Guana Tolomato Matanzas National Estuarine Research Reserve

Oyster Spat Monitoring Final Summary Report (2015 to 2020)

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INTRODUCTION

The Guana Tolomato Matanzas National Estuarine Research Reserve (GTMNERR) encompasses thousands of acres of estuarine habitat in Northeast Florida, where intertidal oyster reefs are abundant (Dix et al. 2019). The eastern oyster, *Crassostrea virginica,* is a keystone species because it builds oyster reef habitat and provides myriad ecosystem services (Bahr and Lanier 1981, Grabowski and Peterson 2007).

Oysters are broadcast spawners, releasing eggs and sperm into the water column where fertilization occurs. The newly formed oyster larvae spend two to four weeks free-floating in the water column until they are large enough to settle (Kennedy et al. 1996). A variety of physical, auditory and chemical cues induce larvae to settle onto hardened substrate, most commonly other oysters (Bonar et al. 1990, Carroll et al. 2015, Crisp 1967, Lillis et al. 2013, O'Beirn et al. 1995, Wheeler et al. 2015). Newly settled oysters are called "spat." This cycle continues, forming new oyster reefs or further building existing ones.

Patterns in larval settlement are an important component of understanding spatial and temporal changes in oyster populations (Eckman 1996). Post-settlement processes lead to the recruitment of oysters into the population, and many population models assume recruitment density is correlated with settlement density (Minchinton and Scheibling 1991, Underwood and Fairweather 1989). Monitoring of larval settlement is commonly conducted by deploying substrate such as hanging oyster shell (Arnold et al. 2008, Metz et al. 2015, Parker et al. 2013, Southworth and Mann 2004, Volety et al. 2009), spat sticks (O'Beirn et al. 1995), and settlement plates (Kim et al. 2010, Metz et al. 2015, Saoud et al. 2000, Supan 1983). The abundance of spat on the substrate over a given period is used as the estimate of settlement. Retrieval of substrate occurs prior to post-settlement mortality processes, such as predation and competition, so spat abundance is assumed to reflect the combination of site-specific larval availability and settlement processes.

It is the goal of the GTMNERR to assess and monitor oyster reef habitat and oyster population dynamics and to keep local oyster harvesters, members of the public, resource managers and scientific communities informed. Baseline monitoring of natural oyster reefs within the GTMNERR and surrounding waters was conducted during 2014 to 2016. Details of the motivations, methods, results, and implications of that assessment are summarized in Marcum et al. (2018). Oyster spat monitoring was initiated in 2015 to collect baseline data on spatial and temporal patterns of oyster settlement in the GTM estuary. Results are expected to inform oyster population assessments, restoration, and research. This final report summarizes GTMNERR oyster spat monitoring from 2015 to 2020, including seasonal and regional trends in oyster settlement over the monitoring period.

METHODS

Site Selection

As in Marcum et al. (2018), a regional approach was adopted for this monitoring program based on perceived differences in water quality, food availability, hydrodynamics, harvesting and management. Regions were created based on the major waterways along the Intracoastal Waterway (ICW): Tolomato River, Guana River, Salt Run and Matanzas River (Figure 1). The Matanzas River was further subdivided into St. Augustine (the northern portion of the river) and Fort Matanzas (the remaining portion of the river to the south). A stratified random sample of three reefs in each region of interest (except for Tolomato) were selected to deploy spat collectors. The Tolomato River region had two spat collectors deployed at either end of the Wright's Landing oyster enhancement area, where 275 m^2 of oyster reefs (28 individual reefs) were created from bagged shell in 2012 and 2013, and one across from the site on a natural reef. In June 2016 and June 2020, one additional spat collector was deployed in the St. Augustine and Tolomato regions, respectively.

