Bimonthly Seagrass Monitoring in the Loxahatchee River Estuary, Jupiter, Florida:

2021 Annual Report

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Executive Summary

Seagrasses are submerged aquatic flowering plants that occupy shallow coastal regions, estuaries, and lagoons. Often regarded as a "keystone" organism, seagrasses support many ecologically and economically vital functions such as nursery habitat for numerous species of familiar fish and shellfish, food for large charismatic animals such as sea turtles and manatees, help mitigate wave energy and stabilizing suspended sediments, and sequestering atmospheric carbon. As important as seagrasses are, these habitats are disappearing at an alarming rate across the globe. The reasons underlying widespread seagrass "die-offs" are varied and covered quite extensively in published scientific literature, which are often attributed to human activities derived from coastal development and agriculture. To this end, seagrasses are often used by resource managers as a sentinel for water quality and general ecosystem health since the sessile nature of seagrass makes them susceptible to degraded coastal systems.

The Loxahatchee River Estuary (LRE) is a relatively small coastal estuary that supports seagrass species common to Florida's east coast including "Shoal Grass" (*Halodule wrightii*), "Manatee Grass" (*Syringodium filiforme*), "Turtle Grass" (*Thalassia testudinum*), as well as the diminutive seagrasses "Johnson's seagrass" (*Halophila ovalis*, formerly *Halophila johnsonii*) and Paddle grass (*Halophila decipiens*). Recognizing the need to understand seagrass community composition and seasonal growth trends as well as long-term impacts associated with human activities, the Loxahatchee River District initiated a seagrass monitoring program during the summer of 2003 and has continued uninterrupted through 2021. During these years, methodology and monitoring sites have changed, but the objective of monitoring the health of the seagrass community has remained.

Five seagrass monitoring sites are located along a salinity gradient within the estuary extending from just inside the Jupiter Inlet upstream into the Northwest Fork of the Loxahatchee River near the historical upstream extent of seagrass. A site located 8km (5 mi) north of the Jupiter inlet in the Intracoastal Waterway/Indian River Lagoon, that once served as a reference site for the monitoring program, was visited and assessed in October 2021. Methodology in use since 2007 utilizes fixed polygons around each seagrass monitoring site. Within each polygon, a fixed number of sample points based on areal size of site, are preselected at random and entered into a high-accuracy GPS that Staff used to navigate to each point while in the field. Divers in the water assessed the seagrass at each point using 1m^2 quadrat subdivided into 100 10cm^2 squares. Metrics such as percent occurrence (frequency), Braun-Blanquet Vegetative Cover estimate, canopy height, and shoot density were determined at each point.

Generally, seagrasses in the LRE have experienced substantial declines in species richness, abundance, and distribution in recent years and that trend continues into 2021. Mean total seagrass percent occurrence decreased from 41% in 2020 to 35% in 2021. The overall decline in seagrass tended to follow the upstream salinity gradient, whereby the greatest seagrass declines were observed at the upstream monitoring sites. Seagrass was absent at the most upstream site where, at its peak averaged over 80% occurrence. Shoal grass was the most abundant and widely distributed seagrass throughout 2021 as it was found at four of the five routine monitoring sites as well as the Hobe Sound site. Shoal grass also expressed an increasing trend in occurrence through the 2021 monitoring season despite having overall lower percent occurrence compared to 2020.

The cause of the long-term decline in seagrass presence and abundance remain unknown, there appears to be a possible correlation between seagrass presence and regional rainfall and storm events, which likely affects water quality from stormwater discharges. For example, there were substantial seagrass declines following the tropical storms of 2004 and again in 2012. In the years following the tropical storm in 2012, annual rainfall has been higher than historical averages. During this same period after 2012, seagrasses experienced a steady decline. Annual rainfall during 2021 was considerably lower compared to previous years dating back to pre-2012. Seagrasses have shown a slight increase in presence through the year, though still below levels seen during previous years. While there is uncertainty about the causes of the recent improvements in seagrass occurrence, it is encouraging to see some positive results in the 2021 monitoring data.

Brief Introduction / Background

Seagrasses are submerged aquatic flowering plants that occupy shallow coastal regions, estuaries, and lagoons around the world. To the casual observer, seagrasses go largely unseen and unnoticed because of their submerged habitat. However, as a keystone organism, they provide valuable ecosystem services including nursery habitat for recreationally and ecologically important fish species, provide food source for charismatic megagrazers like sea turtles and manatees, mitigate wave energy and stabilize sediments that helps slow coastal erosion, and sequesters atmospheric carbon (Duarte, 2002; Bjorndal, 1980; Kirsch et al, 2002; Beck et al 2001, Hansen and Reidenbach, 2013; Fourquarean, et al, 2012). Despite their many important ecological functions and benefits, seagrass loss is accelerating at an alarming rate all over the world (Orth et al, 2006; Waycott et al, 2009). This includes the shallow coastal regions of Florida and the greater Caribbean region which is experiencing rapidly growing human populations and placing increasing pressures on these vulnerable plants (Duarte, 2002). Altered hydrology, nutrient-laden terrestrial runoff, expanding development including seawalls and marine docks, dredging and channelization, and increased boating traffic and recreational use are all threats to seagrass's persistance.

The Loxahatchee River District (LRD), an independent special district of the State of Florida, recognized the need to understand the distribution and composition as well as establish baseline seasonal growth patterns of seagrass beds in the Loxahatchee River estuary and adjacent waters. During the late 1990's, LRD began mapping and monitoring seagrasses in support of planning for restoration of the Loxahatchee River to restore river flows through the Northwest Fork (SFWMD 2006). Because seagrasses represented the most downstream Valued Ecosystem Component (VEC), information was needed to understand natural seasonal variability, species composition, and extent of seagrasses in the Loxahatchee River estuary. Beginning in June 2003 the Loxahatchee River District, in partnership with the South Florida Water Management District (SFWMD), initiated a seagrass monitoring program that continues to this day. Like many long-term monitoring programs, there have been several changes over the years including changes in frequency, methodology, and sites added and removed from the program. The objective of this report is to highlight the 2021 seagrass monitoring results and discuss short term changes by drawing comparison to 2020 and relative to long-term trends.

Sample Site Description and Methods

Study Area

The Loxahatchee River Estuary (LRE) is located in northeastern Palm Beach County and southeastern Martin County, Florida, USA. The estuary connects to the Atlantic Ocean through the Jupiter Inlet and lies between the southern terminus of the Indian River Lagoon (IRL) and the northern terminus of Lake Worth Creek through the Intracoastal Waterway (Figure 1). The estuary encompasses approximately 400 ha and drains a watershed of approximately 700 km^2. Local rainfall averages about 157 cm (62 in) per year and is the primary source of freshwater that enters the estuary primarily through the Northwest Fork with minor additional flow from the North Fork. Freshwater also enters the estuary as runoff from surrounding urban areas through various small tributaries and the local stormwater system. During periods of heavy rainfall, excess stormwater may enter the estuary through the Southwest fork via the C-18 canal and the S-46 flood control structure.

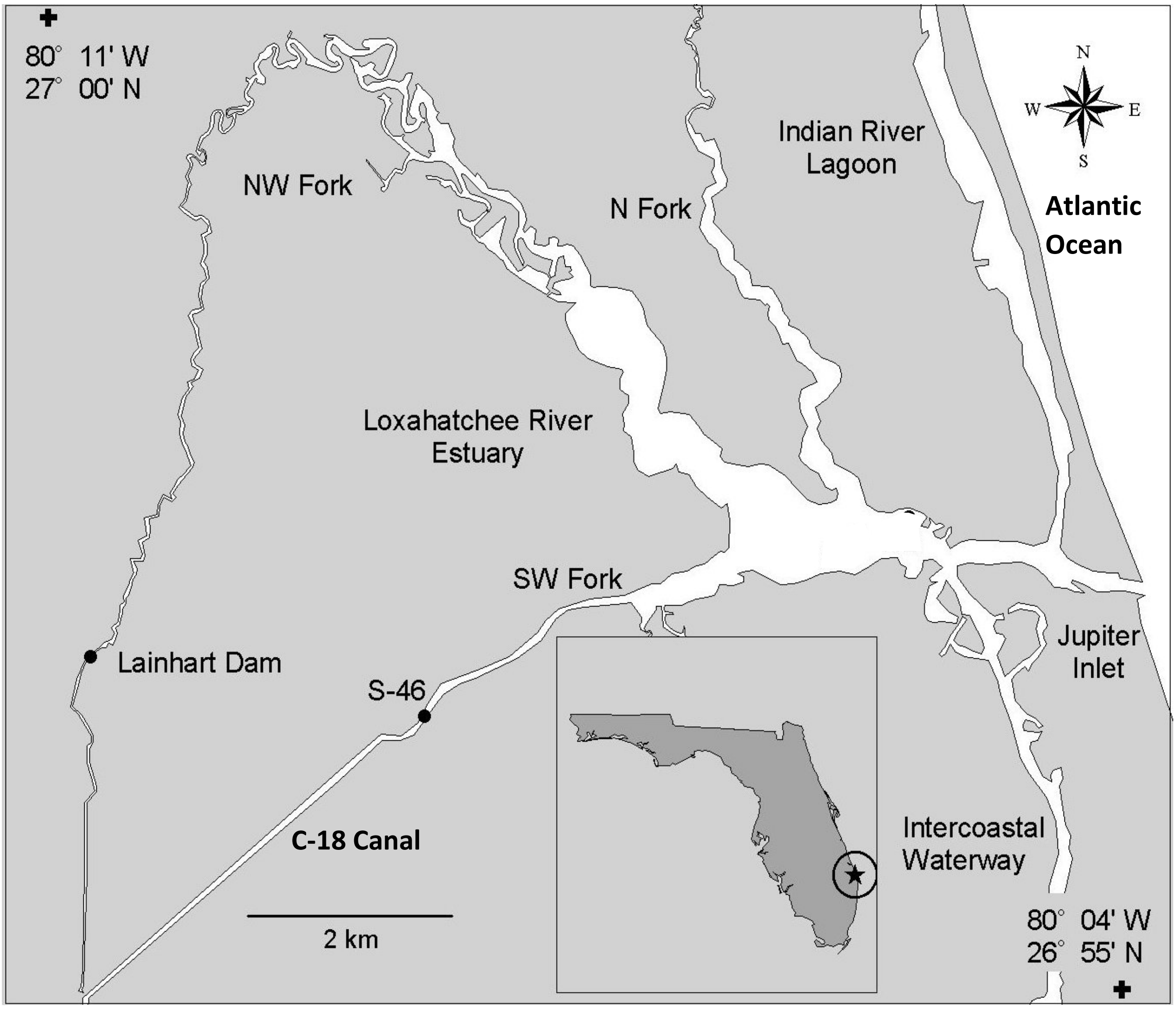


Figure 1. Map showing proximity of the Loxahatchee River Estuary along Florida's eastern coast (inset) and locations of key features of the system. Under normal conditions, freshwater flows through the Northwest Fork and out to the Atlantic Ocean through the Jupiter Inlet. During times of flood control, excess freshwater is diverted to the C-18 Canal and into the Southwest Fork via the S-46 flood control structure.

Seagrass Beds

Early in 2003, preliminary seagrass surveys were conducted in the central embayment of the LRE to identify potential sampling locations where permanent seagrass monitoring sites could be established. The original three seagrass beds were selected based on several factors including proximity to the river forks flowing into the estuary, seagrass abundance, seagrass bed persistence, and community composition.

The North Bay (NB) seagrass monitoring site is located in the northern portion of the central embayment area and is approximately 500 meters west of the railroad bridge (26° 57.044' N, 80° 5.650' W; Figure 2). The North Bay site is 2.49 ha (6.16 acres) and characterized as a shallow cove, seldom more than one meter deep, and is protected from the main boating channel by a sandbar located to the south which spans the length of the seagrass bed (Figure 2). The shoreline can be described as urban residential and is composed mostly of red mangroves (*Rhizophora mangle*) with some seawalls and docks present. Interestingly, throughout the monitoring program, six species of seagrass have been found within this site. *Halodule wrightii* and *Halophila johnsonii* ("shoal grass" and "Johnson's grass", respectively) are the dominant seagrasses currently found at North Bay, but prior to the tropical storms of 2004 this site was dominated by *Syringodium filiforme* ("Manatee grass") with sizeable patches of *Thalassia testudinum* ("turtle grass") and isolated patches of *Halophila decipiens* and *Halophila engalmanii* ("paddle grass" and "star grass" respectively) also present. Following several tropical storms in September 2004, the small, isolated patches *H. engelmannii* disappeared and have not returned. *H. decipiens* first appeared in December 2004 and remains an occasional, albeit inconsistent, species at the North Bay site. The North Bay seagrass bed has been the site of prior monitoring programs, therefore components of this site have been investigated in the past.

The Sand Bar (SB) monitoring site occurs on a shallow sand bar adjacent to, and just south of, the main channel in the central embayment (26° 56.899' N, 80° 5.947' W; Figure 2) and is 3.39 ha (8.39 acres). Northern portions of the Sand Bar and associated seagrasses are often exposed during low tides and receives substantial foot traffic by people that recreate on the sand bar during low tide. The Sand Bar is directly influenced by water flowing from both the Northwest and Southwest Forks of the Loxahatchee River. Currently, the seagrasses *H. wrightii* and *H. johnsonii* are the dominant species encountered at this site. However, *S. filiforme* was once abundant at this site. But following the tropical storms of 2004 has experienced gradual decline in presence and abundance. Additionally, there once were isolated sparse patches of *T. testudinum* located within the site. But, it too, slowly declined following the storms of 2004.

The Pennock Point (PP) monitoring site is located at the western most edge of the central embayment; on the eastern edge of the peninsula created by the confluence Northwest and Southwest forks (26° 56.970' N, 80° 6.673' W; Figure 2). At 1.20 ha (2.96 acres), this site was the smallest of the three original seagrass monitoring sites. Initially the shoreline at this site was a sandy beach adjacent to a vacant lot. In subsequent years, however, the adjacent property has been developed and shoreline is now characterized as hardened seawall with rocky shoreline for wave breaks and multiple docks that extend eastward past the end of the historical seagrass bed. The seagrass bed at this site is shallow and extends approximately fifty meters from shore to a typical depth of 1.5 m. The site is strongly influenced by freshwater flows from both Northwest and Southwest Forks; thus, salinity at this site is highly variable. *H. wrightii* and *H. johnsonii* are the only two seagrass species observed at this location with *H. wrightii* being the dominant species.

The Northwest Fork (NWF) seagrass monitoring site was added in 2007 to better document seagrass status near the upstream extent of seagrasses in the Northwest Fork (26° 57.562' N, 80° 7.315' W; Figure 2). This is the smallest of the monitoring sites at 0.35 ha (0.86 acres) and measures approximately 175 meters long and extends 25 meters out from the sandy shore to a typical depth of 1.4 m. The site is characterized as a shallow sandy embayment along the western shore which is comprised primarily of *Rhizophora mangle* ("Red Mangrove"). The shoreline is urban residential with multiple docks extending out past the edge of the seagrass bed. Due to its location along the salinity gradient, this site is the more influenced by freshwater flowing downstream from the Northwest Fork of the Loxahatchee River and does not experience the clear, marine waters coming in through Jupiter Inlet at high tide. Only *H. wrightii* and *H. johnsonii* have been found at this site.

Figure 2. Sample area map showing location, shape, and relative size of the six seagrass beds. Inset shows the Hobe Sound (HS) seagrass site which is located 8 km (5 mi) north of the Jupiter Inlet. Key river features are indicated; Jupiter Inlet is located 0.8 km east of INL site.

