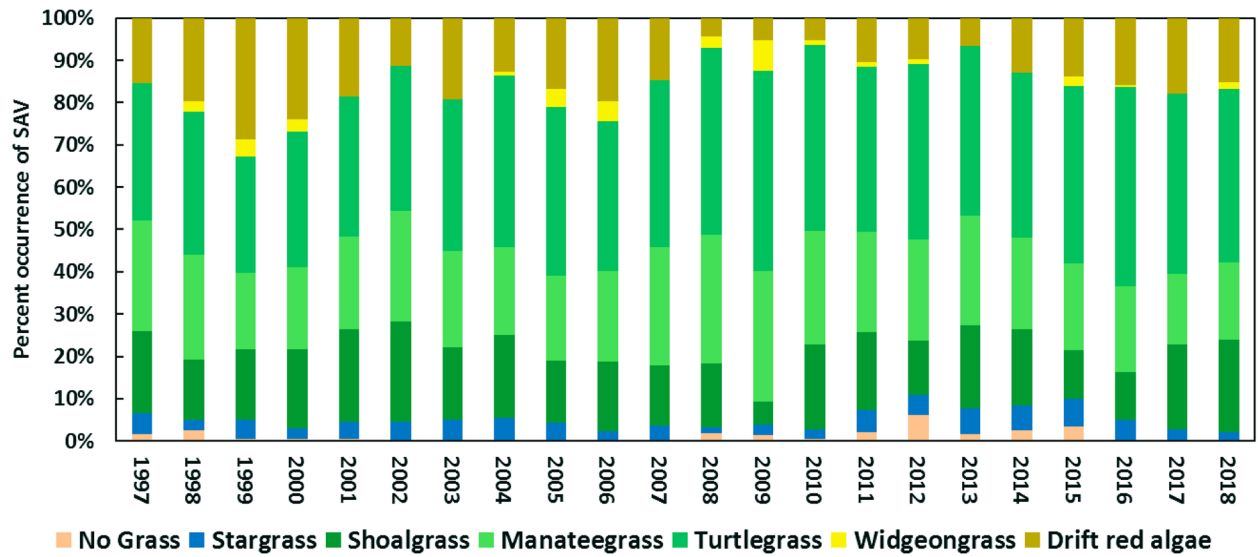


Figure 5. Frequency of occurrence (%) of seagrasses in the St. Martins Marsh, 1997–2018.