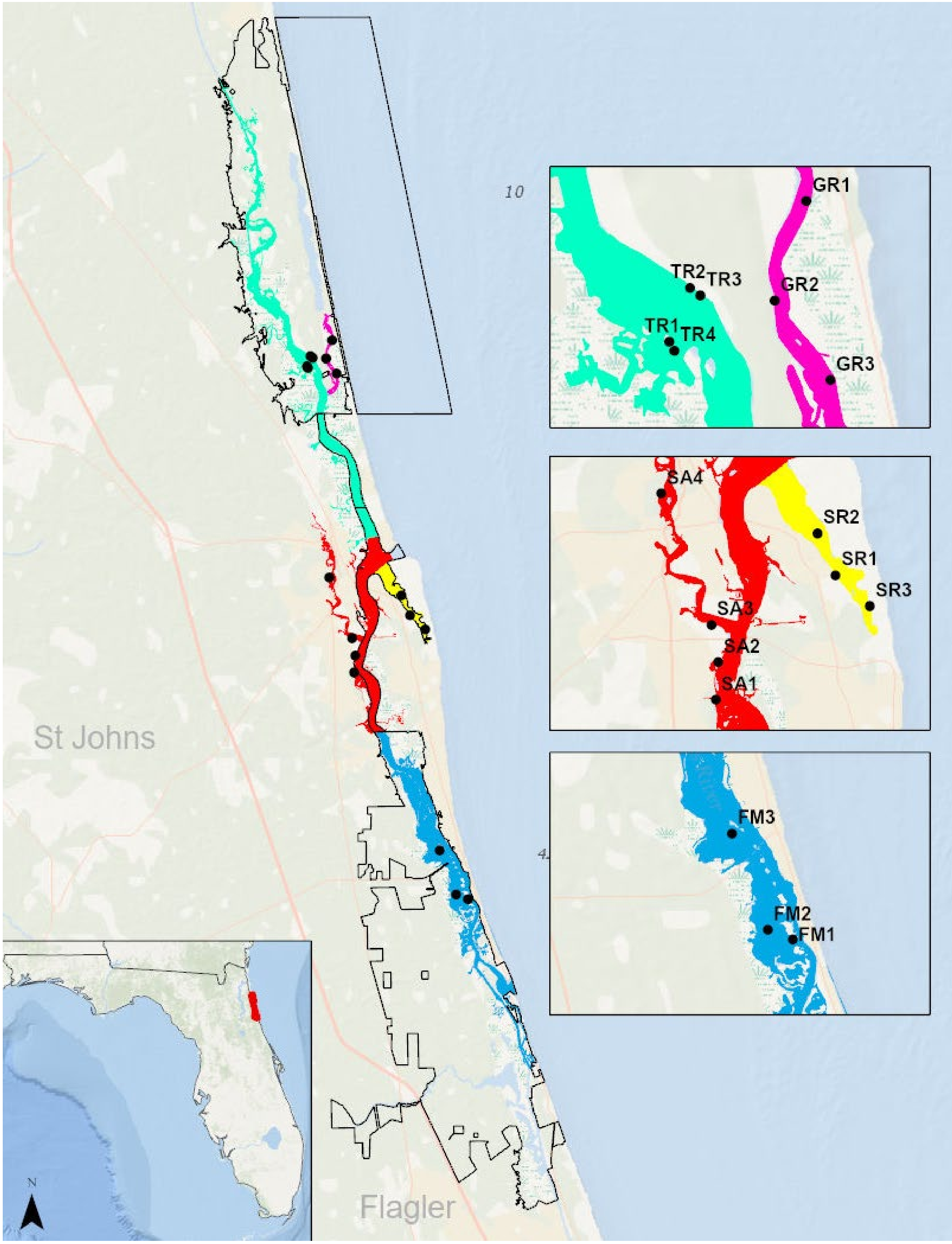

Figure 1. Map of the GTMNERR boundary (black line, bottom inset: red), 2020 spat collector locations (black dots), and regions: Tolomato River (turquoise), Guana River (pink), Salt Run (Yellow), St. Augustine (red), and Fort Matanzas (blue).

Data Collection

Patterns in spat settlement were monitored using the hanging shell method. Samples were collected using T-shaped structures (trees) made from PVC, with shell "stringers" suspended from each side of the crossbar. Each stringer was composed of six cleaned shells, 5 to 10 cm shell height, with holes drilled through, strung onto galvanized wire oriented with the inner concave surface facing down. Prior to deployment, shells were cleaned by soaking in bleach water for 48 hours followed by removal of all fouling organisms by scrubbing with a wire brush. Cleaned shells were then soaked for at least 24 hours in freshwater.

Trees were inserted into the reef at the apparent densest portion of live oyster on the reef and situated so that the shells were at the approximate height of the surrounding live oysters. Once stringers were collected, any fouling organisms were removed from the tree and new stringers were deployed. Retrieved stringers were labeled and stored in a -4°C freezer until processed. Hurricane Matthew affected the study area in October 2016 and spat trees were unable to be collected, resulting in missing data from September and October of that year.

Beginning in October 2019, a handheld YSI was used to measure surface water temperature, dissolved oxygen, salinity and pH at all sites.

Figure 2. Deployed spat tree with shell stringers suspended above the reef (Guana River).

Shell Processing

Shells were assigned numerical IDs based on their position on each stringer, with the topmost shell designated number one and the bottommost number six. The top and bottom shells (one and six, respectively) were discarded and shells two through five were evaluated for spat abundance. The inner surface of the shells was observed under a dissecting microscope and total number of spat was recorded for each shell. A percentage error measurement was used for quality control. One shell from each tree was randomly selected to be recounted by a second observer. The percent error (PE) between the two observations was calculated as follows:

$$\text{PE} = \frac{|Count_1 - Count_2|}{(Count_1 + Count_2)/2} \times 100$$

$Count_1$ was the total spat count from the primary observer and $Count_2$ was the total spat count from the secondary observer. If PE was >10%, and the difference between $Count1$ and $Count2$ was greater than 3, stringers from that tree were re-counted by the primary observer. Percent error was not calculated from January through March as spat settlement was low and rarely exceeded 10 spat per shell.

Data Analysis

In early years of the monitoring, spat were counted using the naked eye or a magnifying glass on both sides of the shells (interior and exterior). A small-scale comparison study determined that spat abundance was significantly higher using a microscope and on the inner surface only. Beginning in December 2017, all processing was done under microscope on the inner surface of the shells. A linear regression equation based on the comparison was developed to correct the non-microscope data for analysis.

Monthly spat counts were averaged first by reef for within-region analyses then by region for between-region analyses. Regional monthly means were averaged by year to evaluate annual change. To evaluate changes in peak settlement over the course of the study, the highest annual reef means were averaged by region for 2015 and 2020.

Water temperature data were averaged across all sites each month to determine monthly water temperature trends for the entire study area.

RESULTS AND DISCUSSION

The spat project was conducted for five consecutive years to monitor spatial and temporal patterns in oyster settlement dynamics. Average annual settlement increased since the start of the project in 2015, reaching the highest regional averages in 2020 in all regions except Guana River (Figure 3). Peak settlement shifted from early summer in 2015 to late summer in 2017, which continued for the remainder of the monitoring (Figure 4). Timing of minor peaks appeared to forecast peak abundance: Reefs with minor peaks that occurred later in the spring had higher spat abundance both during the fall peak as well as annually (Figure 4).

Spat settlement in 2020 was still relatively high into November, contrary to past years of monitoring during which spat averages were at or close to zero, possibly because waters remained relatively warm until December (Figures 4 and 5). In 2020, settlement peaked after increases in temperature (Figure 5). Various studies have shown that warmer water temperatures positively impact oyster settlement by stimulating gamete production, abundance, and duration of the larval life stage (Bahr and Lanier 1981, O'Beirn et al. 1995, Wilson et al. 2005). In addition to temperature, proximity to a major waterway may impact larval availability due to water flow that can affect larval transport, inundation time and food availability.