The Hobe Sound (HS) seagrass monitoring site was added to the seagrass monitoring program as a reference site in June 2005. This site is the largest at 4.62 ha (11.4 acres) and is located along the western shoreline of the Indian River Lagoon about 8 km (5 miles) north of the Jupiter Inlet (27° 0.724' N, 80° 6.061' W; Figure 2) and is considered to be relatively constant as it is unaffected by the freshwater that enters the Loxahatchee River Estuary, nor any substantial stormwater discharges. This seagrass site is characterized as sandy shoreline with a dune that rises well above the water making this site unique among south Florida shorelines. The seagrass bed begins at the shallow shoreline and extends eastward approximately 165 meters where depth increases gradually to almost 2 meters at the offshore edge. Unlike other seagrass sites, the Hobe Sound seagrass bed receives very little public use and is located 200m west of the navigational channel. Historically, the dense seagrass bed is dominated by *S. filiforme* and *H. wrightii* with small, isolated patches of *T. testudinum*. While *H. johnsonii* and *H. decipiens* are encountered here, these species are neither abundant nor common and they are typically limited to the deep outer edge of the bed. Like the North Bay site, the Hobe Sound seagrass bed has been the site of extensive long-term studies and monitoring by partnering agencies (Morris et al 2020). However, this site was dropped from the monitoring program in 2015 to allocate resources to studying seagrasses within the estuary. A 2021 visual site survey revealed that this site had recently experienced substantial and sudden seagrass loss. For the first time since 2015 staff revisited this site using current methodology to document and better gauge the losses. The results of that visit are included with this report.

The Inlet site (INL) seagrass monitoring site was added in 2012 to extend the seagrass monitoring along the downstream extent salinity gradient. This site is among the largest of the monitoring sites at 1.77 ha (4.37 acres) and is located on a shallow area just inside the Jupiter Inlet (26° 56.679' N, 80° 4.756' W; Figure 2). The inlet site is characterized as having the most marine-like conditions often with clear water during incoming tide. This site has also been the focus of many long-term seagrass studies and monitoring by other agencies as well as having the designation as a Johnson's seagrass "critical habitat" since 1992 (NMF 50 CFR Part 226.213). The shoreline is composed primarily of hardened seawall and rocky riprap with some red mangroves present. Depth at the outer edge of bed drops quickly to well over 2 meters toward the main navigational channel. As such, this site is subjected to frequent boat wakes. This site is also popular with swimmers and paddleboarders as well as other recreational users who often come swim and occasionally view green sea turtles (*Chelonia mydas*) and the West Indian manatees (*Trichechus manatus*) that frequent this site. There are small sections of the site that become exposed at low tides. The primary seagrass species at the Inlet are *H. wrightii* and *H. johnsonii* with occasional *H. decipiens*. Historically, small, isolated patches of *S. filiforme and* T. *testudinum* were also found.

Methods

Sample point selection process

The seagrass monitoring program presented here has undergone several method iterations since its inception in June 2003. Table 1 provides a timeline of significant changes made to the seagrass monitoring program. Present methodology utilizes a random point selection process with sampling occurring each April, June, August, and October. The boundary of each seagrass bed is established by a polygon in ArcMap (ESRI) to limit the extent of seagrass sampling. Using the "Fishnet" utility within ArcMap, a point grid with 7.6 m (25 ft) spacing is superimposed onto each seagrass bed. The NWF site, points are spaced at 4.6 m (15 ft) to account for the narrow profile of the bed (Table 2). Each point is assigned a permanent unique ID number and is associated with a GPS location. Prior to each sampling event, points are selected randomly for each seagrass bed. The number of sampling points for each bed ranges from 26 to 32 depending on size of bed and resources available to complete surveys in a reasonable time (see Table 2; more points to cover larger areas). To avoid bias throughout the season, random point selection is done with point replacement each month. As such, the same point may be assessed more than once during each monitoring season. The random points with their associated GPS location are uploaded to ArcGIS Online and accessed via hand-held tablet wirelessly connected to a sub-meter accurate EOS Arrow 100© GPS system. When locating points in the field the GPS receiver antenna is mounted atop a 1-meter tall mast which is then affixed to a small kayak.

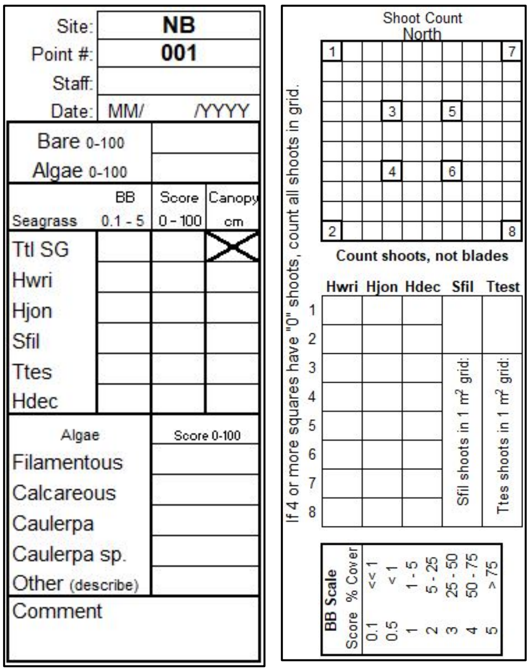
Table 1. Table below is a timeline listing significant changes and occurrences to the seagrass monitoring program.

Date	Procedural Change or Occurrence
6/11/2003	Routine monthly seagrass monitoring in the Loxahatchee River Estuary begins. Three sites; North Bay (NB), Sand Bar (SB) and Pennock Point (PP). Series of Transects at each site covering approximate center of extant seagrass bed. Data collected using 0.25 m^2 quadrat subdivided into 4 squares. Data collected each meter along each transect; seagrass presence as a modified Braun-Blanquet scale (0.1, 0.5, 1-4). Shoot counts and canopy height conducted at near- shore edge of bed, middle of bed , and outer edge of bed; for Manatee Grass only at NB and SB; for Shoal Grass at PP. Water quality collected at each site; approximate center of bed and outer edge of bed.
9/3/2004	Three Hurricanes greatly impacted the region during September: Francis, Ivan, and Jeanne. Seagrass monitoring was not conducted; resumed following month in October.
6/13/2005	The Hobe Sound (HS) seagrass site was added to the monitoring program. Site located in Indian River Lagoon 5 miles (8 km) north of Jupiter Inlet along western shoreline. Three transect lines from shore to outer edge of bed. Shoot counts and canopy height conducted at near- shore edge of bed, outer edge of bed, and middle of bed; for Manatee Grass only.
8/15/2007	End of monthly monitoring frequency. Also last month for transects and 0.25 m^2 quadrats. End of shoot counts; canopy height continued.
10/22/2007	Monitoring frequency changed to bimonthly. Major procedure change from transects to haphazardly deployed weighted buoys inside predefined polygon. Switched to 1 m^2 quadrat subdivided into 25 squares; [(number of squares with seagrass ÷ 25) X 100] to get percent occurrence. Canopy height measured for each species present; no shoot count. Added the Northwest Fork (NWF) site to monitoring program. Smallest and most upstream seagrass site.
12/19/2012	The Jupiter Inlet (INL) site was added to the monitoring program. Routine bimonthly monitoring at HS site ends; was monitored in August and February of each year through 2015.
4/10/15	Seagrass monitoring frequency reduced from 6 times/yr to 3 times/yr; April, June, August to capture peak of growing season.
8/7/2015	Seagrass monitoring ends at HS site.
4/21/2017	Shoot count density is added back to the monitoring program; all species at all sites. Shoots are counted in eight (8) evenly spaced 10 cm^2 sub-squares within each 1 meter quadrat.
8/31/2017	Haphazard seagrass point selection procedure ends.
4/13/2018	Adopt randomized point selection procedure using the “Fishnet” feature of ArcMap (ESRI). A network of points evenly spaced at 25 ft (12 ft at NWF) are located within the original polygon that defines boundary of each seagrass site. Each point has unique identification number; a subset of points selected randomly at each site each month.
10/22/2019	The month of October is added back to seagrass monitoring schedule for a 4 time/yr frequency.
4/29/2021	The 1 m^2 quadrat is changed from 25 sub-squares to 100 sub-squares; improves overall field data collection.
10/28/2021	Monitoring is conducted at Hobe Sound site; plan to monitor site once per year.

Table 2. Table below shows number of total possible grid points for each seagrass bed and the number of selected each month at random to survey at each seagrass bed.

Seagrass Site	Total Point Count	Monthly Sample Point Count
NB	404	32
SB	554	32
INL	306	32
PP	206	26
NWF	148	24
HS	760	32

In the field, a staff member maneuvers the kayak with mast-mounted GPS antenna and tablet to each point where a weighted buoy is placed. Attached to each weighted buoy is a prelabeled waterproof paper ticket containing site ID, Sample point number, staff member, date, and printed boxes for writing field data as well as a table outlining the Braun-Blanquet visual density scale (Figure 3). A diver using snorkeling gear approaches each buoy and places a 1 m^2 grid subdivided into 100 10cm x 10cm squares centered on the weight (Figure 4).


Site: NB
Point #: 001
Staff:
Date: MM/ /YYYY
Bare 0-100
Algae 0-100

Seagrass	BB 0.1 - 5	Score 0 - 100	Canopy cm
Ttl SG			
Hwri			
Hjon			
Sfil			
Ttes			
Hdec			

Algae	Score 0-100
Filamentous	
Calcareous	
Caulerpa	
Caulerpa sp.	
Other (describe)	

Comment

Shoot Count
North
1 2 3 4 5 6 7 8
Count shoots, not blades
If 4 or more squares have "0" shoots, count all shoots in grid.

	Hwri	Hjon	Hdec	Sfil	Ttest
1					
2					
3				Sfil shoots in 1 m^2 grid:	Ttes shoots in 1 m^2 grid:
4					
5					
6					
7					
8					

BB Scale

Score	% Cover
0.1	<< 1
0.5	< 1
1	1 - 5
2	5 - 25
3	25 - 50
4	50 - 75
5	> 75

Figure 3. Above figure shows the pre-printed field ticket on which staff use to record information regarding seagrasses and macro-algae at each sample point.

Figure 4. Image depicts terrestrial representation of 1 m^2 sampling quadrat with 100 10cm x 10cm sub-squares (yellow) placed on seagrass for field evaluation. Number of sub-squares with seagrass present provides Percent Occurrence (PO). Shoot counts are conducted within the eight pink squares as described in the text.

The diver first counts the total number of sub-squares in which neither seagrass nor macro algae (Submerged Aquatic Vegetation or SAV) are present; this number is indicated in the "Bare" entry on the field ticket. Next, the diver counts the total number of squares that contain macro algae, as defined by the broad algal groups listed on each ticket, and records total number in the "Algae" box. The diver then notes in Algae section near bottom of ticket the number of squares occupied by members of each of the broad general algal groups as listed on ticket. For *Caulerpa spp*., divers identifies and records species of this algae group. Unlike other genera of macroalgae, *Caulerpa* spp. are generally easy to visually identify in the field. Once algae are quantified and recorded, diver may gently remove any loose algae, including filamentous benthic mat, to better visualize seagrass assessment (Note: data and discussion regarding macro algae presence and abundance will be addressed in future reports; this report will focus exclusively on the seagrass component of the SAV.)

For seagrass, four metrics are determined within the 1 m^2 quadrat: 1) **seagrass occurrence**; the number of 10 x 10 cm squares in which seagrass is present, 2) **Braun-Blanquet Score**, a visual vegetative cover estimate, 3) **canopy height**, or average blade length for each species, and 4) **shoot counts**, or density of each seagrass species within eight 10 x 10 cm squares at fixed positions within the quadrat (shown in Figure 3). In field studies, "percent occurrence", or sometimes referred to as "percent frequency", is a way to quantify the presence of something within a sampling area. In general terms, this is the number of times an species of interest occurs divided by the total number of possible observations. For this seagrass monitoring program, the percent occurrence is determined for each quadrat in which a diver counts seagrass presence, or "occurrence" in each of the 10 x 10 cm squares. This number is recorded as the "Ttl SG" score. The process is then repeated for each seagrass species observed within the quadrat. The individual species occurrence scores are then written in the respective box on the field ticket. Because each quadrat has 100 squares, the count converts directly to local percent occurrence for that quadrat.

The Braun-Blanquet (BB) score is a vegetative cover estimate widely used in plant studies to convey a visual abundance of vegetation as viewed from above. This subjective visual estimate scale is often used because of the relative ease in the training of its use and the rapid application of its use in the field. This method has been adapted for use for aquatic plant studies including seagrass and is shown below in Table 3 with an abbreviated version of the scale included on each ticket to aid the diver in field scoring determination (see Figure 3). The diver first determines a BB score for total seagrass inclusive of all species. Then the diver determines a BB score for each species present within the 1 m^2 quadrat.

Table 3. The Braun-Blanquet vegetative cover scale is shown. Each reported score is associated with an approximate

Score	Interpretation	% cover
0	Species absent from quadrat	0
0.1	Species present as 1 to 5 shoots	<< 1%
0.5	Species present as only a few shoots (>5)	< 1%
1	Species present as only as several shoots	1 - 5%
2	Species present as only as many shoots	5 - 25%
3	Species present as only as many shoots	25-50%
4	Species present as only as many shoots	50-75%
5	Species present as only as many shoots	> 75%

Because each score represents a range of percent cover, the total seagrass score is not necessarily additive of the individual seagrass species scores. For example, a quadrat with two species of seagrass present can each have a score of 1 and still have a total seagrass score of 1. Conversely, the total seagrass score should not exceed the individual seagrass scores. For example, if each seagrass species had a score of 1, the total seagrass score should not exceed 2.

The third seagrass metric is canopy height reported as average blade length. Within each quadrat, the diver uses fingertips to vertically extend multiple blades of seagrass and using ruler measures the consensus length (cm) from the sediment to the top of the blades. This is repeated at least 3 times from within each quadrat and for each species present. The diver writes the average measurement for each species in the respective box on the field ticket.

The fourth and final seagrass measurement is shoot density. Within each quadrat, eight of the 10 x10cm sub-squares are specially marked for easy identification under water (see Figure 4). Four of the squares are located at each corner of the quadrat, and the remaining four squares are located inward from corners. The diver counts the number of above-ground shoots of each species present in each of the eight squares taking care not to count blades since a seagrass shoot can have multiple blades. As the shoots are counted, their number are written in the appropriate box in the ticket corresponding to the seagrass species and square number. Methods were developed to handle sparse seagrass presence within the quadrat. If any seagrass species occupy four or fewer squares, the seagrass is considered sparse, so the diver counts all shoots within the 1 m^2 quadrat. Since *S. filiforme* and T. *testudinum* are frequently sparse when encountered, all shoots of these two species within the quadrat are counted and recorded.

In addition to collecting seagrass data, a handheld multi-probe water quality instrument is used to collect basic parameters near the center of each seagrass bed. Probes are calibrated prior to field work. Measurements of temperature and salinity are taken just below the surface (30 cm) and near the bottom. For the broad purposes of this report, the top and bottom readings are averaged since the water in this region of the seagrass bed is often shallow (< 0.5 m) and a difference between top and bottom is often negligible if at all.

Calculations

Data from each field ticket is entered into an electronic spreadsheet for data storage and calculations. This report treats each individual quadrat as an independent sub-sample of each seagrass site for each month. Percent occurrence is determined for total seagrass and then repeated for each seagrass species present. Percent occurrence (PO) is calculated by equation shown below.

$$PO = \left(\frac{SG}{Ttl}\right) * 100$$

Where:

SG = the number of 10 x 10 cm squares in which seagrass was present within the quadrat.

*Tt*l = Total number of squares within the 1m^2 quadrat; in this report is 100 squares.

The Braun-Blanquet Vegetative Cover (BBVC) score and seagrass blade length are both reported as a mean of all 1m^2 quadrats for each site during each month.

Shoot density or shoot counts (SC) are normalized to $1m^2$ by equation shown below.

$$\text{Shoot } m^2 = SC_8 * 12.5$$

Where:

SC_8 = Is the numeric sum of seagrass shoots from the eight 10cm x 10cm squares; repeated for each seagrass species.

12.5 = derived from dividing the 100 10cm x 10cm squares inside the quadrat by the 8 squares in which shoot counts were performed.