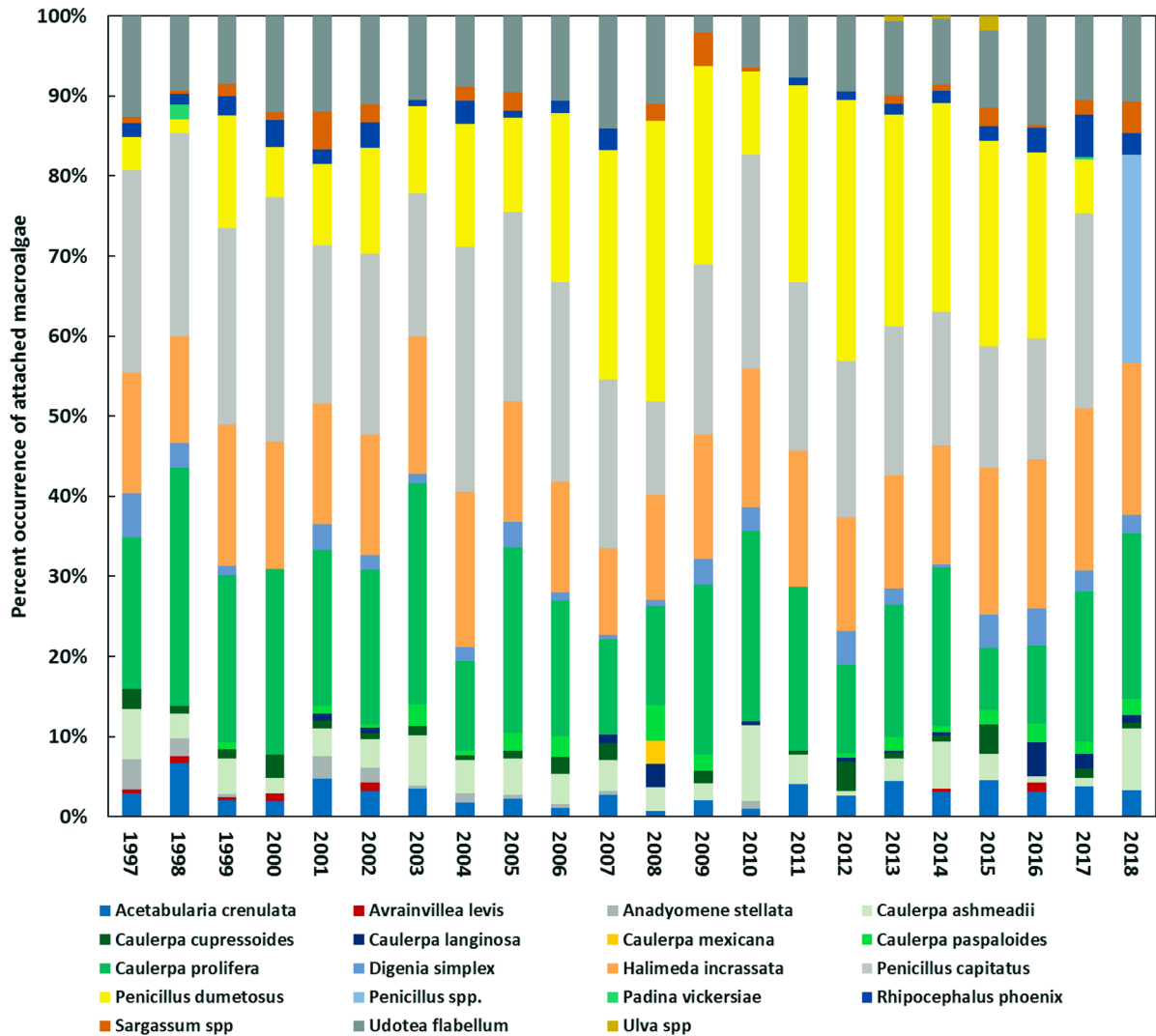


Figure 6. Frequency of occurrence (%) of attached macroalgae in the FDEP sampling grid in the St. Martins Marsh, 1997–2018.

**Table 2.** Percent frequency of occurrence of seagrasses in quadrats sampled in subregions of the Springs Coast, 2012, 2013, 2014. Data are from in-water sampling and interpretation of underwater photography by FWRI.

| Subregion      | Year | No. of quadrats | Shoal-grass | Manatee-grass | Turtle-grass | Stargrass | Widgeon-grass | No seagrass |
|----------------|------|-----------------|-------------|---------------|--------------|-----------|---------------|-------------|
| Anclote        | 2012 | 339             | 5.3         | 21            | 40           | 3.2       | 0             | 45          |
|                | 2013 | 350             | 16          | 25            | 40           | 6         | 0             | 43          |
|                | 2014 | 628             | 8.6         | 18            | 44           | 0.8       | 0             | 41          |
| Spring Hill    | 2012 | 335             | 9.9         | 23            | 59           | 0.3       | 0             | 26          |
|                | 2013 | 350             | 5.7         | 21            | 49           | 2.6       | 4.6           | 41          |
|                | 2014 | 567             | 18          | 19            | 58           | 4.8       | 1.8           | 13          |
| Chassahowitzka | 2012 | 351             | 7.4         | 27            | 68           | 1.7       | 0             | 15          |
|                | 2013 | 410             | 11          | 29            | 51           | 7.1       | 0.5           | 29          |
|                | 2014 | 479             | 12          | 21            | 79           | 2.3       | 2.9           | 1.3         |
| Homosassa      | 2012 | 346             | 9.2         | 32            | 57           | 6.9       | 0             | 15          |
|                | 2013 | 297             | 14          | 43            | 45           | 7.1       | 0             | 7.4         |
|                | 2014 | 272             | 8.5         | 23            | 65           | 2.6       | 0.4           | 6.3         |
| All regions    | 2012 | 1371            | 8           | 26            | 56           | 3         | 0             | 25          |
|                | 2013 | 1407            | 12          | 29            | 46           | 5.7       | 1.3           | 30          |
|                | 2014 | 1946            | 12          | 20            | 62           | 2.6       | 1.3           | 15          |