The Tolomato River (TR) region was established in September 2015 (seven months later than the other regions) and was initially one natural reef (TR1). In 2016, the Wright's Landing reefs (TR2 and TR3) were included. Following the Wright's Landing installment, TR had the highest settlement rate for the duration of the study (Figure 4). This region also experienced the highest increase in settlement both annually and at peak settlement from 2016 to 2020 (Tables 1 and 2, respectively). Aside from consistently having the highest spat settlement, TR had the largest range in mean spat per shell (sps) among reefs (77 sps in 2020). This may be attributed to the settlement success at the two constructed reefs in Wright's Landing, TR2 and TR3, in contrast to the natural reefs. During peak settlement in 2020, TR3 (constructed) averaged 433 (± 50) sps, which was 2.3 times higher than TR4 (natural), which averaged 188 (± 15) sps during this time (Figure 6). While the higher spat average at Wright's Landing reefs could be indicative of artificial reef success, it is also possible that open exposure to water, lack of competing structure in the area and possible entrapment by a sand bar influenced settlement rates.

The Guana River (GR) region is the only one that experienced highest recruitment rates in 2019 and not 2020. Additionally, the region experienced the least increase in spat per shell averages both regionally and during peak settlement over the course of study (Tables 1 and 2, respectively). While the range in spat abundance among reefs in GR was relatively small, GR1 consistently yielded the least amount of spat in the region (Figure 7). Low settlement on GR1 may be attributed to its location in the river: It is located farthest away from the mouth (Figure 1), and thus the ICW, which could affect larval transport and limit availability upstream.

Salt Run (SR) had relatively low spat abundance compared to other regions (Figure 4, Tables 1 and 2). SR2 consistently yielded the highest annual and peak settlement spat per shell averages within the region since 2016 (Figure 8). SR2 is located closest to the mouth of the run (nearest the ICW and an ocean inlet).

The St. Augustine (SA) region experienced a large increase in annual spat settlement over the project period, yielding about 10 times more spat per shell annually in 2020 than in 2015 (Table 1, Figure 3). SA2 yielded the highest spat settlement of the region annually and at peak settlement. SA4 consistently yielded the lowest spat settlement averages since its introduction to the project (Figure 9), which may be a result of its distance from the ICW (Figure 1) and shallower waters.

Oyster settlement in the Fort Matanzas (FM) region was low in 2015 and 2016 then increased and stayed relatively consistent from 2017 through 2020 (Figures 1 and 10). FM1 had the highest spat abundance of the region, averaging over twice as much as other reefs in the region during the last four years of the study (Figure 10). This reef is located the closest to the ICW in the region (Figure 1).

CONCLUSION

Overall, spat settlement increased over the course of the study and peak settlement shifted from early to late summer. Reefs that experienced a minor peak in May as opposed to April tended to yield more spat per shell both annually and during the primary settlement period. The Tolomato River region consistently yielded the highest spat averages.

Environmental factors such as water temperature and distance to the ICW may be important indicators of spat availability and larval settlement. Future research exploring the effects of hydrodynamics and environmental conditions on oyster settlement patterns will be important for predicting population dynamics and planning restoration. The GTMNERR long-term weather and water quality data (NERRSdata.org) will be useful for characterizing environmental conditions. Results of this study illustrate region- and reef-specific variability in oyster settlement patterns and underscore the importance of local monitoring for oyster resource management, restoration and research.

ADDITIONAL TABLES & FIGURES

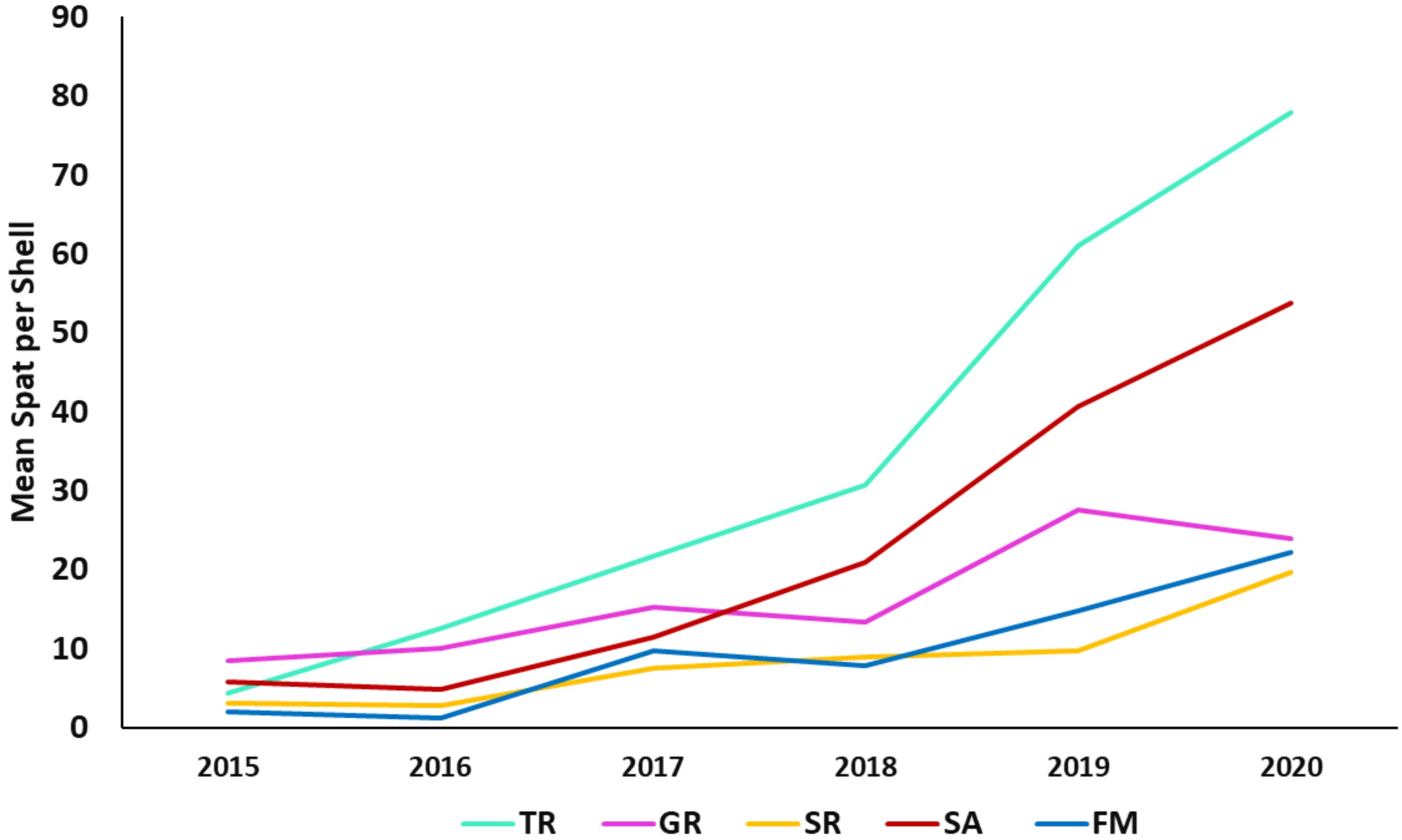

Figure 3*.* Mean annual spat per shell over the course of the study.