If all the shoots within the quadrat were counted, that density is used directly with no further calculation. Shoot density is reported as a mean of all quadrats by species for each site during each month.

Map Figures

One of the key features of using GIS as part of the seagrass monitoring is the ability to generate maps to visualize the spatial seagrass location, presence and changes over time. Each random sample point discussed earlier is associated with a unique identification number and a map coordinate. The point can reference the seagrass data spreadsheet using ArcMap's "Join" feature, which can then be used to create maps based on data collected in the field. Data such as Percent Occurrence, BBVC scores, and shoot density can all be visualized on aerial imagery to better understand the spatial relationships and characteristics of the seagrass beds. Maps displaying such key characteristics are included in the appendix of this report.

Results

Percent Occurrence

Seagrass percent occurrence through the 2021 sampling season showed overall continued decline throughout the LRE (Figure 5). This represents a 13% rate of decline of total seagrass occurrence compared to 2020, which was driven by the concurrent decline of all three dominant species in the LRE: *H. wrightii*, *H. johnsonii*, and *S. filiforme*. The seagrass *H. wrightii* continues to be the most widely

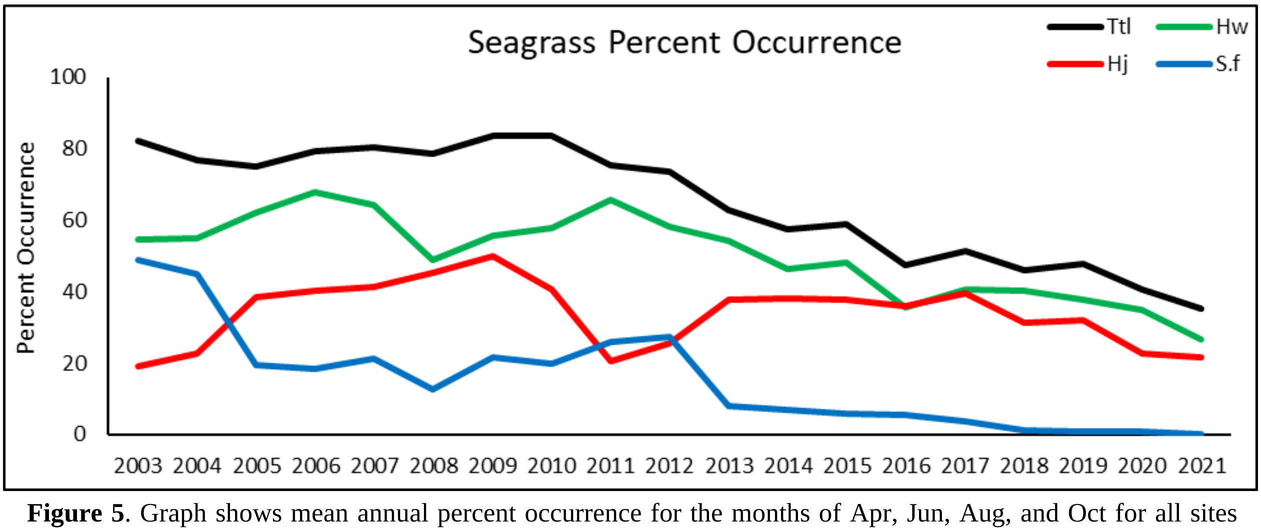


Figure 5. Graph shows mean annual percent occurrence for the months of Apr, Jun, Aug, and Oct for all sites within the LRE; The HS site is excluded from the figure. Data shown are for total (Ttl) seagrass (black line), and the three primary species that historically comprised the seagrass beds of the LRE including *H. wrightii* (green line), *H. johnsonii* (red line), and *S. filiforme* (blue line). While *H. decipiens* and *T. testudinum* have occurred, neither species currently appears consistently during field monitoring.

distributed seagrass, found at all but the NWF site, as well as the species with the overall highest percent occurrence through 2021 at 26.6%. However, this was still a new benchmark low for this species. *H. wrightii* also experienced the sharpest decline among the seagrasses since the previous year (2020) which had an average of 35.1% occurrence for an overall decline of 32% between 2020 and 2021. The diminutive *H. johnsonii* also experienced declines across the estuary, however the recent decline of this seagrass appears to be slowing somewhat from 22.7% in 2020 to 21.5% in 2021 for a rate of only 5% decline. Perhaps the most striking decline was seen with *S. filiforme* which has experienced steady decline following the 2012 season when percent occurrence dropped from 27% to 8%. After the 2021 monitoring *S. filiforme* was encountered only at the North Bay monitoring site and averaged only 0.3%. This is a 57% decline from the 0.7% occurrence observed from the previous year. *S. filiforme* has disappeared from the Sand Bar site and was last documented there in 2018.

The one bright spot among the LRE seagrasses was the relative abundance of *H. decipiens* (not shown in Figure 5). This seagrass has historically only been encountered on rare occasions, but during 2021 had a mean occurrence of 1.7%; a substantial increase compared to 2020 when this seagrass had a near 0% occurrence. Incidentally, the highest overall percent occurrence for this species is 2.1% recorded in 2019.

Despite overall seagrass declines, there is optimism when the short-term trends are examined. While seagrass declines in percent occurrence were steadily declining from month to month in 2020, in 2021 LRD staff observed an increase in percent occurrence through the monitoring season. Among the seagrasses in the LRE, *H. wrightii* appeared to show an overall increasing percent occurrence during 2021 compared to the trend during 2020 (Figure 6 a-d). This species, because of its prevalence across the estuary, is driving the overall increasing trend of total seagrass during 2021. While *H. johnsonii* is not as locally prevalent as *H. wrightii*, it is still found at four of the five sampling sites in the LRE; seagrass was absent from the NWF site where it once was abundant. Examination of short-term trends show that overall *H. johnsonii* remained relatively constant during 2021. This contrasts with the prior year in 2020 when the species showed a continuous decline between April and October. It should be noted, however, that this species has demonstrated rapid and substantial changes in abundance in response to season and tends to peak earlier in the year compared to other seagrass species. During both 2020 and 2021, April showed *H. johnsonii* at higher overall percent occurrence compared to *H. wrightii*, but during both years the occurrence of *H. johnsonii* had decreased substantially below *H. wrightii* by season's end in October.

The seagrass *H. decipiens*, a close relative of and similar in appearance to *H. johnsonii*, was present at both the North Bay and Inlet sites in 2021 (Figure 6 a,d). This seagrass, while far less abundant and widespread than the other species, shares the characteristic with *H. johnsonii* of being highly dynamic, with rapid leaf-pair turnover accompanied with horizontal rhizome expansion. The mean percent occurrence through 2021 was only 1.7%, but at the month-to-month scale showed an increasing trend from 0.5% in April to 2.1%. While this species is not uncommon at the North Bay site, especially in recent years, it is seldom observed at the Inlet site and in fact, prior to 2021 was only encountered once in August 2019 at only 0.4%.

Braun-Blanquet Vegetative Cover

The Braun-Blanquet scores closely resemble the trend seen in the percent occurrence (Figure 7 a-d). This would indicate that what field researchers are seeing reflect the objective data. Most notably field staff noticed an increasing trend in the visible amount of seagrass, especially *H. wrightii*, through 2021 whereas the trend was sharply declining during 2020. However, it should be noted that the BB score represents a range of visible cover and while the mean scores show increasing and decreasing trend, the mean of both years often falls within the same range.

Shoot Density

The seagrass shoot density again supports other field measures in that seagrass appears to have increased through 2021 compared to 2020 during which seagrasses were declining (Figure 8 a-d). The seagrass *H. wrightii* had experienced increased density at all sites between April and June 2020 before sharply decreasing by October. However, density of H. wrightii showed overall increasing density through the summer months before showing a slight decline between August and October.

The shoot density of *H. johnsonii* during 2021 was mixed and depended on the bed. For example, between April and August, *H. johnsonii* shoot density decreased at both NB and INL sites (Figure 8 a,d) before showing a late season increase between August and October. However, at the SB site *H. johnsonii* increased initially between April and June before decreasing through the rest of the year to October. *H. johnsonii* was absent from the PP site throughout 2021. This contrasts sharply with observations from 2020 when *H. johnsonii* shoot density declined sharply from April through October at all monitoring sites.

Hobe Sound Seagrass Site

For the first time since 2015 staff revisited the Hobe Sounds site using current methodology to document and better gauge the losses. Monitoring at the site in 2021 found only two seagrass species; *H. wrightii* and *H. decipiens*. The total seagrass percent occurrence was 7.3% with *H. wrightii* percent occurrence of 2.0% while *H. decipiens* was a bit higher at 5.3%. Seagrass density was also sparse with an average of 5 shoots m^2 of H. wrightii while H. decipiens was slightly higher at 24 shoots m^2. The tallest canopy height was that of H. wrightii at 9 cm while the much smaller H. decipiens had an average canopy of 3 cm. Seagrasses were visually sparse as well with an average BB score for total seagrass of only 0.3, indicating far less than 1% average vegetative cover. The individual scores for *H. wrightii* and *H. decipiens* was 0.1 and 0.2 respectively; a score of 0.1 indicates fewer than five shoots m^2.

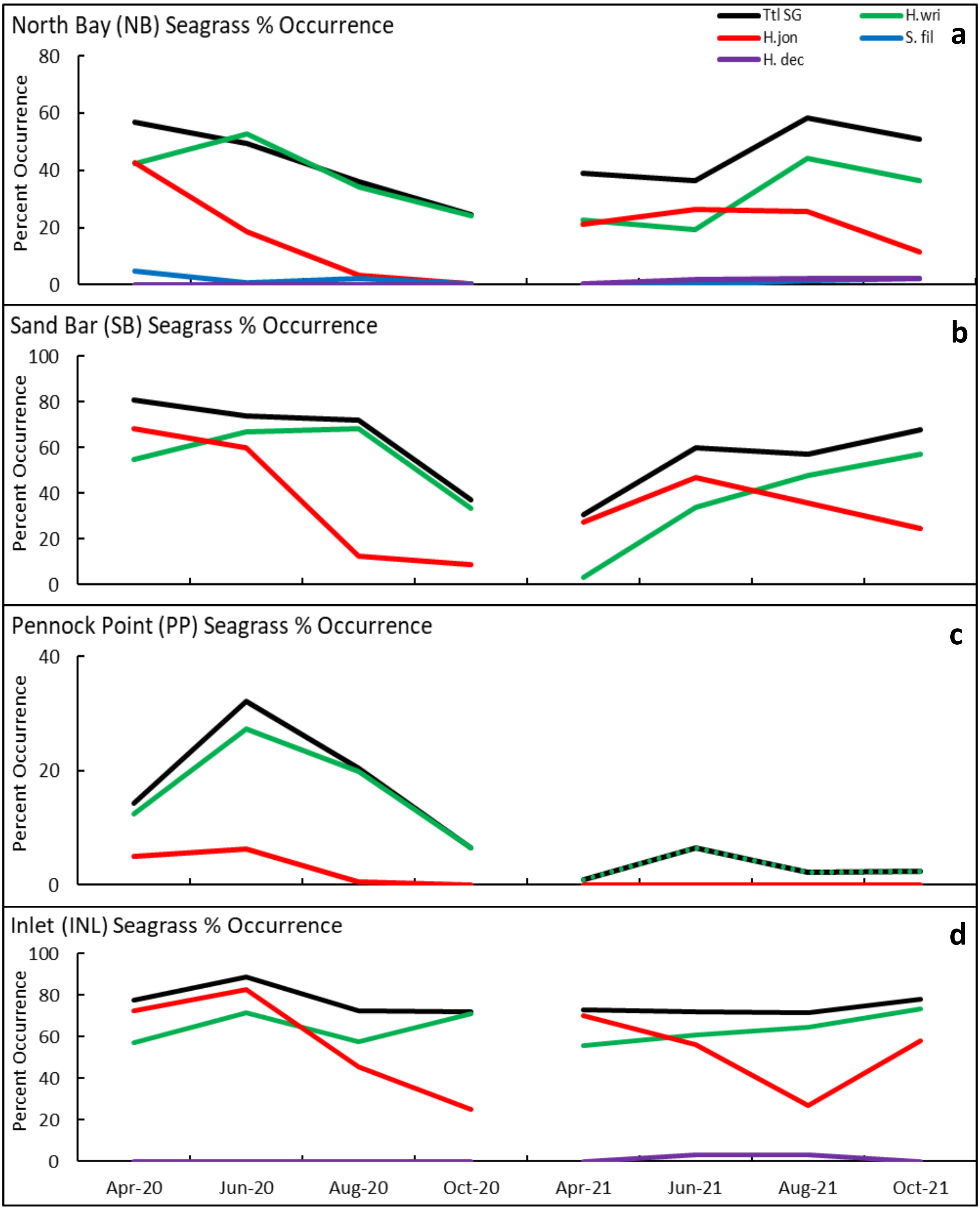


Figure 6 a-d. Graph shows mean percent occurrence across all sites within the LRE for the months of Apr, Jun, Aug, and Oct during 2020 and 2021; The HS site is excluded from the figure. Data shown are for total seagrass (black line), and the three primary species that historically comprised the seagrass beds of the LRE including H. wrightii (green line), H. johnsonii (red line), and S. filiforme (blue line). This graph includes the presence of H. decipiens (purple line).

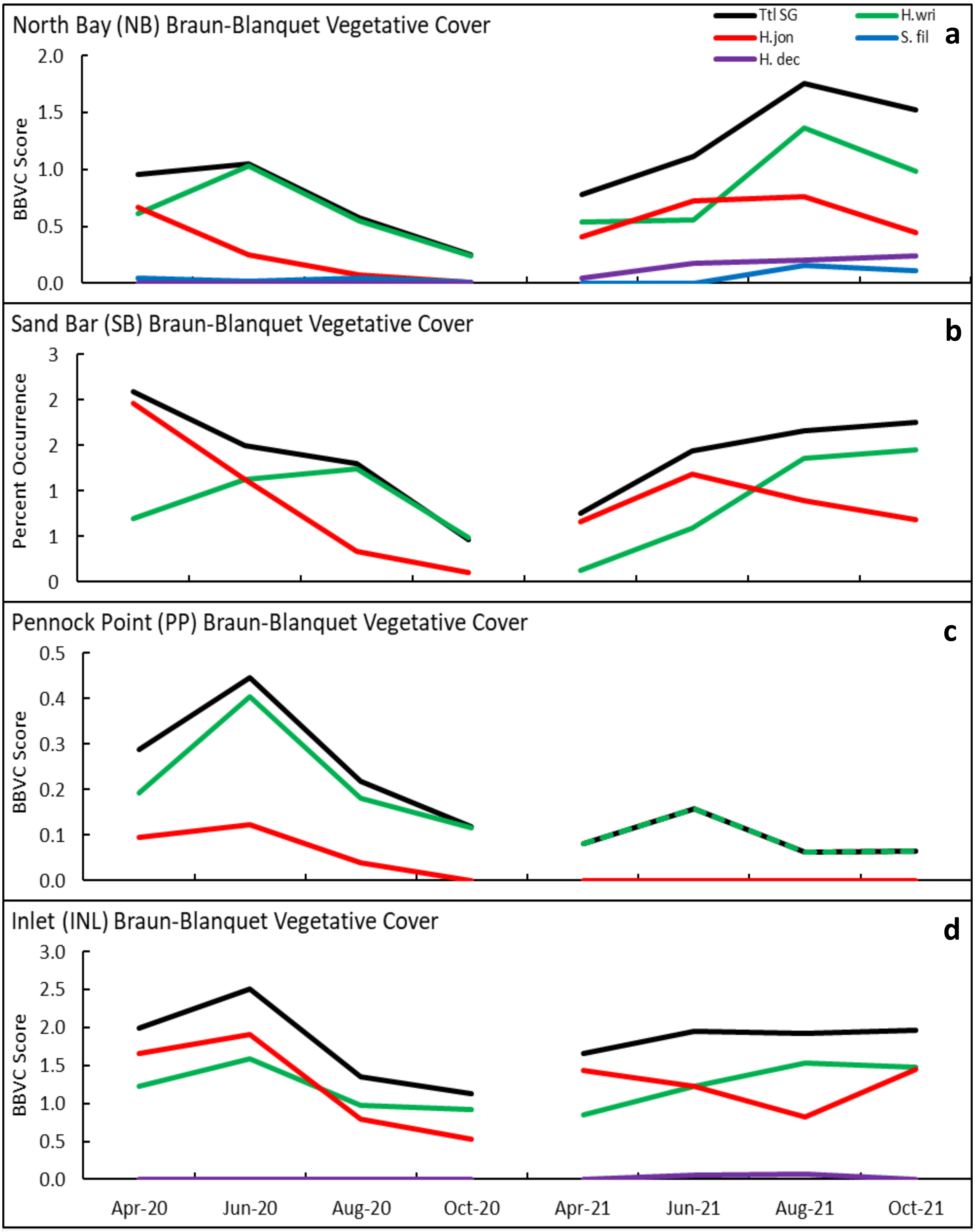


Figure 7 a-d. Graph shows mean Braun-Banquet Vegetative Cover score across all sites within the LRE for the months of Apr, Jun, Aug, and Oct during 2020 and 2021; The NWF site and HS site are excluded from the figure. Data shown are for total seagrass (black line), and the three primary species that historically comprised the seagrass beds of the LRE including H. wrightii (green line), H. johnsonii (red line), and S. filiforme (blue line). This graph includes the presence of H. decipiens (purple line).

