Coastal Rivers Aquatic Vegetation Analysis

For Weeki Wachee, Chassahowitzka, and Homosassa Rivers

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Executive Summary

Beginning in 1998, comprehensive sampling of the Weeki Wachee, Chassahowitzka and Homosassa Rivers was carried out by Frazer et al. (2001). The general objective of that work was to quantitatively describe the physical, chemical and vegetative characteristics of each of these rivers and two others along Florida's Springs Coast. The impetus for the investigation was concern that eutrophication may occur, as a result of elevated nitrate concentrations in groundwater that enters each of the rivers as spring discharge. That work was continued through 2005, and it was noted that the chemical and vegetative character of each river had changed (Frazer et al. 2006). Continued sampling was accomplished through 2011, but the finding from 2006 to 2011 were not comprehensively reported.

The goal of this project was to evaluate the submersed aquatic vegetation (SAV) within the Weeki Wachee, Chassahowitzka, and Homosassa Rivers. This project followed methods previously developed by Frazer et al. (2001, 2006) so that change analysis could be performed to assess trends and support management strategies. The objective of this project was to conduct data collection and analysis with subsequent reporting that summarizes both current vegetation conditions and changes from prior year conditions. The time periods evaluated were 1998-2000, 2003-2011 and 2015.

For each river system, the average SAV percent cover never exceeded 45 percent. For the Weeki Wachee and Homosassa Rivers, there was a continuous decline in total SAV coverage over time. SAV coverage in the Chassahowitzka River increased slightly in 2015 from the 2006-2011 period.

For each river, the mean number of sampling stations without SAV continued to increase between 2003-2005 and 2006-2011. However, this was followed by notable increase in the mean number of sampling stations with SAV in all three rivers between 2015 and the 2006-2011 period. The changes in frequency of occurrence between plants and macroalgae species also varied. Of note, eelgrass (*Vallisneria americana)* was not observed in the Homosassa River and strap-leaf sagittaria (*Sagittaria kurziana)* was not observed in the Weeki Wachee River or the Chassahowitzka River at any of the sampled stations in 2015.

In general, for all three river systems, the mean total SAV biomass values for the 1998, 1999, and 2000 sampling events were noticeably larger than the mean total SAV biomass values for all other sampling events, particularly for the Weeki Wachee River. For all three river systems, comparisons of the mean and median values for the time periods indicate that there has been a general reduction in total SAV biomass since data collection began, and this reduction is statistically significant.

For all sampling events except 1998, 1999, and 2000, either the Homosassa River or Chassahowitzka River had the highest value for angiosperm biomass as a percentage of total SAV biomass (over 50 percent for all sampling events but one), indicating the dominance of angiosperm biomass over macroalgae biomass in these two systems, for the periods monitored. For the Weeki Wachee River angiosperm biomass, the highest percentages of total SAV biomass were noted for the 1998, 1999, and 2000 sampling events (more than 80 percent), which then declined to about 3 percent in 2009, before increasing again for the 2010, 2011, and 2015 periods to more than 60 percent for 2015.

The results of this analysis are intended to inform natural systems managers of SAV changes that have occurred in these three rivers between 1998 and 2015. These results provide a reference point of SAV conditions and may support the development of future strategies and management actions. Frazer et al. (2006) presented an evaluation of water quality and inferred that the reductions in the total SAV biomass from the 1998-2000 period compared to the 2003-2005 period may be related to increasing nutrient concentrations in all three rivers. A similar evaluation of water quality was beyond the scope of work for this project. However, factors like light, salinity, herbivore grazing, and recreational usage are known to regulate SAV abundance and have also changed over the period of record (e.g., Hoyer et al. 2004, Hauxwell et al. 2004, Cichra and Holland 2012) suggesting that any single influence is unlikely to be responsible for long-term changes in SAV abundance. Collectively, this information suggests that a comprehensive evaluation of the environmental factors which influence SAV abundance is warranted, including similar statistical significance tests that were used to evaluate for change over time. These types of analyses would provide useful information that could be used by natural resource managers in the development of ecosystem restoration strategies.

1.0 Introduction

Submersed aquatic vegetation (SAV) plays an important role to the aquatic environment by providing food and habitat for waterfowl, fish, shellfish, and invertebrates. The character and distribution of this vegetation can serve as an important indicator to the health of an aquatic system. Any changes or loss of this vegetation may indicate that the aquatic system is being stressed. Therefore, monitoring of SAV is an essential component to the long-term goals of protecting the aquatic system.

The first comprehensive sampling of the Weeki Wachee, Chassahowitzka and Homosassa Rivers was carried out by Frazer et al. (2001). The general objective of that original work was to describe quantitatively the physical, chemical and vegetative characteristics of each of these rivers and two others along Florida's Springs Coast. The impetus for the investigation was a concern for elevated nitrate concentrations in groundwater that enters each of the rivers as spring discharge.

More recent data for each of the three rivers of interest were collected between 2003 and 2005. A comparison of the findings from the two studies, the first conducted between 1998 and 2000 and the second between 2003 and 2005 was performed by Frazer et al. (2006). They concluded that the chemical and vegetative character of each river had changed markedly in the interim period. Concurrent and subsequent work has shown that light, water velocity, salinity, manatee, and recreation impacts in addition to declining water quality conditions also dramatically influence SAV abundance. Additional monitoring for SAV was carried out between 2006 and 2011. A statistical evaluation of the changes that occurred during that period has not been performed.

Continued monitoring of these systems is essential to document the changes that have occurred in SAV character and distribution and to evaluate the effectiveness of ongoing nutrient reduction strategies and other remediation efforts aimed at reversing the negative effects on submersed aquatic vegetation (SAV). The goal of this project was to evaluate the SAV within the Weeki Wachee, Chassahowitzka, and Homosassa Rivers. This project followed methods previously developed by Frazer et al. (2001) and Frazer et al. (2006) so that change analysis could be performed to assess trends and support management strategies. The objective of this project was to conduct data collection and analysis, with subsequent reporting that summarizes both current vegetation conditions and changes from prior year conditions. The period of record evaluated includes 1998-2000, 2003-2011 and 2015.

2.0 Scope of Project

Sampling for this project was carried out in the Weeki Wachee, Chassahowitzka and Homosassa Rivers in August and September 2015. The materials and methodologies employed were identical to those used in earlier investigations of these same systems. In each system, sampling stations were primarily located below the headsprings and upstream of the coastal salt marsh zone. The objective of this project was to conduct data collection and analysis, with subsequent reporting that summarizes both current vegetation conditions and changes from prior year conditions. The period of record evaluated includes 1998-2000, 2003-2011 and 2015. The focus of this report was a comparison of the temporally distinct, but otherwise identical, data sets. Some additional transects were established and sampled during the 2015 monitoring event to help characterize headspring and tributary areas. The data from these additional transects were not included in the analysis of temporal changes at historical transects.

The results of this analysis are intended to inform water resource managers of SAV conditions and changes that have occurred in these three rivers during the period of record. In addition, these results will help evaluate the status of SAV communities and contribute towards the development of future restoration strategies and management actions.

3.0 Methods

3.1 Study Area

3.1.1 Regional Description

The three rivers in this study, the Weeki Wachee, Chassahowitzka and Homosassa, all occur within a broader region commonly referred to as the Springs Coast, an area of western peninsular Florida that extends from the Pithlachascotee River basin, located north of Tampa Bay, to the Waccasassa River area, which is south of the Suwannee River Basin (Wolfe et al. 1990) (Figure 3-1). The Springs Coast watershed covers approximately 800 square miles [Southwest Florida Water Management District (SWFWMD) 2001] and, as the regional name suggests, spring-fed systems are a prevalent feature. However, rivers that are primarily fed by surface water drainage border the region, with the Waccasassa and Withlacoochee to the north (Levy County) and the Pithlachascotee and Anclote to the south (Pasco County). Each of these rivers, including the focal rivers in this study, discharge directly into the Gulf of Mexico.

It has been estimated that more than a billion gallons of ground water are discharged in the Springs Coast region from a variety of point and diffuse seepage sources (Sinclair 1978). This water is derived primarily from the Upper Floridan aquifer, which is at or near the surface in the Springs Coast region. The quantity and composition of water discharged by many of the springs in this area are strongly influenced by tidal cycles (Yobbi and Knochenmus 1989; Yobbi 1992). The location and interface between the saltwater wedge and the Upper Floridan aquifer and the resultant spring discharge vary with spring location and rainfall. Patterns of ground water movement in this region have been described by Yobbi and Knochenmus (1989) and Jones et al. (1997). The climate is subtropical, with a mean annual precipitation of approximately 140 centimeters (cm) (SWFWMD unpubl. data).

Land use within the Springs Coast region has a rural character despite intensive growth in the last 30 years. This is largely due to extensive and relatively undeveloped coastal marshes and inland swamps, as well as forested properties under the ownership and/or management of both private individuals and government agencies.

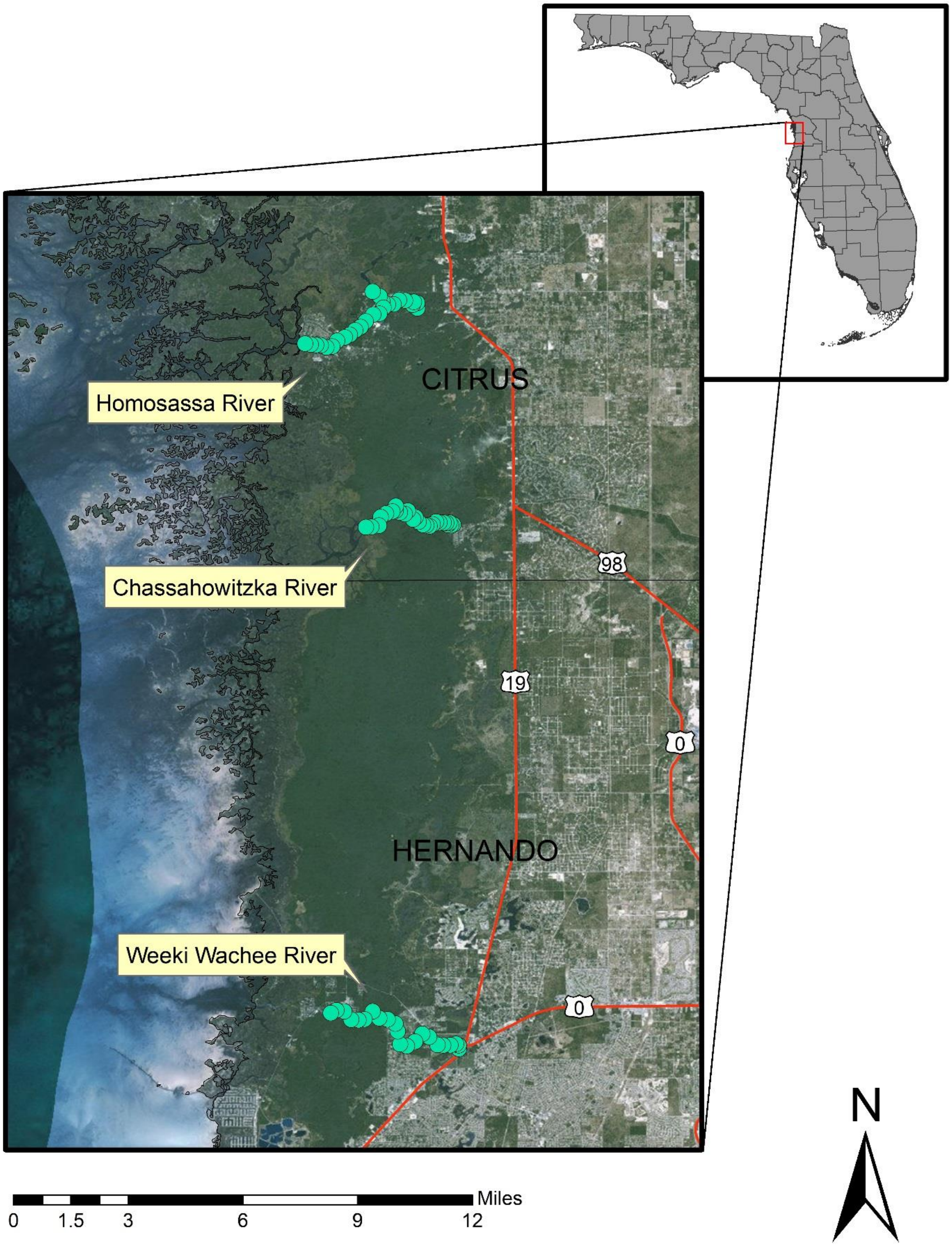

Figure 3-1. Study Area

Development, however, is increasing rapidly in some areas, particularly in the Spring Hill area near the Weeki Wachee River and also in the Crystal River/Homosassa Springs areas (SWFWMD 2001). Continued population growth in the region, fueled by the development of the Springs Coast Parkway, is expected to continue (SWFWMD 2001).

3.1.2 River Descriptions

3.1.2.1 Weeki Wachee River

The Weeki Wachee River, located in western Hernando County, is a spring-fed system that originates in the Weeki Wachee Dune Field (Brooks 1981). This area, which typically has elevations of 20 meters (m) or less, lies within a relic dune system comprised primarily of sand hill vegetation. Down river, the area transitions into a hardwood swamp and, ultimately, into a coastal marsh complex.

The river runs west approximately 7 kilometers (km) from the main spring boil to the beginning of the associated coastal marsh complex and then another 5 km to the Gulf of Mexico. The majority of the Weeki Wachee River is narrow, generally less than 20 m in width. Above the marsh complex, mid-stream channel depth averages 1.4 m (Frazer et al. 2001).

The majority of stream discharge emanates from a main spring boil. However, additional discharge is contributed by several smaller springs along the river, including Twin Dees, Salt and Mud River Springs. Between 1917 and 1974, the average discharge, approximately 0.7 miles west of the main spring, was reported to be approximately 5.0 cubic meters per second ($m^3 s^{-1}$) (Rosenau 1977). Between 1998 and 2000, Frazer et al. (2001) calculated a similar mean discharge value at a corresponding river location, i.e., 5.4 $m^3 s^{-1}$.

The main stream channel is dominated by a sandy substrate (Figure 3-2) that supports the production of only a limited number of native aquatic macrophytes: *Sagittaria kurziana*, *Vallisneria americana* and *Najas guadalupensis* (Frazer et al. 2001). *Sagittaria kurziana*, however, appears to be confined to the uppermost region of the river, just below the main spring, a spatial pattern that may be representative of a local range restriction. In 1991, *Sagittaria kurziana* was found at sampling locations further downstream (SWFWMD 1994). Weeki Wachee River has no recent accounts of *Potamogeton pectinatus*, although it was noted historically occurring in the lower river (SWFWMD 1994). As recently as 2000, filamentous macroalgae (including *Lyngbya* sp.) and nuisance species such as *Hydrilla verticillata* were reported to dominate the submersed vegetative community (Frazer et al. 2001; SWFWMD 1994).

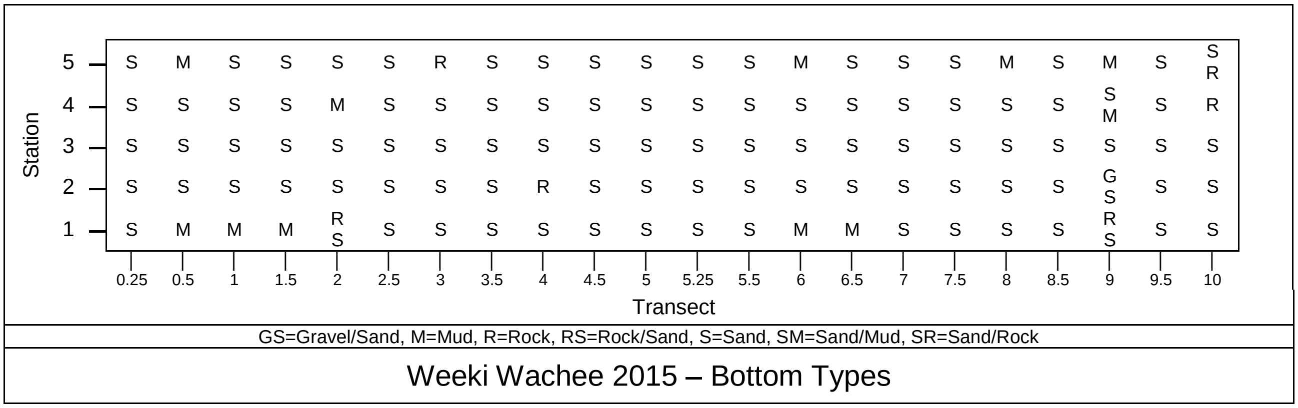

Figure 3-2. Weeki Wachee River Substrate Composition

The lower river flows through a marsh complex and discharges directly into the Gulf of Mexico, as do the other rivers investigated. Low-relief rocky outcrops are common in the shallow waters seaward of the marsh and can be exposed during periods of low water that often occur as a consequence of tides and wind. Except in isolated patches near the river mouth, seagrass coverage is not abundant in the shallow nearshore areas of the estuary.

3.1.2.2 Chassahowitzka River

The Chassahowitzka River, located in southwest Citrus County, is a spring-fed system within the Chassahowitzka Coastal Strip, with elevations below 3 m (Figure 3-1). This area is dominated by flatwoods and swamps that transition into an extensive marsh complex along the Gulf of Mexico. Of the three rivers in this study, the Chassahowitzka River is the least developed. A small residential community and fish camp are present near the headspring, as well as a series of manmade canals immediately adjacent to the area. Development along the river is limited to approximately a dozen homes in the lower river.

The river runs west approximately 4 km from the main spring boil to the beginning of the associated coastal marsh complex and then another 4 km to the Gulf of Mexico. The upper portion of the Chassahowitzka River is narrower. Approximately midway downstream, the river rapidly widens to a maximum width of 175 m. Above the marsh complex, mid-stream channel depth is on average about 1.2 m (Frazer et al. 2001).

The majority of stream discharge emanates from a main spring boil, however, several smaller spring runs in the upper river contribute additional flow (e.g., Chassahowitzka #1, Crab, Baird, and Potter creeks; see Jones et al. 1997 and references therein). Tidal cycles influence both spring discharge and flow within the river (Yobbi 1992). The average discharge between 1998 and 2000, just below Crab Creek, was reported by Frazer et al. (2001) to be 4.0 $m^3\ s^{-1}$. This value is comparable to the long-term average reported by Jones et al. (1997) for the main spring between 1930 and 1972, i.e., 3.9 $m^3\ s^{-1}$, but less than the combined discharge of the spring complex that includes the aforementioned smaller spring runs.

In general, the substrate within the river is dominated by sand or sand/mud mixtures, except near the fringes of the shoreline where mud is more prevalent (Figure 3-3). Small patches of exposed limestone occur sporadically throughout the river. SAV is nearly ubiquitous, although density tends to decline with distance downstream (Yobbi 1992; Frazer et al. 2001), due, in large part, to increased salinity (Hoyer et al. 2004).

Filamentous macroalgae was reported to dominate the SAV community between 1998 and 2000 and was particularly abundant in the upper 2 km of the river (Frazer et al. 2001). Common macrophytes observed during this time period included *Vallisneria americana*, *Potamogeton pectinatus*, *Najas guadalupensis*, *Myriophyllum spicatum*, and *Hydrilla verticillata*.

An extensive marsh system occurs at the mouth of the river and upper estuary. Seaward of the marsh, the water is generally shallow and interspersed with numerous small islands. Some patchy seagrass exists in the estuary seaward of the marsh complex, but macroalgae are more prevalent (Dixon and Estevez 1997). Both attached macroalgae, e.g., *Caulerpa* sp., and unattached (drift) forms are frequently observed in this estuary.

Station	0	0.25	0.5	0.75	1	1.5	2	2.5	3	3.5	4	4.5	5	5.25	5.5	6	6.5	7	7.25	7.5	8	8.5	9	9.5	10
5	SSh	MS	S	R	SM	S	M	M	M	SM	M	SM	S	S	SM	S	M	S	M	M	M	S	M	MS	S
4	SSh	MS	S	S	S	S	S	SM	S	SM	M	S	S	S	SM	S	S	S	SM	S	M	M	S	MS	S
3	S	S	S	S	S	S	S	SM	S	SM	M	S	S	S	SM	S	S	SM	S	SM	S	M	S	MS	S
2	SSh	MS	S	S	S	S	S	SM	SM	SM	M	SM	S	S	M	S	S	SM	SM	S	SM	M	SM	M	MS
1	MS	M	S	S	S	S	S	M	M	M	M	SM	S	S	M	S	M	M	SM	M	M	M	M	M	MS

Transect

M=Mud, MS=Mud/Sand, R=Rock, S=Sand, SM=Sand/Mud, Sand Shell=SSh

Chassahowitzka 2015 – Bottom Types

Figure 3-3. Chassahowitzka River Substrate Composition

3.1.2.3 Homosassa River

The Homosassa River, located in western Citrus County, is a spring-fed system within the Chassahowitzka Coastal Strip (Figure 3-1). This area, which has elevations of 3 m or less, rapidly transitions into an extensive marsh complex that borders the Gulf of Mexico. Development along this river is extensive with residential homes and riverfront businesses.

The river runs west approximately 5 km from the main spring complex to the beginning of the associated coastal marsh complex and then another 7 km to the Gulf of Mexico. The upper portion of the Homosassa River, above the confluence with the Halls River (which is also spring-fed; Jones et al. 1997) is narrower, i.e., approximately 70 m in width. Below the confluence, stream width increases to approximately 150 m or more. Above the marsh complex, mid-stream channel depth averages 2.3 m (Frazer et al. 2001).

The majority of stream discharge emanates from a main spring boil. Smaller spring runs in the upper river contribute additional flow (Jones et al. 1997). Tidal cycles influence both spring discharge and flow within the river (Yobbi and Knochenmus 1989). The average discharge between 1998 and 2000 below the main spring was reported by Frazer et al. (2001) to be 4.6 $m^3\ s^{-1}$. This value agrees well with the longer-term combined discharge measurements reported by Jones et al. (1997) for the main spring and all smaller springs in the upstream complex, i.e., approximately 4.9 $m^3\ s^{-1}$.

The substrate within the Homosassa River is comprised primarily of sand and mud (Figure 3-4), although small, low-relief limestone outcrops are common and occur along the length of the river (Frazer et al. 2001). Historically, the Homosassa River was heavily vegetated (Wolfe et al. 1990) and, in the late 1960s, was reported to be infested with Eurasian watermilfoil, *Myriophyllum spicatum* (Blackburn and Weldon 1967). More recent work in this system indicates that this is no longer the case (Frazer et al. 2001). In comparison to the Weeki Wachee and Chassahowitzka Rivers previously described, SAV is relatively sparse. In fact, SAV was absent in 47 percent of locations sampled in the Homosassa River in 2000. At those stations where SAV did occur, filamentous macroalgae (primarily *Lyngbya* sp.) occurred most frequently and was the primary contributor to the overall vegetative biomass. The non-native macrophyte, *Myriophyllum spicatum*, although less abundant was the still the dominant macrophyte in the system.

The marsh complex in the lower river is extensive, and water clarity is substantially reduced in this area. Salinities are elevated in comparison to those recorded further upstream (Yobbi and Knochenmus 1989; Frazer et al. 2001) and the river takes on a more estuarine character. The reduced light environment and high salinity water are not favorable for the growth of SAV (Hoyer et al. 2004). Water clarity increases again with distance seaward of the mouth. Dense patches of seagrass characterize the nearshore coastal waters (Frazer and Hale 2001; Greenawalt et al. 2004). Unattached macroalgae can be seasonally abundant (Frazer pers. obs.). Low-relief rocky outcrops are present, but are less abundant than in other sampling areas further south along the coast (Frazer et al. 1998).

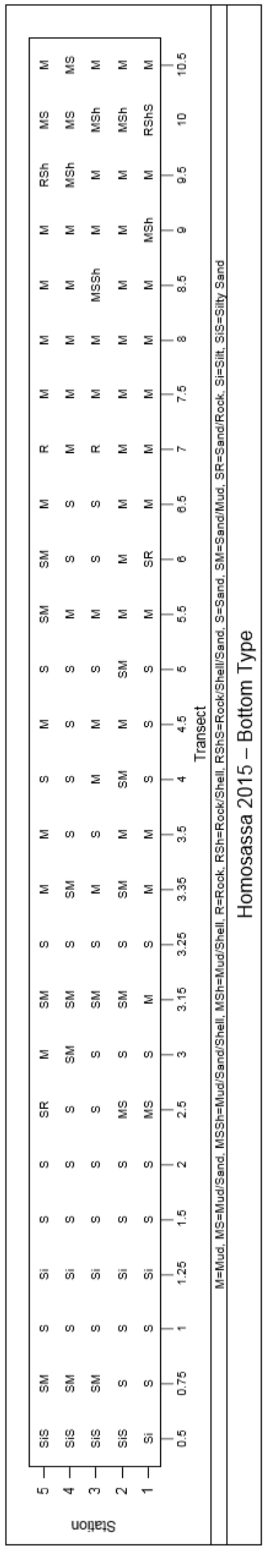

Figure 3-4. Homosassa River Substrate Composition

4.0 Sampling Methods and Analytical Procedures

4.1 Submersed Aquatic Vegetation

4.1.1 Weeki Wachee River

Sampling of SAV included angiosperms (flowering vascular plants) and macroalgae in the Weeki Wachee River was conducted during August and September 2015. Macrophytes and macroalgae were sampled at 20 regularly spaced transects (perpendicular to stream flow) from just below the main spring to the marsh complex. These transects had been sampled previously during 1998-2000 and 2003-2011. Two additional transects were added during the 2015 sampling session, for a total of 22 transects. The additional transects were located at the main spring and upper river. Figure 4-1 presents the locations of the sampled transects. Table 4-1 lists the coordinates of the middle station for each sampled transect.

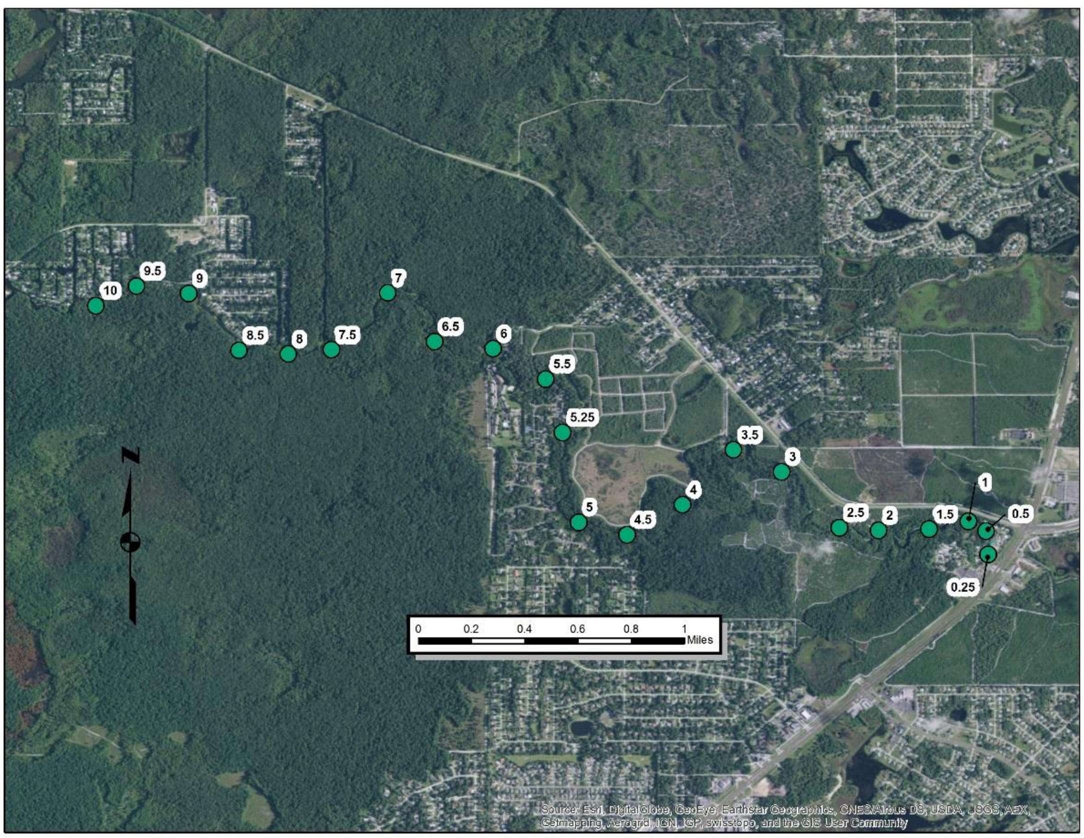

Figure 4-1. Weeki Wachee River Transect Locations

Table 4-1. Middle Station Location (latitude-longitude) for Weeki Wachee River Transects Sampled during the 2015 Monitoring Event

Transect	Station	Latitude	Longitude
0.25*	3	28.51739	-82.57337
0.50*	3	28.51868	-82.57348
1.00	3	28.51920	-82.57445
1.50	3	28.51877	-82.57660
2.00	3	28.51871	-82.57933
2.50	3	28.51886	-82.58147
3.00	3	28.52188	-82.58461
3.50	3	28.52307	-82.58723
4.00	3	28.52009	-82.59000
4.50	3	28.51847	-82.59303
5.00	3	28.51915	-82.59566
5.25	3	28.52402	-82.59653
5.50	3	28.52693	-82.59745
6.00	3	28.52858	-82.60032
6.50	3	28.52896	-82.60350
7.00	3	28.53160	-82.60604
7.50	3	28.52851	-82.60911
8.00	3	28.52828	-82.61144
8.50	3	28.52849	-82.61413
9.00	3	28.53157	-82.61687
9.50	3	28.53198	-82.61971
10.00	3	28.53092	-82.62192

*Denotes a new additional transect sampled in 2015

Along each transect, five stations were sampled for SAV, with one in the middle and two to either side approximately one-third and two-thirds the distance to the shoreline. At each of the resulting 110 stations, a 0.5-m-by-0.5-m [0.25 square meter (m^2)] quadrat was placed on the substrate. Divers removed the above-ground biomass contained within the quadrat and transported it to the surface. It should be noted that no angiosperm biomass was removed at Transect 0.25 because SWFWMD recently conducted restoration efforts this area through plantings of *Vallisneria americana*. Therefore, total SAV and angiosperm biomass was not calculated at this transect.

Macrophytes and macroalgae were separated immediately by hand, and the different fractions were spun in a nylon mesh bag to remove excess water. Samples were then weighed with calibrated hand-held Pesola® scales. Weights were recorded to the nearest 1 gram (g) for samples less than 1 kilogram (kg) and to the nearest 10 g for samples greater than 1 kg. All types of vegetation (unknown macroalgae were preserved for subsequent identification) present in the quadrat were recorded and ranked according to their relative abundances. For convention, the phrase "total vegetative biomass" includes macrophytes and macroalgae (primarily filamentous forms).

Data collected at each station included:

- Estimated total percent cover and percent cover by species, using 0.5-m-by-0.5-m quadrats.
- Substrate type, percent canopy cover, any other adjacent macrophytes that were not in the quadrat.
- All aboveground biomass within the 0.5-m-by-0.5-m quadrat, sorted by taxon, and wet weights measured.
- Any unidentified species. These were bagged, labeled, and placed on ice for identification in the lab.
- Additional qualitative data, including epiphytic coverage, weather conditions, tides, wildlife observed and visual water quality.
- Quantitative data including salinity and water temperature.

SAV abundance was summarized and statistical comparisons were made both within and between the three rivers using the data collected. The results of the field data collection effort were analyzed for the following parameters:

- SAV Coverage for each transect on each river system and for the river system as a whole (percent, average +/- standard error).
- SAV Biomass for each transect on each river system and for the river system as a whole (average kg wet weight/m^2 +/- standard error).
- Angiosperm Biomass for each transect on each river system and for the river system as a whole (average kg wet weight/m^2 +/- standard error).