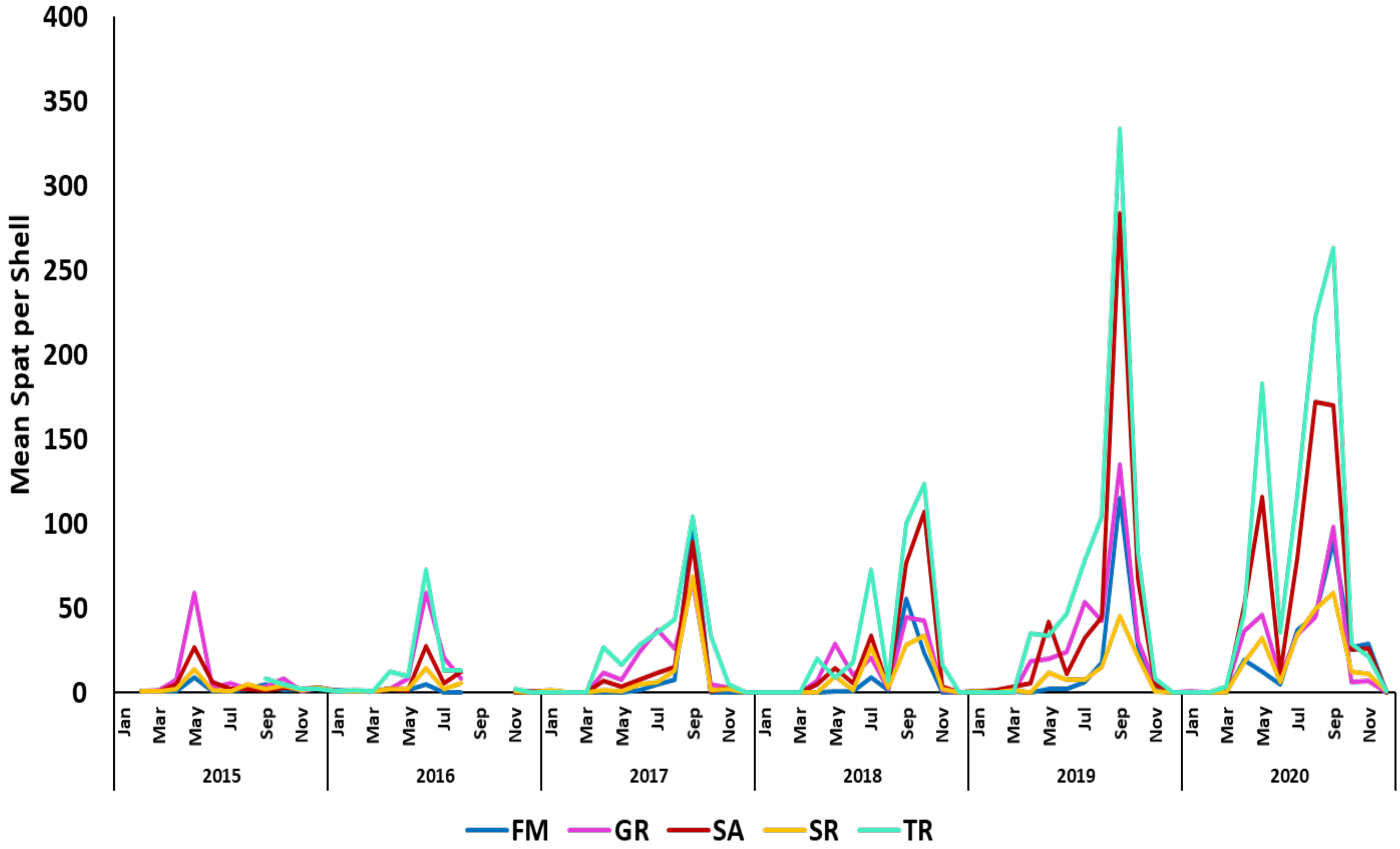

Figure 4. Monthly mean spat per shell for each region over the course of the study: FM - Fort Matanzas (Blue); GR - Guana River (Pink); SA - St. Augustine (Red); SR - Salt Run (Yellow); and TR - Tolomato River (Teal).