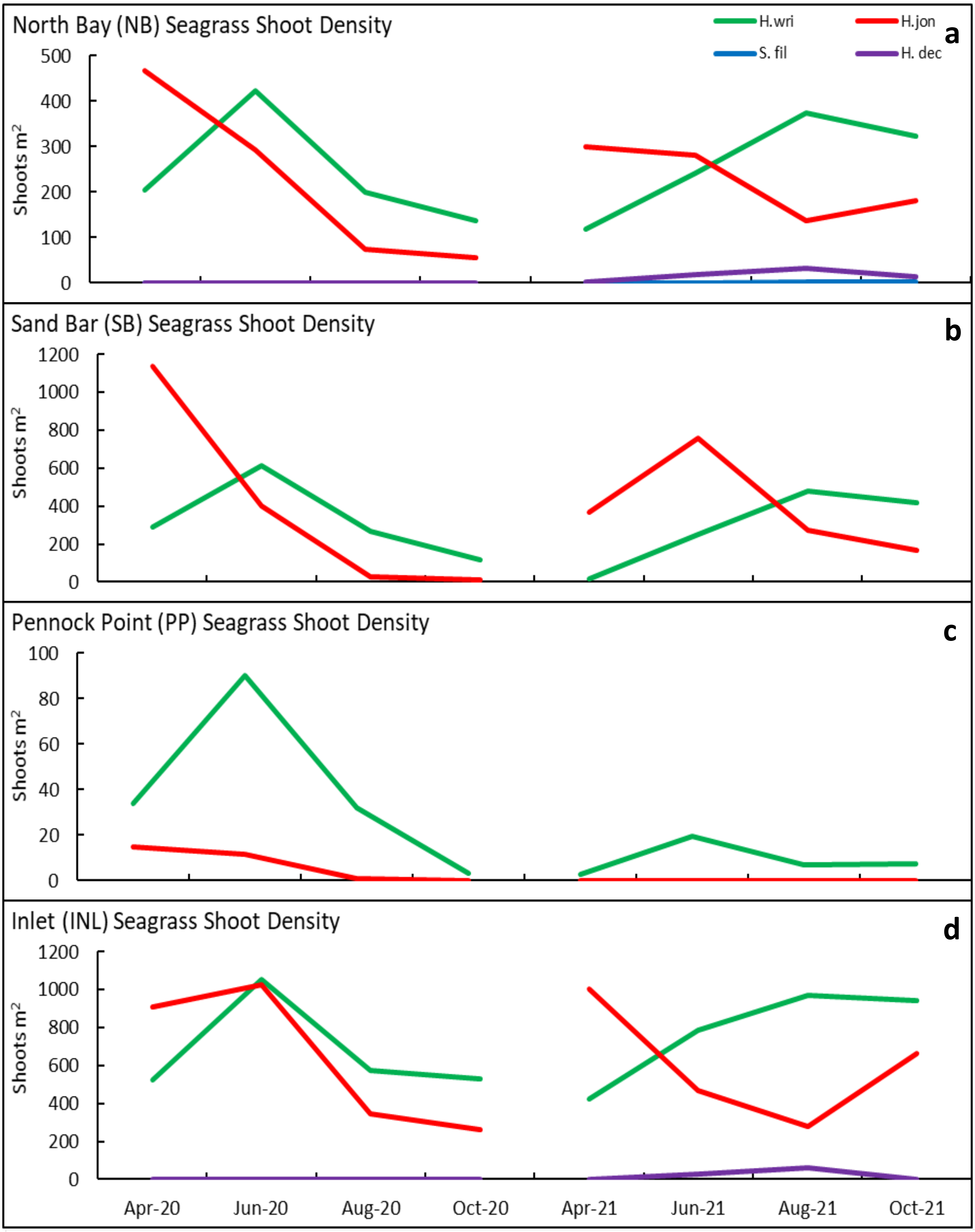


Figure 8 a-d. Above graphs show shoot density as mean number of shoots m^2 for each seagrass species present within each monitoring site during the months of Apr, Jun, Aug, and Oct for both 2020 and 2021. Data include H. wrightii (green line), H. johnsonii (red line), and S. filiforme (blue line), and H. decipiens (purple line). The Hobe Sound and Northwest Fork sites are excluded from this figure due to low abundance and/or absence of seagrass.

Rainfall & Water Quality

During 2021, the LRE benefited from average rainfall with no substantial tropical storms bringing acute rainfall to the region. Annual rainfall during 2021 was 58.4” with each month of the year ending with below average rainfall. This contrasts with recent years which experienced higher than average rainfall since the drought during 2006-07 (Figure 9). Annual rainfall peaked in 2020 when 78.4” of rainfall was recorded. As such, with decreased rainfall in 2021 the seagrasses were subjected to favorable temperatures and salinity throughout the growing season. Figures 10 a & b below show temperature and salinity for each month and at each monitoring site during 2021 monitoring season (blue circles). Overall, temperatures and salinity were both mostly higher than average through the monitoring season at each site. Throughout the season, salinity remained well above average at each site. There were a couple of exceptions, however. August is historically one of the months during the wet season that experiences the highest rainfall totals. By August 2021, the region had been experiencing recent rainfall and thus salinities measured in August were lower than average.

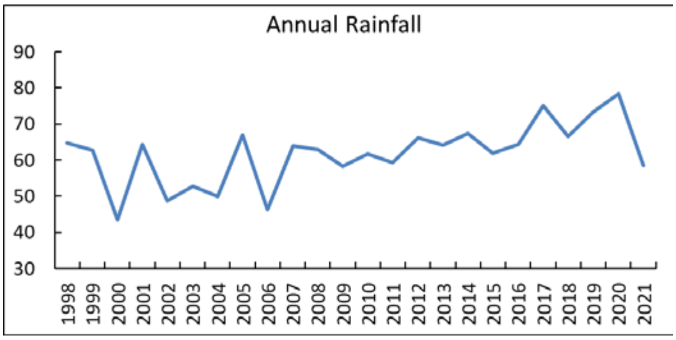


Figure 9. Time-series graph showing annual rainfall totals across the Loxahatchee River watershed. Rainfall data sourced from NEXRAD radar which calculates rainfall within a network of 248 individual 2km x 2km cells that cover the watershed boundaries.

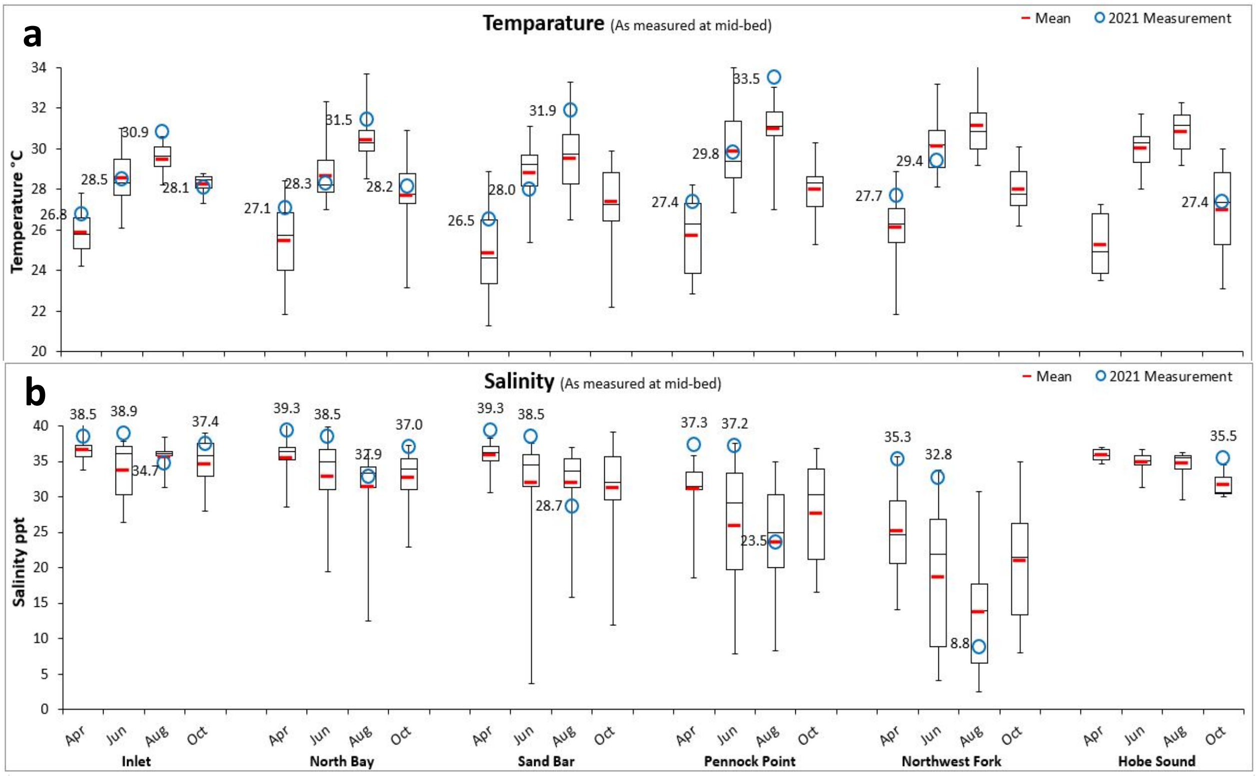


Figure 10 a,b. Box and whisker plots above show temperature and salinity for each monitoring site as measured near mid-bed. Boxes indicate interquartile range of all historical measurements taken for each month at each site. Whiskers indicate historical range of minimum and maximum measurements for each month at each site. The mean for historical range of measurements is indicated by red dash. Blue circles indicate measurements taken during 2021; actual measurement is indicated next to each blue circle. Missing circles are due to malfunctioning instrument; HS only measured in October.

Discussion and Conclusion

Since monitoring began in 2003, seagrasses in the Loxahatchee River Estuary have sustained substantial losses. While seagrass continues to persist at the original three seagrass beds, namely North Bay, Sand Bar, and Pennock Point, the composition, abundance, and community structure have been significantly altered during the 18 years of continuous monitoring. The seagrass *S. filiforme*, once abundant at both North Bay and Sand Bar sites have been in near constant decline since the monitoring program's inception in 2003 and have largely disappeared over the years. This species was last encountered at the Sand Bar site in April 2018 within a solitary 1 m^2 quadrat for a monthly percent occurrence of only 0.4%. This contrast sharply with a peak occurrence of over 36% in August 2004. This species was once the dominant seagrass at the North Bay site when percent occurrence approached 70%. However, in recent years occurrence of this seagrass has fallen to as low as 1% and is now found as isolated sparse patches comprised of only a few shoots. Most recently by late 2021, *S. filiforme* occurrence had increased ever so slightly to just over 2%. Oddly, at North Bay, Johnson's seagrass expressed an opposite trend by increasing occurrence over the years. As *S. filiforme* declined in abundance and became increasingly sparse over time, the diminutive *H. johnsonii* had expanded into regions once occupied by *S. filiforme*. The seagrass *H. wrightii* continues to be the most stable seagrass in terms of abundance and presence throughout the LRE. This seagrass is now the dominant seagrass in terms of presence at all the sites in the bimonthly monitoring program. While this seagrass has experienced substantial loss like the other seagrass species, it appears to be the most resilient seagrass in the LRE and the most able to recover given favorable conditions.

The seagrass *H. johnsonii* continues to be the most dynamic of the seagrasses regarding presence with wildly changing percent occurrence and density not only from year to year but also from month to month. This is mostly attributed to is distinct seasonal response which tends to occur early in the year than most other seagrasses and its ability for rapid horizontal expansion. Like other seagrasses in the LRE, *H. johnsoni*i has experienced substantial losses over the years at most of the monitoring sites. The exception to this trend is the Inlet site where percent occurrence of *H. johnsonii* continues to oscillate between 25% to 85%.

The Northwest Fork seagrass site is currently the only site in the monitoring program to experience a complete loss of seagrass. When monitoring at this site commenced in 2007, total seagrass presence was about 60% with approximately equal abundance of *H. wrightii* and *H. johnsonii*; though these abundances varied considerably at times. Following the 2012 season, both seagrass species experienced sharp declines. By August 2018, *H. johnsonii* had disappeared completely followed *by H. wrightii* by April 2020. No seagrass has been observed at this site even despite a more thorough visual search outside the quadrats.

Perhaps most alarming of all observations made during the 2021 seagrass season was the near complete absence of seagrass from the Hobe Sound site. The HS site was added to the monitoring program as a reference site because it was considered outside the influence of factors that impact seagrasses in the estuarine conditions. Salinity, water clarity, wave energy, foot traffic, boat wake, and runoff all were all deemed non-factors at this site. Despite this, seagrasses had mostly disappeared from this site by 2021. The HS site once boasted a total seagrass percent occurrence of about 90% through 2013 and was dominated by *S. filiforme* and *H. wrightii* with average percent occurrence of about 80% and 36% respectively. This site also had small isolated patches of *T. testudinum* as well as small patches of *H. johnsonii*, though its presence was mostly limited to the offshore outer edge of the seagrass bed. Between 2013 and 2015, when continuous monitoring at this site ended, seagrass declines were already observed. For example, average total seagrass percent occurrence had declined from 91% in August 2013 to 60% by February 2014; the lowest average for any month up to that time. During subsequent monitoring, percent occurrence would only get to 76% and by October 2021 had fallen all the way to 7.3%. The largest proportion of this loss was driven by the loss of *S. filiforme* which through 2013 had an average percent occurrence of 79% with a minimum of 67%. Since 2014, the highest percent occurrence for S. filiforme was 66% in August 2015. During our single day monitoring in October 2021, the only seagrasses present were *H. wrightii* and *H. decipiens* in small, sparse, isolated patches. However, some staff reported seeing some *S. filiforme*, *H. johnson's*, and *H. wrightii* outside of sample quadrats. The sudden and substantial loss of seagrass at this once productive site remain unclear. However visual observations seem to suggests that over grazing by the west Indian manatee as a potential cause. Indeed, the recent collapse of seagrass communities within the manatees range, especially in the northern and middle reaches of the IRL, have led to increased sightings of manatees to the south. It should be noted that this is speculative and is offered here as possible explanation for seagrass decline at this site.