In 2012, 1,371 quadrats were evaluated; 1,407 quadrats were evaluated in 2013; and 1,946 quadrats were assessed in 2014 (Table 2). Like the results for St. Martins Keys, turtlegrass occurred most frequently across the region, followed by manateegrass, and then by much lower frequencies of shoalgrass and stargrass. Widgeongrass was absent throughout the Springs Coast in 2012 and in the Anclote subregion in 2012–2014; it occurred at very low frequencies in other subregions in 2013 and 2014. The number of bare quadrats was greatest in Anclote, and the occurrence of turtlegrass was lower at Anclote than in other subregions. Manateegrass occurred in 18–43% of quadrats across subregions and all years. The occurrence of bare quadrats dropped sharply in the Spring Hill and Chassahowitzka subregions in 2014. In Spring Hill, occurrence of shoalgrass was much greater in 2014 than in 2013, while in Chassahowitzka, the mean occurrence of turtlegrass increased to 79% in 2014. The FO of shoalgrass in the Homosassa subregion in 2012 and 2013 was much lower than values measured by FDEP at the grid near St. Martins Keys.

In addition to identifying the seagrass and macroalgal species present in a quadrat, FWRI also estimated the percentage of the quadrat covered by each species; this estimate is called percent cover, and the evaluation technique is similar to the Braun-Blanquet method. The percent cover of bottom taxa in subregions of Springs Coast in 2012, 2013, and 2014 indicates that the bottom communities are diverse and healthy (Figure 7). Seagrasses and drift red algae were the most common cover in all subregions.

Drift red algae had the second greatest cover in all subregions and were also fairly uniform among subregions and sampling periods, except at Anclote in 2013, where their percent cover was very low (<5%). The percent cover of other taxa was lower and much more variable among subregions and years than the cover of seagrasses and drift red algae. In 2014, *Lyngbya* spp., a cyanobacterium, and a turf-forming red alga were observed in all subregions.

Turtlegrass had greatest percent cover in all subregions in 2012–2014 (Figure 8); manateegrass had the second greatest cover in all subregions but at levels of about half those measured for turtlegrass. Mean percent cover of shoalgrass, stargrass, and widgeongrass was low (2–10%), but varied greatly within subregions, as indicated by the error bars.

A variety of publications are available on the growth and morphology of turtlegrass along gradients in total phosphorus concentration in the water column and the availability of light (Barry et al. 2017, 2018b; Choice et al. 2014). In addition, Barry et al. (2018a) address the contribution of turtlegrass to blue carbon stocks along the Springs Coast.

## Water quality and clarity

In September 2012, 2013, and 2014, FWRI made field water quality measurements of salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentrations as well as the optical water quality parameters light attenuation, chlorophyll-a concentration,