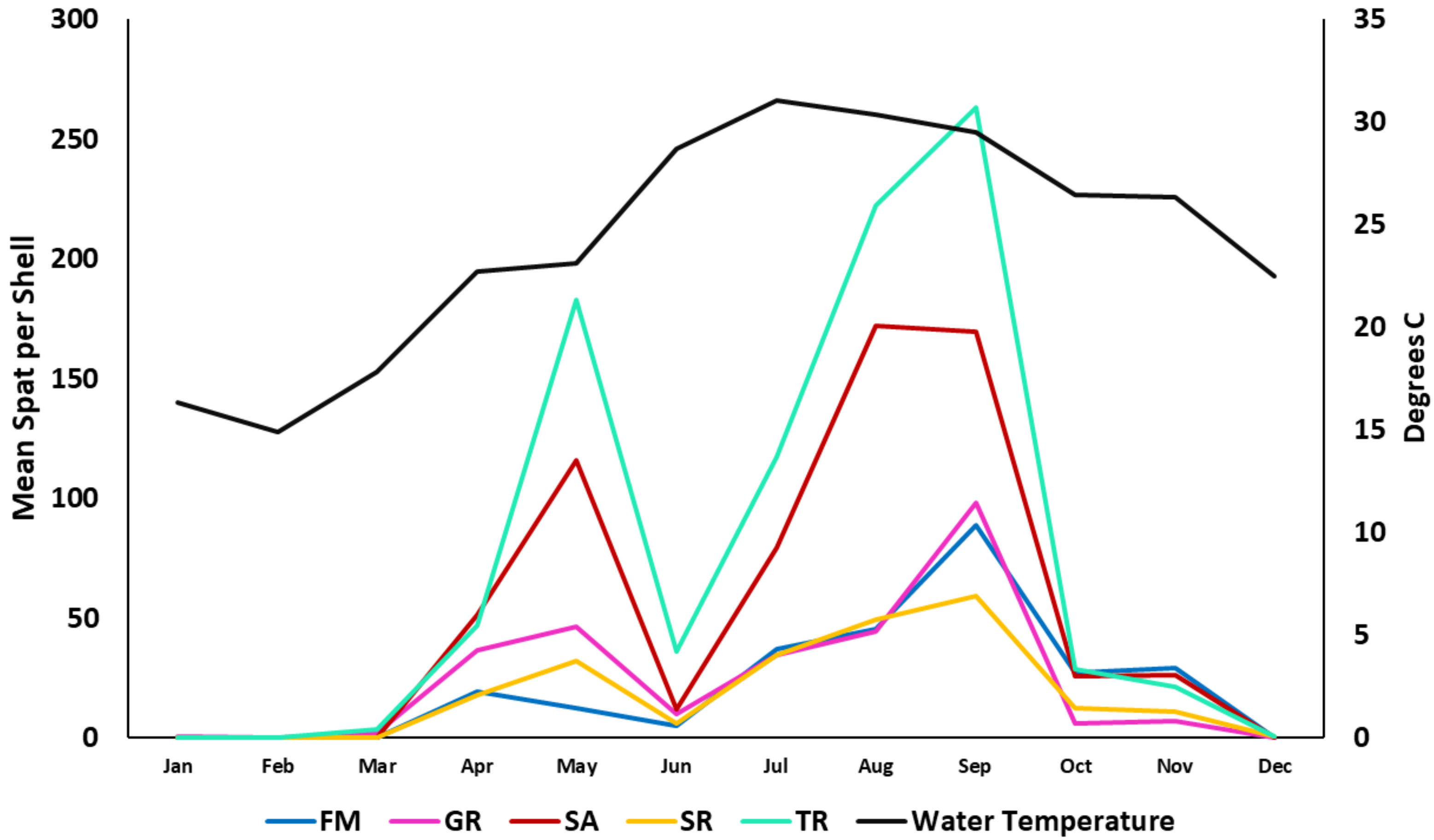

Figure 5. 2020 monthly mean water temperature (C°, black, right axis) and mean spat per shell (left axis) for each region: Fort Matanzas (Blue), Guana River (Pink), St. Augustine (Red) and Tolomato River (Teal).