As of this writing, the cause attributable to LRE seagrass decline remain unknown with any degree of certainty. Many of the stressors that commonly impact coastal shallow-water seagrass communities are present in the LRE including freshwater river flows and stormwater discharges, high volume of boat traffic and associated wake energy, and shoreline construction and navigational waterway dredging. However, without targeted examination, the cause remains undetermined. What the monitoring data does reveal is that major step-wise declines in seagrass presence, especially that of *S. filiforme*, often followed major storm events. For example, following the back-to-back Hurricanes Frances and Jeanne in September 2004, seagrasses experienced major declines which were mostly attributable to the prolonged effect of low and widely variable salinity measured in the estuary in the weeks following the storms (Ridler et al, 2006). The following year, the estuary experienced the effects of Hurricane Wilma which passed directly over the LRE during October 2005. The seagrass *S. filiforme* was especially impacted by these storms as this seagrass declined sharply and never quite recovered even through 2021 (seen in Figure 5). *T. testudinum*, though never a substantial component of the LRE seagrass community, was also severely impacted and has since disappeared from the Sand Bar site and only has an occasional appearance at North Bay; the two sites to historically have this species present. The seagrass *H. engalmannii*, another close relative to *H. johnsonii*, completely disappeared from the North Bay site, the only site where it was ever encountered, and has not been seen since the storms. The other storm to greatly impact the LRE seagrass community was Tropical Storm Isaac which moved through the area in August 2012. This storm was also characterized by intense rainfall and regional flooding which resulted in prolonged freshwater discharges thus affecting salinity. The effects of this storm were felt especially by the more upstream sites of Pennock Point and Northwest Fork. While the Pennock Point site recovered somewhat following the storm, the effects at the Northwest Fork site proved to be deleterious as the seagrass decline continued until complete absence occurred by 2020. Acute intense storms do not appear to be the only meteorological events that affect seagrass presence. In recent years, the Loxahatchee River watershed and surrounding regions have been subjected to much higher than average rainfall and experienced abnormal wet and dry season rainfall patterns (see Figure 9). For example, the long term average annual rainfall for the region is about 62". However, the last year with rainfall below this average was during 2011 with 59.2". Annual rainfall has been on an increasing trend ever since with an average of 68” and a peak in 2020 of 78.4”. It was not until 2021 that rainfall total once again fell below the historic average ending the year at 58.4”.

The seagrasses have appeared to respond to the rainfall and resulting freshwater flows entering the estuary. As annual rainfall increased, there was a corresponding decline in seagrass presence at all but the most downstream site at the Jupiter Inlet. However, following a “normal” rainfall year, there was an apparent increase in seagrass presence as the season progressed. While it is acknowledged that correlation doesn’t mean causation, it is encouraging to see seagrass presence on the increase. It is reasonable to hope that following a decade-long wet period that perhaps a return to an average rainfall period will allow seagrasses a chance to stabilize and even show an overall increased presence.

Seagrasses continue to persist in the Loxahatchee River Estuary. Despite significant losses in recent years, the 2021 monitoring season provided a small bit of hope that seagrasses in the estuary can recover. Staff at the Loxahatchee River District will continue to monitor seagrasses in the LRE into the future, including seagrasses at the Hobe Sound site. This report reflects the major observations of the seagrass community and marks the first of what is hoped to be an annual status report.

For more information and regularly updated interactive databases regarding seagrass work conducted in the Loxahatchee River Estuary, please visit our website at: loxahatcheeriver.org/river/seagrass

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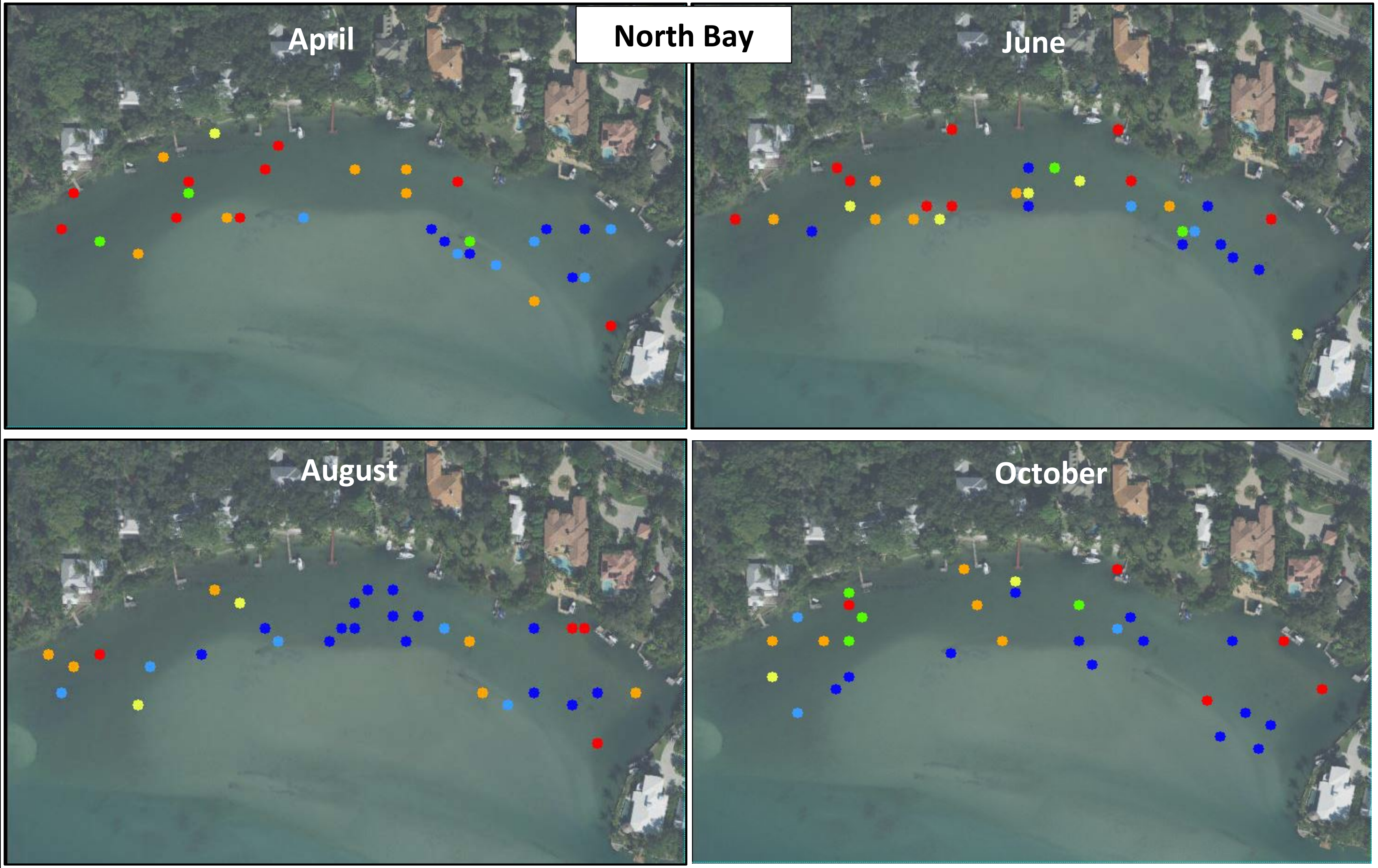


Total Seagrass % Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

Panels above indicate percent occurrence of Total Seagrass presence at the North Bay seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range of total seagrass presence for each point.

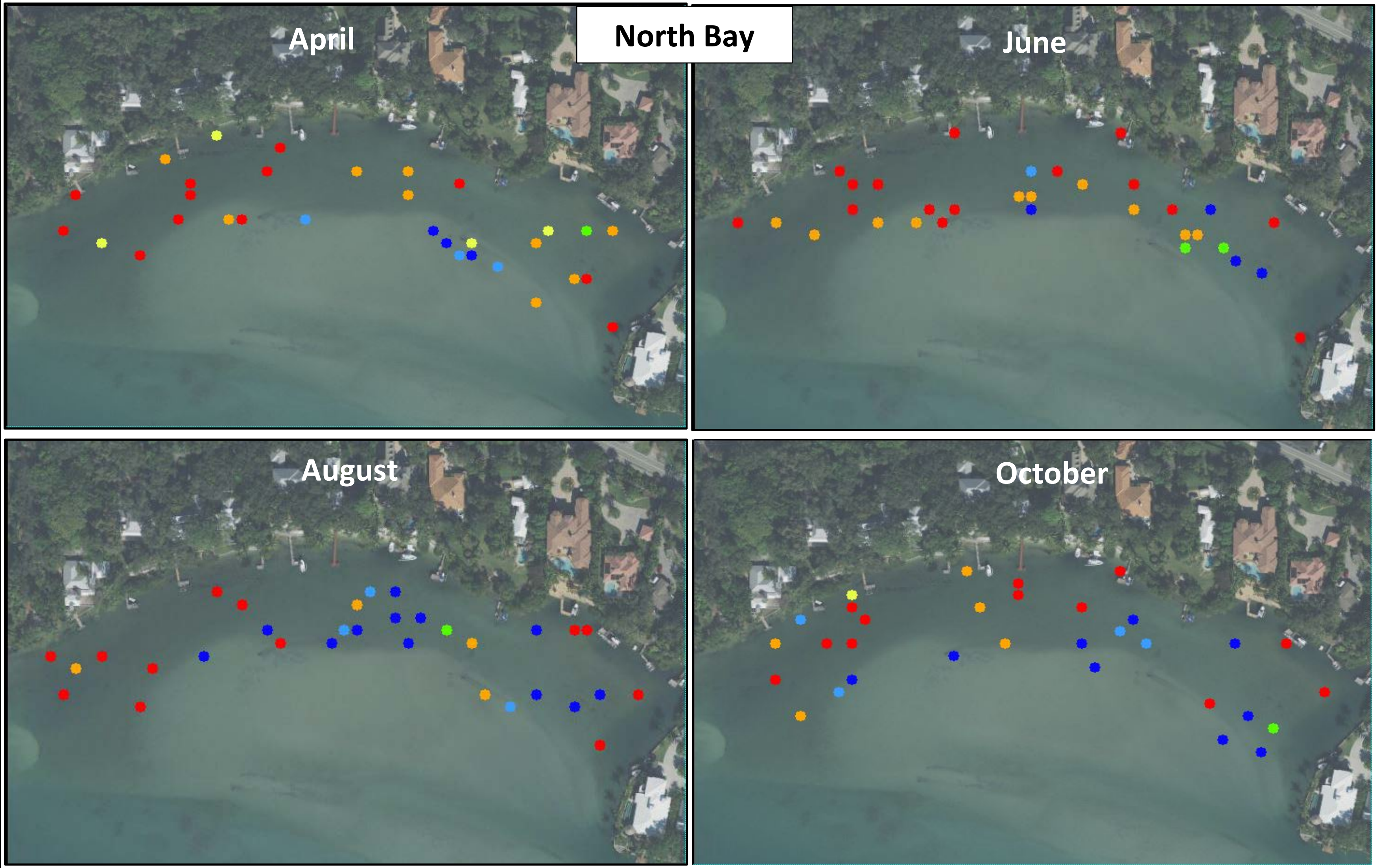
Meters

0 50 100 150

Prepared By: Jerry Metz

center: 26° 57.044' N, 80° 5.650'

N



H. Wrightii % Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

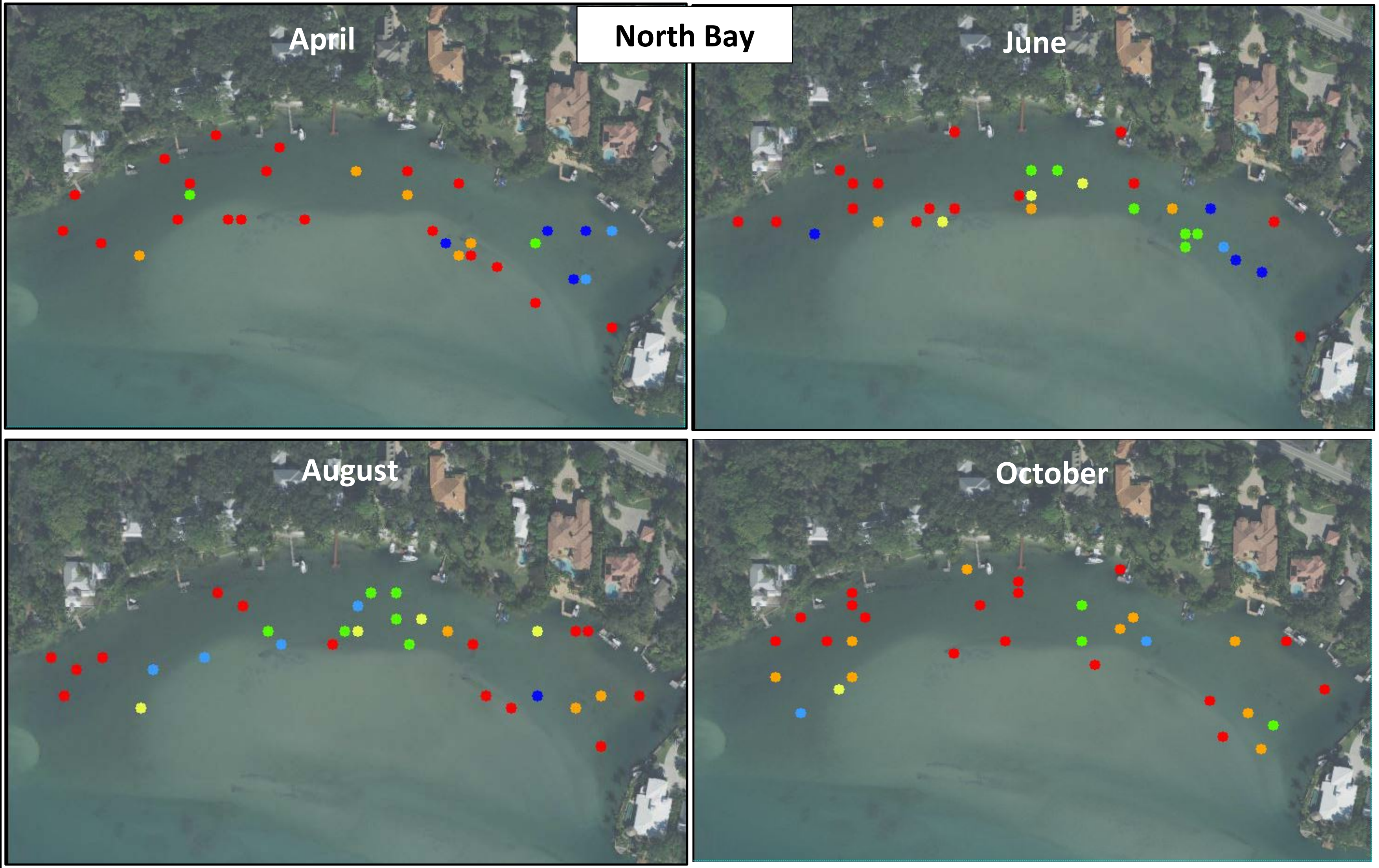
Panels above indicate percent occurrence of *Halodule wrightii* ("shoal grass") at the North Bay seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 57.044' N, 80° 5.650'