- Macroalgae Biomass for each transect on each river system and for the river system as a whole (average kg wet weight/m^2 +/- standard error).

In addition, frequency of occurrence (of stations sampled) of angiosperm and macroalgal species were calculated and charts prepared.

4.1.2 Chassahowitzka River

Sampling of SAV included angiosperms (flowering vascular plants) and macroalgae in the Chassahowitzka River was conducted during August 2015. Macrophytes and macroalgae were sampled at 20 regularly spaced transects (perpendicular to stream flow) from just below the main spring to the marsh complex. These transects had been sampled previously during 1998-2000 and 2003-2011. Five additional transects were added during the 2015 sampling session, for a total of 25 transects. The transects were located at the main spring and in selected channel bifurcations and side tributaries. Figure 4-2 presents the location of the sampled transects. Table 4-2 lists the coordinates of the middle station for each sampled transect.

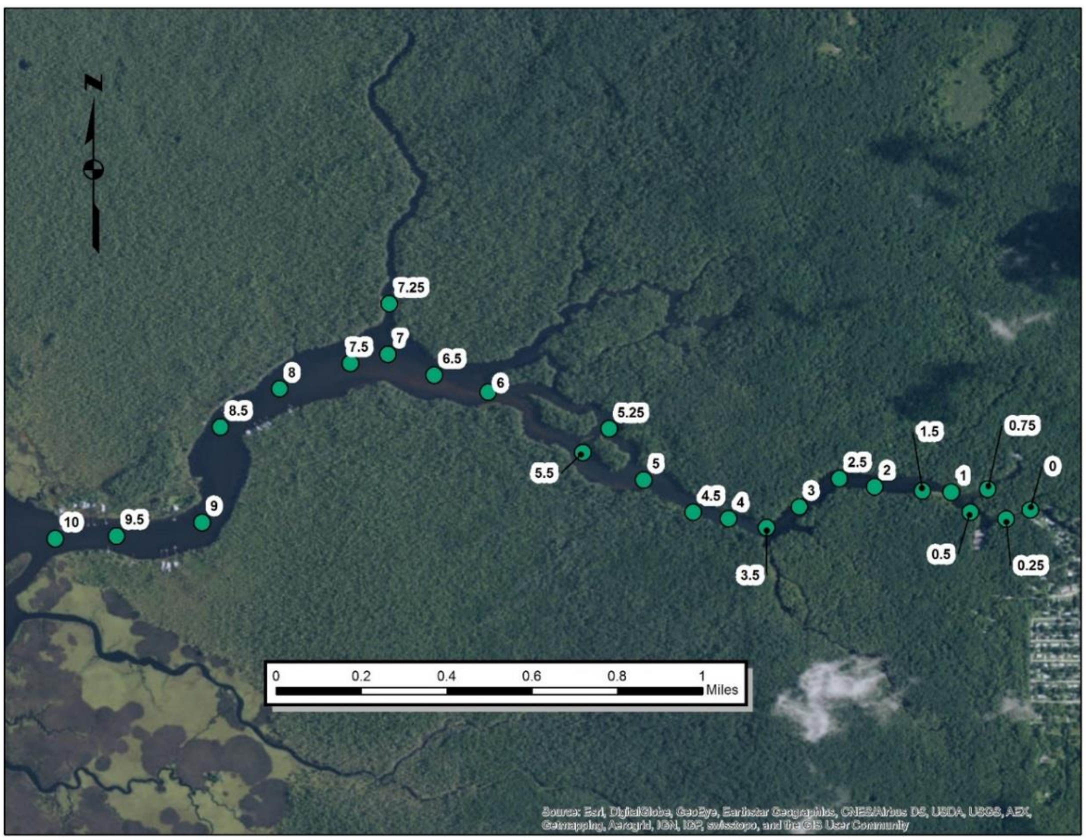

Figure 4-2. Chassahowitzka River Transect Locations

Table 4-2. Middle Station Location (latitude-longitude) for Chassahowitzka River Transects Sampled during the 2015 Monitoring Event

Transect	Station	Latitude	Longitude
0.00*	3	28.71569	-82.57551
0.25*	3	28.71537	-82.57633
0.50	3	28.71560	-82.57754
0.75*	3	28.71640	-82.57694
1.00	3	28.71628	-82.57819
1.50	3	28.71633	-82.57917
2.00	3	28.71647	-82.58079
2.50	3	28.71674	-82.58199
3.00	3	28.71578	-82.58335
3.50	3	28.71508	-82.58446
4.00	3	28.71538	-82.58575
4.50	3	28.71560	-82.58695
5.00	3	28.71670	-82.58863
5.25*	3	28.71843	-82.58981
5.50	3	28.71762	-82.59070
5.75*	3	28.72090	-82.59271
6.00	3	28.71967	-82.59391
6.50	3	28.72025	-82.59575
7.00	3	28.72094	-82.59731
7.25*	3	28.72266	-82.59727
7.50	3	28.72065	-82.59859
8.00	3	28.71978	-82.60099
8.50	3	28.71849	-82.60300
9.00	3	28.71526	-82.60363
9.50	3	28.71480	-82.60653
10.00	3	28.71471	-82.60861

*Denotes a new additional transect sampled in 2015

The same sampling methods and analytical techniques used in the Weeki Wachee River (Section 4.1.1) were used in the Chassahowitzka River.

4.1.3 Homosassa River

Sampling of SAV including angiosperms (flowering vascular plants) including macrophytes and macroalgae in the Homosassa River was conducted during August and September 2015. Macrophytes and macroalgae were sampled at 20 regularly spaced transects (perpendicular to stream flow) from just below the main spring to the marsh complex. These transects had been sampled previously during 1998-2000 and 2003-2011. Six additional transects were added during the 2015 sampling session for a total of 26 transects. The additional transects were located at upstream locations and in the lower Halls River. Figure 4-3 presents the locations of the sampled transects. Table 4-3 lists the coordinates of the middle station for each sampled transect.

The same sampling methods and analytical techniques used in the Weeki Wachee River (Section 4.1.1) were used in the Homosassa River.

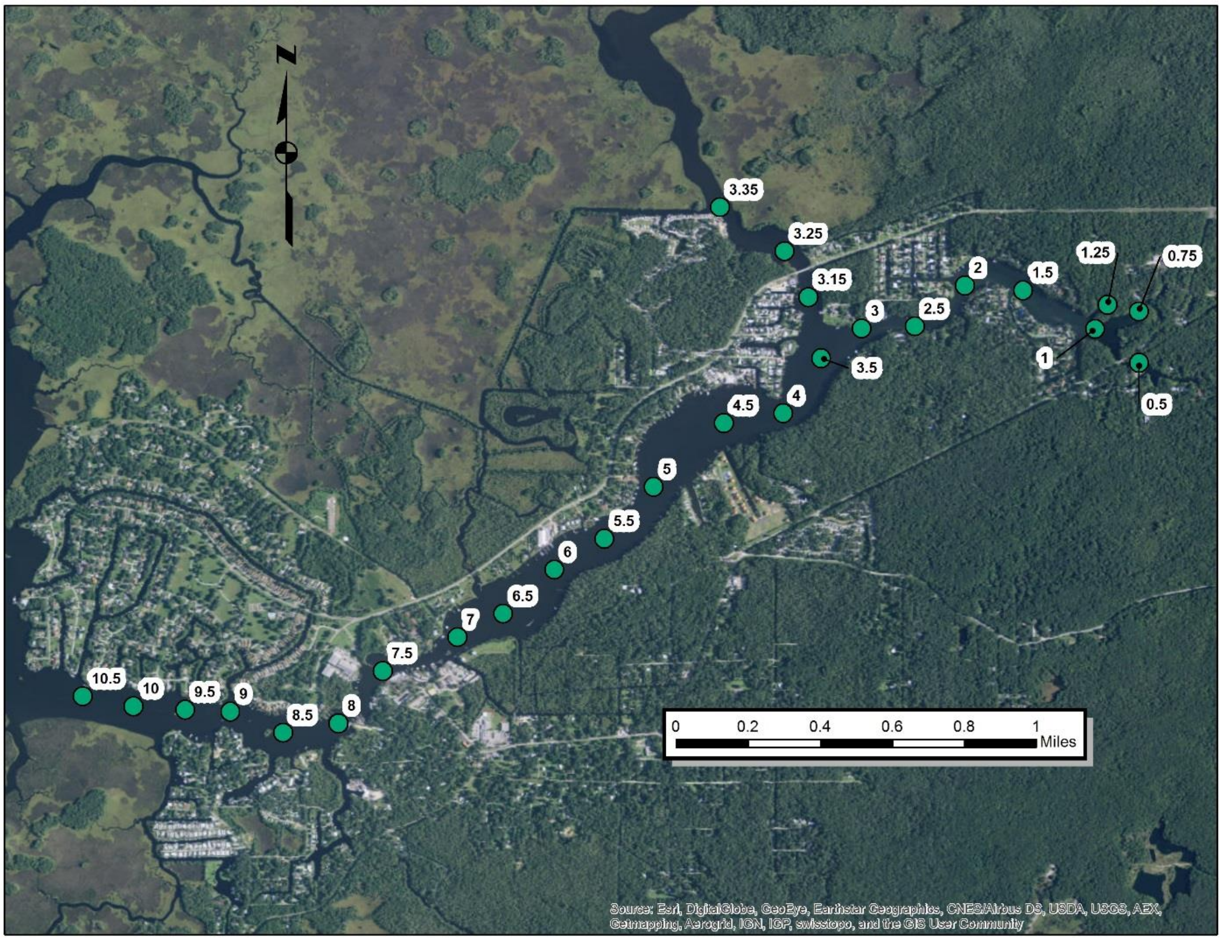

Figure 4-3. Homosassa River Transect Locations

Table 4-3. Middle Station Location (latitude-longitude) for Homosassa River Transects Sampled during the 2015 Monitoring Event

Transect	Station	Latitude	Longitude
0.50*	3	28.79749	-82.58912
0.75*	3	28.79955	-82.58914
1.00	3	28.79884	-82.59090
1.25*	3	28.79983	-82.59039
1.50	3	28.80040	-82.59379
2.00	3	28.80060	-82.59613
2.50	3	28.79895	-82.59815
3.00	3	28.79886	-82.60028
3.15*	3	28.80013	-82.60242
3.25*	3	28.80197	-82.60339
3.35*	3	28.80374	-82.60597
3.50	3	28.79768	-82.60190
4.00	3	28.79547	-82.60343
4.50	3	28.79507	-82.60582
5.00	3	28.79252	-82.60863
5.50	3	28.79042	-82.61062
6.00	3	28.78918	-82.61262
6.50	3	28.78741	-82.61468
7.00	3	28.78647	-82.61652
7.50	3	28.78511	-82.61952
8.00	3	28.78301	-82.62131
8.50	3	28.78263	-82.62353
9.00	3	28.78348	-82.62565
9.50	3	28.78356	-82.62746
10.00	3	28.78369	-82.62954
10.50	3	28.78409	-82.63159

*Denotes a new additional transect sampled in 2015

4.2 Quality Assurance, Data Summaries and Statistical Analyses

All collected data underwent quality assurance procedures to ensure consistency in sample collecting technique and accurate transcription of data from field sheets to electronic spreadsheets. The raw data was reviewed during the course of performing data and change analyses tasks. Values that were flagged for further review were checked by those performing the sample collection and transcription of data to field notes to ensure accuracy. Raw data used in summary figures and tables have been provided to SWFWMD in electronic format. Mean values, where appropriate, were used to summarize vegetative data. Calculations of mean values were dependent on the level of data presentation. For each sampling event, transect means were calculated with data from five sampling stations for vegetation (Section 4.1). The resultant values were subsequently used to calculate annual averages for each transect, that, in turn, were used to calculate means by transect for the 2015 data.

Non-parametric hypothesis tests that are available in SAS© routines provided useful information on the statistical significance of the differences that were seen between the historical data and the 2015 data for the Weeki Wachee, Chassahowitzka, and Homosassa River, as well as the strength of the evidence. The hypothesis tests that were used for this nonparametric data analysis included the Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (McDonald 2014). The SAS© PROC NPAR1WAY routines performed the Kruskal Wallace and Median Two sample tests. The SAS© PROC UNIVARIATE routines were used to provide the Wilcoxon Sign and Signed Rank test statistics.

5.0 Results and Discussion

5.1 Total SAV Coverage

For all river systems, the percent cover never exceeded 45 percent. For the Homosassa and Weeki Wachee Rivers, there was a continuous decline in total SAV coverage over time. SAV coverage for Chassahowitzka River increased slightly in 2015 from the 2006-2011 period.

For each river, the mean number of sampling stations without SAV continued to increase between 2003-2005 and 2006-2011. However, this was followed by notable increase in the mean number of sampling stations with SAV in all three rivers between 2015 and the 2006-2011 period. The changes in frequency of occurrence between plants and macroalgae species also varied. Of note, eelgrass (*Vallisneria americana)* was not observed in the Homosassa River and strap-leaf sagittaria (*Sagittaria kurziana)* was not observed in the Weeki Wachee River or the Chassahowitzka River at any of the sampled stations in 2015.

The mean Weeki Wachee River total SAV percent cover data for the 2015 sampling event were compared to the combined mean total SAV percent cover data for the 2003-2011 sampling events river-wide and by transect (there are no total SAV percent cover data for 1998, 1999, or 2000). The river-wide difference in total SAV percent cover for 2015 compared to the data for 2003-2011 was a reduction of about 20.6 percent.

The mean Chassahowitzka River total SAV percent cover data for the 2015 sampling event were compared to the combined mean total SAV percent cover data for the 2003-2011 sampling events river-wide and by transect (there are no total SAV percent cover data for 1998, 1999, or 2000). The river-wide difference in total SAV percent cover for 2015 compared to the data for 2003-2011 was a reduction of 38.9 percent.

The mean Homosassa River total SAV percent cover for the 2015 sampling event was compared to the mean total SAV percent cover for the combined Homosassa River data from the 2003-2011 sampling events by transect (there are no total SAV percent cover data for 1998, 1999, or 2000). River-wide, the 2015 mean total SAV percent cover was almost 50 percent less than the mean total SAV percent cover for all of the previous sampling events.

Section 6 (Analysis of Distributional and Biomass Changes) presents the results of the detailed statistical analysis of the total SAV coverage data for each of the river systems. Appendix D presents the frequency of occurrence and distributional patterns of SAV in each of the river systems for the period-of-record.

5.2 Total Vegetative Biomass

Figures 5-1 through 5-6 present the mean and standard error for each transect for each of the three rivers for the 2015 period and for the period-of-record. When the data were combined and compared across all sampling events, the Weeki Wachee River-wide mean total SAV biomass was always the highest or second-highest mean value. The Homosassa River-wide mean total SAV biomass was always the smallest. The 1998 and 1999 mean total SAV biomass values for all rivers were the highest observed values compared to the data from all other sampling events, for each river.

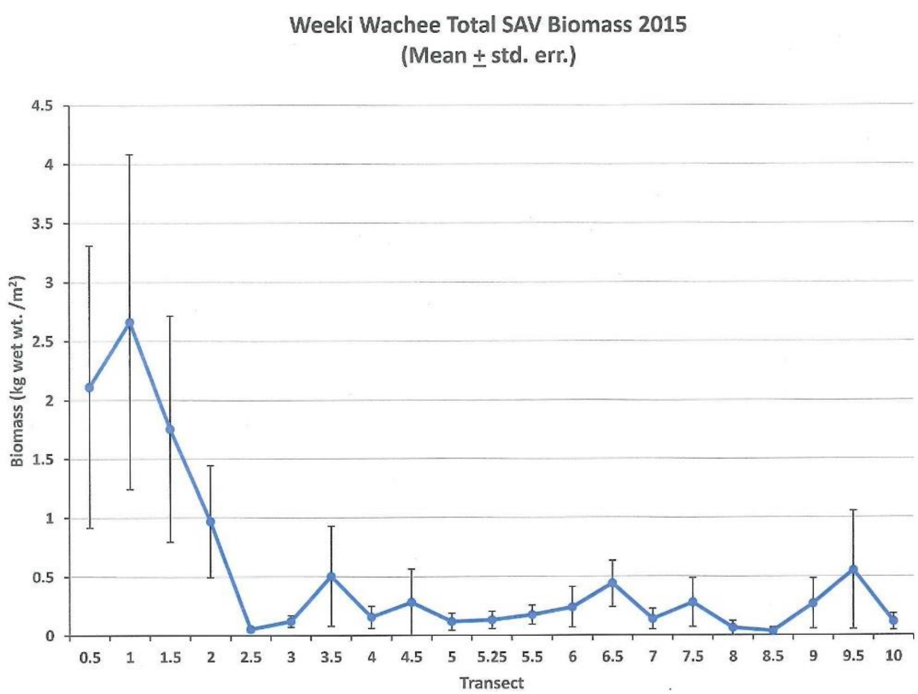

Figure 5-1. Weeki Wachee River SAV Biomass by Transect - 2015

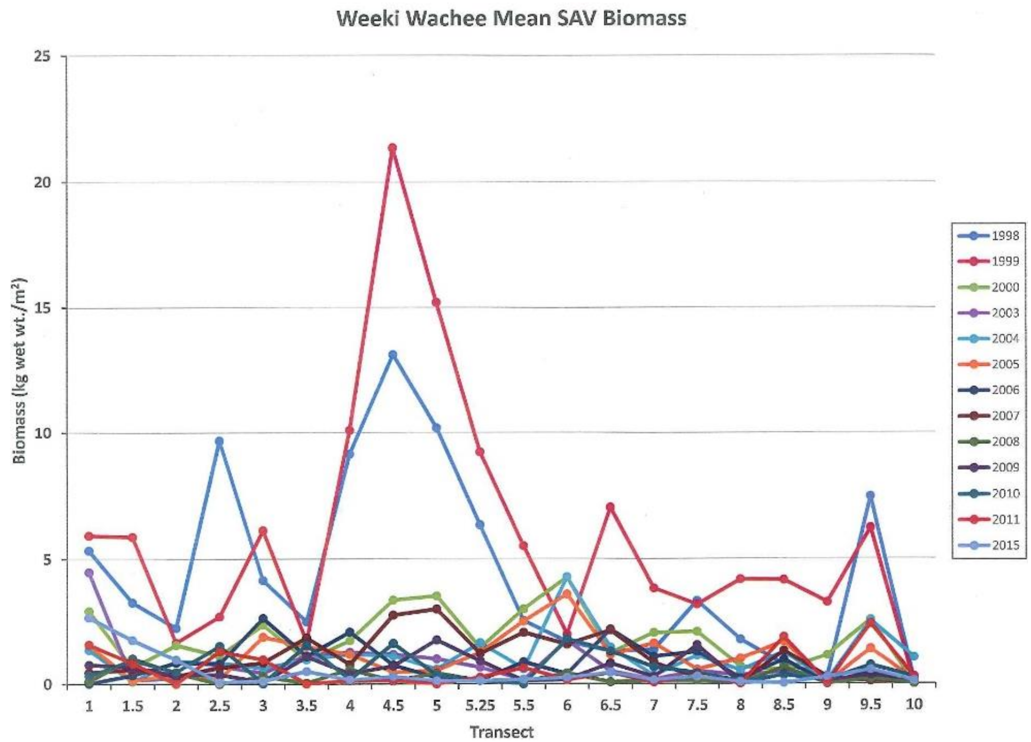

Figure 5-2. Weeki Wachee River SAV Biomass by Transect - Period of Record

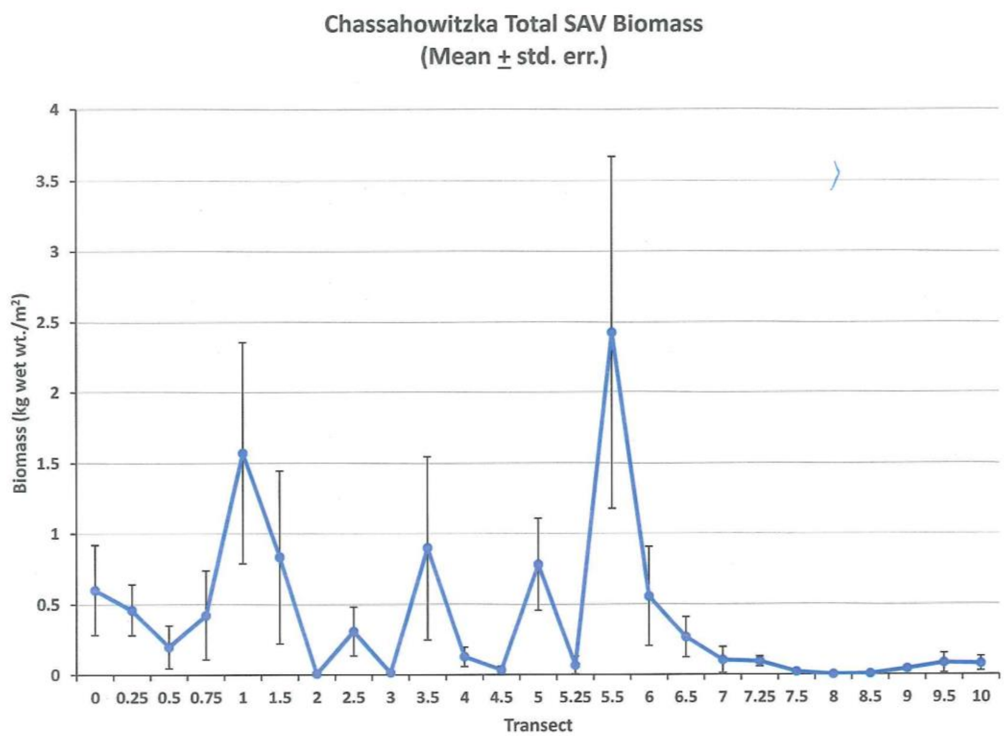

Figure 5-3. Chassahowitzka River SAV Biomass by Transect - 2015

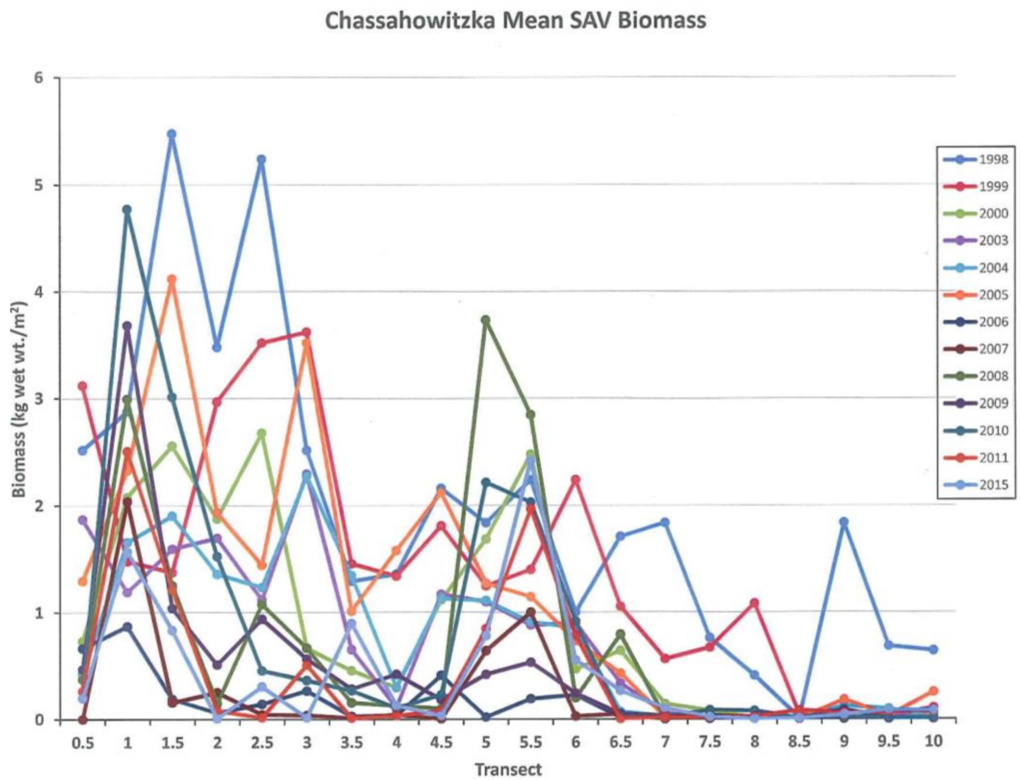

Figure 5-4. Chassahowitzka River SAV Biomass by Transect - Period of Record

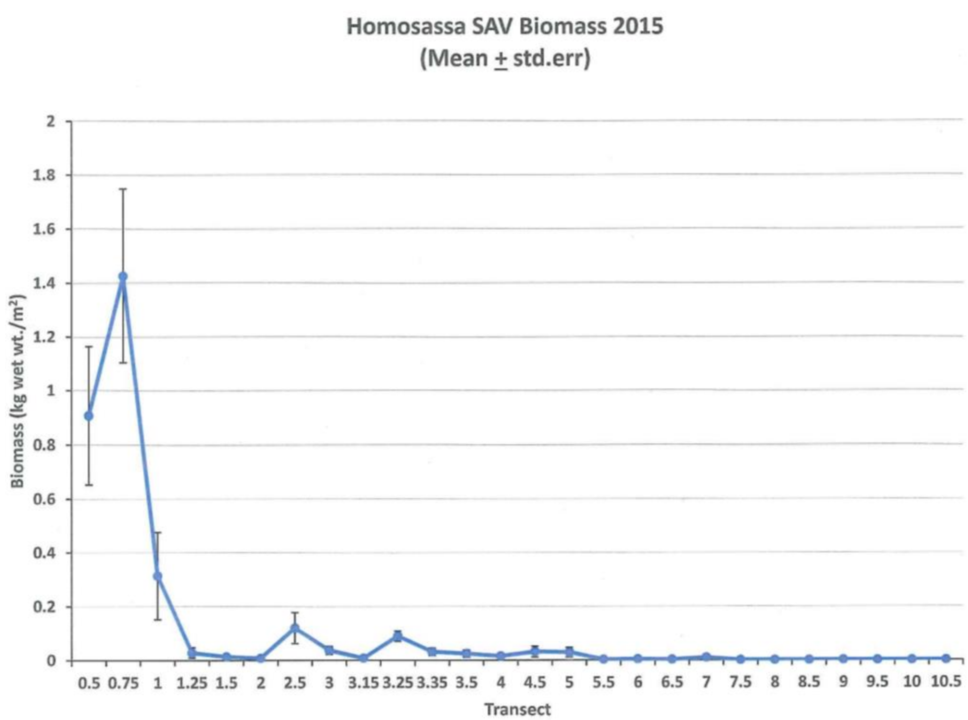

Figure 5-5. Homosassa River SAV Biomass by Transect - 2015

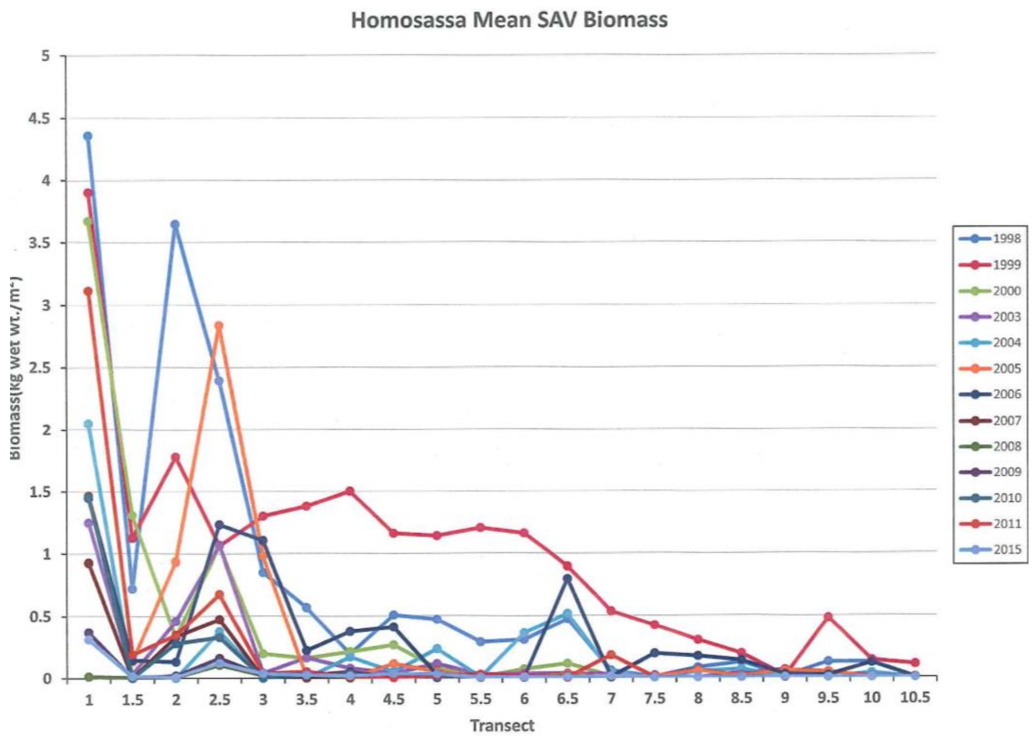

Figure 5-6. Homosassa River SAV Biomass by Transect - Period of Record

5.3 Angiosperm Biomass

Figures 5-7 through 5-12 present the mean and standard error for each transect for each of the three rivers for the 2015 period and for the period of record. For river-wide mean angiosperm biomass compared across the rivers, the Weeki Wachee River mean angiosperm biomass was the highest for 1998, 1999, 2000, 2004, 2006, and 2007. The Chassahowitzka River river-wide mean angiosperm biomass was the highest for 2003, 2005, 2008, 2009, 2010, 2011, and 2015. The river-wide mean angiosperm biomass for the Homosassa River was the lowest for all sampling events.