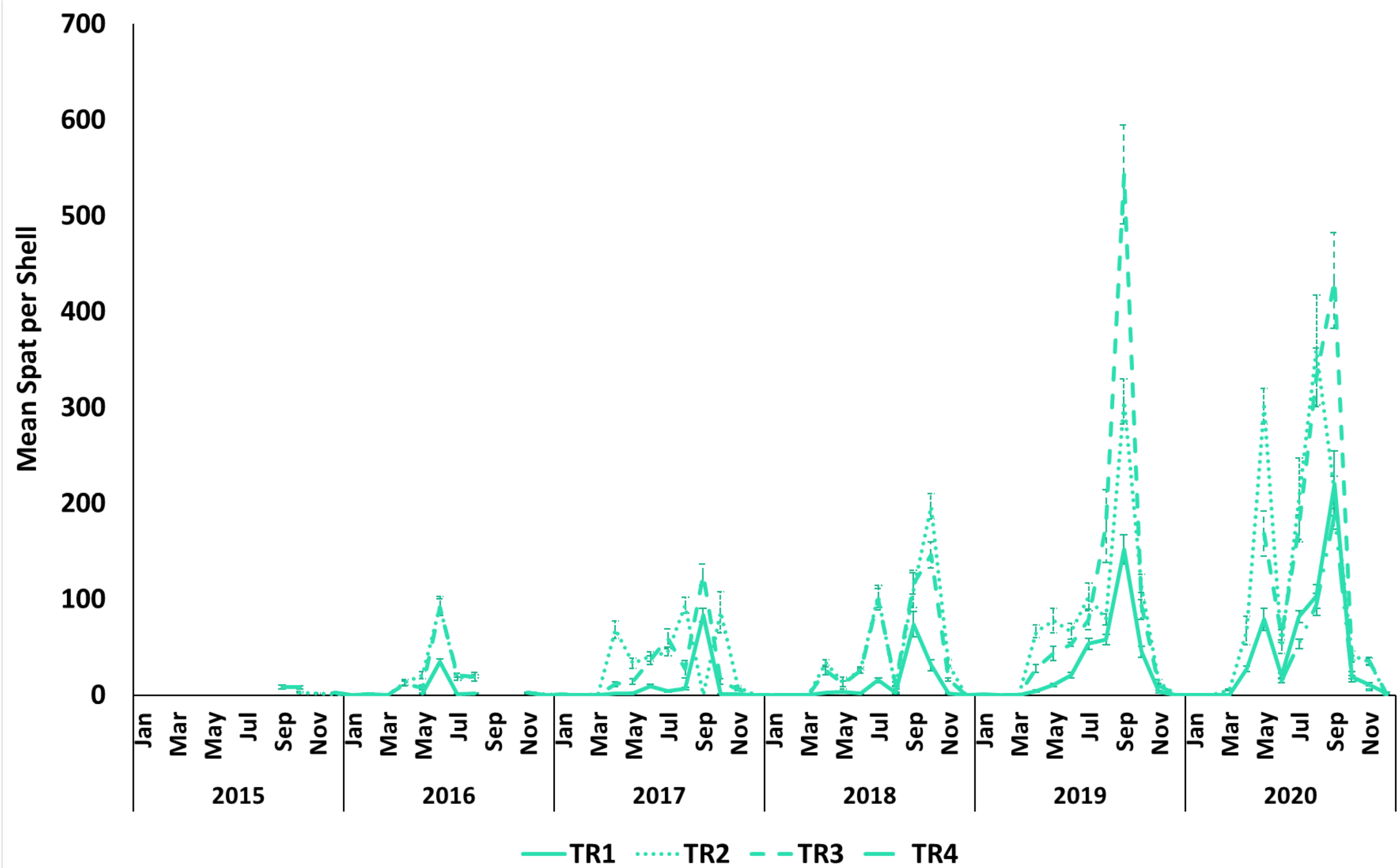

Figure 6. Monthly mean spat per shell for Tolomato River reefs. Standard error bars represent variability between shells for each tree.

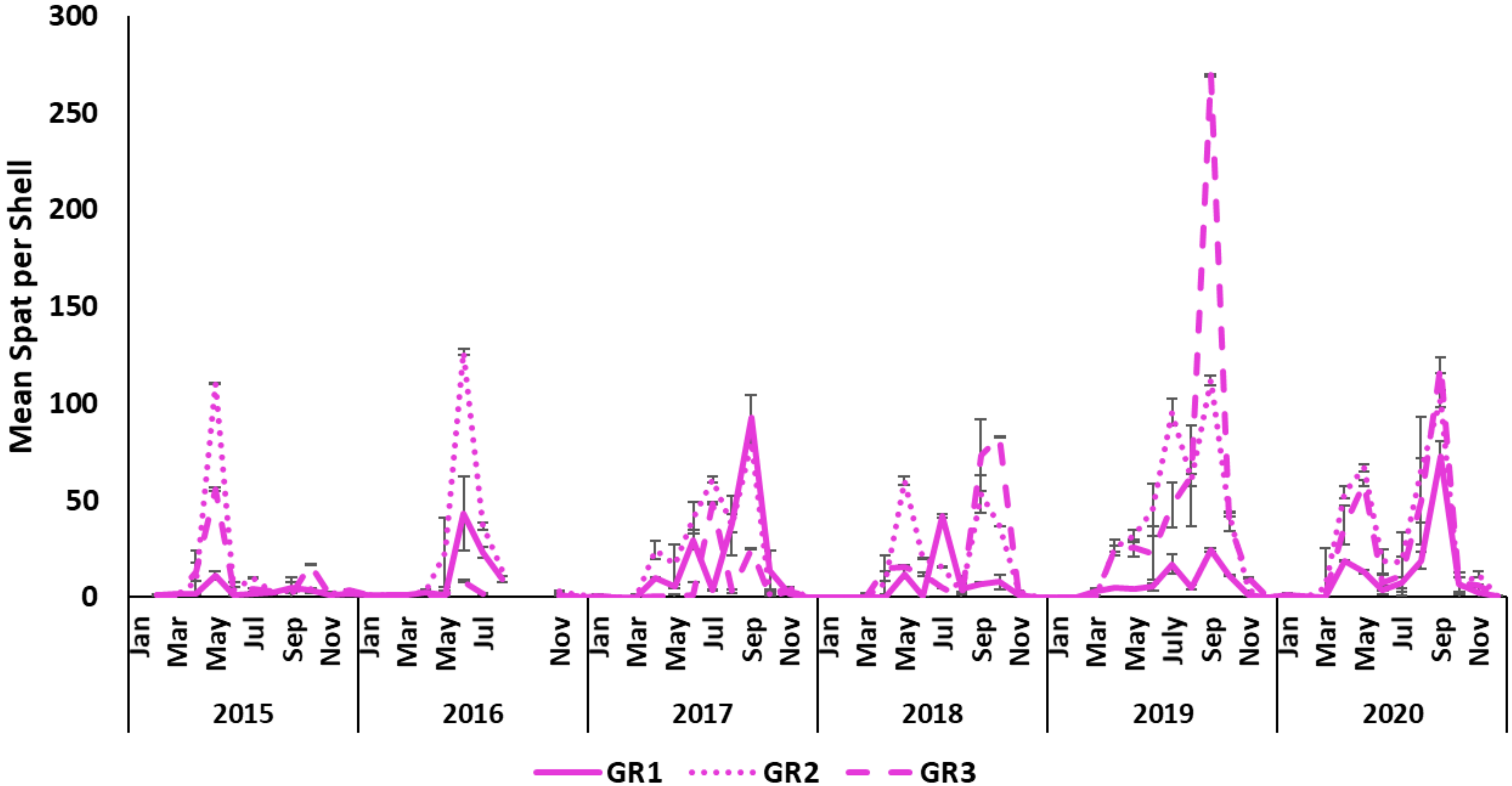

Figure 7. Monthly mean spat per shell for Guana River reefs. Error bars represent variability between shells for each tree.