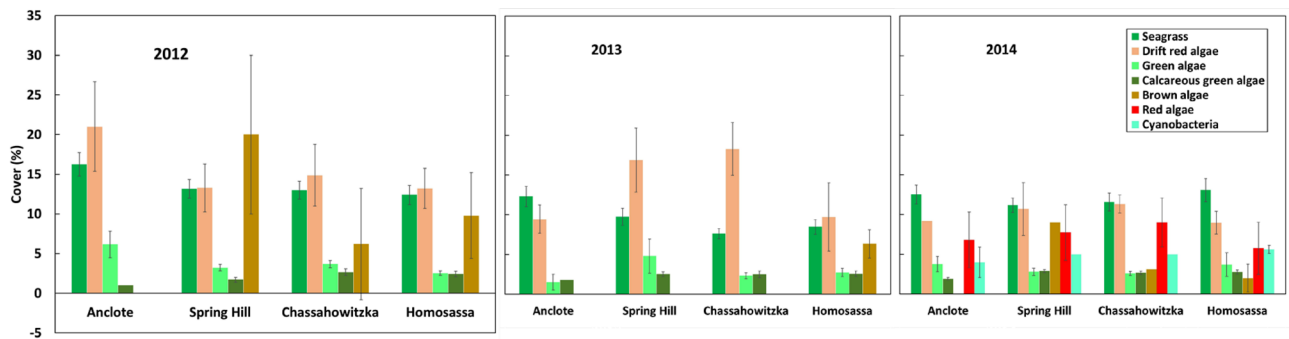
turbidity, total suspended solids, and water color. FWRI also conducted field monitoring of seagrass beds in the Homosassa subregion in 2008. Optical water quality data show that conditions were excellent for seagrass communities in the Springs Coast region in all years (Table 3). Light attenuation ( $k_{\text{par}}$ ) measured using a spherical Licor sensor was very low, indicating that water depth and the light-removal properties of water alone, not light-scattering or light-absorbing components (particles, phytoplankton, color) in the water column, limited the growth of seagrasses. Little variation in  $k_{\text{par}}$  was observed among subregions or sampling years. Levels of turbidity, total suspended solids, color, and chlorophyll-a were very low throughout the region. Slight increases in these parameters were observed in the Homosassa subregion.

Water quality data and assessment of rivers and coastal waters in the region have been collected by staff from the University of Florida and are available from the SWFWMD (<https://www.swfwmd.state.fl.us/resources/data-maps/water-quality-data>).

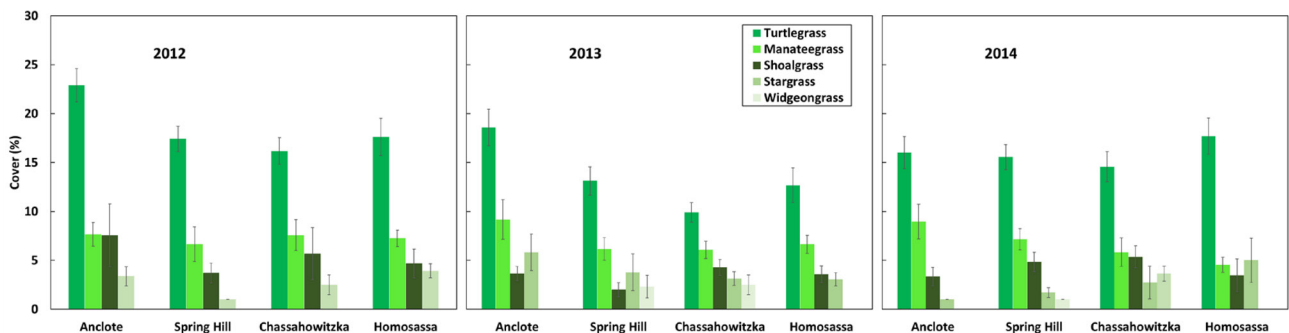
## Watershed management

In 1987, the Florida Legislature passed the Surface Water Improvement and Management (SWIM) Act to