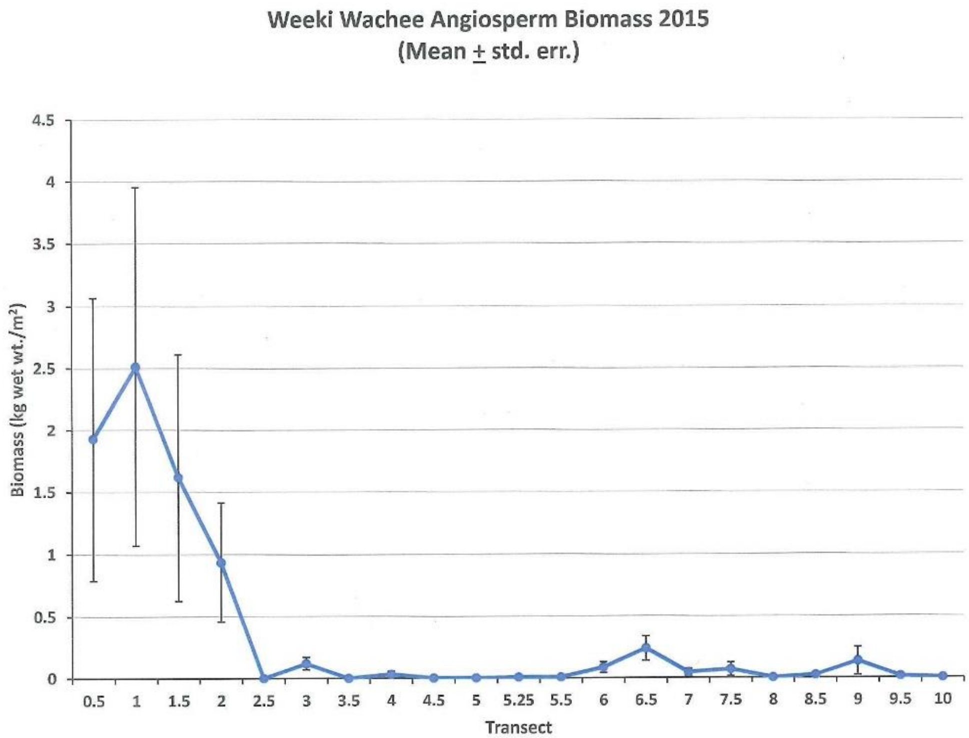

Figure 5-7. Weeki Wachee River Angiosperm Biomass by Transect - 2015

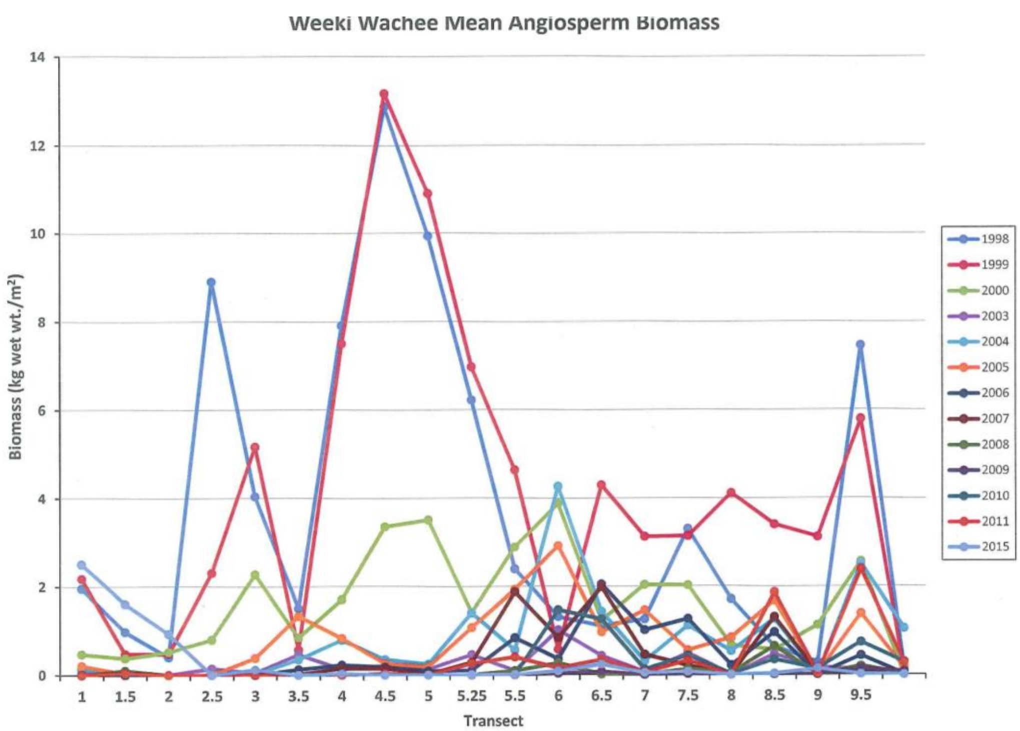

Figure 5-8. Weeki Wachee River Angiosperm Biomass by Transect - Period of Record

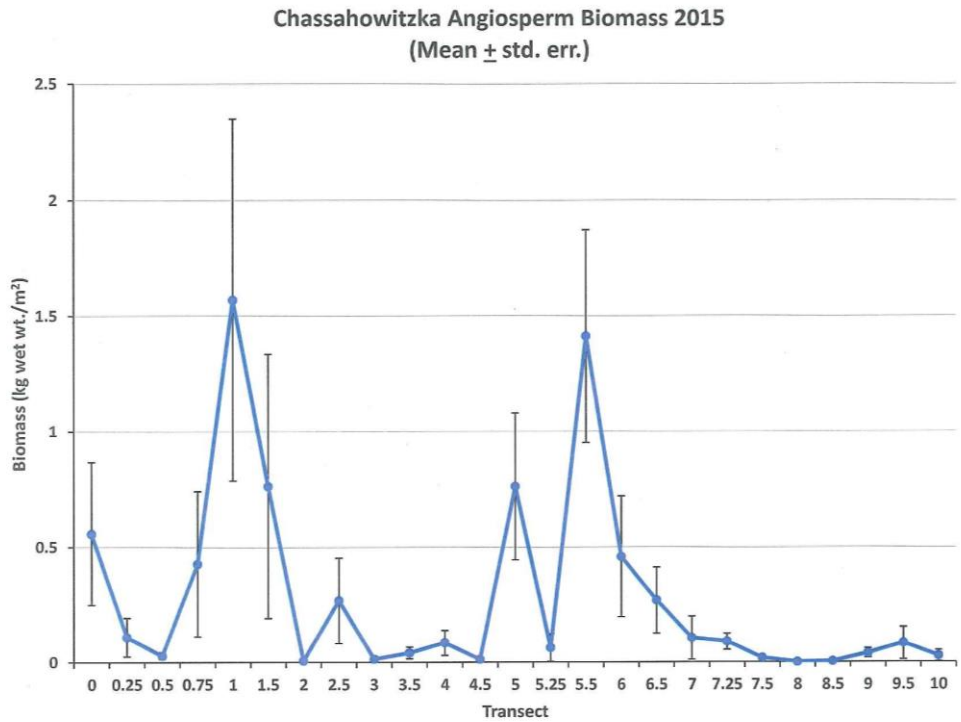

Figure 5-9. Chassahowitzka River Angiosperm Biomass by Transect – 2015

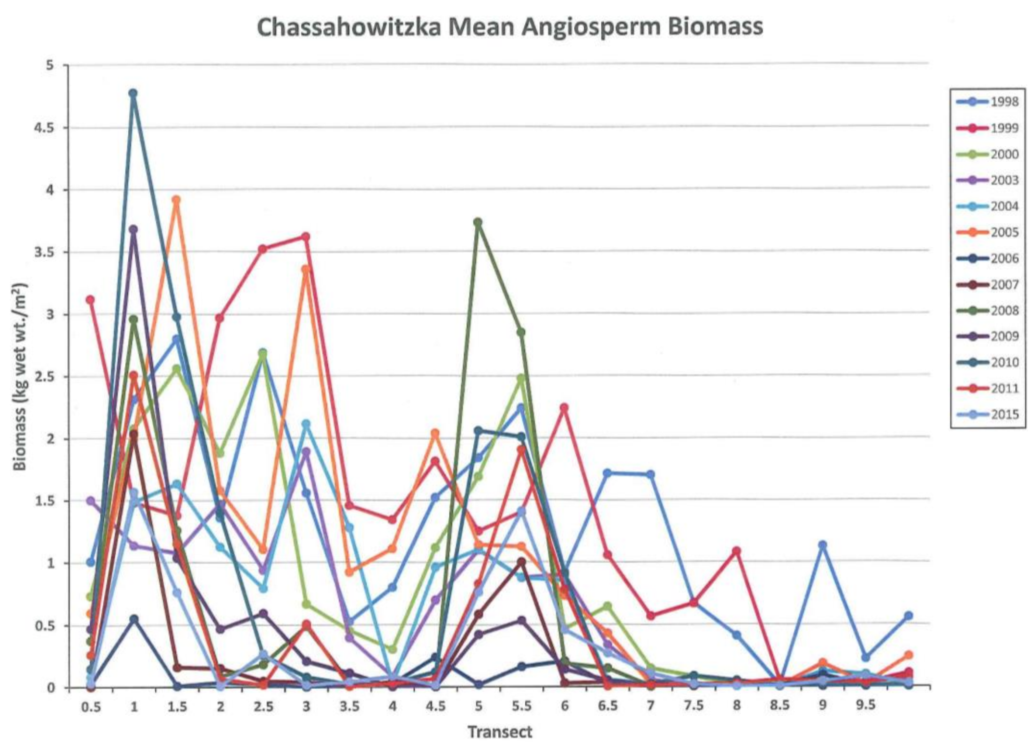

Figure 5-10. Chassahowitzka River angiosperm biomass by transect - Period of Record

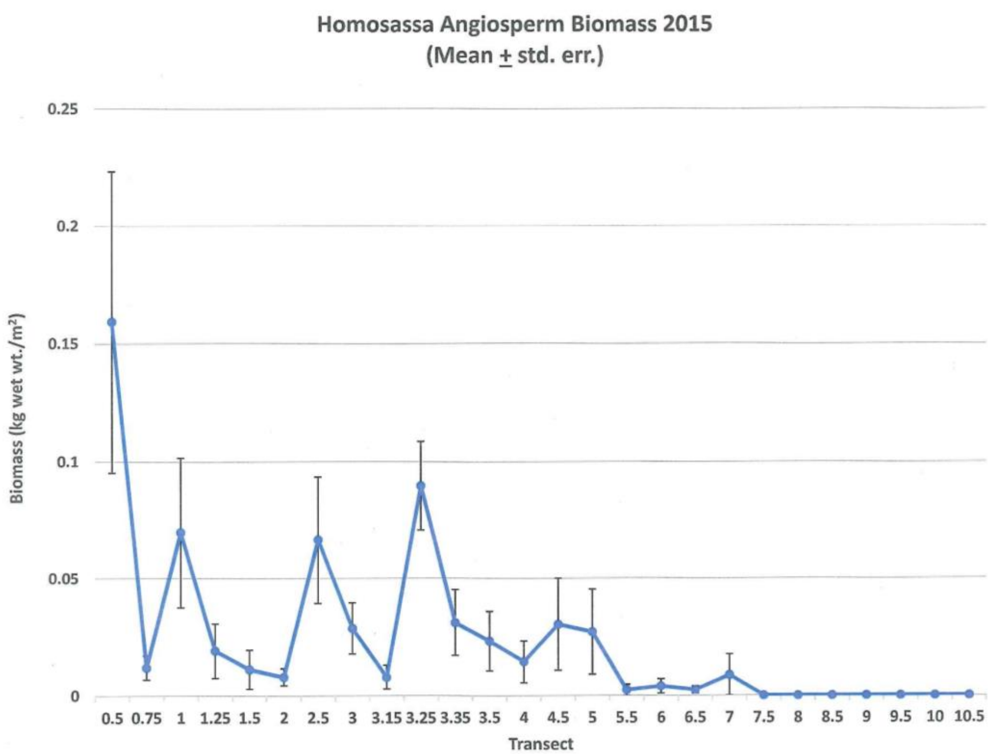

Figure 5-11. Homosassa River angiosperm biomass by transect - 2015

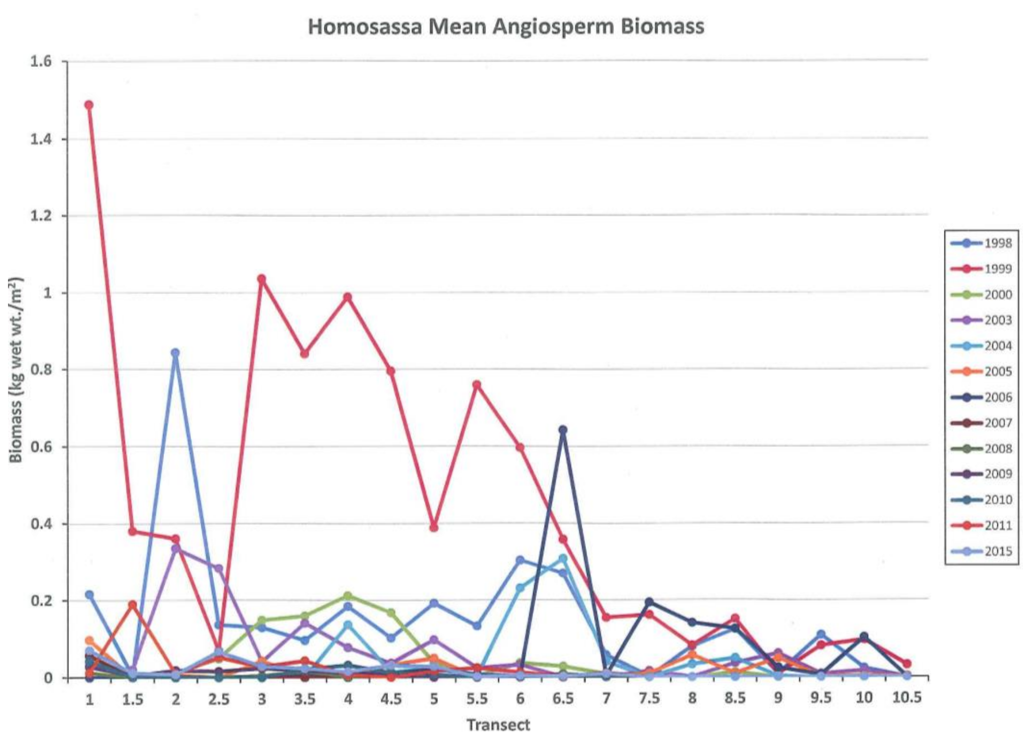

Figure 5-12. Homosassa River angiosperm biomass by transect - Period of Record

5.4 Macroalgal Biomass

Figures 5-13 through 5-18 present the mean and standard error for each transect for each of the three rivers for the 2015 period and for the period-of-record. For macroalgae, the river-wide mean biomass for the Weeki Wachee River was the highest compared to the other two rivers for all sampling events except 1998, when the highest macroalgae biomass was observed for the Chassahowitzka River. For all sampling events except for 1998, 2000, and 2005, the mean macroalgae biomass values for the Homosassa and Chassahowitzka Rivers were notably less than the values for the Weeki Wachee River.

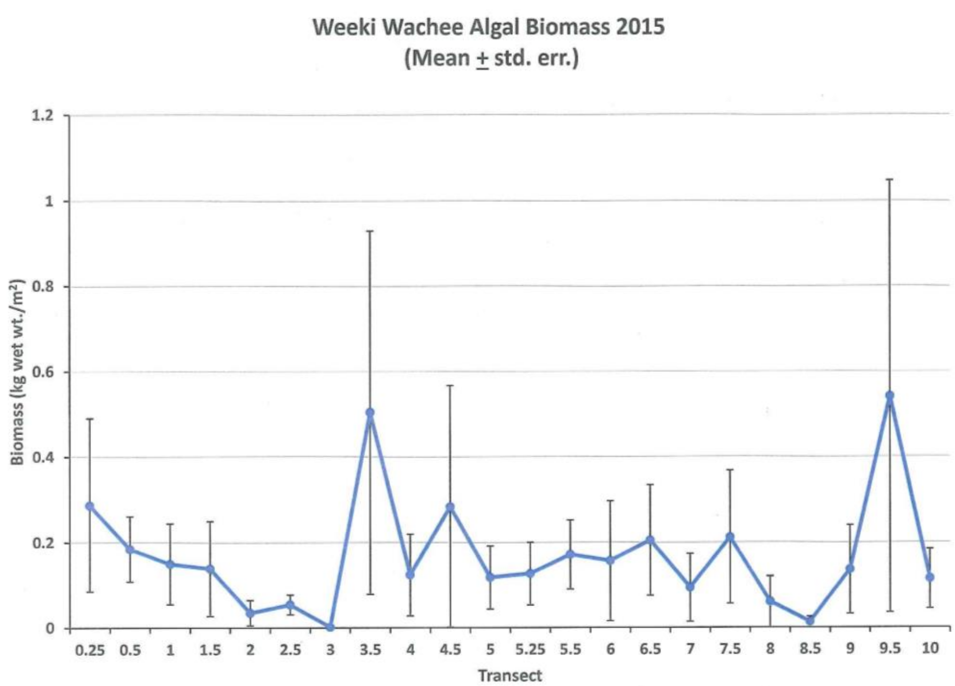

Figure 5-13. Weeki Wachee River Algal Biomass by Transect - 2015

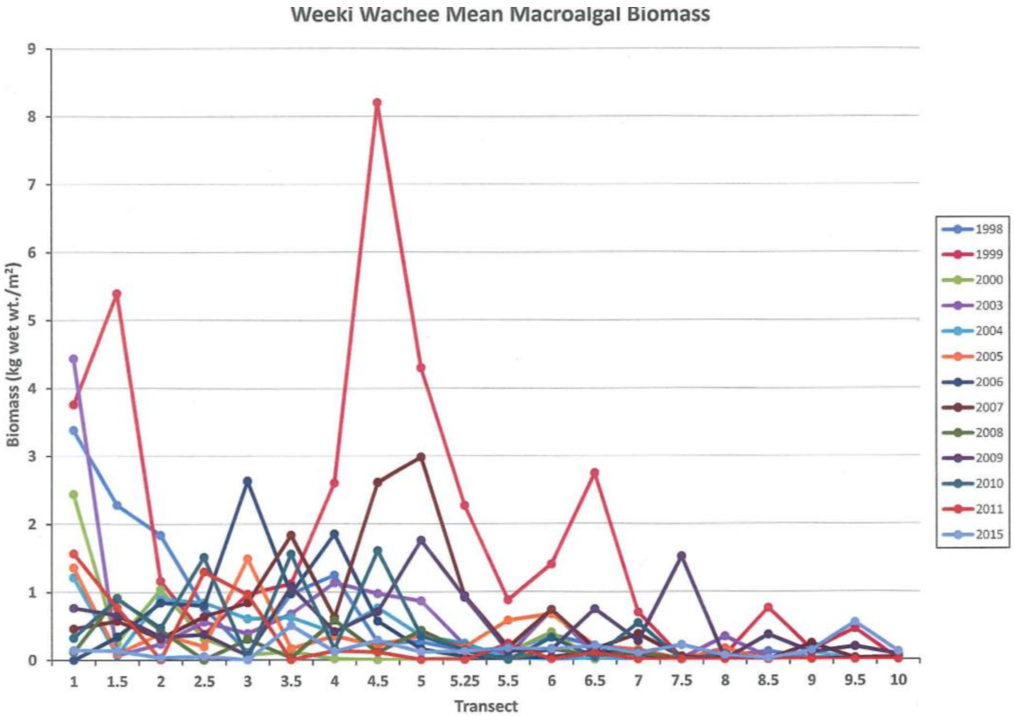

Figure 5-14. Weeki Wachee River Algal Biomass by Transect - Period of Record

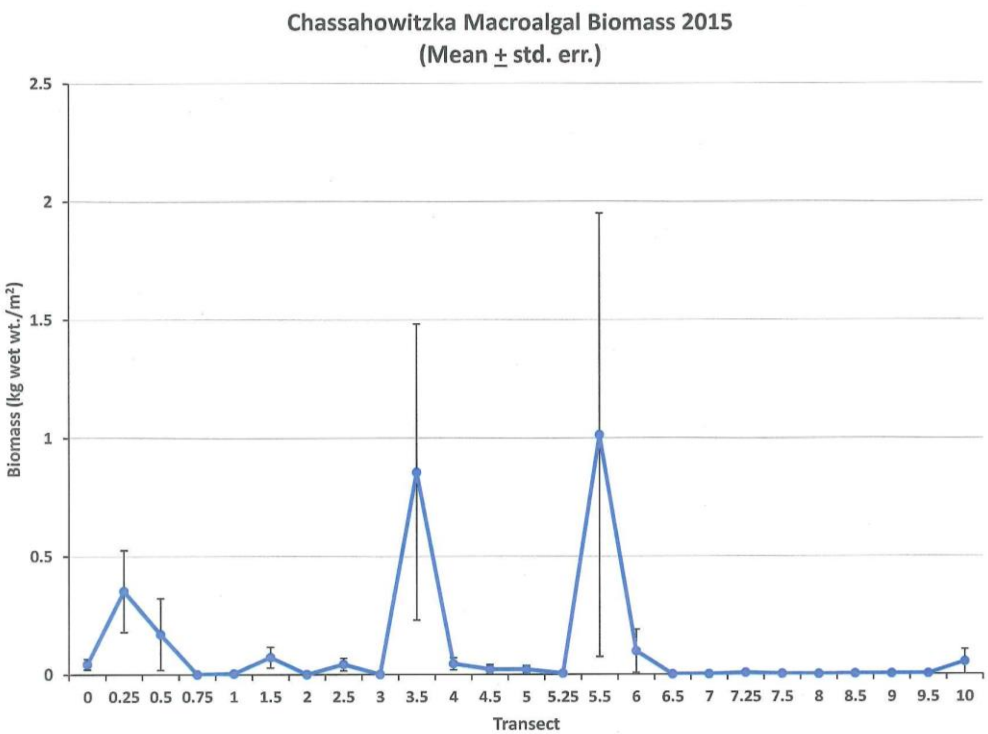

Figure 5-15. Chassahowitzka River Algal Biomass by Transect - 2015

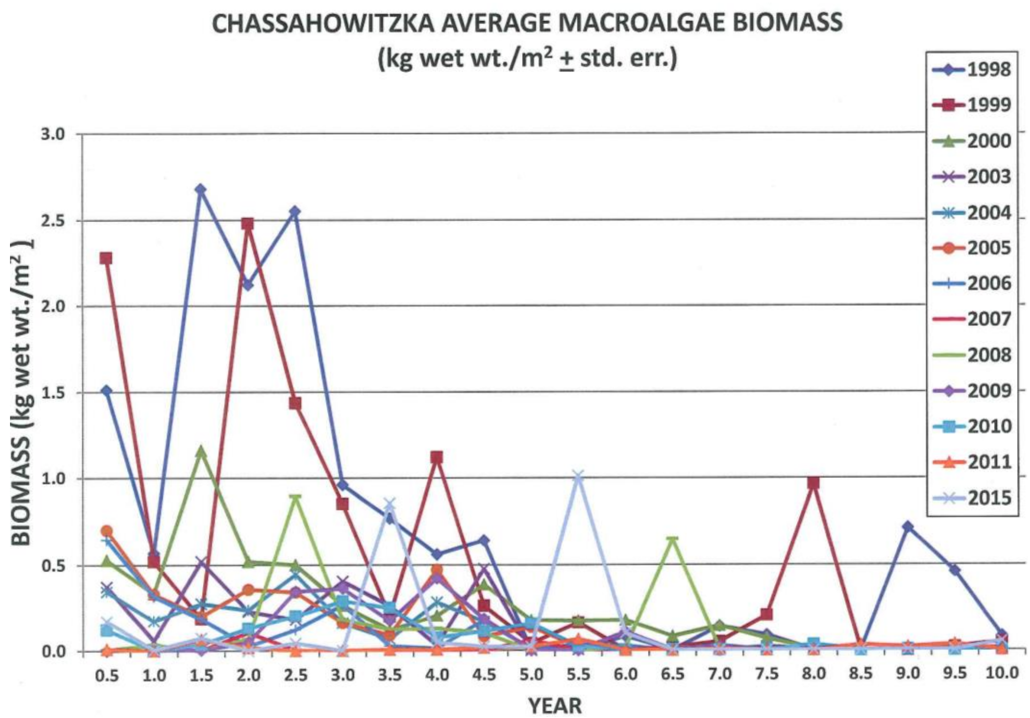

Figure 5-16. Chassahowitzka River Algal Biomass by Transect - Period of Record

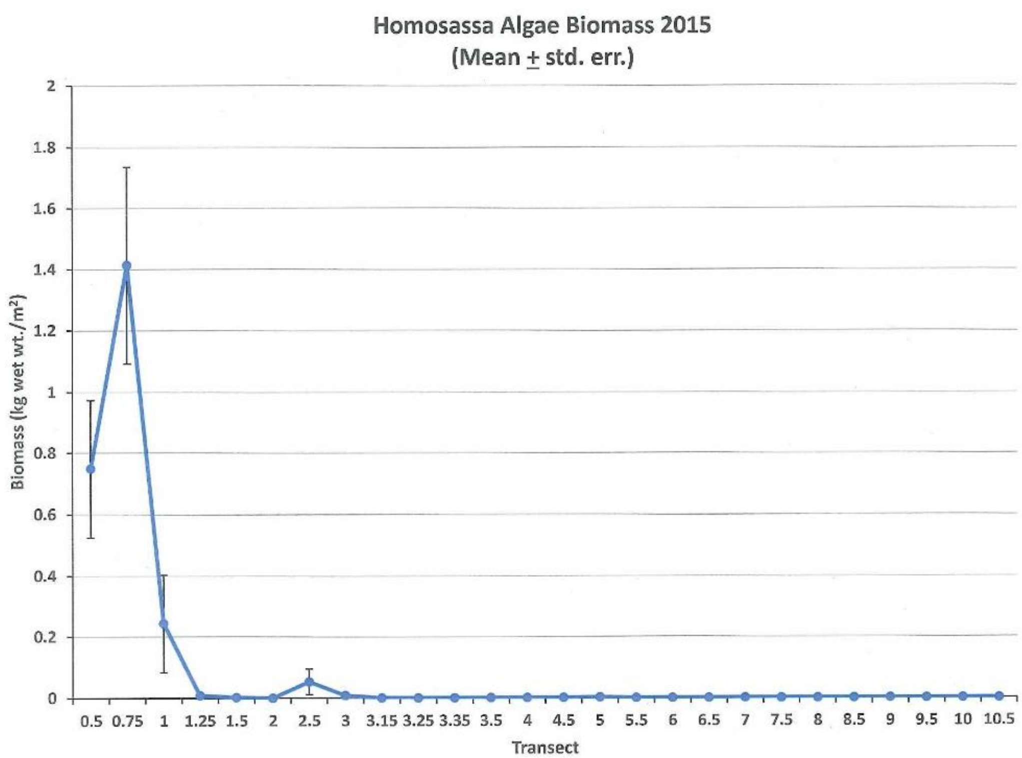

Figure 5-17. Homosassa River Algal Biomass by Transect - 2015

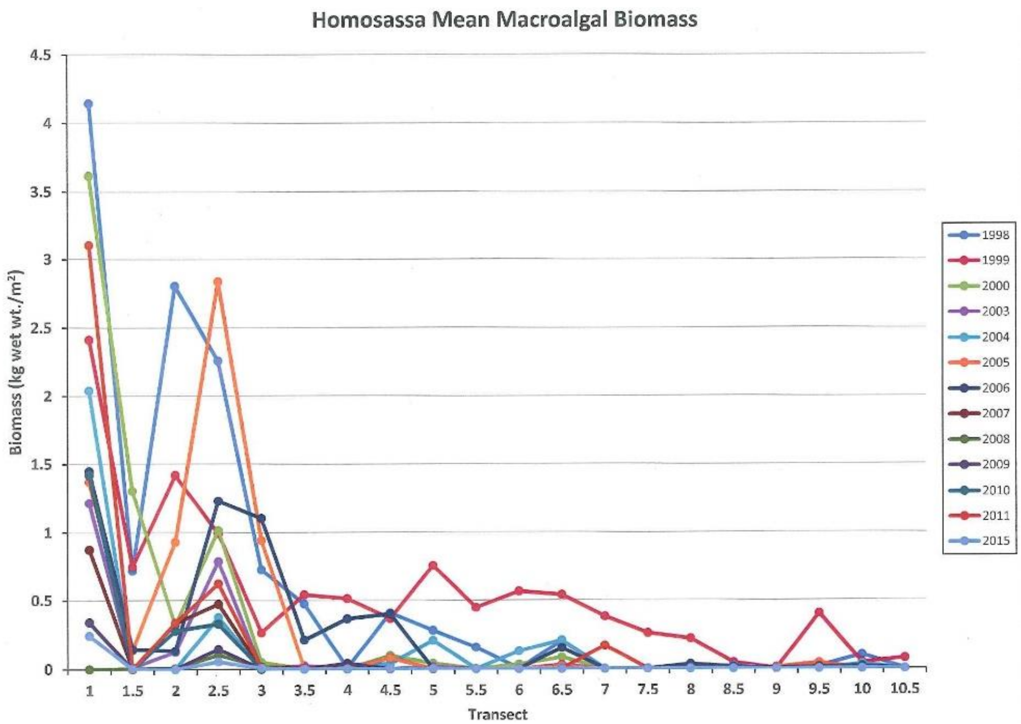

Figure 5-18. Homosassa River Algal Biomass by Transect - Period of Record

6.0 Analysis of Distributional and Biomass Changes

6.1 Discussion of Statistical Methods

This section describes the work that was completed to compare the most recent (2015) SAV data to the historical data, including the use of nonparametric statistical methods to evaluate the statistical significance of any changes. Data have been collected once yearly near the end of the growing season for most of the years between 1998 and 2011. The 1998-2000 and 2003-2005 data were previously described and analyzed in the Frazer et al. studies (2001 and 2006, respectively). These two studies characterized the physical, water quality, and SAV conditions in the Homosassa River on the west coast of Florida for the period of the studies. The Frazer et al. 2006 study suggests that increased nutrients from the watershed are a possible factor in the changes that were observed in the historical SAV data for the Weeki Wachee, Chassahowitzka, and Homosassa Rivers for the 1998-2000 and 2003-2006 periods.

Data were also collected from 2006-2011 but have not previously been analyzed. After a 3-year hiatus, data collection resumed in 2015 by the ATM Team under contract to SWFWMD.
This section presents an analysis of the combined 1998-2000, 2003-2005, 2006-2011, and 2015 data. All of the available data were combined into a single dataset. Differences between the 2015 data and the historical data were analyzed using nonparametric tests to characterize the statistical significance of any differences/similarities that were identified.

One objective of this project is to document the 2006-2011 and 2015 data in a manner similar to Frazer et al. (2001) and Frazer et al. (2006). A second objective is to analyze the data and evaluate any changes in the data over the period of data collection using statistically sound methodologies. The same statistical methods were applied to the data that have been collected from all three rivers.

Non-parametric hypothesis tests that are available in SAS© routines provided useful information on the statistical significance of the differences that were seen between the historical data and the 2015 data for these river systems, as well as the strength of the evidence. The hypothesis tests that were used for this nonparametric data analysis included the Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (McDonald 2014). The SAS©

PROC NPAR1WAY routines performed the Kruskal Wallace and Median Two sample tests. The SAS© PROC UNIVARIATE routines were used to provide the Wilcoxon Sign and Signed Rank test statistics.

For each of these non-parametric tests the ‘null’ hypothesis assumes that the median values of the data distributions being compared are equal and that there are no sampling event or transect effects. The alternative hypothesis is that the distributions of data being compared are different. Most non-parametric tests utilize a ranking system to assign scores and then an estimate is computed for the probability of occurrence (a *p*-value, between 0 and 1). A *p*-value is the probability of occurrence of a value that is at least as extreme as the value being evaluated, assuming the truth of the null hypothesis. In this manner, a *p*-value provides useful information on the strength of the evidence.

In this evaluation the *p*-values were interpreted in the following manner to maintain a minimum of 95 percent level of confidence:

- A small *p*-value (≤0.05) indicates strong evidence *against* the null hypothesis that the distributions of data are identical. Therefore, when the *p*-value was ≤0.05, the null hypothesis was rejected and it was concluded instead that there is a difference in the two data distributions and the difference is statistically significant. This means a change has likely occurred in the data.
- A large *p*-value (>0.05) indicates weak evidence against the null hypothesis that the two distributions of data are identical, so the null hypothesis is not rejected and the two distributions of data are concluded to be statistically not different (i.e., no change has occurred).
- Any *p*-values close to 0.05 were considered to provide no evidence that the distributions are different but also no evidence that the distributions are not different and no substantive conclusion can be drawn from the test.

Before the quality-controlled 2015 data became available for use, an initial analysis was completed using the available historical data for total SAV (kg/m^2 wet weight) on a river-wide scale for all three coastal rivers. For that initial analysis, the data were divided into two sets of data based on continuity of data collection, for ease of analysis: 1998-2000 and 2003-2011. The SAS© NPAR1WAY procedure was used with the two-sample option to determine if the obvious (in plots) differences in the 1998-2000 data and the 2003-2011 data were statistically significant. The results of non-parametric tests were consistent – the river-wide total SAV data for these two periods were statistically different, with a high level of confidence, for all three spring-fed river systems.