N



H. johnsonii
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

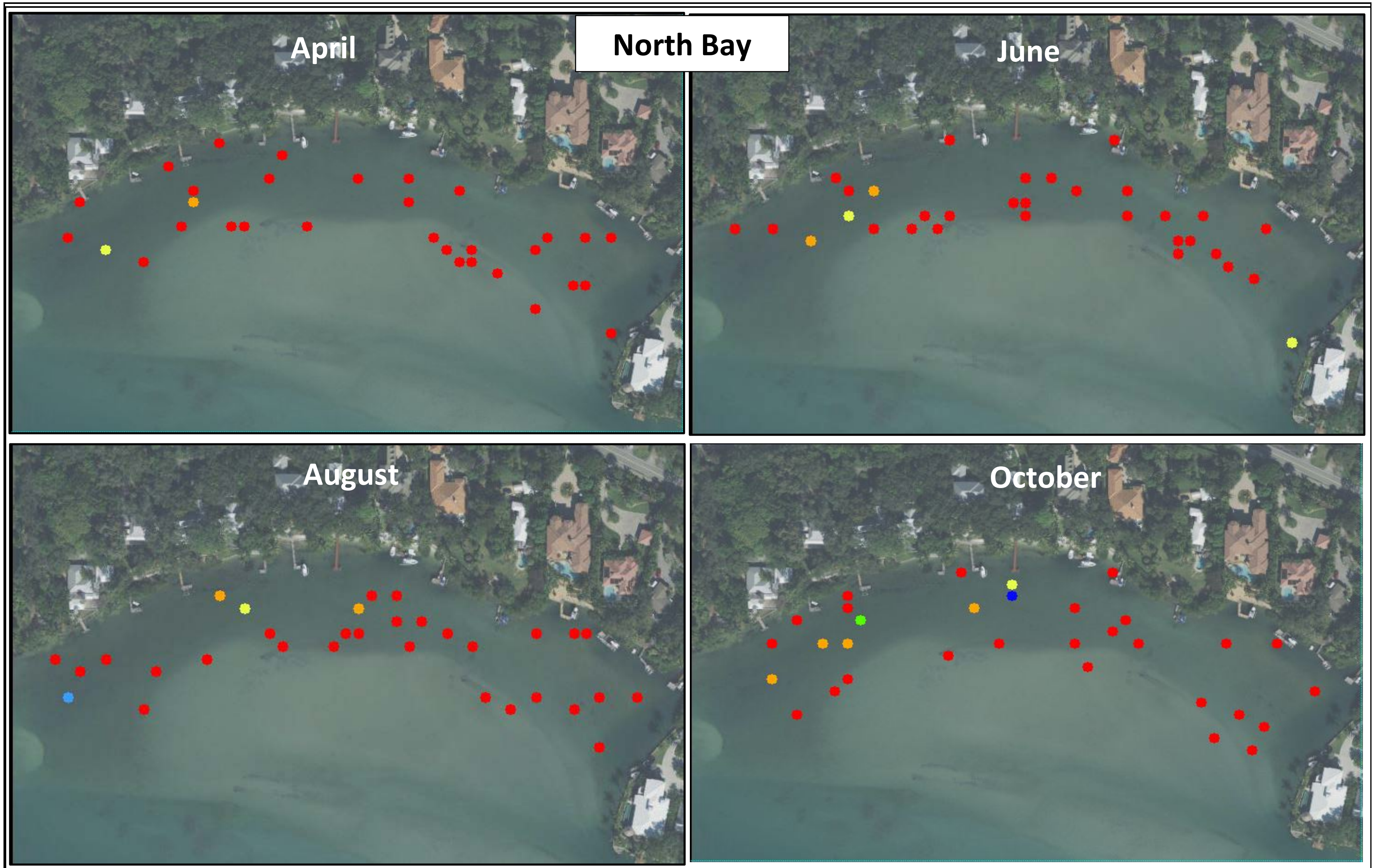
Panels above indicate percent occurrence of *Halophila johnsonii* ("Johnson's grass") at the North Bay seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 57.044′ N, 80° 5.650′

N



H. decipiens
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

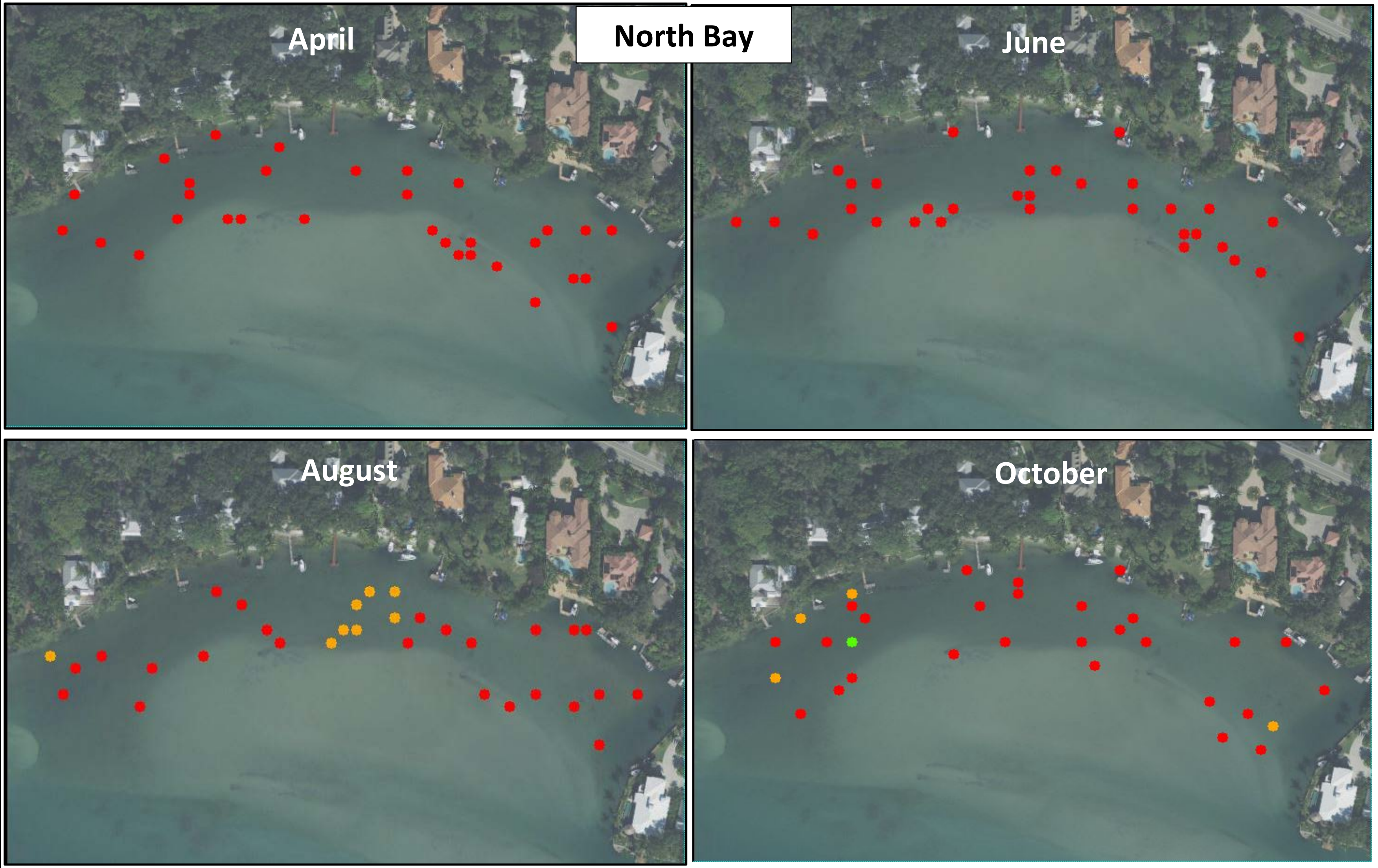
Panels above indicate percent occurrence of *Halophila decipiens* ("paddle grass") at the North Bay seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 57.044' N, 80° 5.650'

N



S. filiforme
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

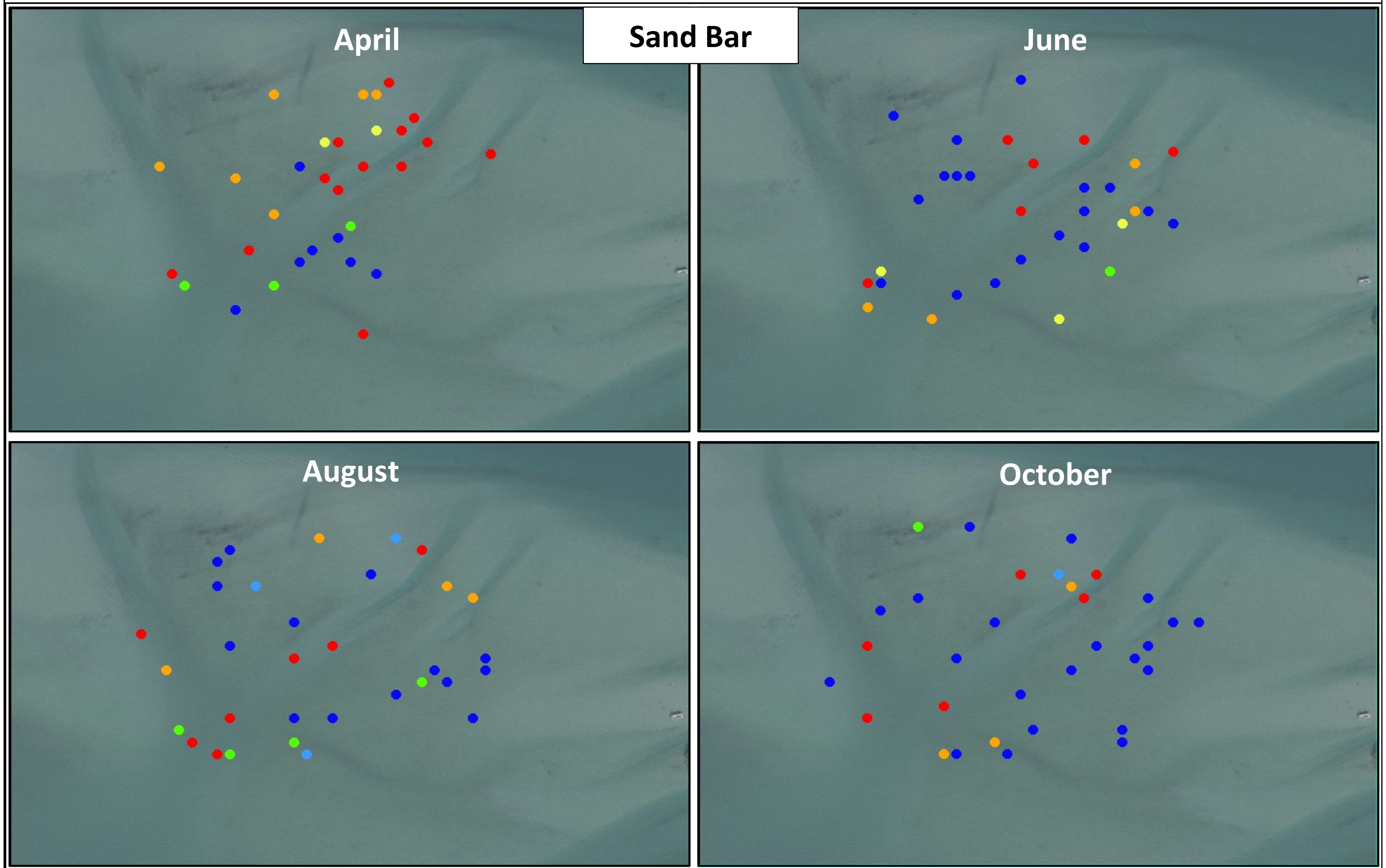
Panels above indicate percent occurrence of *Syringodium filiforme* ("manatee grass") at the North Bay seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 57.044' N, 80° 5.650'

N



Total Seagrass % Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

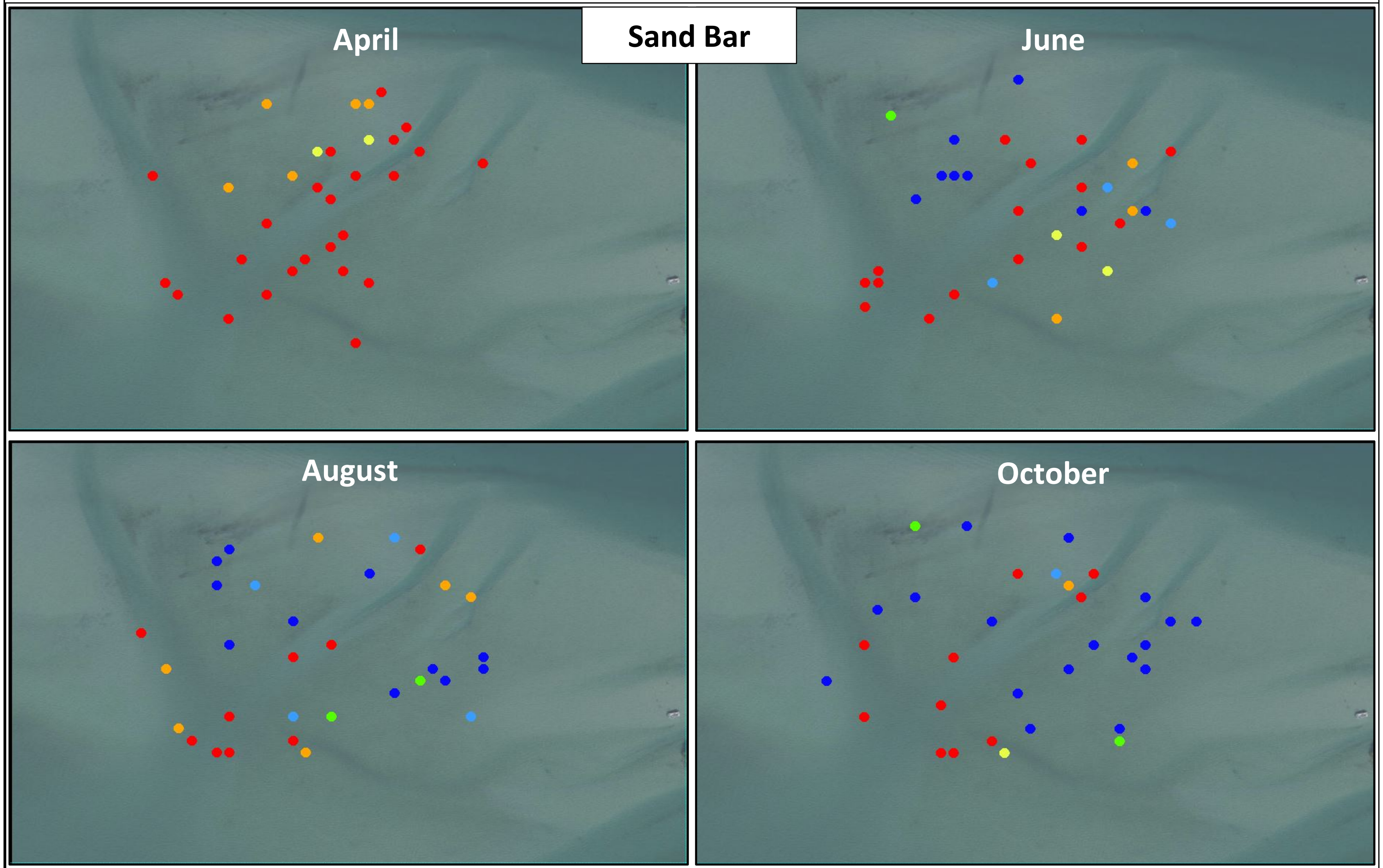
Panels above indicate percent occurrence of Total Seagrass presence at the Sand Bar seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range of total seagrass presence for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 56.899' N, 80° 5.947' W