protect, restore, and maintain Florida's highly threatened surface water bodies. The SWFWMD has produced SWIM plans for each of the springsheds in the Springs Coast region (see General Reference section below). These plans describe each springshed's physical characteristics, natural resources, and conditions and identify the priority issues for each system. The SWIM plans outline restoration and management strategies for each system. The springsheds and their downstream rivers have some common characteristics: the rivers travel short distances (< 10 miles) to the Gulf of Mexico, and all experience nitrate enrichment in spring and river waters, potential decreases in historical flows, and altered aquatic vegetation. The EPA has set 0.35 mg/l as a numeric nutrient criterion for nitrate concentration in springs, and all four rivers exceed this level (Springs Management Plan, SWFWMD). Additional primary issues include sedimentation in the Weeki Wachee system, changing salinity in the Weeki Wachee, Homosassa, and Chassahowitzka river systems, and sea-level rise in the Weeki Wachee River, Crystal River/Kings Bay system, and the Chassahowitzka River. Each SWIM plan describes quantifiable objectives and targets addressing the primary issues, with the goal of restoring healthy spring ecosystems.



**Figure 7.** Mean ( $\pm 2$  standard error) percent cover of macroalgae and seagrass in subregions of Springs Coast, 2012, 2013, 2014. Note difference in vertical scale between 2012 and the other years.



**Figure 8.** Average percent cover ( $\pm 2$  standard error) of seagrass species in subregions of Springs Coast, 2012, 2013, 2014.

Table 3. Average values of optical water quality parameters in subregions of Springs Coast, 2008 (Homosassa only), 2012, 2013, 2014.

| Subregion      | Year | Turbidity (ntu) | Total suspended solids (mg/l) | Color (pcu) | Chlorophyll-a ( $\mu\text{g/l}$ ) | Spherical $k_{\text{par}}$ ( $\text{m}^{-1}$ ) |
|----------------|------|-----------------|-------------------------------|-------------|-----------------------------------|------------------------------------------------|
| Anclote        | 2012 | 1.3             | 2                             | 8.4         | 1.21                              | 0.49                                           |
|                | 2013 | 0.55            | 0.92                          | 7.2         | 0.93                              | 0.36                                           |
|                | 2014 | 0.99            | 2.1                           | 7           | 4.81                              | 0.46                                           |
| Spring Hill    | 2012 | 1.1             | 1.3                           | 4.7         | 1.17                              | 0.37                                           |
|                | 2013 | 0.57            | 1.1                           | 4.5         | 0.66                              | 0.33                                           |
|                | 2014 | 0.87            | 2.8                           | 5.8         | 2.26                              | 0.38                                           |
| Chassahowitzka | 2012 | 1.1             | 1.4                           | 7           | 0.96                              | 0.39                                           |
|                | 2013 | 0.78            | 1.1                           | 6.7         | 0.54                              | 0.37                                           |
|                | 2014 | 0.9             | 3.1                           | 6.1         | 1.16                              | 0.36                                           |
| Homosassa      | 2008 | 1.7             | 3.5                           | 10.2        | 1.24                              | 0.5                                            |
|                | 2012 | 1.3             | 1.6                           | 7.1         | 1.03                              | 0.46                                           |
|                | 2013 | 1.2             | 1.9                           | 5.7         | 1.04                              | 0.41                                           |
|                | 2014 | 1.7             | 4                             | 5.4         | 2.33                              | 0.42                                           |

## Mapping methods, data, and imagery

In winter of 2016, imagery was collected by the SWFWMD and interpreted by Quantum Spatial Inc. (St. Petersburg) using FLUCCS (Florida Department of Transportation 1999). The imagery had 1-foot resolution and was 4-band natural color and color-IR. During photo-interpretation, FLUCCS categories were added to identify the mixture of seagrass, macroalgae, and hard bottom that is common in the region. The minimum mapping unit was 0.25 acre. Contact the SWFWMD for more information.