6.2 Weeki Wachee River

This section describes an analysis of the most recent (2015) SAV data from the Weeki Wachee River, including a comparison to the historical data and the use of appropriate nonparametric statistical methods to evaluate the statistical significance of the differences. It presents an analysis of the combined 1998-2000, 2003-2005, 2006-2011, and 2015 Weeki Wachee River SAV data. All of the available data were combined into a single dataset and differences between the 2015 data and the historical data were identified. An evaluation of the differences used nonparametric tests to understand the statistical significance of any differences/similarities that were identified.

Data were collected from the Weeki Wachee River once yearly near the end of the growing season for most of the years between 1998 and 2011. For the 1998-2000 and 2003-2005 data, the Frazer et al. studies (2001 and 2006, respectively) characterized the Weeki Wachee River physical, water quality, and SAV conditions for the periods of the studies and analyzed the changes that were seen including the reduction of SAV for the later period of data collection. Data from the Weeki Wachee River were also collected by others from 2006-2011 but have not previously been analyzed. After a 3-year hiatus, data collection in the Weeki Wachee River resumed in 2015 by the ATM Team under contract to SWFWMD.

One objective of this project was to document the 2006-2011 and 2015 data from the Weeki Wachee River in a manner similar to the Frazer et al. studies (2001 and 2006). A second objective was to analyze the data and evaluate any changes in the data over the period of data collection using statistically sound methodologies.

6.2.1 Description of the Data

Prior to the 2015 data collection effort, data on the vegetative community in the Weeki Wachee River were collected once each year for 1998, 1999, 2000, 2003, 2004, 2005, 2006, 2007, 2008, 2008, 2009, 2010, and 2011 using 20 transects with five stations on each transect. No data were collected in 2001, 2002, 2012, 2013, or 2014. The SAV data that were collected included:

- Biomass for total SAV, macroalgae, and angiosperm
- Bottom substrate type
- Percent of canopy shading
- Percent of total SAV cover

For 2015, the data were collected in the same manner as previous sampling events, and the same parameters were measured. For 1998, 1999, and 2000, there are no percent total SAV cover data. Data for bottom substrate type and percent of canopy shading were not included in this study.

Plots of river-wide total SAV, angiosperm, and macroalgae mean biomass (wet weight) values for the Weeki Wachee River are presented as Figures 6-1, 6-2, and 6-3 by year of sampling event, along with the percentage of total SAV for angiosperm and macroalgae. The average total SAV percent cover for each year is shown on Figure 6-4. A comparison of the information in these figures is provided in the following summary.

1. The river-wide mean total SAV biomass for the Weeki Wachee River was highest in 1999, followed by 1998 and 2000. The mean total SAV biomass was smallest in 2008. The 2015 mean total SAV biomass values for 2003-2015 were about one-fourth of the 1998 and 1999 mean total SAV biomass values.
2. The river-wide mean angiosperm biomass was highest in 1999 followed by 1998 and 2000. The mean angiosperm biomass was smallest in 2009 and 2008. The 2015 mean angiosperm biomass was greater than 2008, but not by very much. The percent of total SAV biomass that was angiosperm biomass ranged from almost 0 in 2009 to 86 percent in 2000.

3. The river-wide mean macroalgae biomass for the Weeki Wachee River was highest in 1999. For all other sampling events, the mean macroalgae biomass was much smaller, only about one-third of the 1999 macroalgae biomass. The 2015 macroalgae biomass was the smallest of all sampling events. The percent of total SAV biomass that was macroalgae ranged from a low of about 13 percent of the total SAV biomass in 1998 and 2000 to almost 98 percent of total SAV biomass for 2009.
4. The river-wide total SAV percent cover values for the Weeki Wachee River range from a low of about 25 percent in 2006 to a high of 44 percent in 2005. The 2015 total SAV percent cover was similar to about half of the other sampling events (no data for 1998-2000).

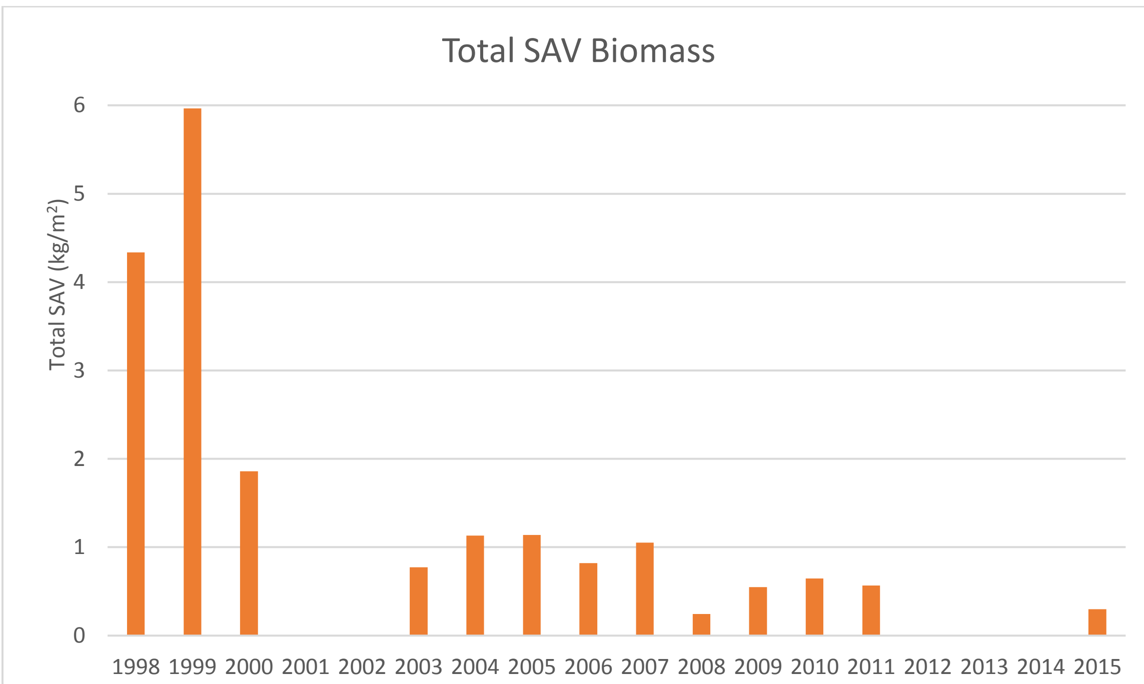

Figure 6-1. River-Wide Mean Total SAV Biomass (kg/m^2 wet) by Sampling Event for the Weeki Wachee River. N=100 for each year

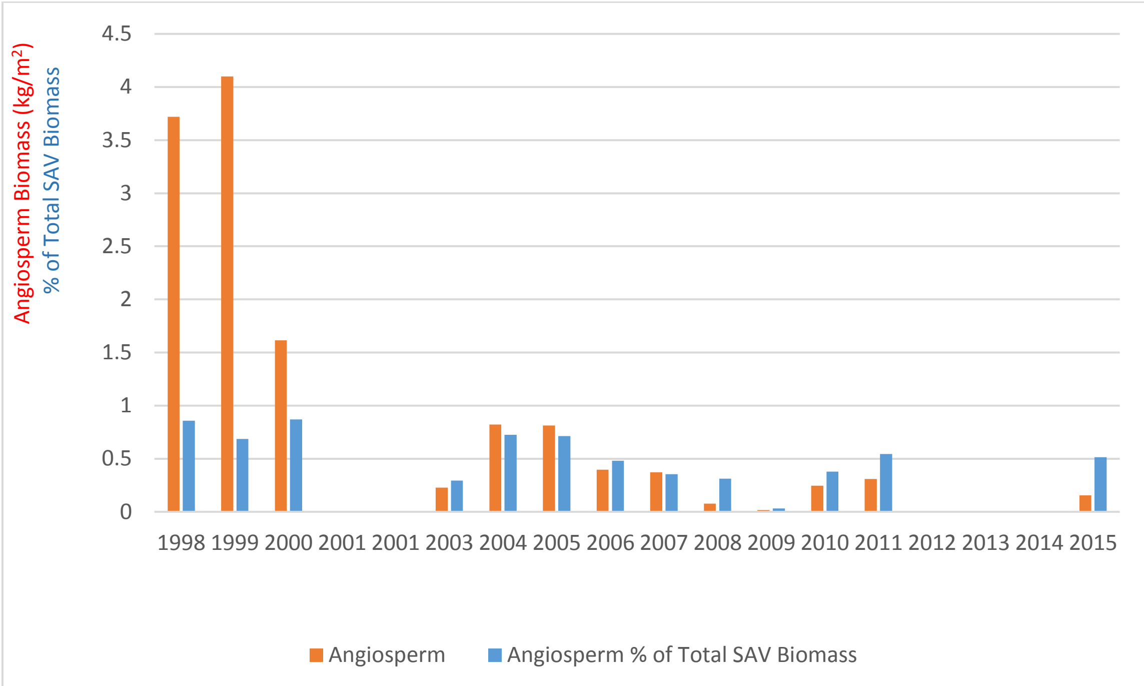

Figure 6-2. River-Wide Mean Angiosperm Biomass (kg/m²) and Angiosperm Percent of Total SAV Biomass by Sampling Event for the Weeki Wachee River. N=100 for each year

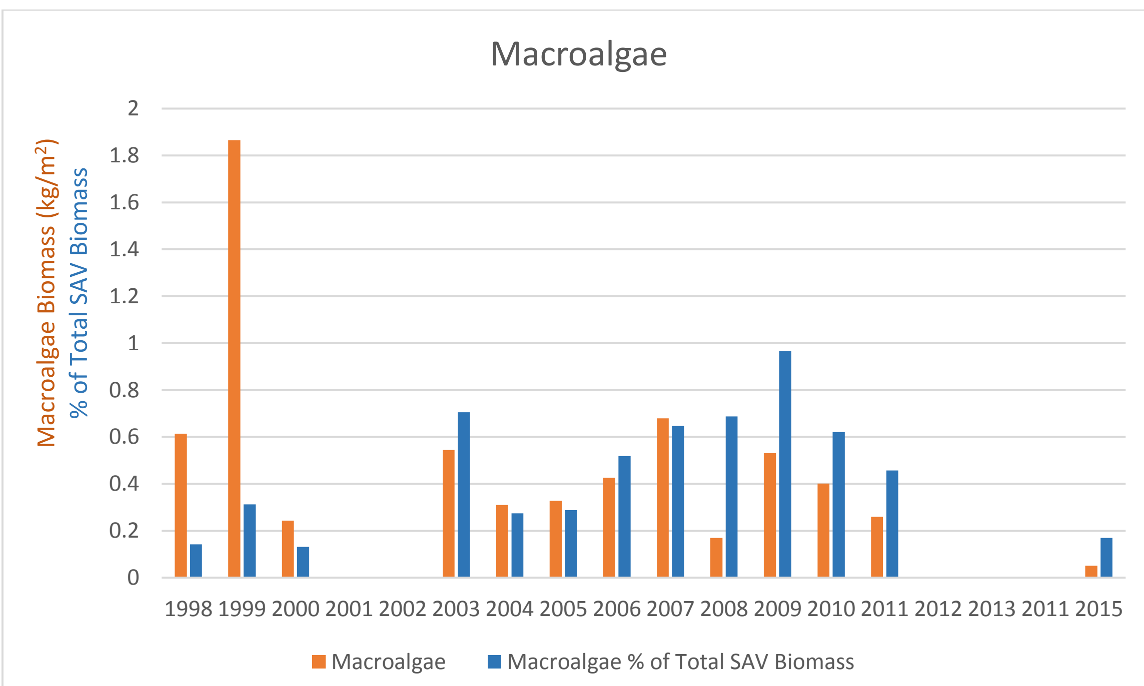

Figure 6-3. River-Wide Mean Macroalgae Biomass (kg/m² wet) and Macroalgae Percent of Total SAV Biomass by Sampling Event for the Weeki Wachee River. N=100 for each year

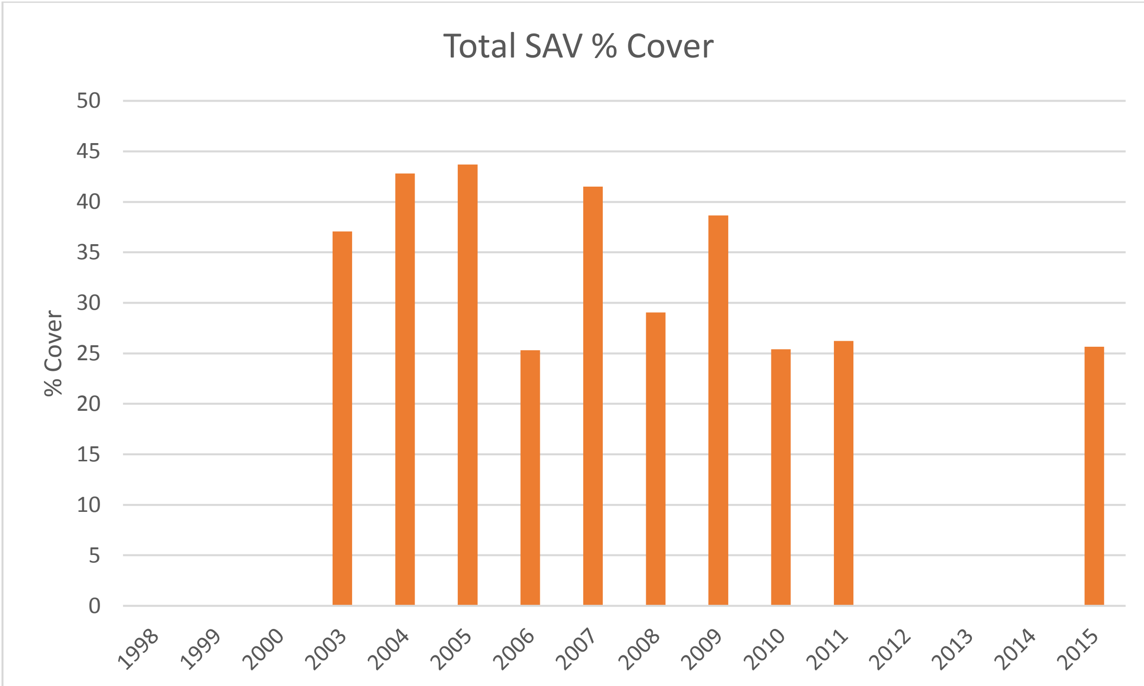

Figure 6-4. River-Wide Mean Percent Total SAV Cover by Sampling Event for the Weeki Wachee River. N=100 for each year.

6.2.2 Overview of Statistical Procedures

Figure 6-5 presents a histogram for Weeki Wachee River total SAV biomass data, indicating that most samples had little or no SAV present when data were collected and that the distribution is skewed. For this reason, non-parametric SAS© routines were used to analyze the statistical significance of the differences in the data.

6.2.3 Comparison of the 2015 Data and the Historical Data for the Weeki Wachee River

6.2.3.1 Total SAV Biomass

The total SAV biomass data for 2015 from the Weeki Wachee River were compared to the total SAV biomass data from all of the other years, river-wide and by transect, to identify and analyze any differences. River-wide, the mean total SAV biomass for the 2015 sampling event was only about one-fifth of the mean total SAV biomass for all other sampling events combined, a 77.4 percent decrease (Table 6-1).

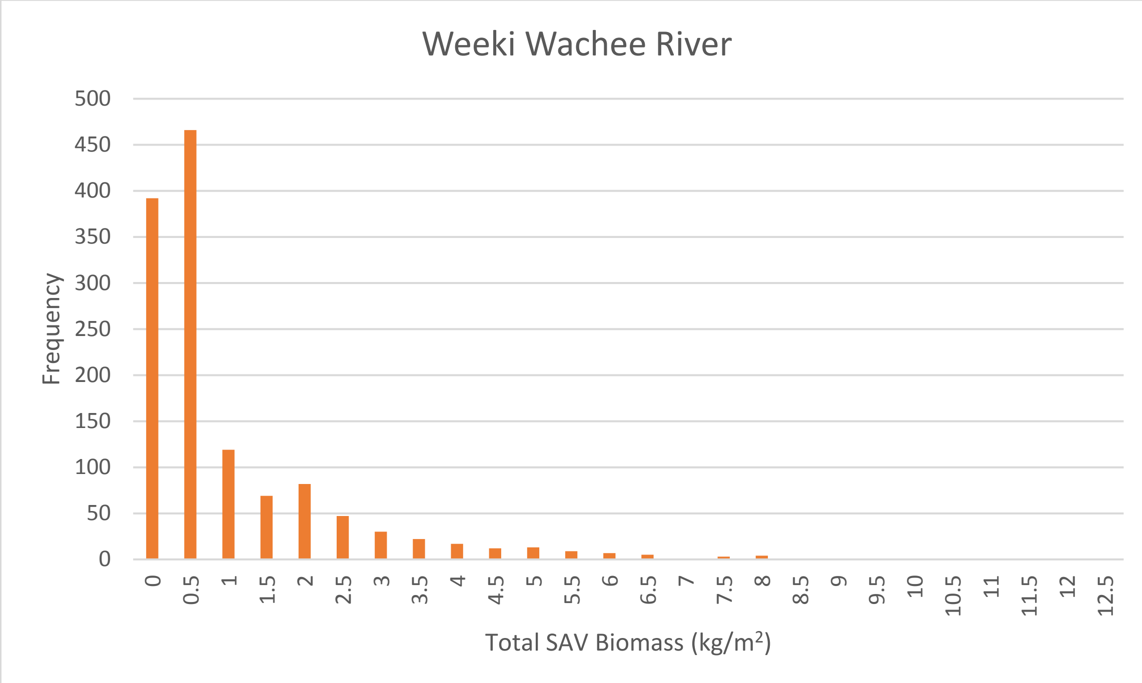

Figure 6-5. Histogram for Total SAV Biomass Data by Transect Collected from the Weeki Wachee River between 1998 and 2015, Non-Continuously. (N=1300)

By transect (Table 6-2), the change in total SAV biomass for 2015 compared to the 1998-2011 data ranged from -100 percent to +21.28 percent, with 17 out of 20 transects indicating lower 2015 total SAV biomass compared to the combined historical data. Fourteen of those transects experiencing more than 90 percent decreases. For the three transects with higher 2015 total SAV biomass than the 1998-2011 data, the total SAV biomass increases are all less than 34 percent. The Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample nonparametric tests indicate that the differences between the 2015 total SAV biomass data and the combined 1998-2011 total SAV biomass data shown in Tables 6-1 and 6-2 are statistically significant, with at least 95 percent confidence.

Table 6-1. River-Wide Mean Total SAV Biomass for the Weeki Wachee River for All Previous Years (combined) Compared to the Mean Total SAV Biomass for 2015.

1998-2011 Total SAV Biomass (kg/m²)	2015 Total SAV Biomass (kg/m²)	Difference: 1998-2011 minus 2015 (kg/m²)	% Increase/Decrease
1.59*	0.30*	1.29	-77.36%

* statistically significant difference with at least 95% confidence

Table 6-2. Comparison of Total SAV Biomass for the Weeki Wachee River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values.

Transect	1998-2011 Total SAV biomass (kg/m^2)	2015 Total SAV biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kgm/m^2)	% Increase/Decrease
1	2.0726	2.5136	-0.44	+21.28%
1.5	1.2121	1.6184	-0.41	+33.52%
2	0.7810	0.9392	-0.16	+20.26%
2.5	1.6543	0.0264	1.63	-8.40%
3	1.7016	0.1200	1.58	-92.95%
3.5	1.2012	0.0000	1.20	-100.00%
4	2.3985	0.0328	2.37	-98.63%
4.5	3.8926	0.0000	3.89	-100.00%
5	3.0673	0.0000	3.07	-100.00%
5.25	1.9528	0.1320	1.82	-93.24%
5.5	1.5086	0.0056	1.50	-99.63%
6	1.8414	0.0856	1.76	-95.35%
6.5	1.6387	0.2384	1.40	-85.45%
7	1.0287	0.0464	0.98	-95.49%
7.5	1.2250	0.0688	1.16	-94.38%
8	0.7395	0.0016	0.74	-99.78%
8.5	1.1996	0.0216	1.18	-98.20%
9	0.4677	0.1336	0.33	-71.43%
9.5	2.0420	0.0128	2.03	-99.37%
10	0.1816	0.0000	0.18	-100.00%
Average	1.59*	0.30*	1.29	-77.36%

* statistically significant difference with at least 95% confidence

6.2.3.2 Total SAV Percent Cover

The mean Weeki Wachee River total SAV percent cover data for the 2015 sampling event were compared to the combined mean total SAV percent cover data for the 2003-2011 sampling events river-wide and by transect (there are no total SAV percent cover data for 1998, 1999, or 2000). The river-wide difference in total SAV percent cover for 2015 compared to the data for 2003-2011 was a reduction of about 20.6 percent, as presented in Table 6-3. Table 6-4 presents the change in total SAV percent cover for 2015 compared to the historical data, by transect. For 16 transects, the 2015 total SAV percent cover was less than the historical data. For the other four transects, the 2015 total SAV percent cover was greater than the historical data. For transects with reduced total SAV percent cover for 2015, the reductions ranged from -1 percent to about -95.4 percent. Total SAV percent cover for four transects was greater than the 2015 total SAV percent cover, three of which were more than 95 percent increases.

The following nonparametric tests indicate that the differences shown in Tables 6-3 and 6-4 between the 2015 total percent SAV cover data and the combined 2003-2011 total percent SAV cover data were statistically significant, with at least 95 percent confidence: Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E1 for test results).

Table 6-3. River-Wide Mean SAV Percent Cover for the Weeki Wachee River for 2003-2011 (combined) Compared to the Mean Total SAV Percent Cover for 2015.

2003-2011 Total SAV % Cover	2015 Total SAV % Cover	Difference: 2003-2011 minus 2015	% Increase/Decrease
34.41*	25.65*	8.76	-20.59%

* statistically significant difference with at least 95% confidence

Table 6-4. Comparison of Total SAV Percent Cover Data for the Weeki Wachee River by Transect for 2003-2011 (combined) and for 2015

Transect	2003-2011 mean Total SAV % Cover	2015 mean Total SAV % Cover	Difference: 2003-2011 minus 2015	% Increase/Decrease
1	41.29	62.00	-20.71	+50.16%
1.5	28.98	57.40	-28.42	+98.08%
2	28.42	56.00	-27.58	+97.03%
2.5	32.67	8.20	24.47	-74.90%
3	43.16	18.00	25.16	-58.29%
3.5	30.56	25.00	5.56	-18.18%
4	46.51	28.40	18.11	-38.94%
4.5	46.24	21.00	25.24	-54.59%
5	41.31	10.20	31.11	-75.31%
5.25	31.87	11.00	20.87	-65.48%
5.5	30.33	11.00	19.33	-63.74%
6	47.09	28.00	19.09	-40.54%
6.5	40.73	34.00	6.73	-16.53%
7	28.84	28.60	0.24	-0.85%
7.5	31.53	22.00	9.53	-30.23%
8	17.40	8.00	9.40	-54.02%
8.5	31.80	5.20	26.60	-83.65%
9	19.44	38.00	-18.56	+95.43%
9.5	46.98	25.00	21.98	-46.78%
10	23.02	16.00	7.02	-30.50%
Average	34.41*	25.65*	8.76	-20.59%

* statistically significant difference with at least 95% confidence

6.2.3.3 Angiosperm

The Weeki Wachee River mean angiosperm biomass data for 2015 were compared to data from the other sampling events, river-wide and by transect. The data in Table 6-5 indicate that the river-wide mean angiosperm biomass for 2015 was 0.29 kg/m^2, which is 0.77 kg/m^2 less than the mean angiosperm biomass for all previous years combined, a more than 72 percent decrease. By transect (Table 6-6), the angiosperm biomass differences for 2015 ranged from 100 percent decrease to a 781 percent increase (only one transect). The majority of transects experienced decreases in mean angiosperm biomass compared to the historical data. The following nonparametric tests indicate that the differences shown in Tables 6-5 and 6-6 between the 2015 angiosperm biomass data and the combined 1998-2011 angiosperm biomass data are statistically significant, with at least 95 percent confidence: Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E1 for results).

6.2.3.4 Macroalgae

The Weeki Wachee River mean macroalgae biomass data for 2015 were compared to data from all the other years, river-wide and by transect, to estimate the differences in the 2015 data compared to the previously collected data. The data in Table 6-7 indicate that the river-wide mean macroalgae biomass for 2015 was 0.05 kg/m^2 which is 0.48 kg/m^2 less than the mean macroalgae biomass for the historical data, a 79.2 percent difference. The macroalgae biomass decreased significantly for 2015 for all transects except one (a 12 percent increase); decreases for 2015 ranged from 5 percent to over 98 percent with 15 transects experiencing more than an 80 percent decrease in mean macroalgae biomass. For a number of transects with more than a 90 percent decrease in macroalgae biomass values, the historical data were already very small for the 1998-2011 period (see Table 6-8). The following nonparametric tests indicate that the differences shown in Tables 6-7 and 6-8 between the 2015 macroalgae biomass data and the combined 1998-2011 macroalgae biomass data are statistically significant, with at least 95 percent confidence: Wilcoxon Signed and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E1 for results).

Table 6-5. River-Wide Change in Mean Angiosperm Biomass for the Weeki Wachee River for All Previous Years (combined) Compared to the Mean Angiosperm Biomass for 2015.

1998-2011 Angiosperm biomass (kg/m^2)	2015 Angiosperm biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
1.06*	0.29*	0.77	-72.29%

* statistically significant difference with at least 95% confidence

Table 6-6. Comparison of Angiosperm Biomass for the Weeki Wachee River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values.

Transect	1998-2011 Angiosperm biomass (kg/m^2)	2015 Angiosperm biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
1	0.42	2.5136	-2.0939	498.86%
1.5	0.18	1.6184	-1.4347	780.84%
2	0.12	0.9392	-0.8221	701.82%
2.5	1.01	0.0264	0.9883	-97.40%
3	1.00	0.12	0.8771	-87.97%
3.5	0.44	0	0.4365	-100.00%
4	1.61	0.0328	1.5734	-97.96%
4.5	2.55	0	2.5488	-100.00%
5	2.08	0	2.0842	-100.00%
5.25	1.52	0.0064	1.5095	-99.58%
5.5	1.31	0.0056	1.3071	-99.57%
6	1.43	0.0856	1.3414	-94.00%
6.5	1.27	0.2384	1.0291	-81.19%
7	0.83	0.0464	0.7820	-94.40%
7.5	1.08	0.0688	1.0159	-93.66%
8	0.68	0.0016	0.6792	-99.76%
8.5	1.09	0.0216	1.0723	-98.03%
9	0.41	0.1336	0.2798	-67.68%
9.5	1.98	0.0128	1.9711	-99.35%
10	0.17	0	0.1714	-100.00%
Average	1.06*	0.29*	0.7658	-72.29%

* statistically significant difference with at least 95% confidence

Table 6-7. River-Wide Change in Mean Macroalgae Biomass for the Weeki Wachee River for All Previous Years (combined) Compared to the Mean Macroalgae Biomass for 2015. Additional significant figures shown due to small biomass values.

1998-2011 Macroalgae biomass (kg/m^2)	2015 Macroalgae biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
0.53*	0.05*	0.48	-79.21%

* statistically significant difference with at least 95% confidence

Table 6-8. Change in Macroalgae Biomass for the Weeki Wachee River by Transect as Measured by the Difference between the Macroalgae Biomass for All Previous Years (combined) Compared to the Macroalgae Biomass for 2015 and the percentage of increase or decrease

Transect	1998-2011 Macroalgae biomass (kg/m^2)	2015 Macroalgae biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
1	1.6529	0.2662	1.3867	-83.90%
1.5	1.0283	0.1756	0.8527	-82.92%
2	0.6639	0.0970	0.5668	-85.38%
2.5	0.6395	0.0054	0.6342	-99.16%
3	0.7045	0.0122	0.6923	-98.27%
3.5	0.7647	0.0504	0.7143	-93.41%
4	0.7923	0.0157	0.7766	-98.02%
4.5	1.3438	0.0284	1.3154	-97.89%
5	0.9831	0.0118	0.9714	-98.80%
5.25	0.4369	0.1264	0.3105	-71.07%
5.5	0.1959	0.0177	0.1783	-90.98%
6	0.4144	0.0242	0.3902	-94.15%
6.5	0.3712	0.0443	0.3269	-88.06%
7	0.2003	0.0140	0.1863	-93.01%
7.5	0.1403	0.0281	0.1122	-79.98%
8	0.0587	0.0062	0.0525	-89.50%
8.5	0.1057	0.0034	0.1022	-96.74%
9	0.0543	0.0270	0.0273	-50.32%
9.5	0.0581	0.0554	0.0028	-4.77%
10	0.0102	0.0114	-0.0012	+12.16%
Average	0.53*	0.05*	0.48	-79.21%

* statistically significant difference with at least 95% confidence
Note: Additional significant figures shown due to small biomass values.

6.2.4 Discussion of Results

The available data on SAV presence and abundance in the Weeki Wachee River include data that have been collected once a year noncontinuously since 1998. In general, there is ample information for assessing the data collected in 2015 within the context of the available data record. These data indicate that neither the angiosperm nor macroalgae biomasses dominated the Weeki Wachee River total SAV biomass. Even so, in 2009, the macroalgae biomass was almost 97 percent of the toal SAV biomass.

The findings of the Weeki Wachee River SAV data analysis described herein are summarized as follows.

1. The mean total SAV biomass values for the 1998 and 1999 sampling events are two to three times greater than the mean total SAV biomass values for all other sampling events.
2. River-wide, the 2015 mean total SAV biomass was more than 77 percent lower than the 1998-2011 mean value. This difference was statistically significant (95 percent confidence).
3. By transect, the 2015 total SAV biomass data indicate a range of decreases of 8 percent to 100 percent compared to the historical data for 17 of the 20 transects. Small increases (<35 percent) in total SAV biomass were observed for three transects.
4. The mean total SAV percent cover was never higher than about 45 percent and never lower than about 25 percent (no data from 1998-2000). The 2015 mean total SAV percent cover was higher than the mean total SAV percent cover for the historical data for three sampling events but lower than the total SAV percent cover for six sampling events.
5. River-wide, the 2015 mean total SAV percent cover was lower than the mean for the historical data by about 20.6 percent. This difference is statistically significant (95 percent confidence).
6. By transect, the 2015 mean total SAV percent cover data was less than the mean of the total SAV percent cover for the combined historical data for 17 transects, with

decreases ranging from about 1 percent decrease to 75 percent. Two of the three increases for transects were greater than 97 percent.

7. The mean values for angiosperm biomass for the 1998 and 1999 sampling events were noticeably higher than all other sampling events by 2 to more 10 times greater. For the 2009 sampling event, the angiosperm biomass mean was significantly lower than all other sampling events (almost 0).
8. River-wide, the mean 2015 angiosperm biomass was 72.3 percent less than the combined 1998-2011 mean, and the difference is statistically significant (95 percent confidence).
9. By transect, the 2015 angiosperm biomass data was significantly higher than the historical data for three transects (500 percent to almost 800 percent increases), with large decreases for the other transects. Because much of the historical and 2015 angiosperm biomass data are small, care should be used in interpreting the large increases and reductions for the 2015 sampling event compared to the historical data.
10. The mean macroalgae biomass for the 1999 sampling event was at least three times higher than the macroalgae biomass for all other sampling events. The 2015 mean macroalgae biomass was the lowest of all sampling events.
11. River-wide, the mean 2015 macroalgae biomass was about 79 percent lower than the 1998-2011 mean macroalgae biomass and this difference is statistically significant (95 percent confidence).
12. By transect, the 2015 mean macroalgae biomass was lower than the combined 1998-2011 mean macroalgae biomass for all transects except one, with reductions ranging from about 5 percent to 98.8 percent.