N



H. wrightii
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

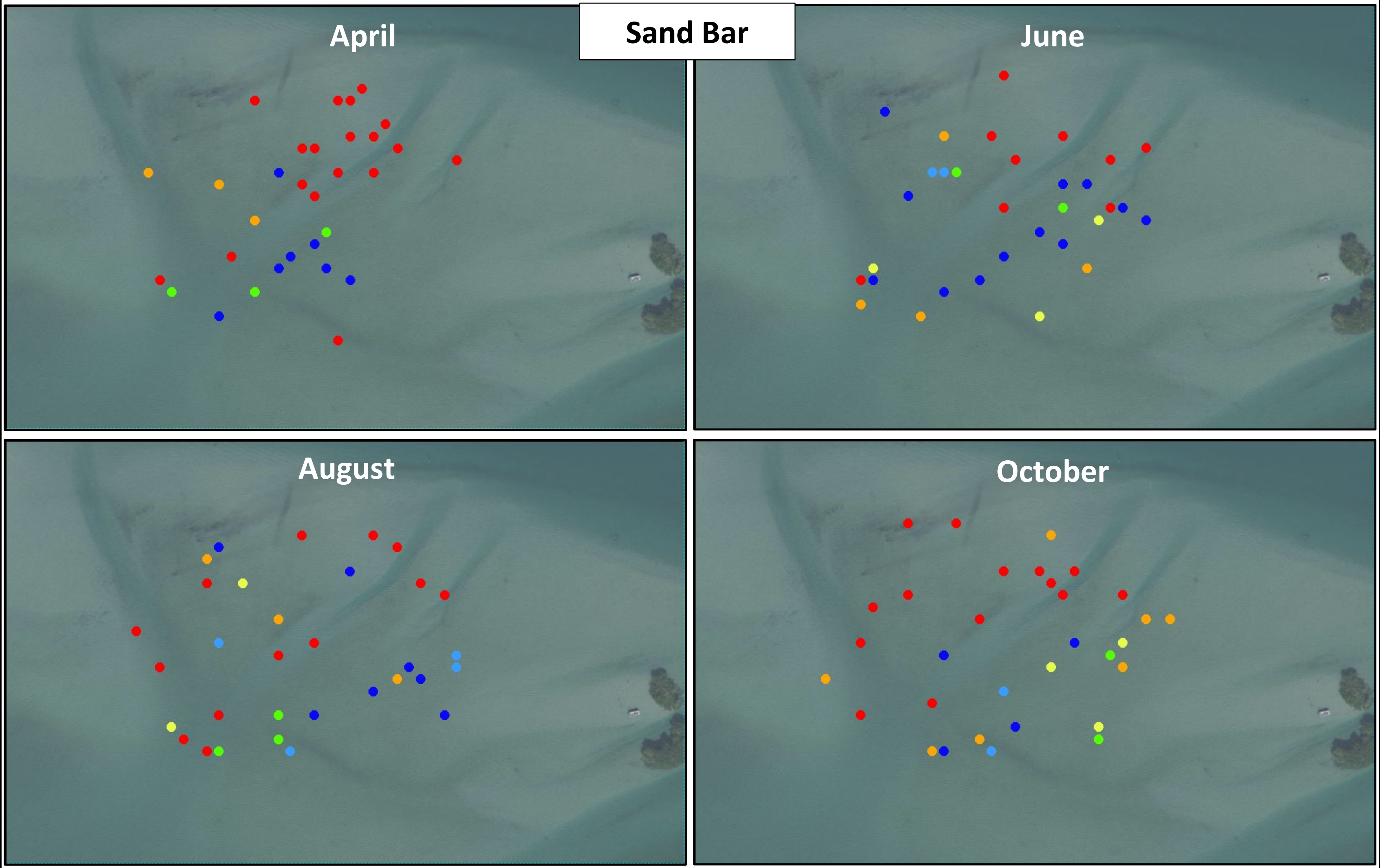
Panels above indicate percent occurrence of *Halodule wrightii* ("shoal grass") at the Sand Bar seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 56.899' N, 80° 5.947' W

N



H. johnsonii
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

Panels above indicate percent occurrence of *Halophila johnsonii* (“Johnson’s grass”) at the Sand Bar seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

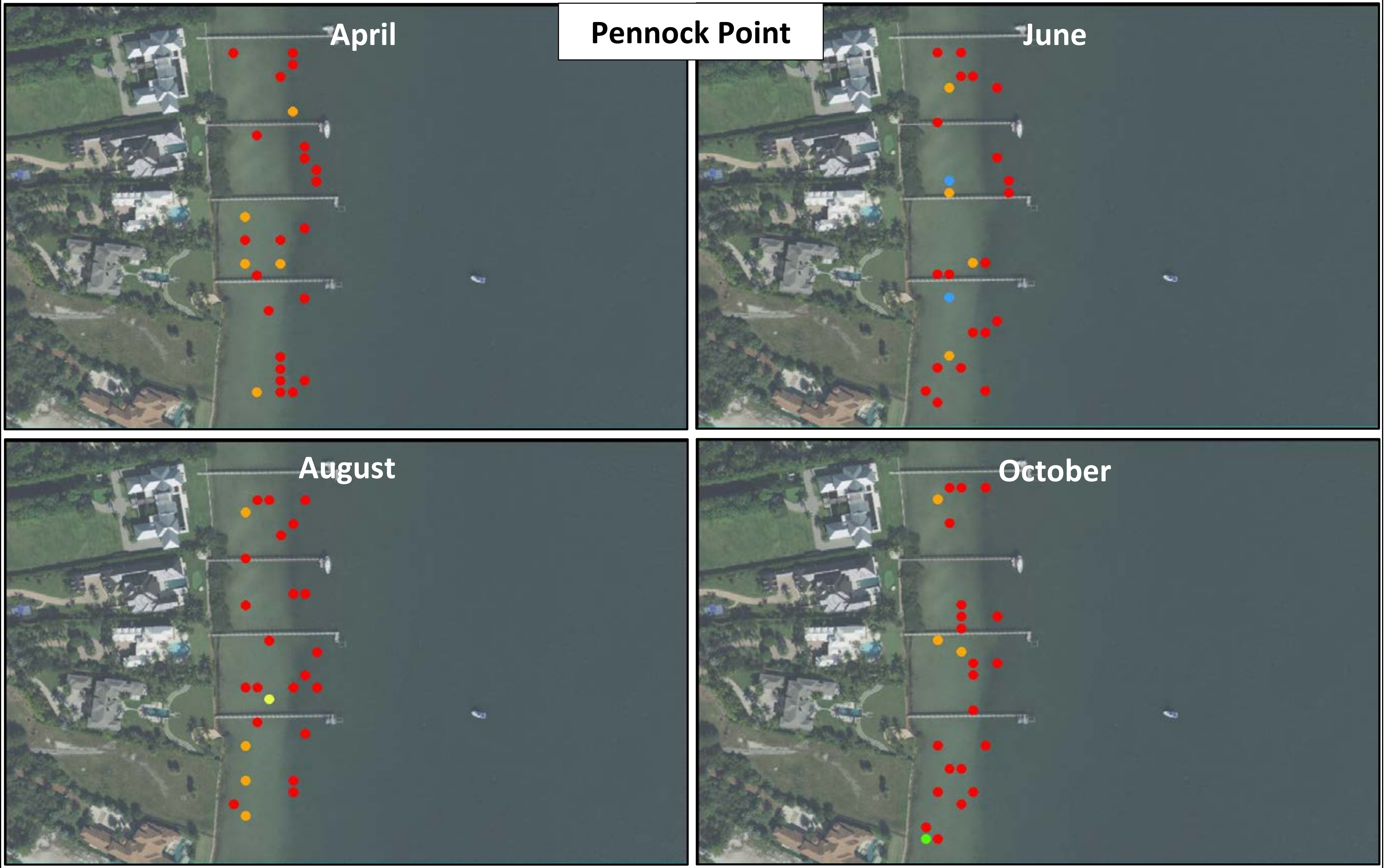
Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 56.899’ N, 80° 5.947’ W

N

LOXAHATCHEE RIVER ENVIRONMENTAL CONTROL DISTRICT · 1971 ·



Total Seagrass % Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

Panels above indicate percent occurrence of Total Seagrass presence at the Pennock Point seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range of total seagrass presence for each point. *Halodule wrightii* ("shoal grass") was the only species present.

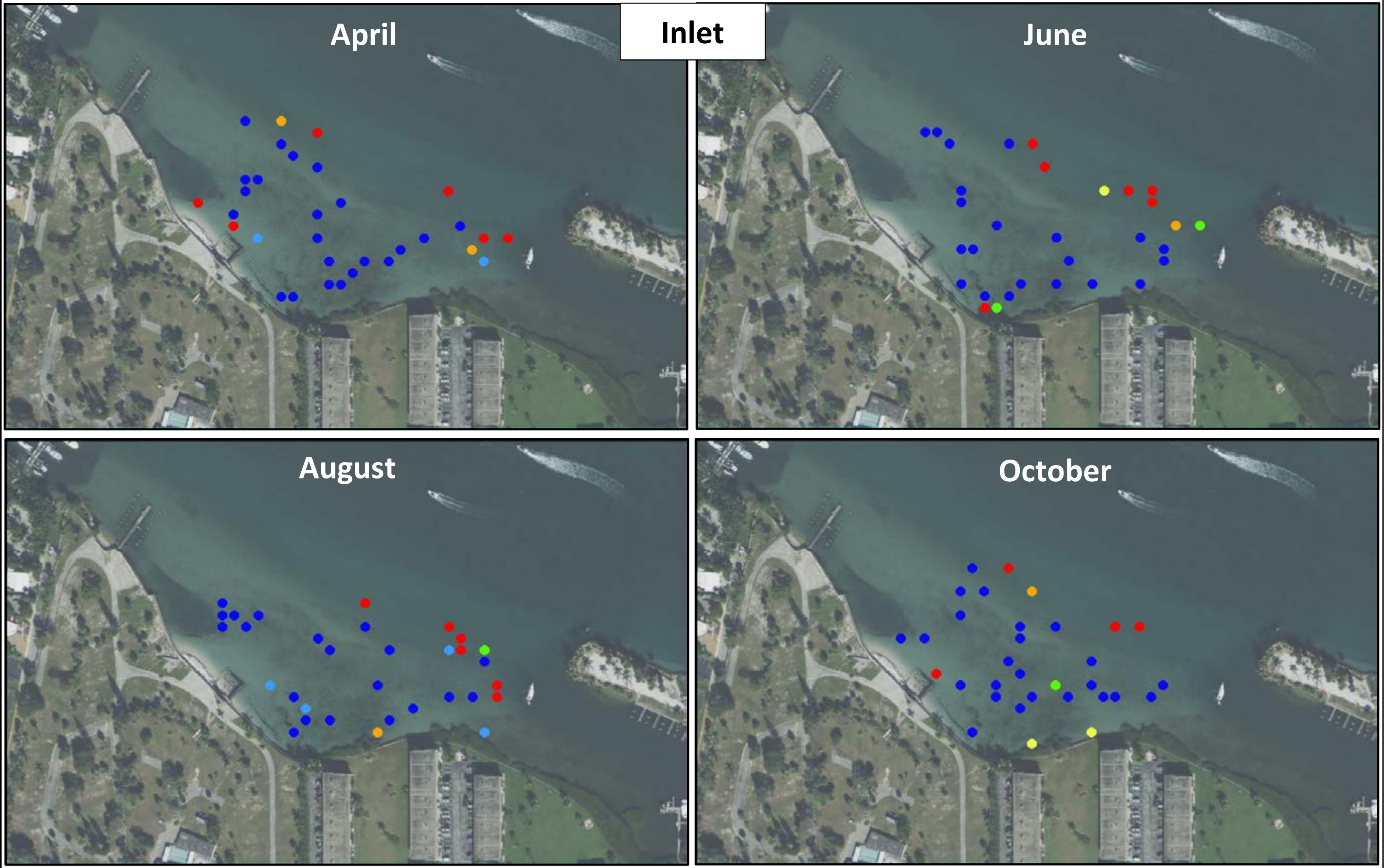
Meters

0 50 100 150

Prepared By: Jerry Metz

center: 26° 56.970' N, 80° 6.673' W

N



Total Seagrass % Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

Panels above indicate percent occurrence of Total Seagrass presence at the Inlet seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range of total seagrass presence for each point.