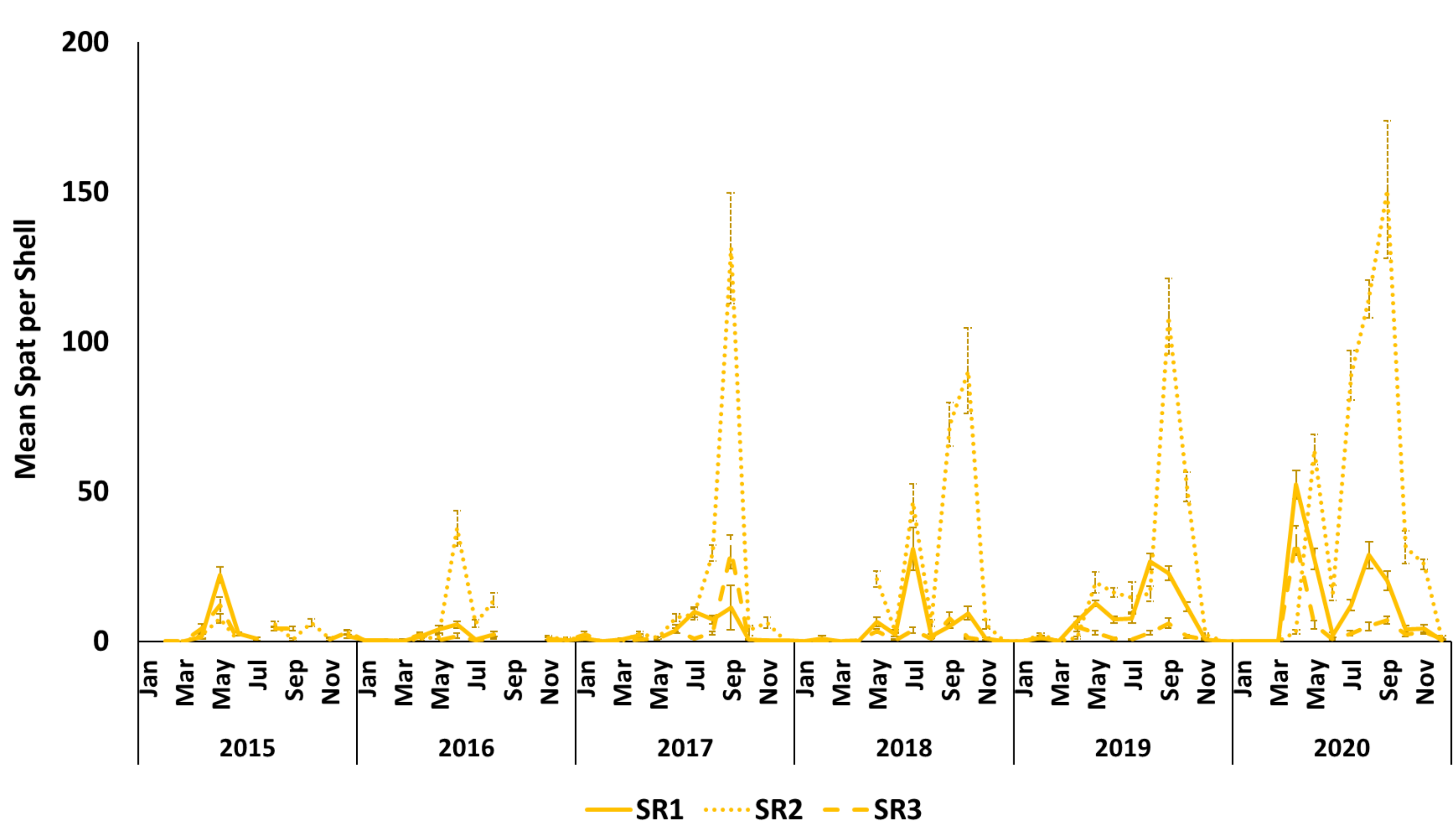

Figure 8. Mean spat per shell for Salt Run reefs. Standard error bars represent variability between shells for each tree.