In general, for the Weeki Wachee River for all SAV data categories, SAV was reduced in presence and abundance for the 2015 sampling event. These data indicate that neither the angiosperm nor macroalgae biomasses dominated the Weeki Wachee River total SAV biomass. Even so, in 2009, the macroalgae biomass was almost 97 percent of the toal SAV biomass. The angiosperm portion was the most volitile for 2015, with large increases in biomass for the three most upstream transects and almost 100 percent reductions compared to the historical data for most of the other transects.

As will be seen for the Homosassa and Chassahowitzka Rivers SAV data, there was a large difference between the 1998-1999, and sometimes 2000 biomass data and the biomass data for all of the other sampling events. Because there is no total SAV percent cover data for 1998, 1999, and 2000, a similar comparison cannot be made.

6.3 Chassahowitzka River

This section describes an analysis of the most recent (2015) SAV data from the Chassahowitzka River that compares the 2015 data to the historical data, including the use of appropriate nonparametric statistical methods to evaluate the statistical significance of the differences. It presents an analysis of the combined 1998-2000, 2003-2005, 2006-2011, and 2015 Chassahowitzka River SAV data. All of the available data were combined into a single dataset and differences between the 2015 data and the historical data were identified. An evaluation of the differences used nonparametric tests to understand the statistical significance of any differences/similarities that were identified.

Data have been collected from the Chassahowitzka River once yearly near the end of the growing season for most of the years between 1998 and 2011. For the 1998-2000 and 2003-2005 data, the Frazer et al. studies (2001 and 2006) characterized the Chassahowitzka River physical, water quality, and SAV conditions for the periods of the studies and analyzed the changes that were seen, including the reduction of SAV for the later period of sampling. Data from the Chassahowitzka River were also collected from 2006-2011 but have not previously been analyzed. After a 3-year hiatus, data collection in the Chassahowitzka River resumed in 2015.

One objective of this project is to document the 2006-2011 and 2015 data from the Chassahowitzka River in a manner similar to the Frazer et al. studies (2001 and 2006). A second objective is to analyze the data and evaluate any changes in the data over the period of data collection using statistically sound methodologies.

6.3.1 Description of the Data

Prior to the 2015 data collection effort, data on the vegetative community in the Chassahowitzka River were collected once each year for 1998, 1999, 2000, 2003, 2004, 2005, 2006, 2007, 2008, 2008, 2009, 2010, and 2011 using 20 transects with five stations on each transect. No data were collected in 2001, 2002, 2012, 2013, or 2014. The SAV data that were collected included:

- Biomass for total SAV, macroalgae, and angiosperm
- Bottom substrate type
- Percent of canopy shading
- Percent of total SAV cover

For 1998, 1999, and 2000 there are no percent total SAV cover data.

Plots of river-wide total SAV, angiosperm, and macroalgae mean wet weight (biomass) values for the Chassahowitzka River are presented as Figures 6-6, 6-7, and 6-8 by year of sampling event, along with the percentage of total SAV for angiosperm and macroalgae. The average percent total SAV cover for each year is shown on Figure 6-9. A comparison of the information in these figures is provided in the following summary.

1. The river-wide mean biomass of total SAV for the Chassahowitzka River was highest in 1998 followed by 1999 and 2005. The mean total SAV biomass was smallest in 2006 and 2007. The 2015 mean total SAV biomass was third smallest and similar to the mean total SAV biomass for 2009 and 2011.
2. The river-wide mean angiosperm biomass was highest in 1998 followed by 2005 and 1999. Similar to total SAV biomass, the mean biomass of angiosperm was smallest in 2006 and 2007, and the 2015 mean angiosperm biomass was similar to the mean angiosperm biomass for 2009 and 2011. The percent of total SAV biomass that was angiosperm ranged from about slightly above 40 percent to 96 percent for 2015, the highest amongst the sampling events.
3. The river-wide mean macroalgae biomass for the Chassahowitzka River was highest in 1998, followed by 1999. For all other sampling events, the mean macroalgae

biomass was much smaller. For 2015, the macroalgae biomass was very small, similar to the 2007 and 2011 sampling events. The percent of total SAV biomass that was macroalgae ranged from a low (2015) of about 3 percent of the total SAV biomass to almost 60 percent of total SAV biomass for 2006. Except for 2006, the percent of total SAV biomass that was macroalgae was below 40 percent of total SAV biomass and for 2007, 2011, and 2015 the percent of total SAV biomass that was macroalgae was less than 10 percent of total SAV biomass.

4. The river-wide total SAV percent cover values for the Chassahowitzka River range from a low of about 12 percent in 2007 to a high of 50.4 percent in 2005. The 2015 total SAV percent cover (about 25 percent) was mid-range when compared to all of the data (no data for 1998-2000).

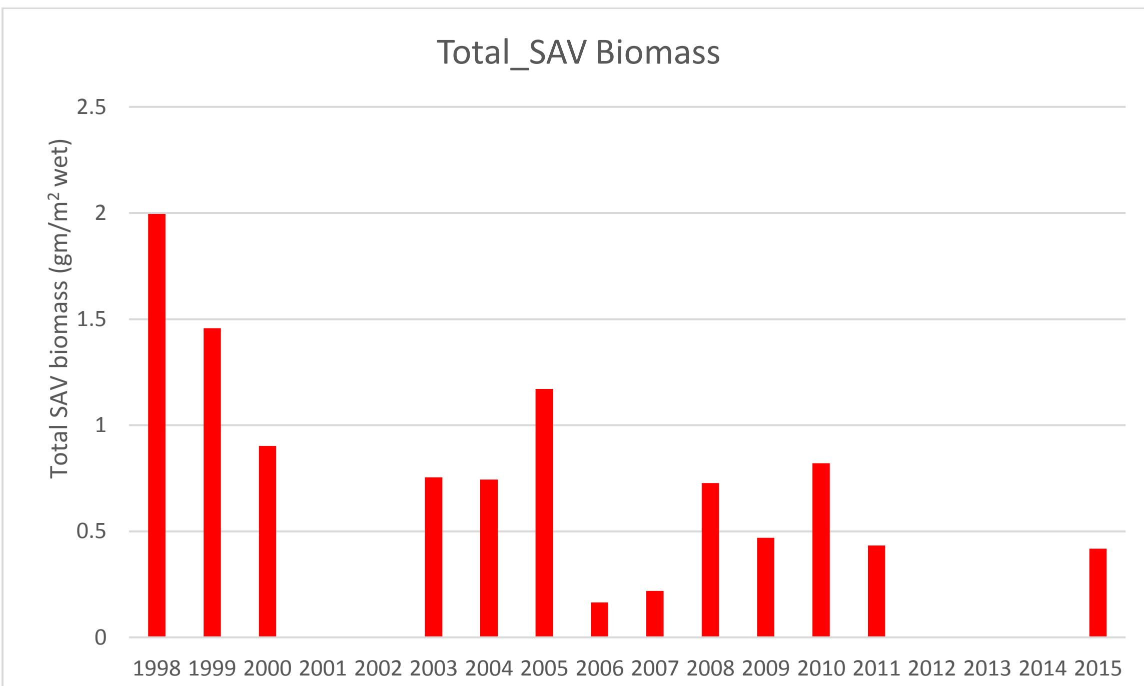

Figure 6-6. River-Wide Average Total SAV Biomass (kg/m^2 wet) by Sampling Event for the Chassahowitzka River. N=100 for each year.

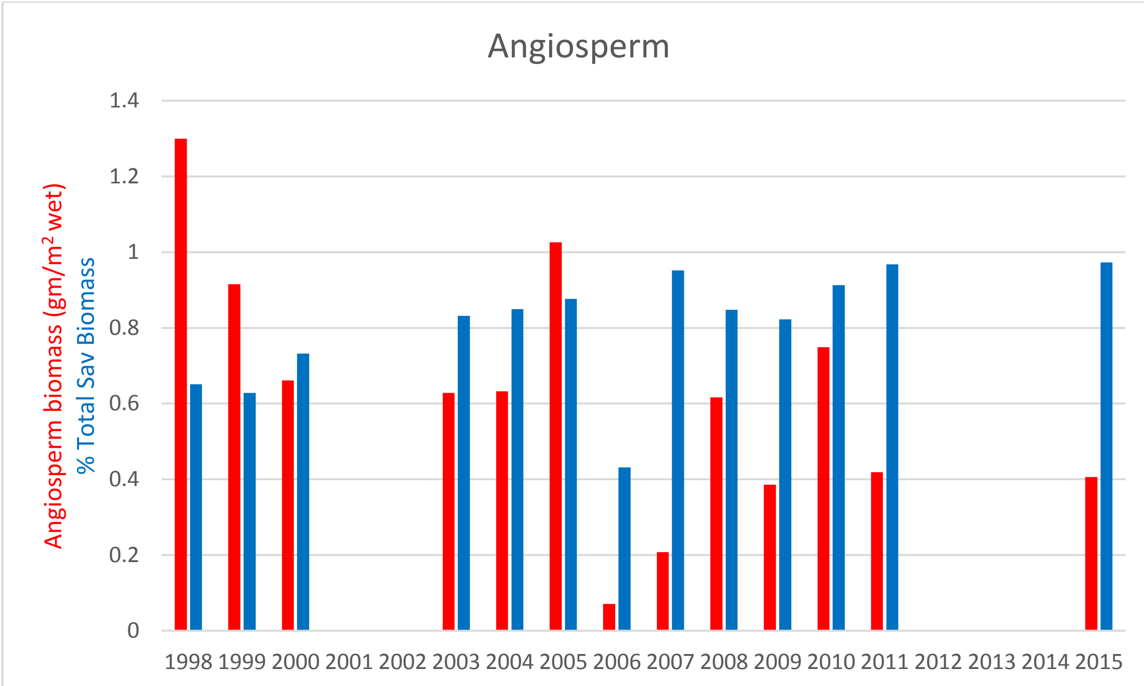

Figure 6-7. River-Wide Average Angiosperm Biomass (kg/m^2 wet) and Angiosperm Percent of Total SAV Biomass by Sampling Event for the Chassahowitzka River. N=100 for each year.

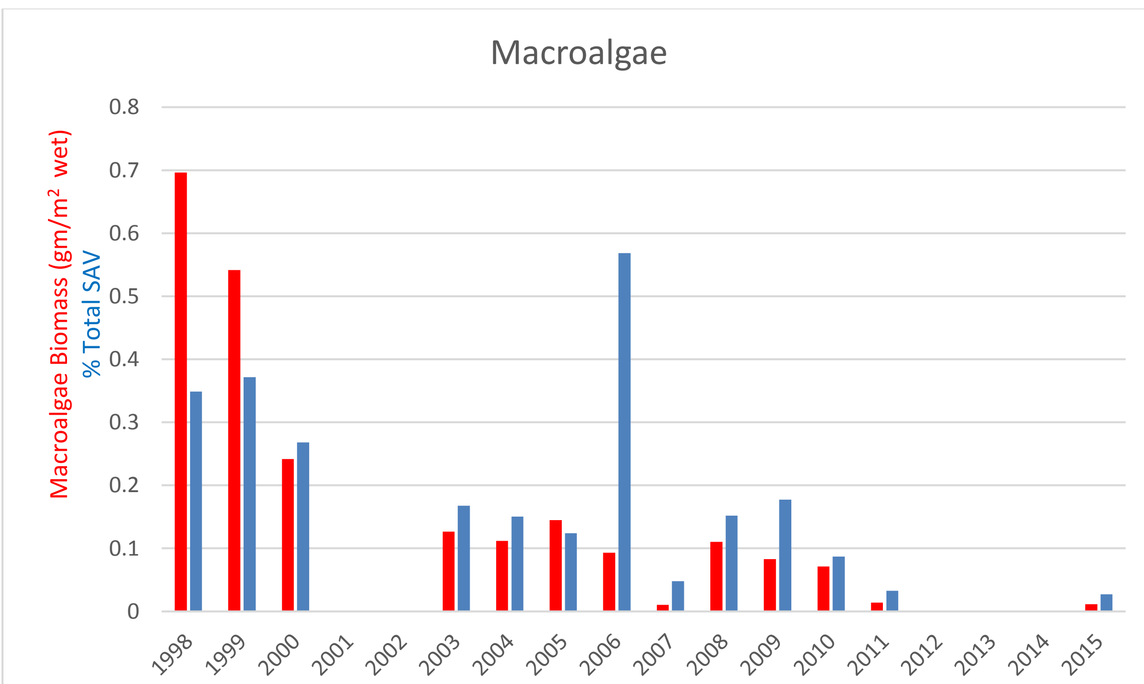

Figure 6-8. River-Wide Average Macroalgal Biomass (kg/m^2 wet) and Macroalgal Percent of Total SAV Biomass by Sampling Event for the Chassahowitzka River. N=100 for each year.

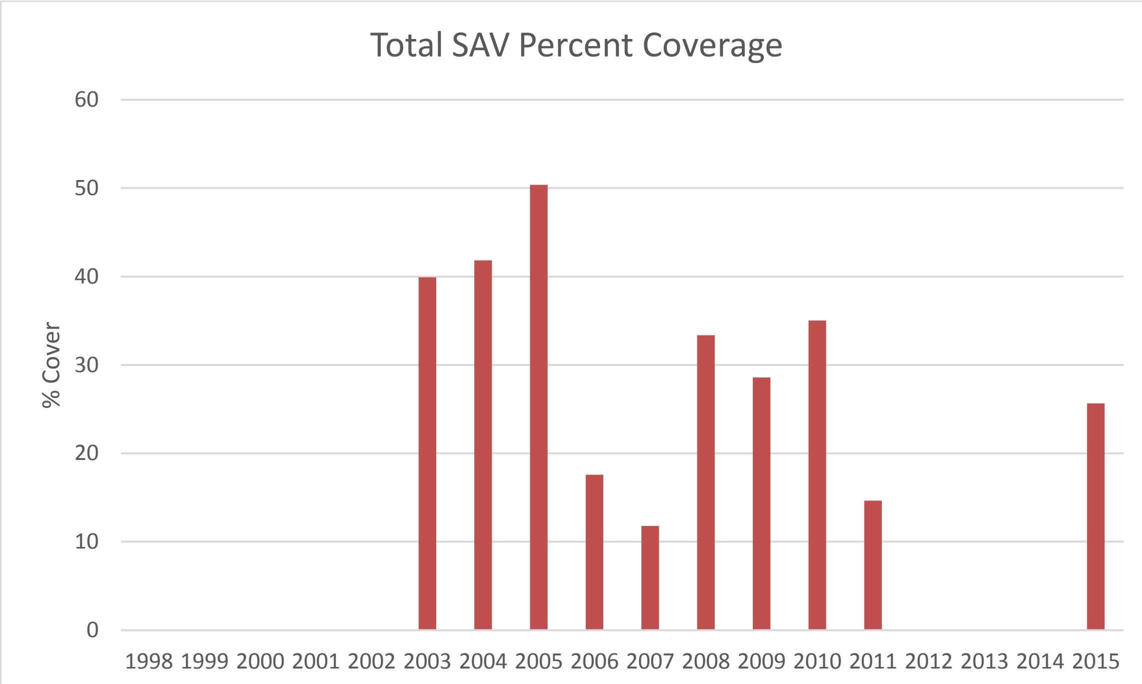

Figure 6-9. River-Wide Average Percent Total SAV Cover by Sampling Event for the Chassahowitzka River. N=100 for each year.

6.3.2 Overview of Statistical Procedures

Figure 6-10 presents a histogram for Chassahowitzka River total SAV biomass data indicating that most samples had little or no SAV present when data were collected and that the distribution is skewed. For this reason, non-parametric SAS© routines were used for the analysis of the data.

6.3.3 Comparison of the 2015 Data and the Historical Data from the Chassahowitzka River

6.3.3.1 Total SAV Biomass

The total SAV biomass data for 2015 from the Chassahowitzka River were compared to the total SAV biomass data from all of the other years, river-wide and by transect, to identify and analyze any differences. River-wide, the mean total SAV biomass for the 2015 sampling event was about half of the mean total SAV biomass for all other sampling events combined (Table 6-9).

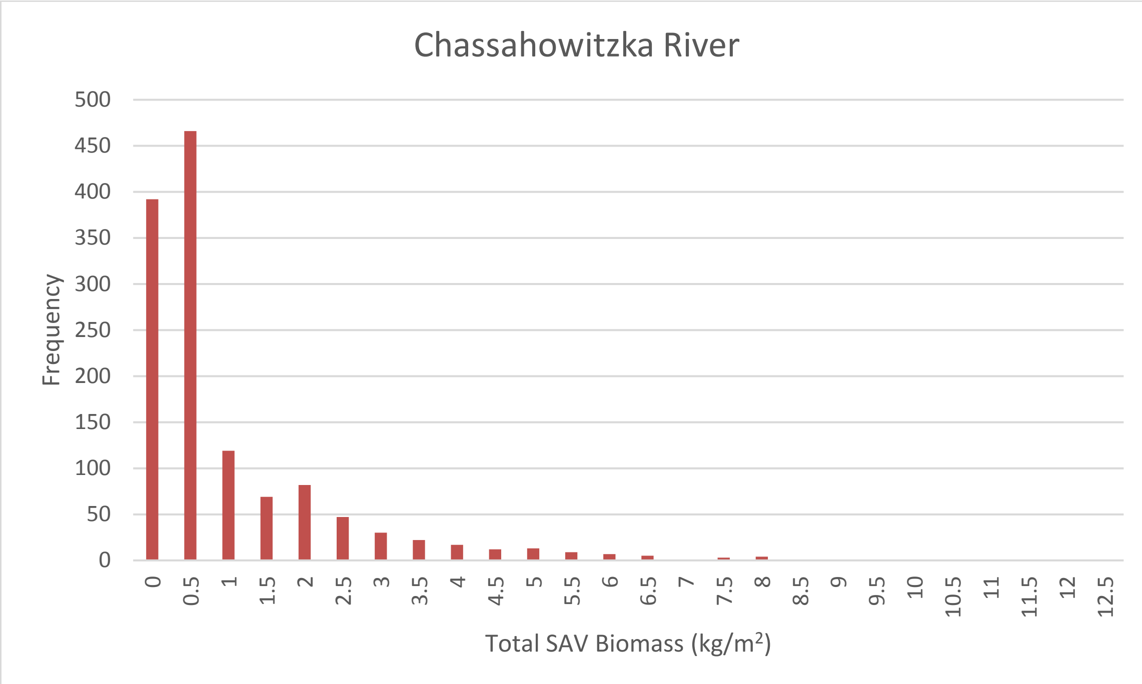

Figure 6-10. Histogram for Total SAV Biomass Data by Transect Collected from the Chassahowitzka River between 1998 and 2015, Non-Continuously. (N=1300)

Table 6-9. River-Wide Mean Total SAV Biomass for the Chassahowitzka River for All Previous Years (combined) Compared to the Mean Total SAV Biomass for 2015.

1998-2011 Total SAV biomass (kg/m^2)	2015 Total SAV biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
0.82*	0.42*	0.40	-49.9

* statistically significant difference with at least 95% confidence

By transect (Table 6-10), the change in total SAV biomass for 2015 compared to the 1998-2011 data ranged from -99.52 percent to +65.04 percent, with 17 out of 20 transects indicating lower 2015 total SAV biomass compared to the combined historical data. For the three transects with higher total SAV biomass than the 1998-2011 data, the range of total SAV biomass increases for 2015 are +4.92 percent, +54.4 percent, and +65.04 percent. For the Chassahowitzka River data, there are no 2015 transects with 100 percent decrease in mean total SAV biomass values compared to the historical data (see Table 6-10), as seen in the Homosassa River total SAV biomass data. The Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample nonparametric tests indicate that the differences between the 2015 total SAV biomass data and the combined 1998-2011 total SAV biomass data shown in Tables 6-9 and 6-10 are statistically significant, with at least 95 percent confidence.

Table 6-10. Comparison of Total SAV Biomass (gm/m^2) for the Chassahowitzka River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values.

Transect	1998-2011 Total SAV biomass (kg/m^2)	2015 Total SAV biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kgm/m^2)	% Increase/Decrease
0.5	1.001	0.199	0.802	-80.10%
1	2.373	1.572	0.801	-33.77%
1.5	1.993	0.834	1.159	-58.17%
2	1.326	0.006	1.320	-99.52%
2.5	1.493	0.309	1.184	-79.32%
3	1.443	0.014	1.429	-99.06%
3.5	0.582	0.897	-0.315	+54.14%
4	0.481	0.129	0.352	-73.20%
4.5	0.877	0.034	0.843	-96.08%
5	1.344	0.782	0.563	-41.86%
5.5	1.469	2.424	-0.955	+65.04%
6	0.716	0.555	0.161	-22.49%
6.5	0.430	0.268	0.162	-37.74%
7	0.230	0.105	0.126	-54.51%
7.5	0.140	0.019	0.120	-86.25%
8	0.136	0.001	0.136	-99.41%
8.5	0.014	0.006	0.008	-59.02%
9	0.198	0.041	0.157	-79.38%
9.5	0.079	0.083	-0.004	+4.92%
10	0.100	0.078	0.021	-21.34%
Average	0.821*	0.418*	0.404	-49.86%

* statistically significant difference with at least 95% confidence

6.3.3.2 Total SAV Percent Cover

The mean Chassahowitzka River total SAV percent cover data for the 2015 sampling event were compared to the combined mean total SAV percent cover data for the 2003-2011 sampling events river-wide and by transect (there are no total SAV percent cover data for 1998, 1999, or 2000). The river-wide difference in total SAV percent cover for 2015 compared to the data for 2003-2011 was a reduction of 38.9 percent, as presented in Table 6-11. Table 6-12 presents the change in total SAV percent cover for 2015 compared to the historical data, by transect. For

10 transects (half of the transects), the 2015 total SAV percent cover was less than the historical data. For the other 10 transects, the 2015 total SAV percent cover was greater than the historical data. For transects with reduced total SAV percent cover for 2015, the reductions ranged from -13.1 percent to -98.13 percent. For transects with greater 2015 values of total SAV percent cover, the increased percent cover ranged from +10.9 percent to +454.4 percent.

In general, the data indicate that total SAV percent cover was lower for the downstream stations. The following nonparametric tests indicate that the differences shown in Tables 6-11 and 6-12 between the 2015 total percent SAV cover data and the combined 1998-2011 total percent SAV cover data were statistically significant, with at least 95 percent confidence: Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E2 for test results).

Table 6-11. River-Wide Mean SAV Percent Cover for the Chassahowitzka River for 2003-2011 (combined) Compared to the Mean Total SAV Percent Cover for 2015.

2003-2011 Total SAV % Cover	2015 Total SAV % Cover	Difference: 2003-2011 minus 2015	% Increase/Decrease
30.34*	25.67*	4.67	-38.90%

* statistically significant difference with at least 95% confidence

6.3.3.3 Angiosperm

The Chassahowitzka River mean angiosperm biomass data for 2015 were compared to data from the other sampling events, river-wide and by transect. The data in Table 6-13 indicate that the river-wide mean angiosperm biomass for 2015 was 0.41 kg/m^2, which is 0.23 kg/m^2 less than the mean angiosperm biomass for all previous years combined, about a 35 percent decrease. By transect (Table 6-14), the angiosperm biomass change for 2015 ranged from a 99.2 percent decrease to a 130 percent increase. The majority of transects experienced decreases in mean angiosperm biomass compared to the historical data. Increase in angiosperm biomass are seen for Transects 3.5, 5.5, and 9.5, although the increase for Transect 9.5 is from a very small angiosperm biomass to a slightly higher but still very small angiosperm biomass. The following nonparametric tests indicate that the differences shown in Tables 6-13 and 6-14 between the 2015 angiosperm biomass data and the combined 1998-2011 angiosperm biomass data are statistically significant, with at least 95 percent confidence:

Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E2 for results).

Table 6-12. Comparison of Percent SAV Cover Data for the Chassahowitzka River by Transect for 2003-2011 (combined) and for 2015

Transect	2003-2011 mean Total SAV % Cover	2015 mean Total SAV % Cover	Difference: 2003-2011 minus 2015	% Increase/Decrease
1	49.24	23.00	26.24	-53.29%
1.5	80.56	70.00	10.56	-13.10%
2	48.60	32.00	16.60	-34.16%
2.5	39.64	1.00	38.64	-97.48%
3	46.67	28.00	18.67	-40.00%
3.5	53.33	1.00	52.33	-98.13%
4	27.27	40.20	-12.93	+47.43%
4.5	35.69	14.00	21.69	-60.77%
5	42.69	7.40	35.29	-82.67%
5.5	44.11	51.00	-6.89	+15.62%
6	52.80	76.00	-23.20	+43.94%
6.5	36.38	45.00	-8.62	+23.70%
7	14.80	48.00	-33.20	+224.32%
7.5	4.96	16.20	-11.24	+226.91%
8	2.78	15.40	-12.62	+454.40%
8.5	3.18	0.20	2.98	-93.71%
9	2.60	1.40	1.20	-46.15%
9.5	9.07	10.00	-0.93	+10.29%
10	7.62	18.40	-10.78	+141.40%
10.5	4.91	15.20	-10.29	+209.50%
Average	30.34	25.67	4.67	-38.90%

* statistically significant difference with at least 95% confidence

Table 6-13. River-Wide Change in Mean Angiosperm Biomass for the Chassahowitzka River for All Previous Years (combined) Compared to the Mean Angiosperm Biomass for 2015.

1998-2011 Angiosperm biomass (kg/m^2)	2015 Angiosperm biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
0.63*	0.41*	0.23	-35.15

* statistically significant difference with at least 95% confidence

Table 6-14. Comparison of Angiosperm Biomass for the Chassahowitzka River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values.

Transect	1998-2011 Angiosperm biomass (kg/m^2)	2015 Angiosperm biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
0.50	0.458	0.029	0.429	-93.71%
1.00	2.179	1.572	0.607	-27.87%
1.50	1.551	0.803	0.748	-48.21%
2.00	0.799	0.006	0.792	-99.20%
2.50	0.909	0.294	0.614	-67.60%
3.00	1.118	0.014	1.105	-98.78%
3.50	0.408	0.897	-0.488	+119.59%
4.00	0.205	0.118	0.087	-42.56%
4.50	0.660	0.034	0.626	-94.79%
5.00	1.295	0.782	0.513	-39.63%
5.50	1.427	2.424	-0.997	+69.90%
6.00	0.682	0.555	0.127	-18.64%
6.50	0.365	0.268	0.097	-26.66%
7.00	0.197	0.105	0.092	-46.79%
7.50	0.107	0.018	0.089	-82.79%
8.00	0.051	0.001	0.050	-98.42%
8.50	0.011	0.005	0.006	-56.10%
9.00	0.136	0.041	0.095	-70.05%
9.50	0.036	0.083	-0.047	+130.05%
10.00	0.088	0.078	0.009	-10.64%
Average	0.634*	0.406*	0.228	-35.15%

* statistically significant difference with at least 95% confidence

6.3.3.4 Macroalgae

The Chassahowitzka River mean macroalgae biomass data for 2015 were compared to data from all of the other years, river-wide and by transect, to estimate the differences in the 2015 data compared to the previously collected data. The data in Table 6-15 indicate that the river-wide mean macroalgae biomass for 2015 was 0.0114 kg/m^2 which is 0.1758 kg/m^2 less than the mean macroalgae biomass for the historical data. The macroalgae biomass decreased significantly for 2015 for all transects. Decreases for 2015 ranged from 68.61 percent to 100 percent, with 14 transects experiencing 100 percent decreases in mean macroalgae biomass. For a number of transects with 100 percent decrease in macroalgae biomass values, the historical data were already very small for the 1998-2011 period (see Table 6-16). The following nonparametric tests indicate that the differences shown in Tables 6-15 and 6-16 between the 2015 macroalgae biomass data and the combined 1998-2011 macroalgae biomass data are statistically significant, with at least 95 percent confidence: Wilcoxon Signed and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E2 for results).

Table 6-15. River-Wide Change in Mean Macroalgae Biomass for the Chassahowitzka River for All Previous Years (combined) Compared to the Mean Macroalgae Biomass for 2015.

1998-2011 Macroalgae biomass (kg/m^2)	2015 Macroalgae biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
0.1872*	0.0114*	0.1758	-96.17%

* statistically significant difference with at least 95% confidence
Note: Additional significant figures shown due to small biomass values.

Table 6-16. Change in Macroalgae Biomass for the Chassahowitzka River by Transect as Measured by the Difference between the Macroalgae Biomass for All Previous Years (combined) compared to the macroalgae biomass for 2015 and the percentage of increase or decrease

Transect	1998-2011 Macroalgae biomass (kg/m^2)	2015 Macroalgae biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
0.5	0.5428	0.1704	0.3724	-68.61%
1	0.1940	0.0000	0.1940	-100.00%
1.5	0.4420	0.0304	0.4116	-93.12%
2	0.5275	0.0000	0.5275	-100.00%
2.5	0.5845	0.0144	0.5701	-97.54%
3	0.3248	0.0000	0.3248	-100.00%
3.5	0.1734	0.0000	0.1734	-100.00%
4	0.2758	0.0112	0.2646	-95.94%
4.5	0.2166	0.0000	0.2166	-100.00%
5	0.0497	0.0000	0.0497	-100.00%
5.5	0.0420	0.0000	0.0420	-100.00%
6	0.0339	0.0000	0.0339	-100.00%
6.5	0.0651	0.0000	0.0651	-100.00%
7	0.0334	0.0000	0.0334	-100.00%
7.5	0.0327	0.0008	0.0319	-97.56%
8	0.0858	0.0000	0.0858	-100.00%
8.5	0.0027	0.0008	0.0019	-70.73%
9	0.0617	0.0000	0.0617	-100.00%
9.5	0.0431	0.0000	0.0431	- 100.00%
10	0.0119	0.0000	0.0119	-100.00%
Average	0.1872*	0.0114*	0.1758	-96.17%

* statistically significant difference with at least 95% confidence
Note: Additional significant figures shown due to small biomass values.

6.3.4 Discussion of Results

The available data on SAV presence and abundance in the Chassahowitzka River include data that have been collected once a year noncontinuously since 1998. In general, there is ample information for assessing the data collected in 2015 within the context of the available data record. These data indicate that the largest contribution to the Chassahowitzka River total SAV biomass comes from the angiosperm biomass. For all sampling events, the angiosperm biomass portion was at least 50 percent of the total SAV biomass. For four sampling events, the angiosperm biomass was more than 90 percent of the total SAV biomass. The macroalgae biomass was as low as about 10 percent and never exceeded 50 percent of the total SAV biomass. Because of this, increases and decreases in angiosperm biomass drive the change in total SAV biomass to a great extent.

The findings of the Chassahowitzka River SAV data analysis described herein are provided in the following summary.

1. The event-mean values for total SAV biomass for the 1998 and 1999 sampling events are greater than two times the mean total SAV biomass for all other sampling events, except 2005.
2. River-wide, the mean 2015 total SAV biomass was slightly less than 50 percent of the 1998-2011 mean value. This difference was statistically significant (95 percent confidence).
3. By transect, the 2015 total SAV biomass data indicate a range of decreases of 21.3 percent to 99.4 percent for 17 of the 20 transects. A small increase in total SAV biomass was observed at Transect 9.5 (about 5 percent). Transects 3.5 and 5.5 showed increases of about 54 percent and 65 percent, respectively.
4. The event-mean total SAV percent cover was highest from 2003 to 2005 and was lower from 2006 to 2011 (no data from 1998-2000). The 2015 mean total SAV percent cover value was higher than the total SAV percent cover for three sampling events but lower than the total SAV percent cover for six sampling events.
5. River-wide, the 2015 mean total SAV percent cover was lower than the mean for the historical data by about 39 percent, and this difference is statistically significant (95 percent confidence).