To characterize previously unmapped offshore benthic habitats, a mapping project in 2012 used available imagery from the Quickbird and WorldView-2 satellites, object-based image analysis, and other photo-interpretation techniques. This was a collaborative project between NSU and FWRI, and the objectives were to map features of the continental shelf west of the Springs Coast and to map the offshore extent of seagrasses in optically shallow waters. Field assessments of bottom characteristics provided accuracy assessment of the mapping process and included videos acquired from drop-cameras deployed from research vessels and in-water bottom surveys using scuba. The first mapping effort covered more than 1,100  $\text{km}^2$  using a combination of photo-interpretation and automated machine-based classification. In 2016, a collaborative effort between FWRI and NSU was funded to expand the offshore map and characterize offshore benthic communities. The NSU–FWRI map identified large areas of sand covered with algae, areas that had been expected to be seagrass based on aerial signatures or previous mapping efforts. Collectively these efforts have mapped 1,750  $\text{km}^2$  along the

Springs Coast. Contact Renee Duffey at FWRI for more information.

In April 2007, digital aerial imagery of the Springs Coast region was collected at 1:12,000 scale for FWRI and SWFWMD. The imagery was obtained using a Z/I digital mapping camera with position determined using airborne GPS procedures and an Applanix inertial measurement unit. Benthic habitats were classified and mapped from the imagery by Avineon Inc. using FLUCCS (Florida Department of Transportation 1999). ArcMap shapefiles of benthic habitats are distributed on the GIS database at SWFWMD and are available upon request. This digital imagery is available from the FWRI Marine Resources Aerial Imagery Database (MRAID, <http://atoll.floridamarine.org/mraid>).

## Monitoring methods and data

FDEP conducted seagrass surveys twice annually in the St. Martins Keys region west of Homosassa from 1997 through 2006. Since 2007, these sites have been monitored each summer. Researchers use 1- $\text{m}^2$  quadrats to survey 25 fixed-position sites. Species composition and percentage cover of seagrass and macroalgae are estimated using four randomly placed quadrats at each site, for a total of 100 samples. At the same time as seagrass assessment, the presence and number of bay scallops and sea urchins in each quadrat are recorded, as well as sediment type and an assessment of epiphyte density on seagrass blades. Field-condition measurements (depth, water temperature, salinity, pH, dissolved oxygen concentration, turbidity) are recorded at each site as well. These data are available upon request.

FWRI conducted annual seagrass monitoring in the fall in Homosassa coastal waters in 2008 and throughout the Springs Coast region in 2012, 2013, and 2014. Sites were chosen using a spatially-distributed random-sampling design developed by the EPA-EMAP. The design ensured full spatial coverage of the selected region, but the randomized selection of a point within each delineated hexagon permitted the use of parametric statistics for analysis. Each year, a different point was chosen in each hexagon for sampling. Fifty-eight sites in the Homosassa subregion were sampled in 2008, and 150 sites throughout the Springs Coast were sampled in 2012, 2013, and 2014. FWRI also made field water quality measurements (salinity, water temperature, water depth, Secchi depth, pH, and dissolved oxygen concentrations) and measured the following optical water quality parameters: light attenuation, chlorophyll-a, turbidity, total suspended solids, and water color. At each of the 150 sites, cover of seagrass, macroalgae, and coral were estimated in 10 0.25-m<sup>2</sup> quadrats thrown haphazardly around the anchored boat. At sites where conditions prohibited quadrat assessment by snorkeling divers, quadrats were photographed using an in-water camera, and species cover was assessed by evaluating digital images.

## Optical water quality measurements

Measurements of optical water quality (OWQ) parameters—chlorophyll-a, color, turbidity, total suspended solids (TSS), and light attenuation—are an essential part of the field assessments of seagrasses. 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 by 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 an estimate of phytoplankton abundance, 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).

During the field monitoring program carried out by FWRI in 2012–2014, water samples were collected at each site for measurements of OWQ parameters. Chlorophyll-a concentrations were determined by filtering trip-

licate 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 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 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-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 the *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 1985); units were nephelometric turbidity units (ntu). TSS was measured gravimetrically following method 2540 D of *Standard Methods* (1985) by filtering water samples through combusted, tared GFC glass fiber filters. Filters were then dried at 50°C for at least five days and re-weighed using a 5-place Mettler balance.

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