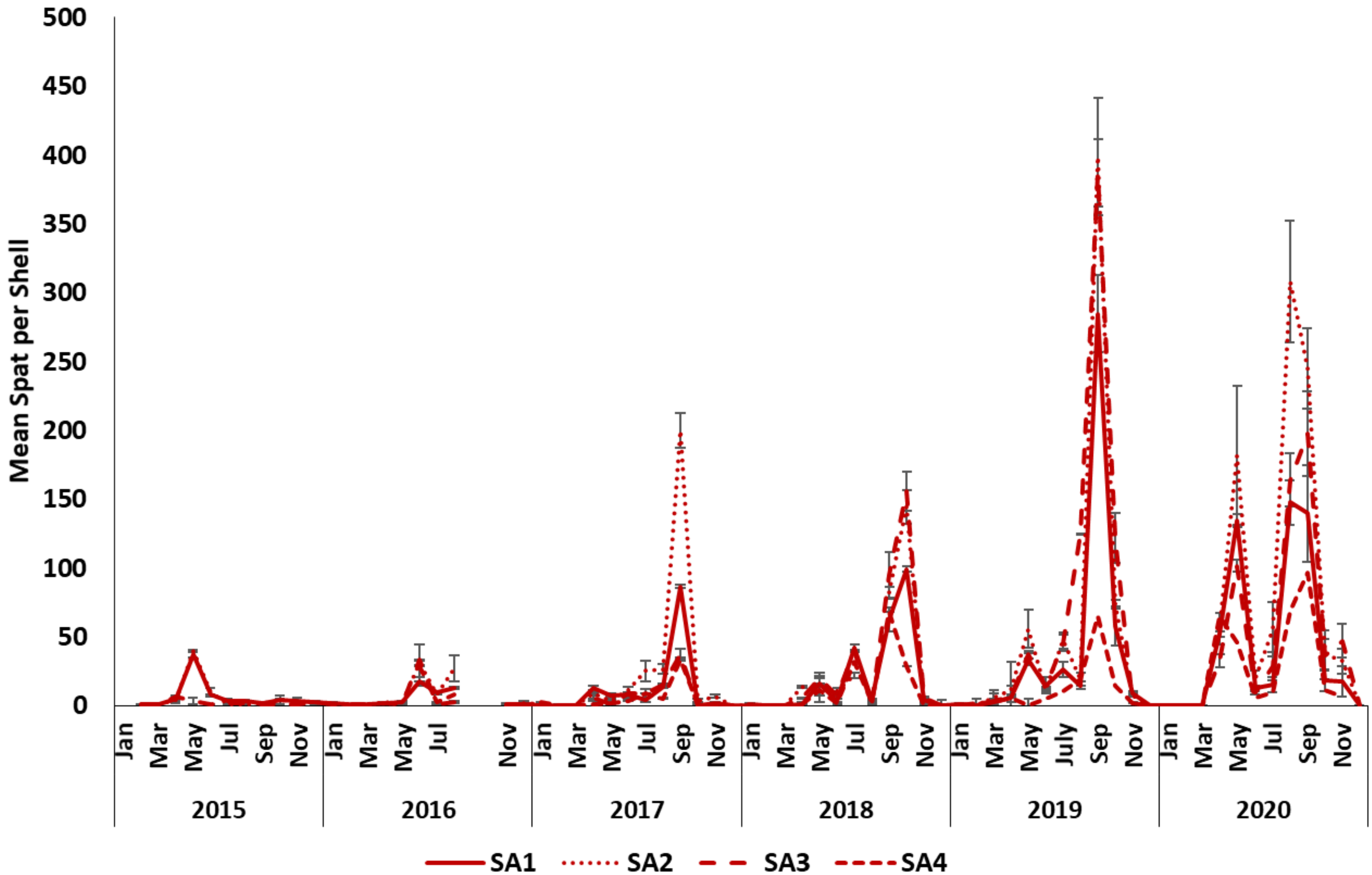

Figure 9*.* Monthly mean spat per shell for St. Augustine reefs. Standard error bars represent variability of shells for each tree.

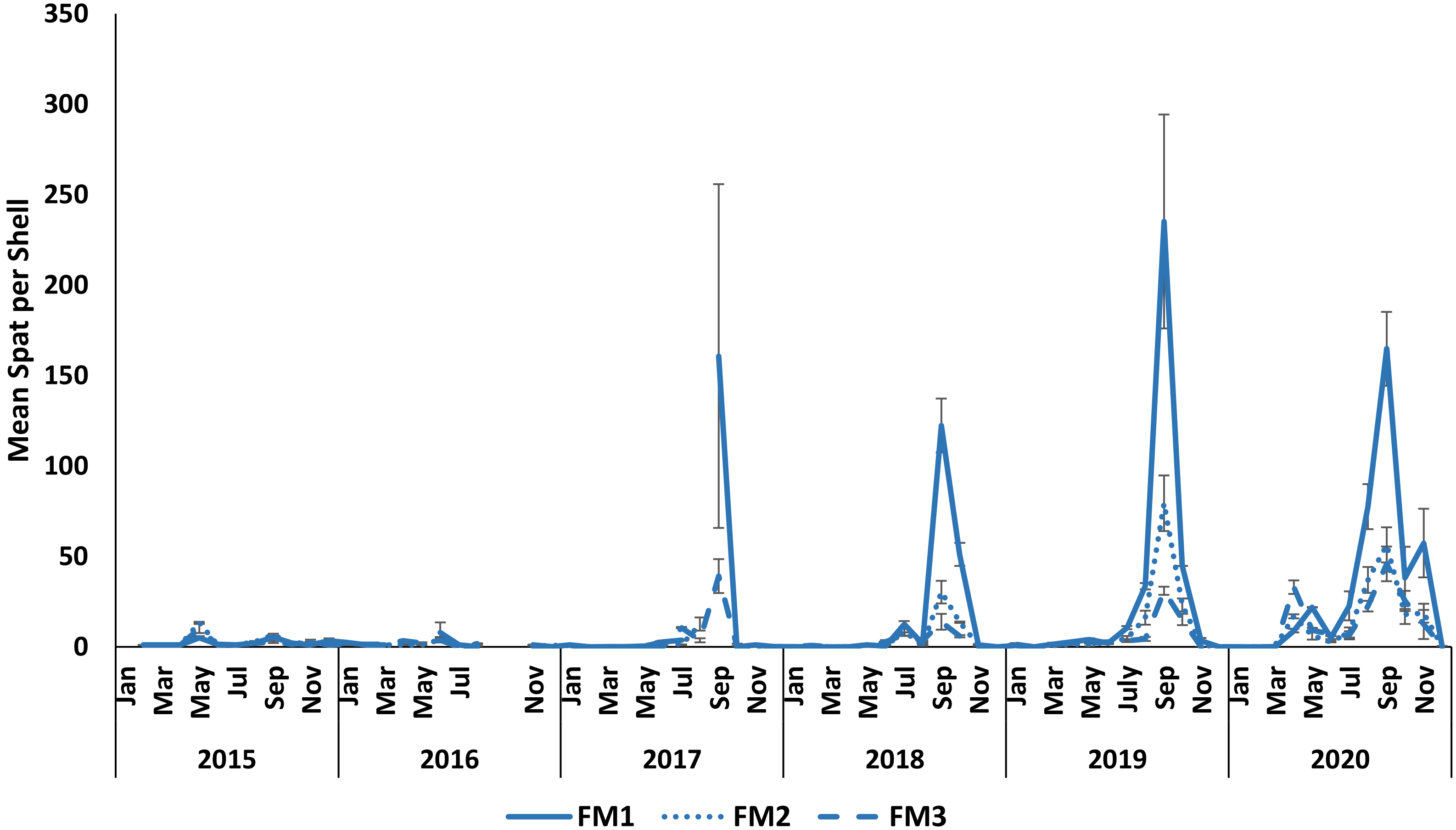

Figure 10. Monthly mean spat per shell for Fort Matanzas reefs. Error bars represent variability between shells for each tree.

Table 1. Regional changes in annual mean spat per shell with standard errors at start and end of study

Region	2015	2020	Difference	% Change

TR	4.32 (±1.54)	77.87 (±27.60)	73.56	1,803
GR	8.40 (±5.14)	23.91 (±8.57)	15.51	285
SR	3.08 (±1.24)	19.65 (±6.00)	16.56	638
SA	4.94 (±3.06)	53.79 (±18.85)	48.86	1,089
FM	2.03 (±0.82)	22.14 (±7.63)	20.11	1,091

Table 2. Regional changes in peak mean spat per shell with standard errors at start and end of study

Region	2015	2020	Difference	% Change
TR	8.25 (±6.36*)	263.16 (±56.89)	254.91	3,190
GR	59.13 (±28.74)	98.21 (±13.80)	39.08	166
SR	13.92 (±4.23)	59.38 (±45.84)	45.46	427
SA	35.56 (±12.19)	172.09 (±49.85)	136.53	484
FM	9.13 (±2.74)	89.00 (±38.00)	79.88	975

*Standard deviation, only one reef was monitored that month

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