6. By transect, the difference between the 2015 mean total SAV percent cover data and the mean of the combined historical data indicates a wide range of change for 2015, ranging from 98.1 percent decrease to 454.4 percent increase.
7. The event-mean value for angiosperm biomass for the 1998 sampling event was noticeably higher than all other sampling events. The 2006 sampling event angiosperm biomass mean was significantly lower than all other sampling events. The 2015 angiosperm biomass was greater than three sampling events but lower than 10 sampling events.
8. River-wide, the mean 2015 angiosperm biomass was slightly more than 35 percent of the 1998-2011 mean angiosperm biomass (a decrease) and this difference is statistically significant (95 percent confidence).
9. By transect, the 2015 angiosperm biomass data indicate a range of decreases of 10.6 percent to 99.2 percent for 17 of the 20 transects. For three transects, the increases in angiosperm biomass ranged from almost 70 percent to more than 130 percent.
10. The event-mean value for macroalgae biomass for the 1998 sampling event was at least two times higher than all other sampling events. For 2006, 2020, and 2015, the mean macroalgae biomass was noticeably lower than all other sampling events.
11. River-wide, the mean 2015 macroalgae biomass was about 96 percent lower than the 1998-2011 mean macroalgae biomass and this difference is statistically significant (95 percent confidence).
12. By transect, the 2015 macroalgae biomass was lower than the combined 1998-2011 mean macroalgae biomass for all transects, with reductions ranging from 68.6 percent to 100 percent (12 transects with no macroalgae biomass observed in 2015).

The largest mean total SAV biomass contributions came from three transects that were near the head of the Chassahowitzka River but they were not the most upstream stations. Near mid-stream (Transects 5 through 6.5), there is a scondary peak of total SAV biomass before tailing off at the western stations. That pattern is similar for 2015, except that the total SAV biomass values are only about half of the historical mean values. For all Chassahowizka River transects, there are only a limited number of 1998-2011 or 2015 mean total SAV biomass values that were as small as the values observed for the Homosassa River data (historical and 2015). The same general reduction in total SAV biomass as was seen in the Homosassa River data after 1998-2000 is also noted in the Chassahowitzka River data. Even so, for the 2015 Chassahowitzka River total SAV biomass data, the majority of the transects experienced a 70 percent or greater reduction compared to all of the other transect data.

While decline over time is seen for the total SAV percent cover data, the event-mean data were quite variable and only reached 50 percent cover for one sampling event. By transect, the 2015 Chassahowitzka River total SAV percent cover data indicate that the number of transects that experienced reductions was equal to the number of transects that experienced increases in total SAV percent cover data for 2015 compared to the historical data.

In contrast to what was seen in the Homosassa River data (Section 6.4), the macroalgae percent of total SAV biomass for all but one sampling event was considerbly less than 50 percent of the total SAV biomsss, with the angiosperm biomass portion dominating the total SAV biomass for all sampling events except one (2006). While reductions in angiosperm biomass for 2015 are also noted, no transects experienced 100 percent reduction, and three transects had increases of greater than 100 percent. Even so, the river-wide reduction in angiosperm biomass was an average of about 35 percent for 2015. In addition, for 2015, the reduction in macroalgae biomass was severe, with the data from 14 transects indicating a 100 percent reduction and another 3 transects with greater than 95 percent reduction for 2015.

6.4 Homosassa River

This section describes the work that was completed to compare the most recent (2015) SAV data from the Homosassa River to the historical data, including the use of nonparametric statistical methods to evaluate the statistical significance of any changes. Data have been collected once yearly near the end of the growing season for most of the years between 1998 and 2011. The 1998-2000 and 2003-2005 data were previously described and analyzed in the Frazer et al. studies (2001 and 2006, respectively). These two studies characterized the physical, water quality, and SAV conditions in the Homosassa River on the west coast of Florida for the period of the studies. Frazer et al. (2006) suggest that increased nutrients from the watershed are a possible factor in the changes that were observed in the historical SAV data for the Weeki Wachee, Chassahowitzka, and Homosassa Rivers for the 1998-2000 and 2003-2006 periods.

Data were also collected from 2006-2011 but have not previously been analyzed. After a 3-year hiatus, data collection resumed in 2015. This section presents an analysis of the combined 1998-2000, 2003-2005, 2006-2011, and 2015 data. All of the available data were combined into a single dataset and differences between the 2015 data and the historical data were evaluated analyzed using nonparametric tests to characterize the statistical significance of any differences/similarities that were identified.

One objective of this project is to document the 2006-2011 and 2015 data in a manner similar to the Frazer et al. studies (2001 and 2006). A second objective is to analyze the data and evaluate any changes in the data over the period of data collection using statistically sound methodologies.

6.4.1 Description of the Data

Prior to the 2015 data collection effort, data on the vegetative community in the Homosassa River were collected once each year for 1998, 1999, 2000, 2003, 2004, 2005, 2006, 2007, 2008, 2008, 2009, 2010, and 2011 using 20 transects with five stations on each transect. No data were collected in 2001, 2002, 2012, 2013, or 2014. In 2015, the SAV data were collected by the ATM Team in a manner similar to the previous data collection efforts. The data that were collected included biomass for total SAV, macroalgae, and angiosperm; bottom substrate type; percent of canopy shading; and total SAV percent cover. For 1998, 1999, and 2000, there are no total SAV percent cover data.

For the Homosassa River data as described herein, plots of river-wide mean wet weight (biomass) values for total SAV, angiosperm, and macroalgae are presented as Figures 6-11, 6-12, and 6-13 by year of sampling event, along with the percentage of total SAV for angiosperm and macroalgae. Average total SAV percent cover for each sampling event is shown on Figure 6-14. A comparison of the information in these figures is provided in the following summary.

1. The river-wide mean biomass of total SAV was highest in 1999, followed by 1998 and 2000, although the 2000 mean biomass is not much higher than some of the mean biomass values in the immediately following years. In contrast, there are several years where the mean biomass was very small (2008, 2009, and 2015).
2. The river-wide mean biomass of angiosperm was highest in 1999, followed by 1998. After 2007, mean angiosperm biomass was very small, with a slight increase in 2011 and 2015.
3. The river-wide mean biomass of macroalgae was highest in 1998 at the beginning of data collection, followed by several cycles of decrease then increase, before bottoming out at a very low macroalgal mean biomass for 2015.
4. The percent of total SAV biomass that was angiosperm ranged from about 3 percent to 50 percent, with most values at the low end of the range. The highest year was 1998, followed by 1999. For all other years, the percent of total SAV biomass was much smaller.
5. The percent of total SAV biomass that was macroalgae ranged from about 50 percent to 96 percent. The highest year was 2007, but for all years, the percent of total SAV biomass was more than 50 percent.
6. The river-wide mean total SAV percent cover values range from a low of 2.5 percent in 2008 to a high of 32 percent in 2006. In general, total SAV percent cover was noticeably higher from 2003-2006 and lower from 2007-2015 (no data for 1998-2000).

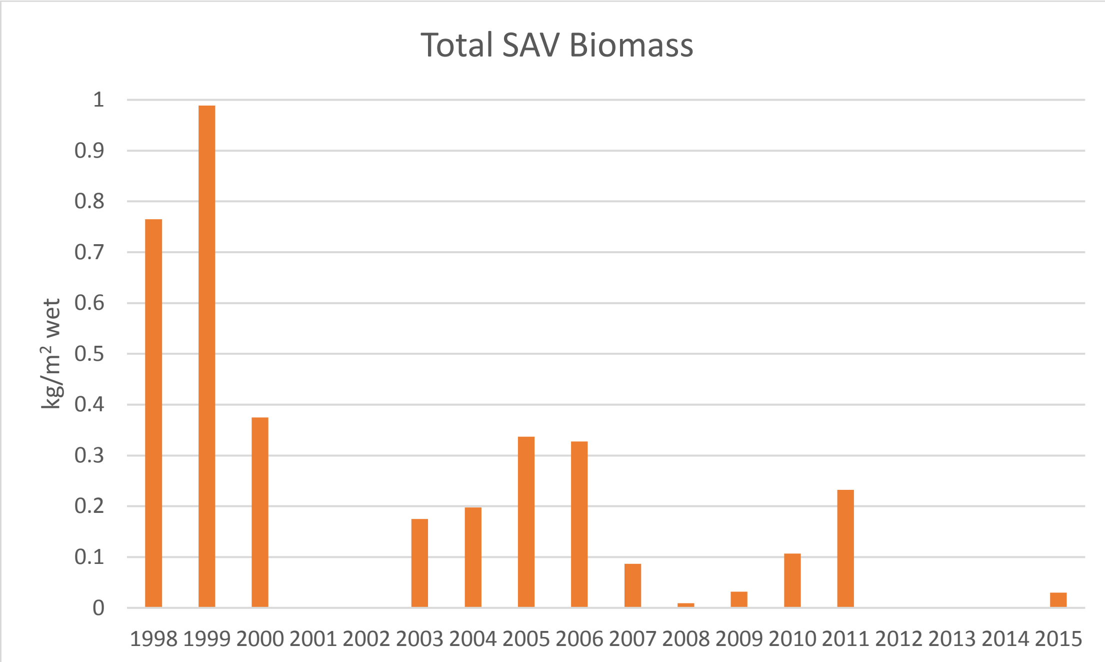

Figure 6-11. River-Wide Mean Total SAV biomass (kg/m² wet) by Sampling Event for the Homosassa River. N=100 for each year.

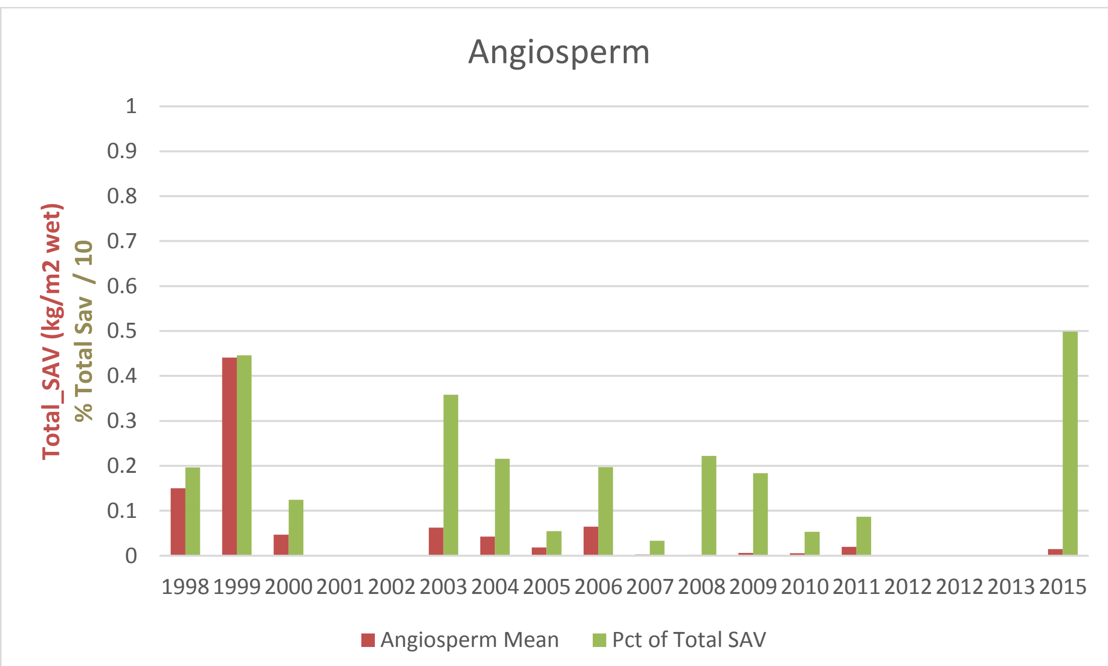

Figure 6-12. River-Wide Mean Angiosperm Biomass (kg/m² wet) and Angiosperm Percent of Total SAV Biomass by Sampling Event for the Homosassa River. N=100 for each year.

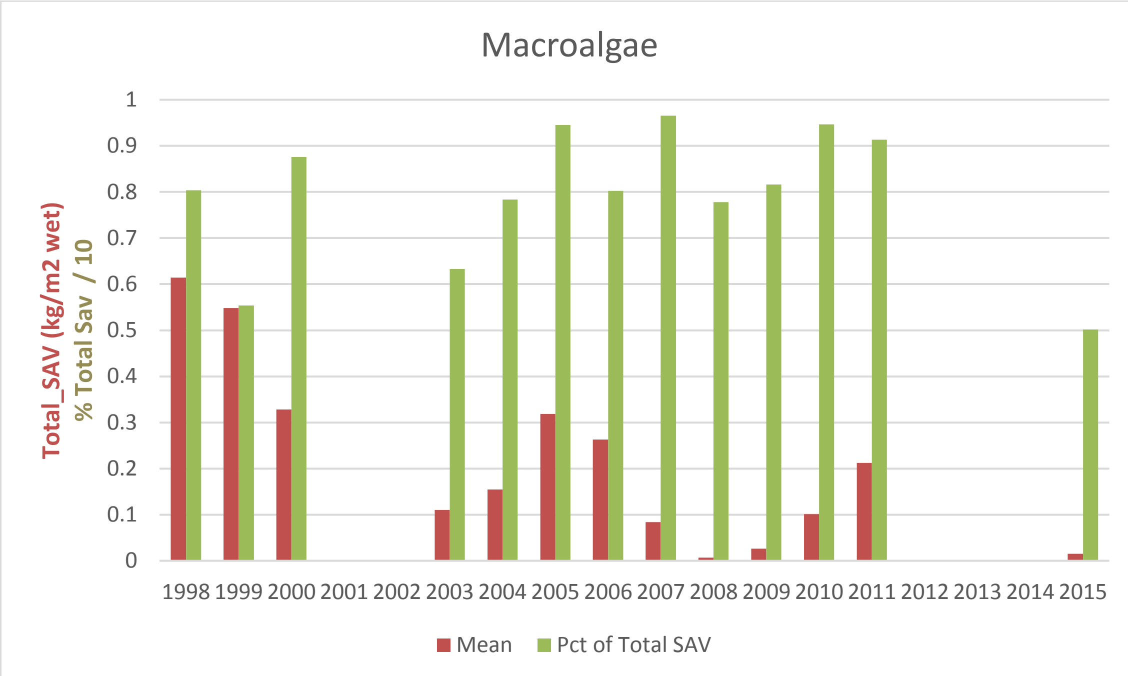

Figure 6-13. River-Wide Mean Macroalgal Biomass (kg/m^2 wet) and Macroalgal Percent of Total SAV Biomass by Sampling Event for the Homosassa River. N=100 for each year.

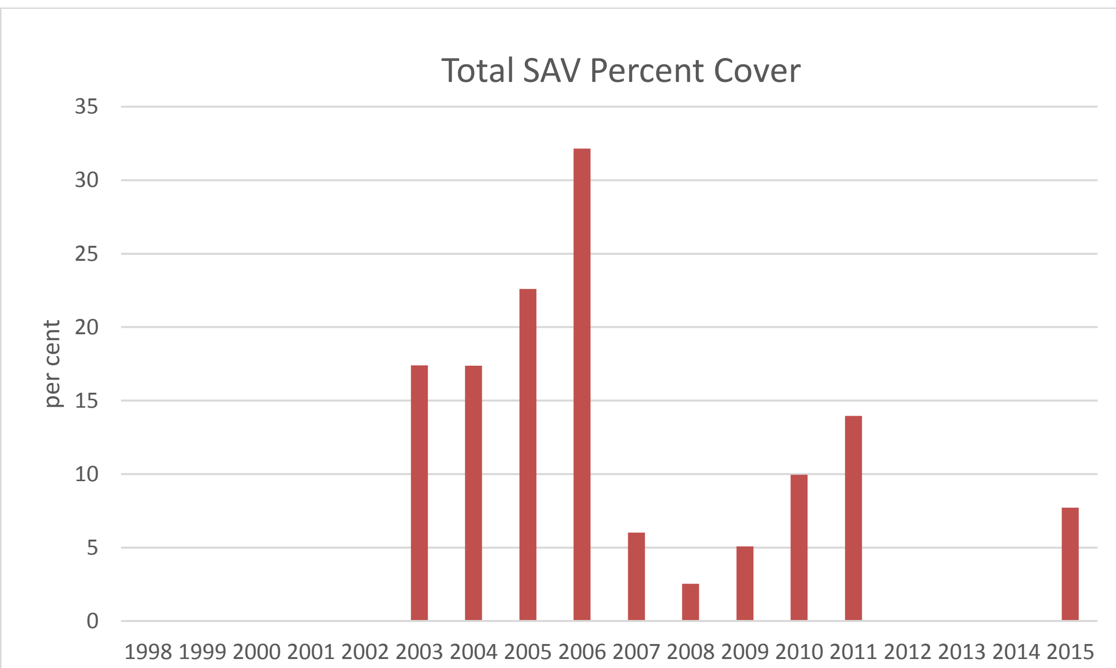

Figure 6-14. River-Wide Mean Total SAV Percent Cover By Sampling Event for the Homosassa River. N=100 for each year

6.4.2 Overview of Statistical Procedures

Figure 6-15 presents a histogram of total SAV biomass indicating that, for most transects, there was little or no SAV present when data were collected and that the distribution is skewed. For this reason, non-parametric SAS© routines were used for the analysis of the data.

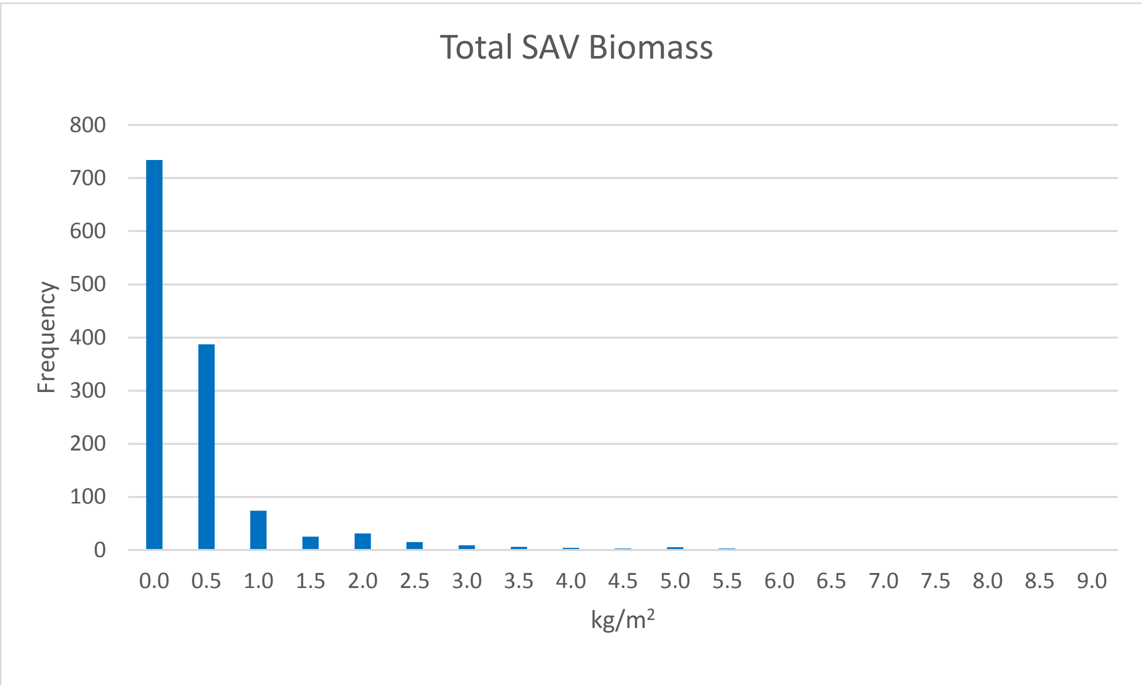

Figure 6-15. Histogram for Total SAV Biomass Data by Transect Collected from the Homosassa River between 1998 and 2015, Non-Continuously. (N=1300).

6.4.3 Comparison of the 2015 Data and the Historical Data

6.4.3.1 Total SAV Biomass

To begin the analysis, the total SAV biomass data for 2015 were compared to data from all of the other years – river-wide and by transect – to estimate any differences. River-wide, the mean total SAV biomass for the 2015 sampling event was the second smallest mean total SAV biomass (see Figure 6-11); only the mean total SAV biomass for 2008 was smaller. The 2009 mean total SAV biomass was not much larger than the 2015 mean total SAV biomass. The river-wide mean total SAV biomass for 2015 was 0.0302 kg/m^2, which is 0.27 kg/m^2 less than the mean total SAV biomass for all previous years combined, a 90 percent decrease. By transect (Table 6-17), the total SAV biomass decreases for 2015 ranged from 83.1 percent to

100 percent, with all transects indicating lower 2015 total SAV biomass compared to the combined historical record. It is important to note that for a number of transects with 100 percent decrease the historical data and/or 2015 mean total SAV biomass values were very small (see Table 6-18). The following nonparametric tests indicate that the differences between the 2015 total SAV biomass data and the combined 1998-2011 total SAV biomass data shown in Tables 6-17 and 6-18 are statistically significant, with at least 95 percent confidence: Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests.

6.4.3.2 Total SAV Percent Cover

The mean Homosassa River total SAV percent cover for the 2015 sampling event was compared to the mean total SAV percent cover for the combined Homosassa River data from the 2003-2011 sampling events by transect (there are no total SAV percent cover data for 1998, 1999, or 2000). The river-wide results for change in total SAV percent cover are presented in Table 6-19. River-wide, the 2015 mean total SAV percent cover was almost 50 percent less than the mean total SAV percent cover for all of the previous sampling events. Table 6-20 presents the change in total SAV percent cover for 2015 by transect. With the exception of two transects, the mean total SAV percent cover in 2015 was less than the mean total SAV percent cover over the 2003 – 2011 sampling period by 16 percent to 100 percent. A 100 percent change resulted when no SAV were observed in 2015 for a particular transect but the historical mean total percent SAV cover (2003-2011) was appreciable. Increases in total SAV percent cover for 2015 were noted as well; for Transect 5.5, the increase in total SAV percent cover was greater than 100 percent. In general, the data indicate that total SAV percent cover was lower at the downstream transects. The following nonparametric tests indicate that the differences shown in Tables 6-19 and 6-20 between the 2015 total percent SAV cover data and the combined 1998-2011 total percent SAV cover data were statistically significant, with at least 95 percent confidence: Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E3 for test results).

Table 6-17. River-Wide Change in Mean Total SAV Biomass for the Homosassa River for All Previous Years (combined) Compared to the Mean Total SAV Biomass for 2015. Additional significant figures shown due to small biomass values.

1998-2011 mean total SAV biomass (kg/m^2)	2015 mean total SAV biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
0.3027	0.0302	0.2725	-90.02%

* statistically significant difference with at least 95% confidence

Table 6-18. Comparison of Mean Total SAV Biomass (gm/m2) for the Homosassa River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values

Transect	1998-2011 mean total SAV biomass (kg/m^2)	2015 mean total SAV biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/Decrease
1	2.0033	0.3100	1.6933	-84.53%
1.5	0.3042	0.0100	0.2942	-96.71%
2	0.6900	0.0100	0.6800	-98.55%
2.5	0.9800	0.1200	0.8600	-87.76%
3	0.3792	0.0400	0.3392	-89.45%
3.5	0.2175	0.0200	0.1975	-90.80%
4	0.2175	0.0200	0.1975	-90.80%
4.5	0.2125	0.0300	0.1825	-85.88%
5	0.1775	0.0300	0.1475	-83.10%
5.5	0.1283	0.0000	0.1283	-100.00%
6	0.1608	0.0000	0.1608	-100.00%
6.5	0.2383	0.0000	0.2383	-100.00%
7	0.0708	0.0100	0.0608	-85.88%
7.5	0.0533	0.0000	0.0533	-100.00%
8	0.0550	0.0000	0.0550	-100.00%
8.5	0.0475	0.0000	0.0475	-100.00%
9	0.0133	0.0000	0.0133	-100.00%
9.5	0.0558	0.0000	0.0558	-100.00%
10	0.0358	0.0000	0.0358	-100.00%
10.5	0.0083	0.0000	0.0083	-100.00%
Average	0.3025*	0.0300*	0.2725	-94.67%

* statistically significant difference with at least 95% confidence

Table 6-19. River-Wide Mean SAV Percent Cover for the Homosassa River for 2003-2011 (combined) Compared to the Mean Total SAV Percent Cover for 2015.

2003-2011 mean Total SAV % Cover	2015 mean Total SAV % Cover	Difference: 2003-2011 minus 2015	% Increase/Decrease
14.12*	7.78*	6.34	-49.85%

* statistically significant difference with at least 95% confidence

Table 6-20. River-Wide Mean SAV Percent Cover for the Homosassa River for 2003-2011 (combined) Compared to the Mean Total SAV Percent Cover for 2015.

Transect	2003-2011 mean percent SAV cover	2015 mean percent SAV cover	Difference: 2003-2011 minus 2015	% Increase/Decrease
1	63.44	47.00	16.44	-25.92%
1.5	9.56	8.00	1.56	-16.28%
2	35.67	2.40	33.27	-93.27%
2.5	57.71	35.40	22.31	-38.66%
3	24.38	13.00	11.38	-46.67%
3.5	12.42	6.40	6.02	-48.48%
4	14.20	7.40	6.80	-47.89%
4.5	10.80	20.00	-9.20	85.19%
5	9.04	7.60	1.44	-15.97%
5.5	0.89	2.00	-1.11	125%
6	6.18	2.00	4.18	-67.63%
6.5	15.73	1.20	14.53	-92.37%
7	3.84	3.00	0.84	-21.97%
7.5	2.93	0.00	2.93	-100.00%
8	3.67	0.00	3.67	-100.00%
8.5	5.27	0.00	5.27	-100.00%
9	2.56	0.20	2.36	-92.17%
9.5	1.11	0.00	1.11	-100.00%
10	2.87	0.00	2.87	-100.00%
10.5	0.07	0.00	0.07	-100.00%
Averages	14.12*	7.78*	6.34	-49.85%

* statistically significant difference with at least 95% confidence

6.4.3.3 Angiosperm

The Homosassa River mean angiosperm biomass data for 2015 were compared to data from the other years, river-wide and by transect. The data in Table 6-21 indicate that the river-wide mean angiosperm biomass for 2015 was about 0.015 kg/m^2, which is about 0.057 kg/m^2 less than the mean angiosperm biomass for all previous years combined, an almost 81 percent decrease. By transect (Table 6-22), the angiosperm biomass decreases for 2015 ranged from 59.5 percent to 100 percent, with almost all transects indicating decreases in mean angiosperm biomass compared to the historical data. Only Transect 2.5 indicated an increase in angiosperm biomass, with a 31.3 percent increase for 2015. For a number of transects with 100 percent change, the historical mean angiosperm biomass values were already very small (see Table 6-22). The following nonparametric tests indicate that the differences shown in Tables 6-21 and 6-22 between the 2015 angiosperm biomass data and the combined 1998-2011 angiosperm biomass data are statistically significant, with at least 95 percent confidence: Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E3 for results).

6.4.3.4 Macroalgae

The Homosassa River mean macroalgae biomass data for 2015 were compared to data from all of the other years, river-wide and by transect, to estimate the differences in the 2015 data compared to the previously collected data. The data in Table 6-23 indicate that the river-wide mean macroalgae biomass for 2015 was 0.0156 kg/m^2, which is 0.2151 kg/m^2 less than the mean macroalgae biomass for all previous sampling events. Table 6-24 indicates that, by transect, the macroalgae biomass decreases for 2015 ranged from 86.68 percent to 100 percent, with all transects indicating decreases in mean macroalgae biomass. For a number of transects with 100 percent decrease the historical data and/or 2015 mean macroalgae biomass values were very small. The following nonparametric tests indicate that the differences shown in Tables 6-23 and 6-24 between the 2015 macroalgae biomass data and the combined 1998-2011 macroalgae biomass data are statistically significant, with at least 95 percent confidence: Wilcoxon Signed and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (see Appendix E3 for results).

Table 6-21. River-Wide Change in Mean Angiosperm Biomass for the Homosassa River for All Previous Years (combined) Compared to the Mean Angiosperm Biomass for 2015. Additional significant figures shown due to small biomass values.

1998-to-2011 mean (kg/m²)	2015 mean (kg/m²)	Difference: 1998-to-2011 mean minus 2015 mean (kg/m²)	% Increase/Decrease
0.0720*	0.0149*	0.0571	-80.96%

* statistically significant difference with at least 95% confidence

Table 6-22. Comparison of Angiosperm Biomass for the Homosassa River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values.

Transect	1998-to-2011 mean	2015 mean	Difference: 1998-to-2011 mean minus 2015 mean	% Increase/Decrease
1	0.1710	0.0696	0.1014	-59.29%
1.5	0.0499	0.0112	0.0387	-77.54%
2	0.1328	0.0080	0.1248	-93.98%
2.5	0.0506	0.0664	-0.0158	31.31%
3	0.1208	0.0288	0.0920	-76.17%
3.5	0.1123	0.0232	0.0891	-79.33%
4	0.1379	0.0144	0.1235	-89.56%
4.5	0.0972	0.0304	0.0668	-68.72%
5	0.0692	0.0280	0.0412	-59.54%
5.5	0.0795	0.0024	0.0771	-96.98%
6	0.1015	0.0040	0.0975	-96.06%
6.5	0.1352	0.0024	0.1328	-98.23%
7	0.0228	0.0088	0.0140	-61.46%
7.5	0.0322	0.0000	0.0322	-100.00%
8	0.0324	0.0000	0.0324	-100.00%
8.5	0.0422	0.0000	0.0422	-100.00%
9	0.0126	0.0008	0.0118	-93.65%
9.5	0.0170	0.0000	0.0170	-100.00%
10	0.0200	0.0000	0.0200	-100.00%
10.5	0.0027	0.0000	0.0027	-100.00%
Averages	0.07198	0.01492	0.05706	-0.8096

* statistically significant difference with at least 95% confidence

Table 6-23. Comparison of Macroalgae Biomass for the Homosassa River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values.

1998-to-2011 mean (gm/m²)	2015 mean (gm/m²)	Difference: 1998-to-2011 mean minus 2015 mean (gm/m²)	% Increase/Decrease
0.2307*	0.0156*	0.2151	-98.60%

* statistically significant difference with at least 95% confidence

Table 6-24. Comparison of Macroalgae Biomass for the Homosassa River by Transect for 1998-2011 (combined) and for 2015. Additional significant figures shown due to small biomass values.

Transect	1998-to-2011 mean (kg/m²)	2015 mean (kg/m²)	Difference: 1998-to-2011 mean minus 2015 mean (kg/m²)	% Increase/Decrease
1	1.8319	0.2440	1.5879	-86.68%
1.5	0.2553	0.0024	0.2529	-99.06%
2	0.5564	0.0000	0.5564	-100.00%
2.5	0.9300	0.0536	0.8764	-94.24%
3	0.2591	0.0080	0.2511	-96.91%
3.5	0.1060	0.0008	0.1052	-99.25%
4	0.0799	0.0008	0.0791	-99.00%
4.5	0.1154	0.0008	0.1146	-99.31%
5	0.1081	0.0008	0.1073	-99.26%
5.5	0.0501	0.0000	0.0501	-100.00%
6	0.0603	0.0000	0.0603	-100.00%
6.5	0.1029	0.0000	0.1029	-100.00%
7	0.0457	0.0008	0.0449	-98.25%
7.5	0.0217	0.0000	0.0217	-100.00%
8	0.0223	0.0000	0.0223	-100.00%
8.5	0.0059	0.0000	0.0059	-100.00%
9	0.0009	0.0000	0.0009	-100.00%
9.5	0.0392	0.0000	0.0392	-100.00%
10	0.0161	0.0000	0.0161	-100.00%
10.5	0.0061	0.0000	0.0061	-100.00%
Averages	0.2307*	0.0156*	0.2151	-98.60%

* statistically significant difference with at least 95% confidence

6.4.4 Discussion of Results

Data on SAV presence and abundance have been collected from the Homosassa River once a year noncontinuously since 1998. The data indicate that the largest contribution to the Homosassa River total SAV biomass comes from the macroalgae biomass. For all sampling events, the macroalgae biomass portion was at least 50 percent of the total SAV biomass. For four sampling events, the macroalgae biomass was more than 90 percent of the total SAV biomass. For some transects, the 2015 angiosperm biomass was as low as about 10 percent and never exceeded 50 percent of the total SAV biomass. Because of this, increases and decreases in macroalgae biomass drive the change in total SAV biomass to a great extent. In general, there is ample information for assessing the data collected in 2015 within the context of the available data record.