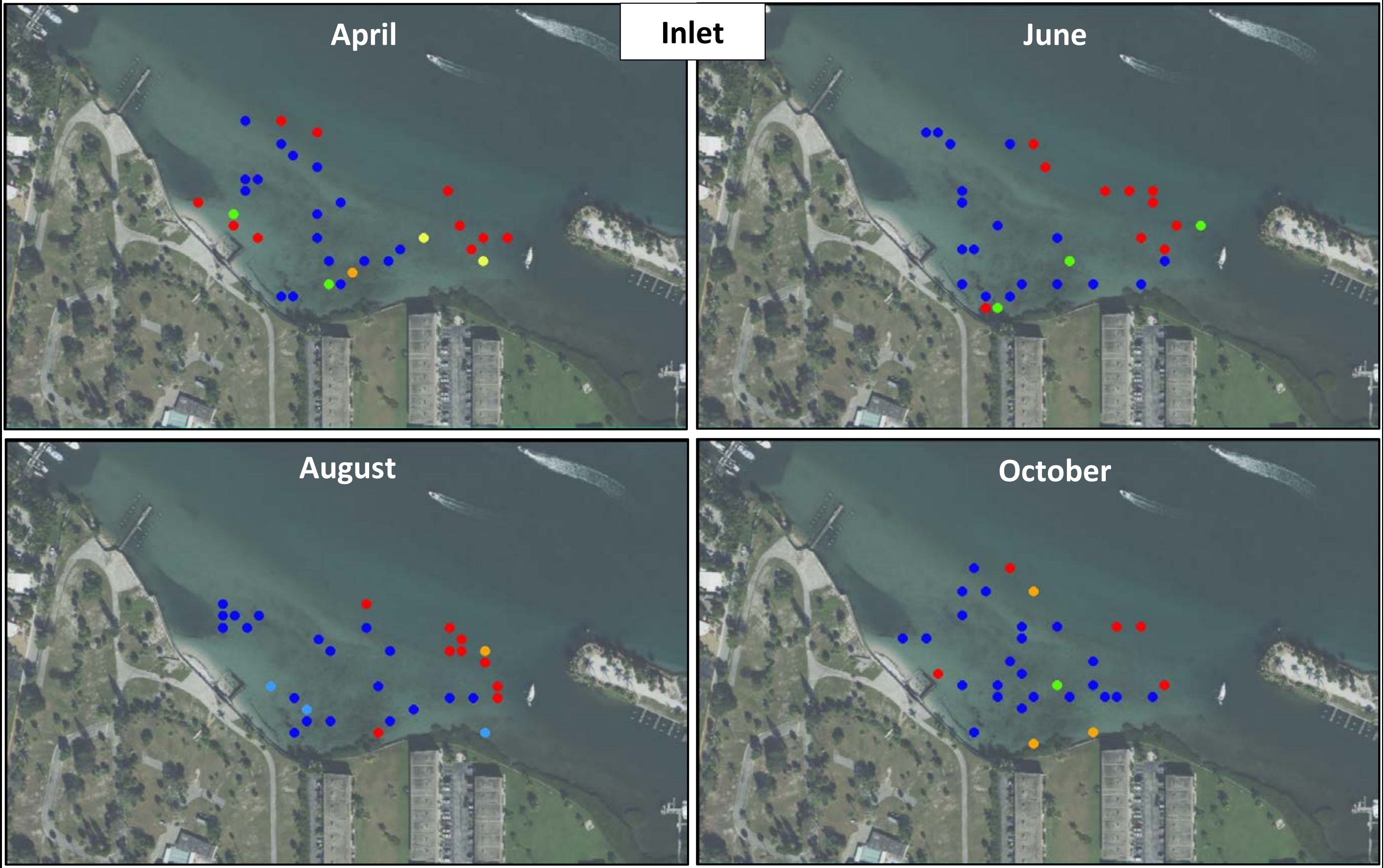
Meters

0 50 100 150

Prepared By: Jerry Metz

center: 26° 56.679′ N, 80° 4.756′ W

N



H. wrightii
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

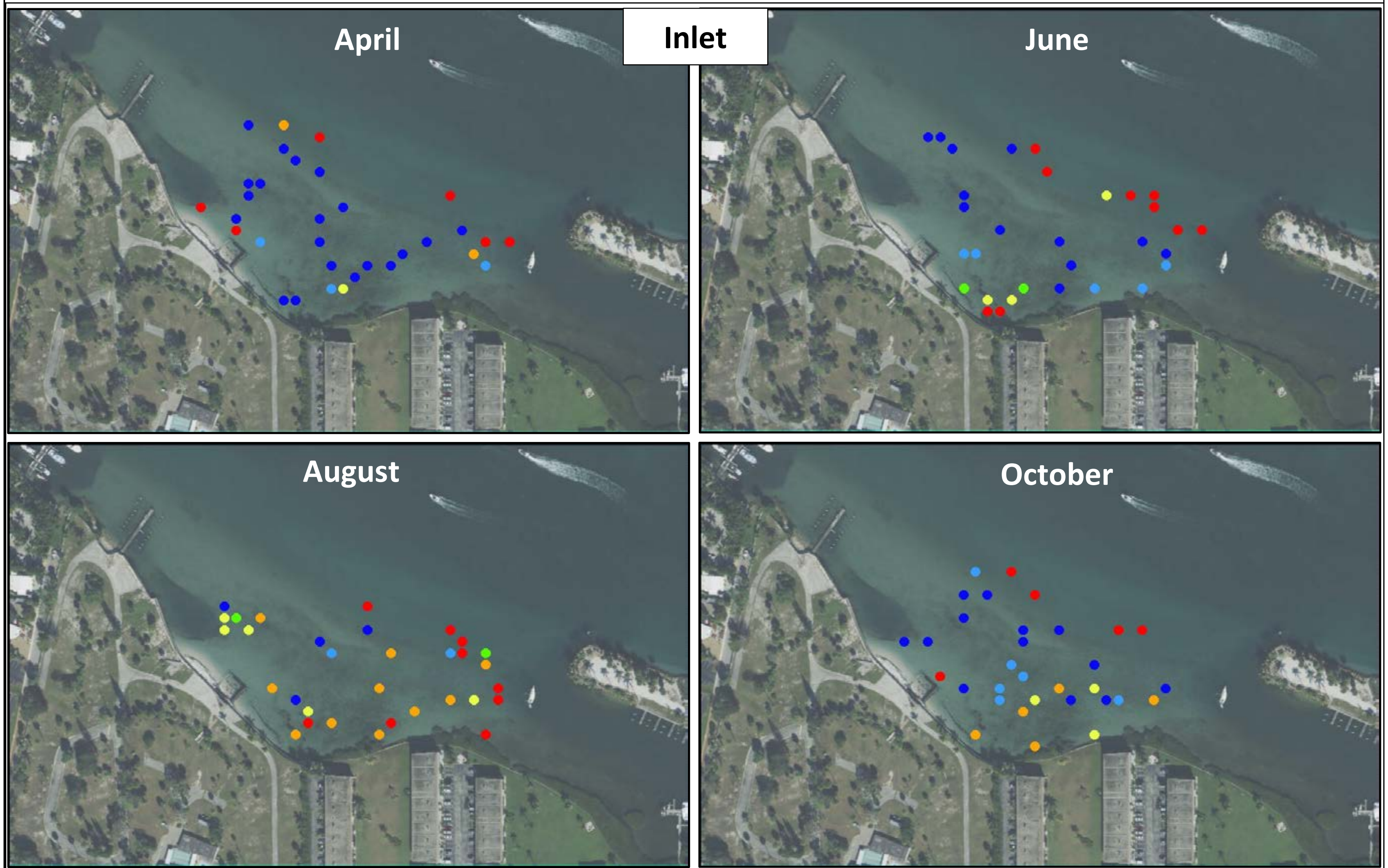
Panels above indicate percent occurrence of *Halodule wrightii* ("shoal grass") at the Sand Bar seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 56.679′ N, 80° 4.756′ W

N



H. johnsonii
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

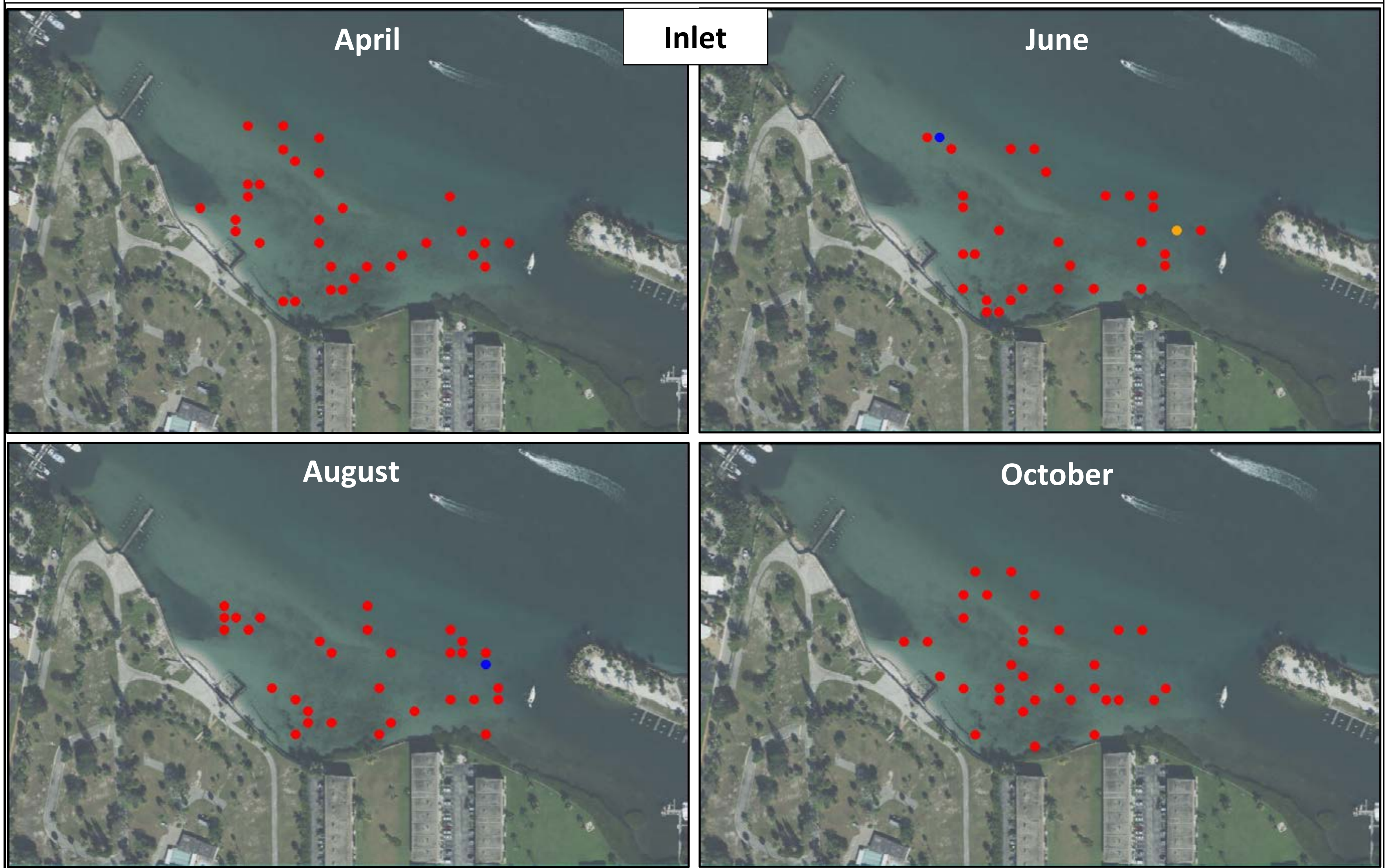
Panels above indicate percent occurrence of *Halophila johnsonii* ("Johnson's grass") at the Inlet seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

Meters
0 50 100 150

Prepared By: Jerry Metz

center: 26° 56.679' N, 80° 4.756' W

N

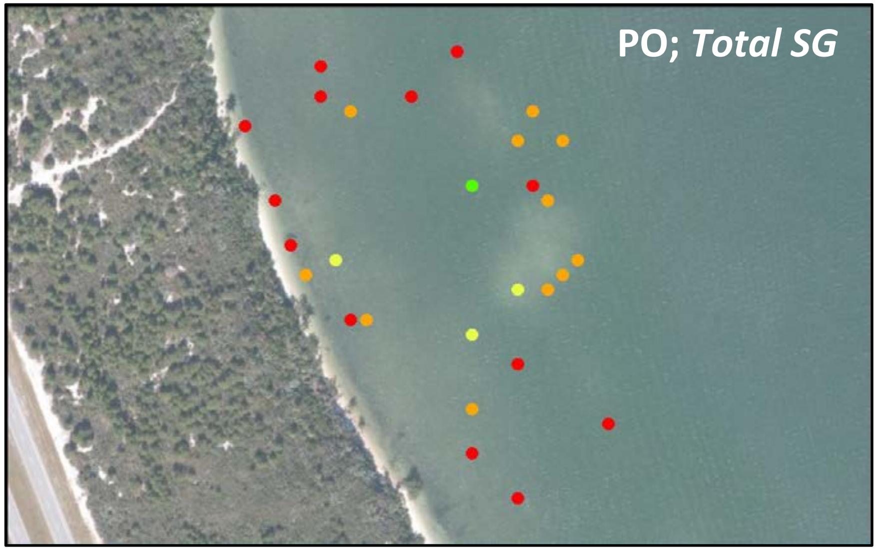


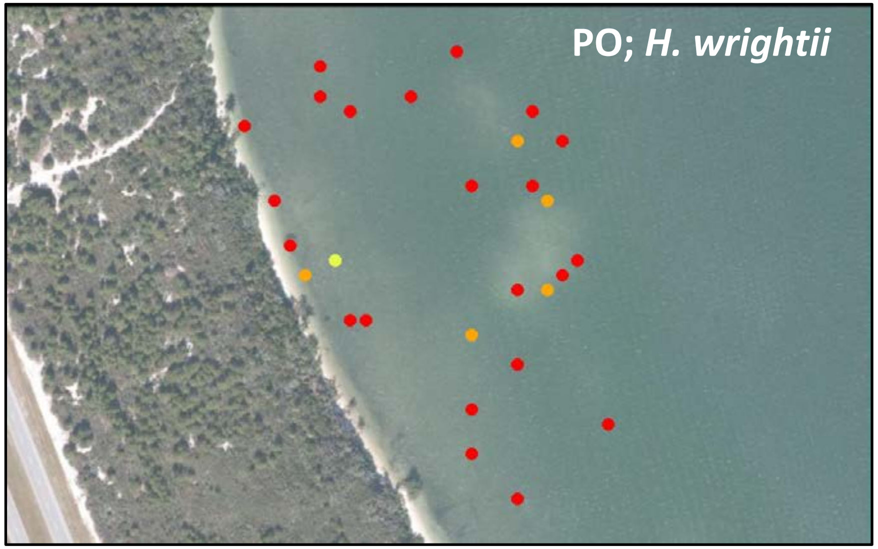
Panels above indicate percent occurrence of *Halophila decipiens* ("paddle grass") at the Inlet seagrass site at each seagrass sampling point during each of the four sampling months during 2021. Legend at left indicates percent occurrence range for each point.

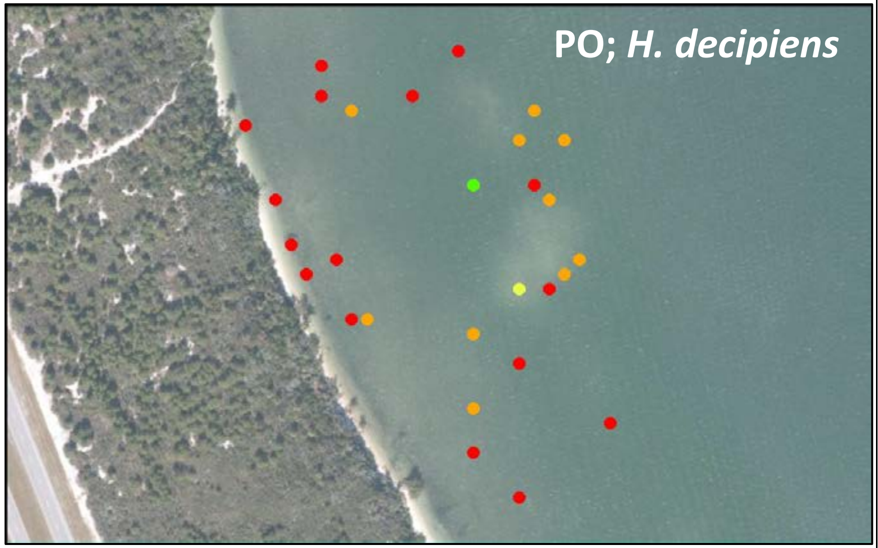
Prepared By: Jerry Metz

center: 26° 56.679' N, 80° 4.756' W

Hobe Sound







Seagrass
% Occurrence

- 0
- 1 - 20
- 21 - 40
- 41 - 60
- 61 - 80
- 81 - 100

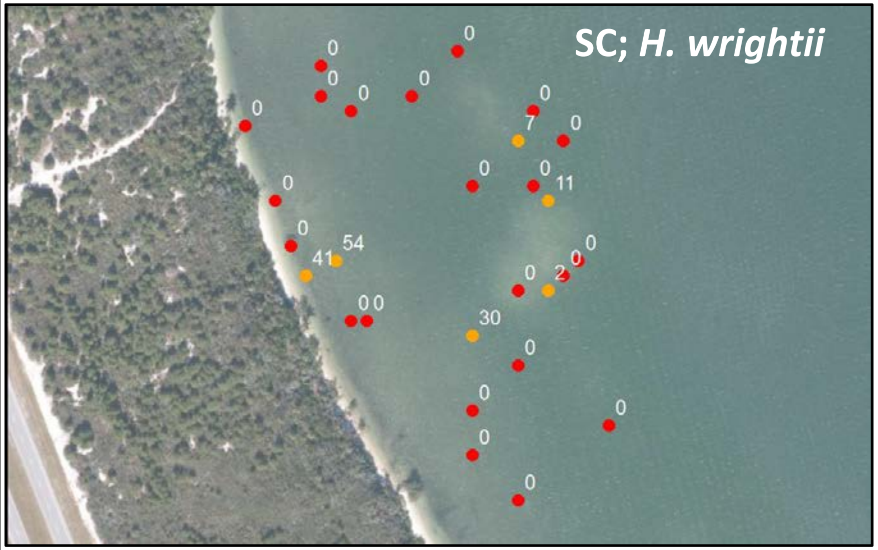
Panels above show seagrass percent occurrence associated with each sampling point at the Hobe Sound (HS) site during October 2021; the only month monitoring was conducted at this site. Legend at left indicates percent occurrence range of seagrass as indicated on each panel.

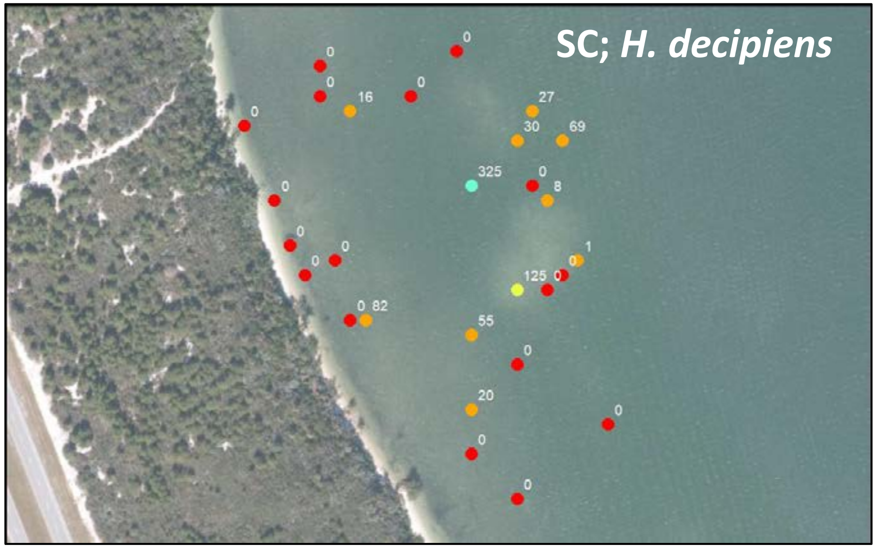
Meters
0 50 100 150

Prepared By: Jerry Metz

N

Hobe Sound





Seagrass Shoot Density m²

Panels above show seagrass shoot density (SC) of H. wrightii (left) and H. decipiens (right) associated with each sampling point at the Hobe Sound (HS) site during October 2021; the only month monitoring was conducted at this site. Legend at left indicates percent occurrence range of seagrass as indicated on each panel.

Meters

0 50 100 150

Prepared By: Jerry Metz

N