Other findings of the Homosassa River SAV data analysis described herein are provided in the following summary.

1. River-wide, the mean 2015 total SAV biomass was about 10 percent of the 1998-2011 mean value, a reduction of about 90 percent. This difference was statistically significant (95 percent level of confidence).
2. The mean values for total SAV biomass for the 1998 and 1999 sampling events are about 2 times the mean total SAV biomass for all other sampling events.
3. By transect, the 2015 total SAV biomass data indicate a range of decreases of 83 to 100 percent, with a 100 percent difference in total SAV biomass for 11 of 20 transects, mostly located along the western half of the Homosassa River.
4. Total SAV percent cover was highest from 2003 to 2006 and was noticeably lower from 2007 to 2015; 2015 was the highest total SAV percent cover since the 2006 peak value.
5. The overall difference between the 2015 mean total SAV percent cover and the mean for the historical data was a reduction of about 50 percent, and this difference is statistically significant (95 percent level of confidence).
6. The differences between 2015 and the 1998-2011 angiosperm and macroalgae biomass data were about 81 percent and 99 percent decreases, respectively.

7. Angiosperm and macroalgae biomass for 2015 each comprised about 50 percent of the total SAV biomass in 2015.

When all of the raw data are examined, it is seen that the largest mean total SAV biomass contributions for each sampling event came from three transects: 1, 2, and 2.5. In contrast, all other transect means were consistently small over time, contributing little information on any changes in total SAV. More than 700 of the more than 1,300 total SAV biomass values are zero, most of which were recorded at the downstream transects. This large number of zero and very small values have a strong effect on mean and median values.

When total SAV biomass data collected after 2004 were compared to the data collected from 1998-2003 and compared over time, a general reduction in total SAV biomass was seen, as noted previously in the Frazer et al. studies (2001 and 2006). If the SAV conditions of 1998-2000 are considered to be representative of the long-term SAV conditions, then the SAV data collected in the years that followed are indicating that SAV biomas declined significantly after 2000. For the 2015 data, the majority of the transects indicate that there has been an 85 to 100 percent decrease in biomass compared to all of the previous sampling events. While the macroalgae comprise the largest total SAV biomass portion, there was little difference in the percentage of change (reduction) compared to the change for the lower-biomass angiosperm. Decline with time is also seen for the total SAV percent cover data, though the percentage of decline varies widely between transects. The overall change over time for the total SAV percent cover has been a percent reduction of about 50 percent. For a number of the downstream transects, the total SAV percent cover and, consequently, the total SAV biomass, was zero.

It appears that the key to obtaining a better understanding of the trajectrory of SAV in the Homosassa River may be best accomplished by focusing on the data from Transects 1 through 3.5. The SAV biomass was small at the downstream transects for all of the sampling events, from beginning of data collection to the end, making it more difficult to identify changes that have ocurred over time.

6.5 Inter-River Comparisons

This section presents an analysis of the SAV data that have been collected from the Weeki Wachee, Chassahowitzka, and Homosassa Rivers on the west coast of Florida, hereafter collectively called “the rivers.” For the first three tasks in this project, each river was analyzed individually to compare the recently collected 2015 data to the historical data collected between 2000 and 2011. Appropriate nonparametric statistical methods were used to evaluate the statistical significance of the differences that were seen between the data distribution of the 2015 data and the distribution of the combined historical data. For the first three tasks, the question that was being answered was this: were the 2015 data similar to the previously collected (historical) data?

All of the data were combined then compared across the rivers to better understand the changes that have occurred in the presence and abundance of SAV in these coastal systems. One key question that is addressed in this section is this: are the changes in SAV that were noted in the previous three sections common to all of the rivers? In addition, when all of the information has been evaluated, were there any general trends noted, and, if so are these trends important?

6.5.1 Description of the Collected Data and the Analyses

Data were previously collected from each river system once yearly near the end of the growing season for most of the years between 1998 and 2011 from 20 transects with five stations on each transect. The data collected from 1998-2000 and 2003-2005 were previously documented and analyzed by Frazer et al. (2003 and 2006, respectively). The data collected from 2006-2011 had not been characterized or analyzed prior to this project. After a 3-year hiatus, data collection resumed in 2015.

The data that were collected and analyzed included the following parameters: total SAV biomass (kg/m^2), angiosperm biomass (kg/m^2), macroalgae biomass (kg/m^2), angiosperm biomass as a percentage of total SAV biomass (percent), macroalgae biomass as a percentage of total SAV biomass (percent), and total SAV percent cover (percent). For 1998, 1999, and 2000, there are no total SAV percent cover data.

For the three initial analyses presented in the previous three sections, the results of the individual river analyses focused on the differences between the 2015 data and the historical data, by each river. For the analyses described herein, the data from all three rivers were combined into a single database and the focus shifted to across-river comparisons and analysis of the changes over time that were observed. Non-parametric hypothesis tests that are available in SAS© routines provided useful information on the statistical significance of the differences that were seen as well as the strength of the evidence. The hypothesis tests that were used included the Wilcoxon Sign and Signed Rank, Kruskal Wallace, and Median Two-Sample tests (McDonald 2014).

6.5.2 Comparison of the Data by Sampling Events for All Three Rivers

When the data were combined and compared across all sampling events, the Weeki Wachee River-wide mean total SAV biomass was always the highest or second-highest mean value. The Homosassa River-wide mean total SAV biomass was always the smallest (Figure 6-16). The 1998 and 1999 mean total SAV biomass values for all rivers were the highest observed values compared to the data from all other sampling events, for each river (Figure 6-16).

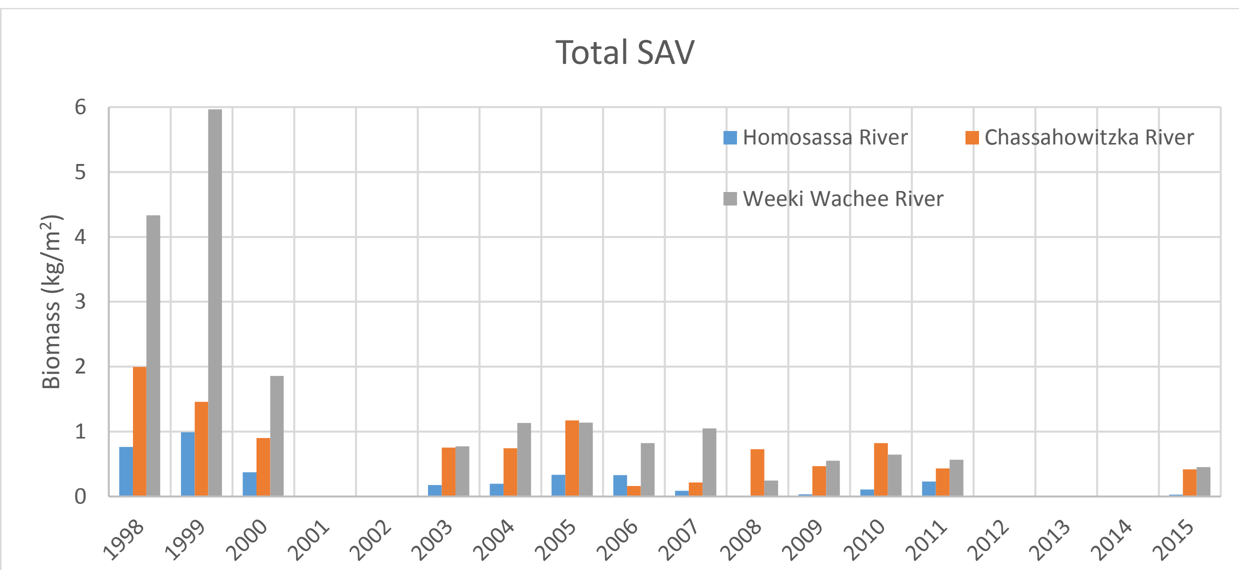

Figure 6-16. River-Wide Mean Total SAV Biomass (kg/m^2 wet weight) by Sampling Event and River. N=100 for each year, for each river.

For river-wide mean angiosperm biomass compared across the rivers (Figure 6-17), the Weeki Wachee River mean angiosperm biomass was the highest for 1998, 1999, 2000, 2004, 2006, and 2007. The Chassahowitzka River river-wide mean angiosperm biomass was the highest for 2003, 2005, 2008, 2009, 2010, 2011, and 2015. The river-wide mean angiosperm biomass for the Homosassa River was the lowest for all sampling events (Figure 6-17). To better present the Homosassa River variability, the data are isolated in Figure 6-18.

For macroalgae (Figure 6-19), river-wide mean biomass for Weeki Wachee River was the highest compared to the other two rivers for all sampling events except 1998, when the highest macroalgae biomass was observed for Chassahowitzka River (Figure 6-19). For all sampling events except for 1998, 2000, and 2005, mean macroalgae biomass values for the Homosassa and Chassahowitzka Rivers were notably less than the values for Weeki Wachee River.

For total SAV percent cover (Figure 6-20), the data indicate considerable variability over time and between river systems. The Weeki Wachee River-wide mean values were above 25 percent for all sampling events, and were the most stable and highest values for 5 of the 13 events. The Homosassa River total SAV percent cover varied from about 2 percent (2008) to more than 30 percent (2006). For the Chassahowitzka River, the total SAV percent cover ranged from more than 12 percent (2007) to about 50 percent (2005).

Figure 6-21 compares the river-wide mean angiosperm biomass as a percentage of total SAV biomass for all the rivers. For the Homosassa River, the river-wide mean angiosperm biomass as a percentage of total SAV biomass was never below 50 percent. The same is true for the Chassahowitzka River data for all sampling events except 2006. In contrast, the Weeki Wachee River mean angiosperm biomass as a percentage of total SAV biomass varied from more than 85 percent in 1998 and 2000 to less than 5 percent in 2009.

Similarly, for river-wide mean macroalgae biomass as a percentage of total SAV biomass (Figure 6-22), the highest values by sampling event, in general, occurred in Homosassa River, with about half the years indicating over 50 percent of the total SAV biomass was macroalgae biomass. For Chassahowitzka River, macroalgae as a percent of total SAV biomass declined from almost 70 percent in 1998 to less than 5 percent in 2007, 2011, and 2015.

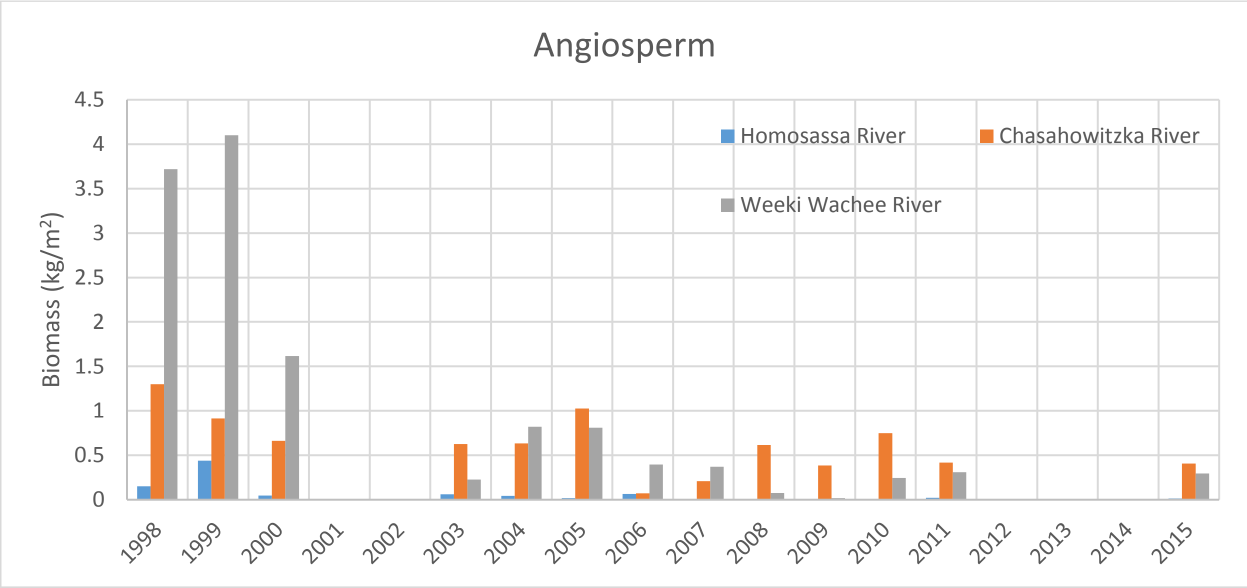

Figure 6-17. River-Wide Mean Angiosperm Biomass (kg/m² wet weight) by Sampling Event and River. N=100 for each year, for each river.

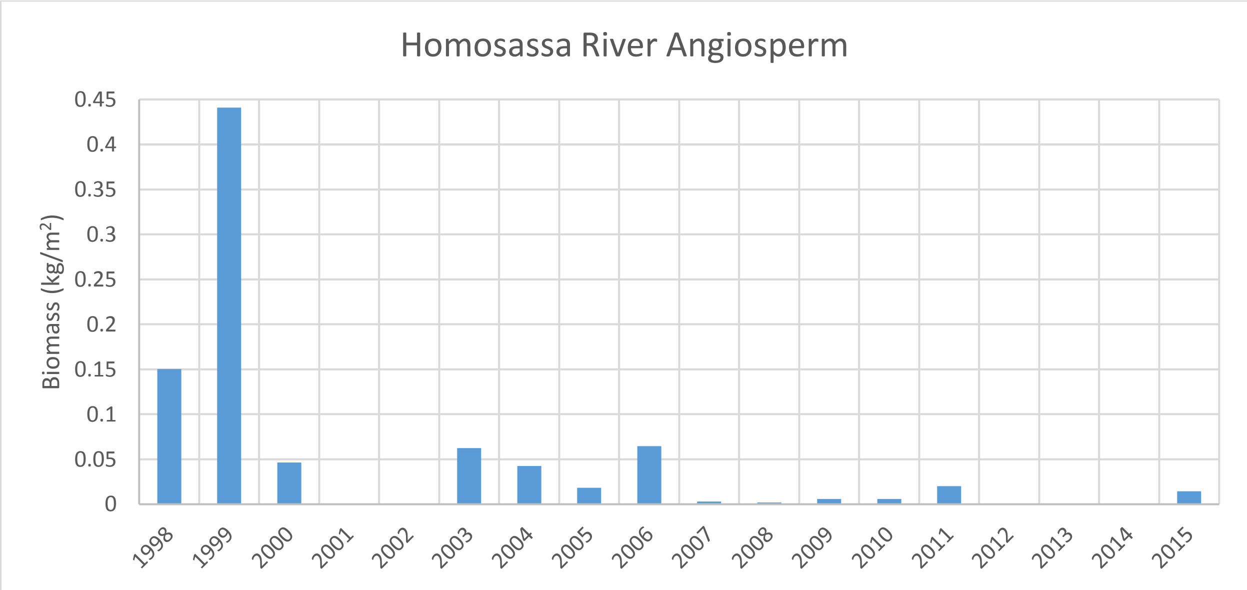

Figure 6-18. Angiosperm Biomass (kg/m² wet weight) by Sampling Event for the Homosassa River Only. N=100 for each year

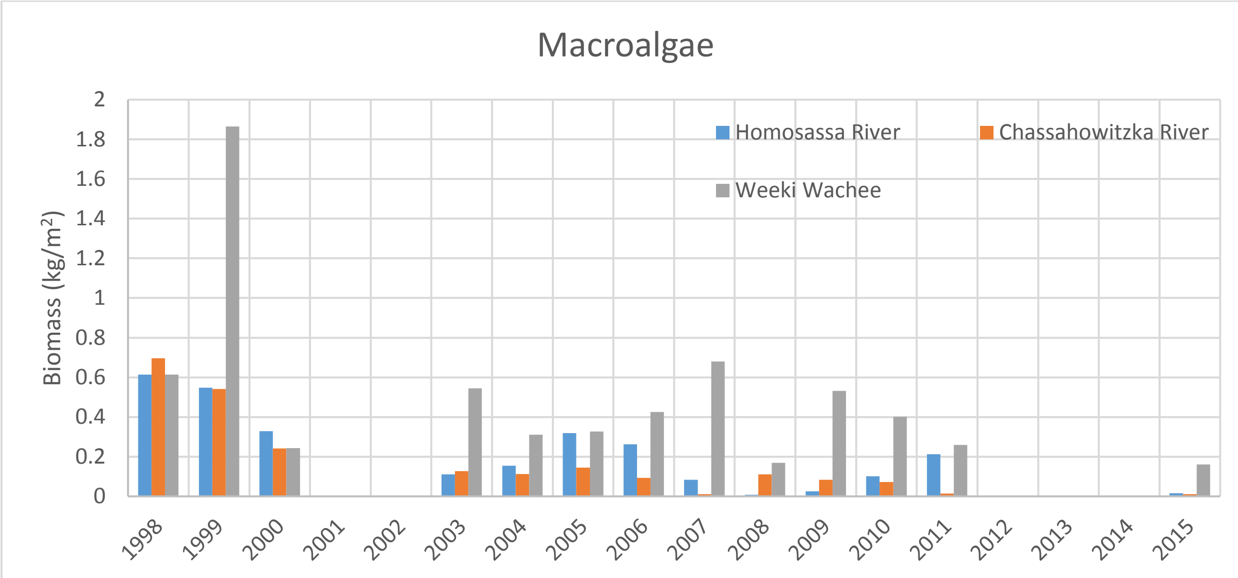

Figure 6-19. River-Wide Mean Macroalgae Biomass (kg/m² wet weight) by Sampling Event and River. N=100 for each year, for each river.

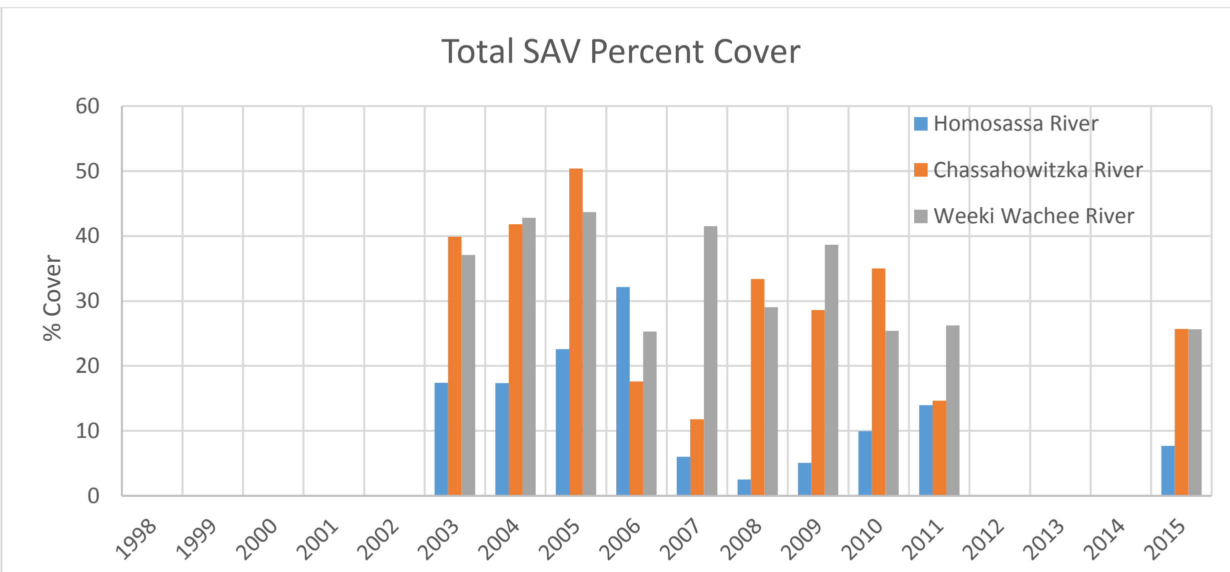

Figure 6-20. River-Wide Mean Total SAV Percent Cover by Sampling Event and River. N=100 for each year, for each river.

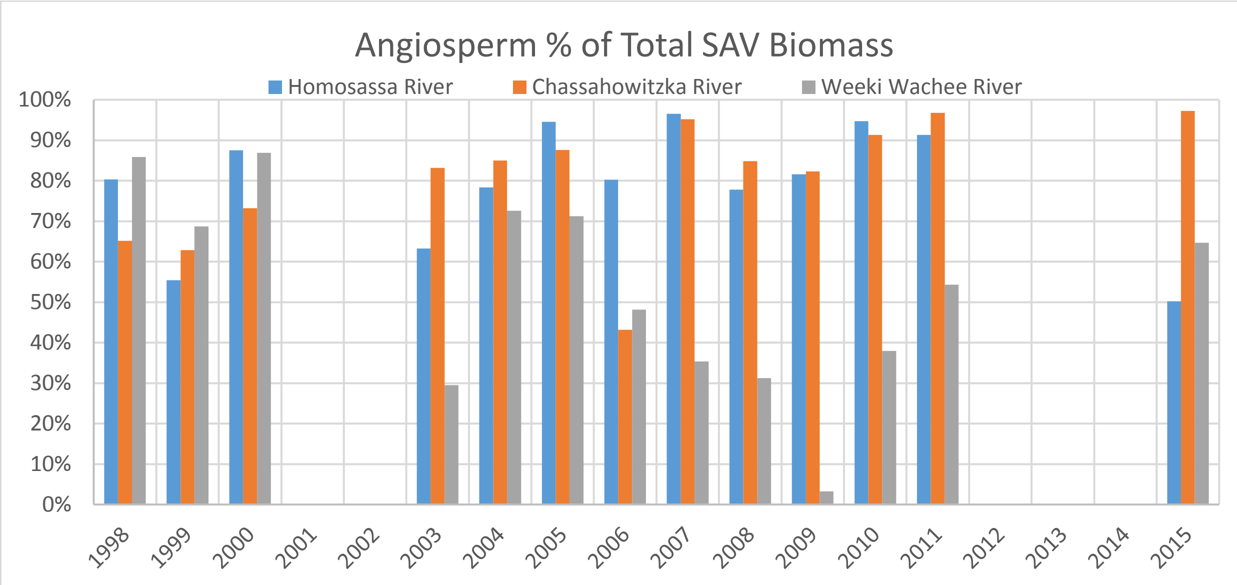

Figure 6-21. River-Wide Mean Angiosperm Biomass as a Percent of Total SAV Biomass by Sampling Event for the Rivers. N=100 for each year, for each river.

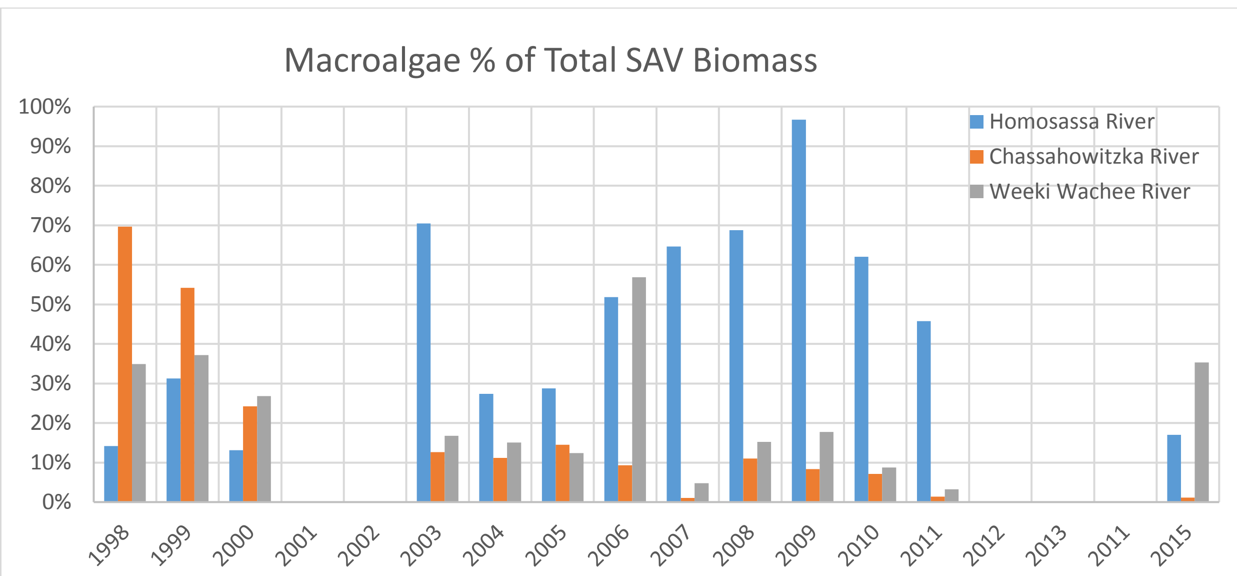

Figure 6-22. River-Wide Mean Macroalgae Biomass as a Percent of Total SAV Biomass by Sampling Event for the Rivers. N=100 for each year, for each river.

When the total SAV biomass (kg/m^2) values from all three rivers were summed to create a composite mean value and graphed (Figure 6-23), it can be seen that there is a general decline in total SAV biomass over time. The 2015 summed value is the lowest of all sampling events, although it is similar to the summed values for 2008 and 2009.

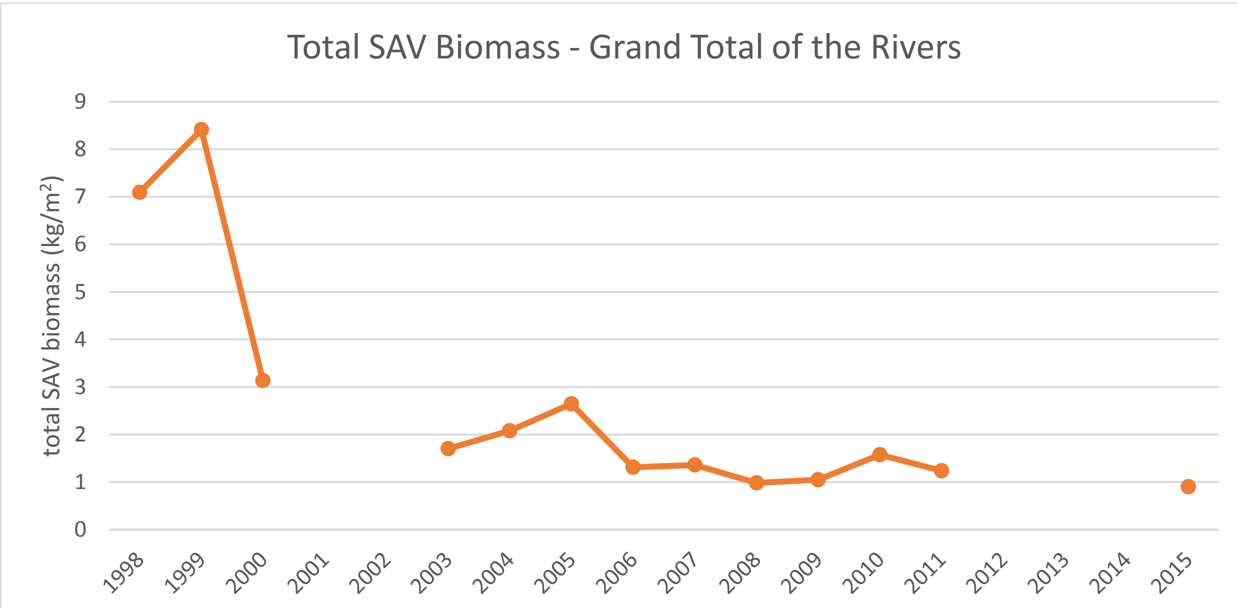

Figure 6-23. Sum (grand total of the rivers) for River-Wide Mean Total SAV Biomass for All Three Rivers.

6.5.3 Comparison of the 2015 SAV Data to Pooled Data from Previous Sampling Events

The 2015 river-wide mean total SAV biomass, angiosperm biomass, macroalgae biomass, and percent of total SAV cover were compared to the combined data from all of the other years to identify and analyze the differences. Those results are summarized in Tables 6-25 through 6-28. As indicated in Table 6-25, all of the river systems experienced a reduction in mean total SAV biomass in 2015 compared to the mean for the data from all other years combined. Nonparametric statistics determined that, within each separate river system, the differences seen in the 2015 data compared to the historical data for all parameters were statistically significant, with at least 95 percent confidence. The largest percent reduction was seen in the Homosassa River data, (about 90 percent reduction) followed by the Weeki Wachee River (77.4 percent reduction) and the Chassahowitzka River (49 percent reduction).

Table 6-25. River-Wide Mean Total SAV Biomass (wet weight) for 1998-2011 Compared to the Mean Total SAV Biomass for 2015 for Each of the Rivers. For the 1998-2011 data N=1200. For the 2015 data N=100.

River	1998-2011 mean total SAV biomass (kg/m^2)	2015 mean total SAV biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/ Decrease
Weeki Wachee River	1.59	0.45	1.14	-71.47%
Chassahowitzka River	0.82	0.42	0.40	-49.00%
Homosassa River	0.30	0.03	0.27	-90.02%

For the angiosperm biomass data (Table 6-26) the river-wide reduction in 2015 compared to the historical data ranged from a low of about 35 percent in the Chassahowitzka River to a high of about 81 percent in the Homosassa River. For the Homosassa River, both the mean value for the 2015 data (N=100) and the mean value for the historical data (N=1200) are very small.

Table 6-26. River-Wide Mean Angiosperm Biomass (wet weight) for 1998-2011 Compared to the Mean Angiosperm Biomass for 2015 for Each of the Rivers. For the 1998-2011 data, N=1200. For the 2015 data, N=100.

River	1998-2011 Angiosperm biomass (kg/m^2)	2015 Angiosperm biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/ Decrease
Weeki Wachee River	1.06	0.29	0.77	-72.29%
Chassahowitzka River	0.63	0.41	0.23	-35.15
Homosassa River	0.0720	0.0144	0.0571	-80.96%

For the macroalgae biomass data, the percent reductions for 2015 compared to the historical data for both the Homosassa River and the Chassahowitzka River were more than 95 percent (Table 6-27), while the difference between the mean for the historical macroalgae data (N=1200) and the mean of the 2015 data for the Weeki Wachee River was a difference of 48.5 percent. The differences shown by Table 6-27 between the historical macroalgae biomass and the 2015 macroalgae biomass were statistically significant, with at least 95 percent confidence.

Table 6-27. River-Wide Mean Macroalgae Biomass (wet weight) for 1998-2011 Compared to the Mean Macroalgae Biomass for 2015 for Each of the Rivers. For the 1998-2011 data N=1200. For the 2015 data N=100.

River	1998-2011 Macroalgae biomass (kg/m^2)	2015 Macroalgae biomass (kg/m^2)	Difference: 1998-2011 minus 2015 (kg/m^2)	% Increase/ Decrease
Weeki Wachee River	0.53	0.16	0.37	-48.50%
Chassahowitzka River	0.1872	0.0114	0.1758	-96.17%
Homosassa River	0.2307	0.0151	0.2151	-98.60%

All of the river systems experienced a reduction in mean total SAV percent cover in 2015 compared to the mean for the data from all other years combined (Table 6-28). The 2015 mean total SAV percent cover values for Chassahowitzka and Weeki Wachee Rivers were almost identical. The largest percent reduction in total SAV percent cover for 2015 compared to the historical data was seen in the Homosassa River data, (almost 50 percent reduction), followed by the Chassahowitzka River (almost 39 percent reduction) and then the Weeki Wachee River (20.6 percent reduction). Values shown in Table 6-28 for individual periods are statistically significant, with at least 95 percent confidence.

Table 6-28. River-Wide Mean Total SAV Percent Cover for 2003-2011 Compared to the Mean Total SAV Percent Cover for 2015 for Each of the Rivers. For the 2003-2011 data N=900. For the 2015 data N=100.

River	2003-2011 Mean Total SAV % Cover	2015 Mean Total SAV % Cover	Difference: 2003-2011 minus 2015	% Increase/ Decrease
Weeki Wachee River	34.41	25.65	8.76	-20.59%
Chassahowitzka River	30.34	25.67	4.67	-38.90%
Homosassa River	14.12	7.71	6.34	-49.85%

6.5.4 Changes in SAV Data over Time

Because the data can be easily organized into four periods of data collection and analysis, the data were also compared across river systems by period of time. The four periods of time are:

- 1998-2000
- 2003-2005
- 2006-2011
- 2015

The 1998-2000 data were previously analyzed and the results presented in Frazer et al. (2003). The 2003-2005 data were also previously analyzed as presented in Frazer et al. (2006). The 2006-2011 data and the 2015 data have not previously been evaluated for changes over time.

The differences between the rivers for total SAV biomass for each period are presented in Figure 6-24. In general, the Weeki Wachee River total SAV biomass was the highest for all four periods, and the Homosassa River mean total SAV biomass was the smallest. For all rivers, there was a noticeable continuous decline in total SAV biomass over time.

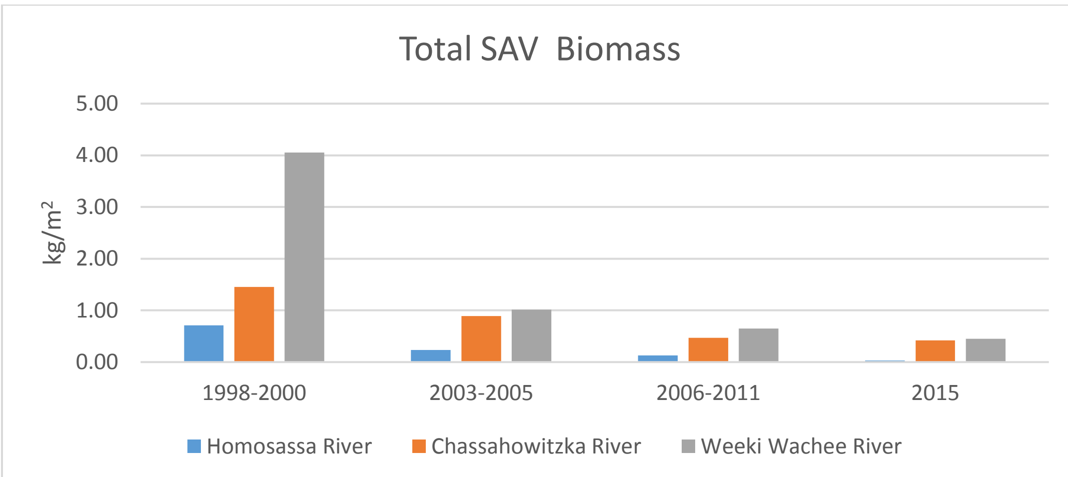

Figure 6-24. River-Wide Mean Total SAV Biomass by Sampling Event Periods for Each of the Rivers. N=100 for each year, for each river.

Figure 6-25 presents the changes in mean angiosperm biomass between the rivers for each period. The Weeki Wachee River angiosperm biomass was the largest angiosperm biomass for the 1998-2000 period, and the Chassahowitzka River angiosperm biomass was the largest for the last two periods. The Homosassa River angiosperm biomass was the smallest for all periods. In order to better view the variability in the Homosassa River mean angiosperm biomass, these values are isolated in Figure 6-26. For all rivers, there was a continuous decline in total SAV biomass over time, but the differences between the 2015 angiosperm biomass and the 2006-2011 angiosperm biomass are relatively small.

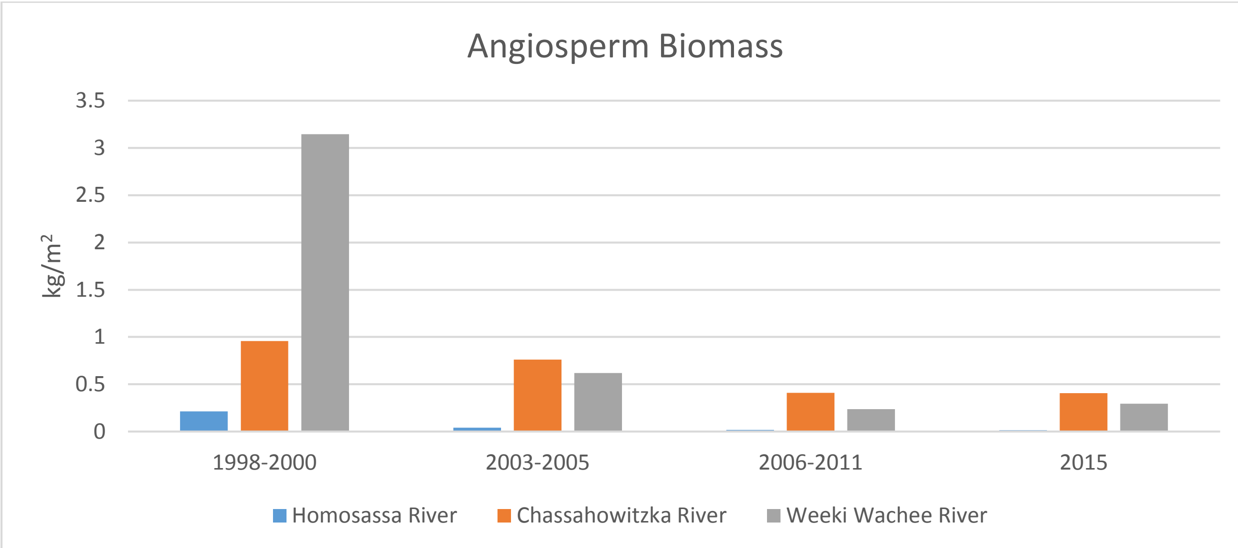

Figure 6-25. River-Wide Mean Angiosperm Biomass by Sampling Event Period for Each of the Rivers. N=300 for 1998-2000 and 2003-2005. N=600 for 2006-2011. N= 100 for 2015.

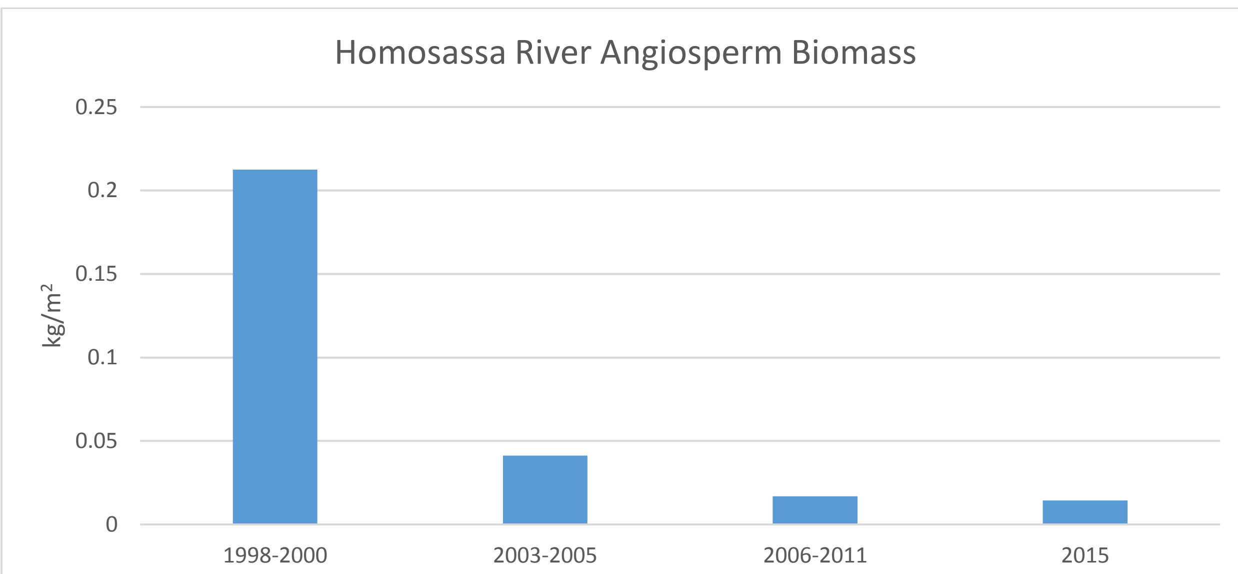

Figure 6-26. For Homosassa River Only, River-Wide Mean Angiosperm Biomass by Sampling Event Period. N=300 for 1998-2000 and 2003-2005. N=600 for 2006-2011. N= 100 for 2015.

Figure 6-27 presents the macroalgae biomass differences between the rivers by sampling event periods. The Weeki Wachee River macroalgae biomass was the highest for all periods. The Homosassa River mean macroalgae biomass was the smallest for 2015, and the Chassahowitzka River mean macroalgae biomass values were the smallest for the other three periods, though the Homosassa and Chassahowitzka River values were similar for the 1998-2000 period. The continuous decline over time in biomass that was seen for total SAV and angiosperms is only seen in the Homosassa River macroalgae biomass data.

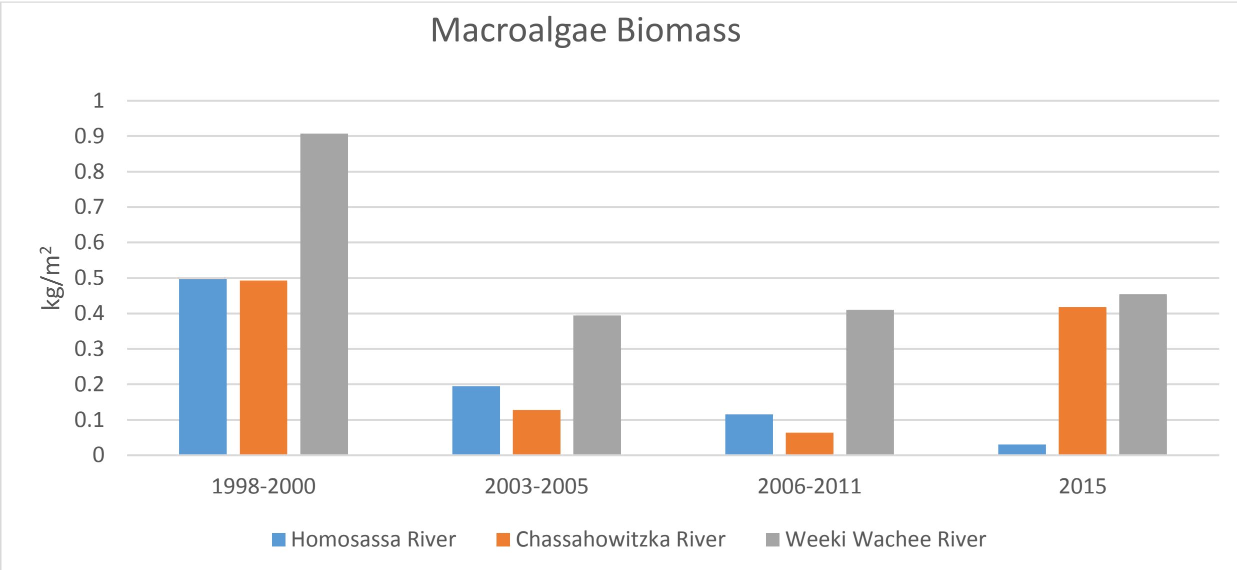

Figure 6-27. River-Wide Mean Macroalgae Biomass by Sampling Event Periods for Each of the Rivers. N=300 for 1998-2000 and 2003-2005. N=600 for 2006-2011. N= 100 for 2015.

Figure 6-28 compares the river-wide mean angiosperm biomass as a percentage of total SAV biomass for all rivers. For the Homosassa River, the river-wide mean angiosperm biomass as a percentage of total SAV biomass was the smallest and was always below 50 percent. For the Weeki Wachee River data, the river-wide mean angiosperm biomass as a percentage of total SAV biomass varied from more than 36 percent to about 78 percent. The Chassahowitzka River angiosperm biomass as a percentage of total SAV biomass increased over time, from about 66 percent in 1998-2000 to more than 97 percent in 2015.

For macroalgae biomass as a percentage of the total SAV biomass, the Homosassa River macroalgae as a percentage of total SAV biomass always exceeded 50 percent. For the Chassahowitzka River, the macroalgae biomass as a percentage of the total SAV biomass was always below 50 percent (Figure 6-29).

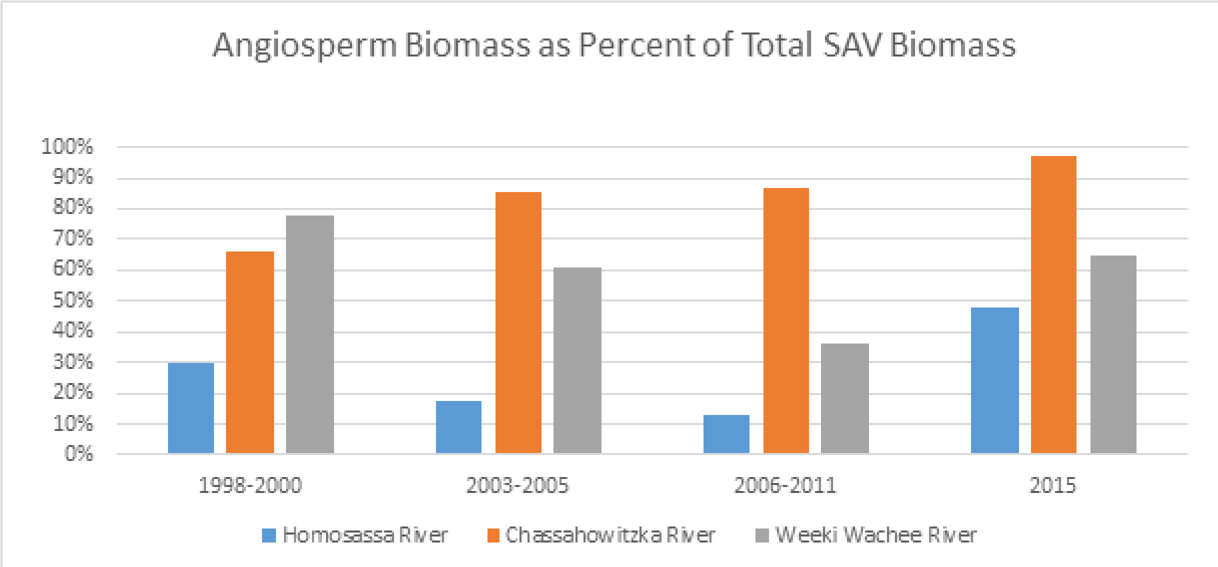

Figure 6-28. River-Wide Mean Angiosperm Biomass as a Percent of Total SAV Biomass by Sampling Event for the Rivers. N=300 for 1998-2000 and 2003-2005. N=600 for 2006-2011. N= 100 for 2015.

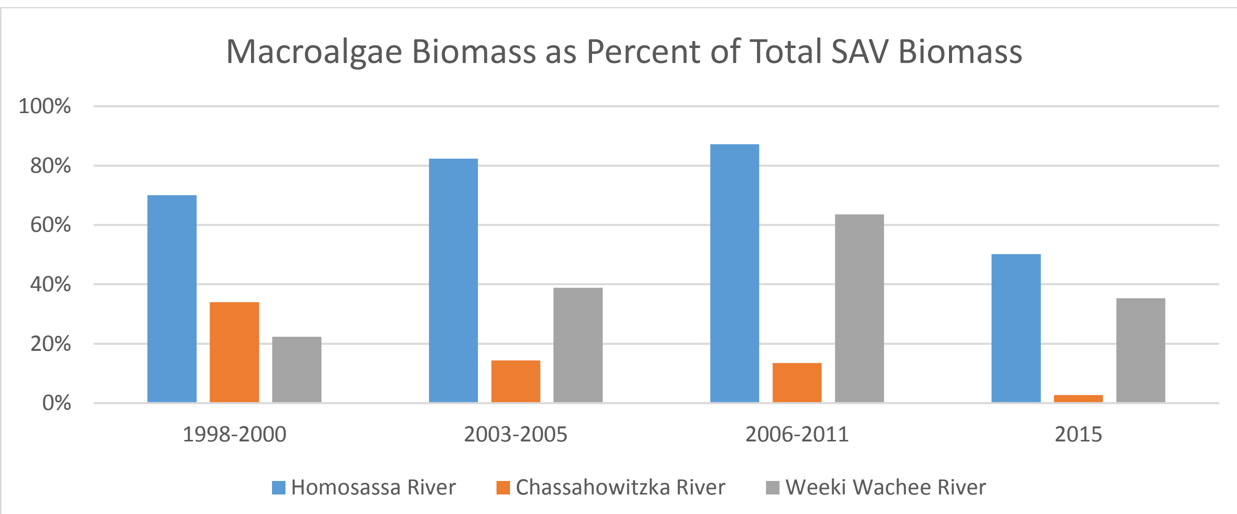

Figure 6-29. River-Wide Mean Macroalgae Biomass as a Percent of Total SAV Biomass by Sampling Event For The Rivers. N=300 for 1998-2000 and 2003-2005. N=600 for 2006-2011. N= 100 for 2015.

The Weeki Wachee River macroalgae biomass as a percentage of the total SAV biomass varied from 22 percent (1998-2000) to more than 63 percent in 2006-2011. Figures 6-28 and 6-29 together indicate that the Homosassa River is dominated by macroalgae, while the Chassahowitzka and Weeki Wachee Rivers are dominated by angiosperm.

Figure 6-30 presents the differences between the rivers for total SAV percent cover, for each period. For all river systems, the percent cover never exceeded 45 percent. For the 2003-2005 period, the Chassahowitzka River total SAV percent cover was the highest. For the 2006-2011 period, the Weeki Wachee River total SAV percent cover was the highest, and for 2015 the mean total SAV percent cover for these two rivers was about the same. For all three periods the Homosassa River mean total SAV percent cover was the smallest. For the Homosassa and Weeki Wachee Rivers, there was a continuous decline in total SAV percent cover over time.

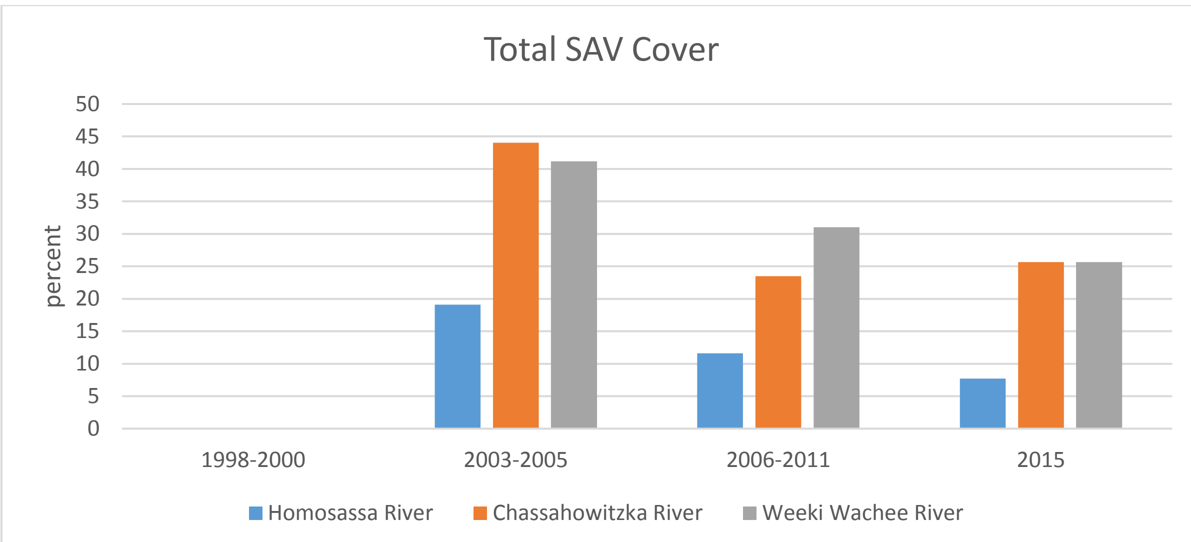

Figure 6-30. River-Wide Mean Total SAV Percent Cover by Sampling Event Periods for Each of the Rivers. N=100 for each year, for each river. No total SAV percent cover data exist for the 1998-2000 period. N=300 for 2003-2005. N=600 for 2006-2011. N= 100 for 2015.

Table 6-29 presents a comparison of the results from four nonparametric tests that were implemented to evaluate the statistical significance of the differences in the total SAV biomass data distributions for the four periods of data collection. All of the tests indicate that there are differences in the data distributions for all periods for the Homosassa and Weeki Wachee Rivers, and for three of the four periods for the Chassahowitzka River.

For the Chassahowitzka River, the statistical significance tests for the comparison between the 2006-2011 data and the 2015 data indicate that the data from the two periods are not different, meaning no change has occurred as measured by the data, and it can be assumed that they came from similar distributions.

Table 6-29. Results of Nonparametric Tests for Statistical Significance of Differences in the Data Distributions of the Various Periods Analyzed. See text for confidence explanations

System	Data Comparison	Sign	Sign Rank	Kruskal-Wallace	Median 2-Sample	Confidence
Weeki Wachee River	1998-2000 vs 2003-2005	<.0001	<.0001	<.0001	<.0001	very high
	2003-2005 vs 2006-2011	0.1591	0.0208	0.0002	0.0004	high
	2006-2011 vs 2015	<.0001	<.0001	0.0714	0.2804	low
	2003-2005 vs 2015	<.0001	<.0001	0.0001	0.0054	very high
Chassahowitzka River	1998-2000 vs 2003-2005	<.0001	<.0001	<.0001	<.0001	very high
	2003-2005 vs 2006-2011	<.0001	<.0001	<.0001	<.0001	very high
	2006-2011 vs 2015	0.5856	0.1093	0.9411	0.8525	low
	2003-2005 vs 2015	<.0001	<.0001	<.0001	<.0001	very high
Homosassa River	1998-2000 vs 2003-2005	<.0001	<.0001	<.0001	<.0001	very high
	2003-2005 vs 2006-2011	0.4452	0.0046	<.0001	<.0001	high
	2006-2011 vs 2015	0.2891	0.0333	0.0001	0.0001	low
	2003-2005 vs 2015	<.0001	<.0001	0.0046	0.0419	high

Confidence in the combined results of the four different tests was also assessed by comparing across the p-values from the statistical significance tests. A low p-value for an individual comparison indicates that the probability that the two distributions being compared are different is large. Since multiple statistical significance test were used, confidence in the combined results of the four nonparametric tests was assumed to be “very high” if all four tests produced p-values of <0.0001. Confidence was assessed as “high” if at least one test resulted in a p-value of <00001 and no other values p-values were higher than the threshold of p=0.05 (95 percent confidence), thereby indicating some ambiguity in the various test results. Confidence was assessed as “low” if there were no p-values of <0.0001 and only one p-value exceeded 0.05. Confidence was assessed as “very low” if there were no p-values of <00001 and two or more p-values exceeded 0.05. No data comparisons were assessed as “very low” confidence in the combined results of the tests.

The test results in Table 6-29 indicate that the data from the 1998-2000 period were different from the 2003-2005 data for all rivers, and there is little ambiguity in this result. The 2003-2005 data and the 2006-2011 data from all rivers were also seen to be different, with either high confidence (Homosassa and Weeki Wachee Rivers) or very high confidence (Chassahowitzka River). The 2015 data from the Homosassa and Weeki Wachee Rivers were found to be different from the 2003-2005 data with high and very high confidence, respectively. The 2015 data from the Chassahowitzka River were found to be different from the 2006-2011 data with low confidence, i.e., these two sets of data are not different and can be combined into one dataset.

Median SAV biomass values for the periods of similar data are presented in Table 6-30. For all rivers the median period values decreased over time. Because the differences in the periods are statistically significant, the differences in the median values (used for the statistical significance testing) and the declining trend over time can also be considered as statistically significant.

Table 6-30. Median Total SAV Biomass (wet weight) Values by Period for All Rivers Based on the Results of the Nonparametric Significance Test as Presented in Table 6-29.

Year	N	Weeki Wachee River (kg/m^2)	Chassahowitzka River (kg/m^2)	Homosassa River (kg/m^2)
1998-2000	300	4.33	1.46	0.76
2003-2005	300	1.13	0.75	0.20
2006-2011	600	0.61	0.43*	0.10
2015	100	0.45		0.03

*2006-2011 and 2015 data combined, N=700

6.5.5 Discussion and Conclusions

This analysis of SAV data collected from the Weeki Wachee, Chassahowitzka, and Homosassa Rivers began with development of a fresh database from all the raw data collected to date, some of which were previously analyzed as documented in the Frazer et al. studies (2003 and 2006). It is noteworthy that a comparison of the river-wide mean values for the 1998, 1999, and 2000 sampling events and the 2003, 2004, and 2005 sampling events presented in Figures 6-16 through 6-19 are the same mean parameter values presented in Table 4 of Frazer et al. (2006). This concordance in the descriptive statistics of the common data of the two datasets data provides confidence that the mean and median values for the 2006-2011 and 2015 time periods computed for this project are accurate, and the results from the cross-period comparisons made herein are reasonable. In addition, for the analyses described herein, it was concluded that there are ample existing and new (2015) information and data for identifying and assessing all the data that were collected during the 1998-2015 time period, noncontinuously.

Both differences and similarities were seen when the data were compared across the rivers for the full period of 1998-2015 where data are available. In general, for all three river systems, the mean total SAV biomass values for the 1998, 1999, and 2000 sampling events were noticeably larger than the mean total SAV biomass values for all other sampling events, particularly for the Weeki Wachee River. Also, for all three river systems the river-wide 2015 mean total SAV biomass values were less than the mean total SAV biomass value for the combined data from the other sampling events, and this difference was statistically significant for each river system with 95 percent confidence.

The variability in the angiosperm data between the rivers is relatively large. For example, the Weeki Wachee River mean angiosperm biomass was the highest for 1998, 1999, 2000, 2004, 2006, and 2007, and the Chassahowitzka River river-wide mean angiosperm biomass was the highest for 2003, 2005, 2008, 2009, 2010, 2011, and 2015. For the 1998 and 1999 sampling events, the Weeki Wachee River mean angiosperm biomass values were higher than any other mean angiosperm biomass values by 2 to more than 10 times greater. The river-wide mean angiosperm biomass for the Homosassa River was much smaller than the other rivers for all sampling events.

For macroalgae, the lowest river-wide mean value of biomass for the Homosassa and the Chassahowitzka Rivers was observed for the 2015 sampling events. For the Weeki Wachee River, the lowest river-wide mean macroalgae biomass value was measured in 2009 (almost 0).

Mean total SAV percent cover was highly variable across the rivers and across sampling events. In general, the Homosassa River mean total SAV percent cover values were less than half of the values observed for the Chassahowitzka and Weeki Wachee Rivers.

For all sampling events except 1998, 1999, and 2000, either the Homosassa or Chassahowitzka Rivers had the highest value for angiosperm biomass as a percentage of total SAV biomass (more than 50 percent for all sampling events but one), indicating the dominance of angiosperm biomass over macroalgae biomass in these two coastal systems, for the periods monitored. For the Weeki Wachee River angiosperm biomass, the highest percentages of total SAV biomass were noted for the 1998, 1999, and 2000 sampling events (more than 80 percent), which then declined to about 3 percent in 2009, before increasing again for the 2010, 2011, and 2015 periods to more than 60 percent for 2015.

One of the objectives of this project was to evaluate the changes in the data, initially for only the differences seen in the 2015 data as compared to all of the other data that have been collected. For the initial evaluation, the mean and median values for the 2015 data were found to be less than the mean and median values for the combined pre-2015 data for all of the rivers. When the data were compared across all three rivers and across time through the use of nonparametric statistical significance tests, it was found that the data from the Homosassa and Weeki Wachee Rivers can both be divided into four periods that are statistically different with at least 95 percent confidence. For the Chassahowitzka River, the differences between the 2006-2011 data and the 2015 data are not statistically different. When combined, the Chassahowitzka River 2006-2011 and 2015 data constitute a period of similar data, with at least 95 percent confidence. This means that the Chassahowitzka River data divide into three different periods of data, and the differences were found to be statistically significant, with at least 95 percent confidence. Comparisons of the mean and median values for the various different periods indicate that there has been a general reduction in total SAV biomass since data collection began, and this reduction is statistically significant.

7.0 Concluding Remarks

This report documents the collection of SAV in 2015 and analyzes changes to frequency of occurrence, SAV cover and SAV biomass between 1998 and 2015. This section provides the key findings.

For all river systems, the percent cover never exceeded 45 percent. For the Homosassa and Weeki Wachee Rivers, there was a continuous decline in total SAV coverage over time. SAV coverage for Chassahowitzka River increased slightly in 2015 from the 2006-2011 period.

Both differences and similarities were seen when the data were compared across the rivers for the full period of 1998-2015 where data are available. In general, for all three river systems, the mean total SAV biomass values for the 1998, 1999, and 2000 sampling events were noticeably larger than the mean total SAV biomass values for all other sampling events, particularly for the Weeki Wachee River. Also, for all three river systems, the river-wide 2015 mean total SAV biomass values were less than the mean total SAV biomass value for the combined data from the other sampling events, and this difference was statistically significant for each river system with 95 percent confidence.

Comparisons of the mean and median values for the various different periods indicate that there has been a general reduction in total SAV biomass since data collection began, and this reduction is statistically significant. For all sampling events except 1998, 1999, and 2000, either the Homosassa or Chassahowitzka Rivers had the highest value for angiosperm biomass as a percentage of total SAV biomass (more than 50 percent for all sampling events but one), indicating the dominance of angiosperm biomass over macroalgae biomass in these two coastal systems, for the periods monitored. For the Weeki Wachee River angiosperm biomass, the highest percentages of total SAV biomass were noted for the 1998, 1999, and 2000 sampling events (more than 80 percent), which then declined to about 3 percent in 2009 before increasing again for the 2010, 2011, and 2015 periods to more than 60 percent for 2015.

The mean number of sampling stations devoid of SAV continued to increase between 2003-2005 and 2006-2011. However, this was followed by notable decreases in the mean number of sampling stations devoid of SAV in all three rivers between 2015 and the 2006-2011 period. The frequency of occurrence between plants and macroalgae species varied. Of note is that *Vallisneria americana* was not observed in sampled locations of the Homosassa River. Also, *Sagittaria kurziana* was not observed in sampled locations of the Weeki Wachee River and has not been observed in the Chassahowitzka River since 2004.

The results of this analysis are intended to inform water resource managers of changes in SAV that have occurred in these three rivers during a period of 1998 to 2015. In addition, these results will help guide the development of future strategies and management actions. Frazer et al. (2006) also presented an evaluation of water quality and inferred that the reductions in the total SAV biomass observed when the 1998-2000 data were compared to the 2003-2005 data may be related to increasing nutrient concentrations in all three rivers. A similar evaluation of water quality and other data (e.g., herbivores, recreation, and light availability) was beyond the scope of work for this project. However, the results of these analyses suggest that a similar evaluation of the available environmental data from the three rivers for the 2006-2015 period is warranted, including the use of the same or similar statistical significance tests that were used for testing the SAV data to evaluate any changes over time and space as were done for the SAV data. These types of analyses would be very useful to water resource managers as they work to develop ecosystem restoration strategies.

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