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The Status of Virginia's Public Oyster Resource 2022

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Part I. OYSTER RECRUITMENT IN VIRGINIA DURING 2022

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) monitors recruitment of the Eastern oyster, *Crassostrea virginica* (Gmelin, 1791), annually from late spring through early fall, by deploying spatfall[1] (settlement and recruitment of larval oysters to the post metamorphic form termed spat) collectors (shellstrings) at various sites in three Virginia western Chesapeake Bay tributaries. The survey provides an estimate of a particular area's potential for receiving a "strike" or settlement (set) of oysters on the bottom and helps describe the timing of recruitment events in a given year. Information obtained from this monitoring effort provides an overview of long-term recruitment trends in the lower Chesapeake Bay and contributes to the assessment of the current oyster resource condition and the general health of the Bay. These data are also valuable to parties on both the public side (Virginia Marine Resources Commission (VMRC), Conservation Replenishment Department) and private industry who are interested in potential timing and location of shell plantings in order to optimize recruitment of spat on bottom cultch (shell that is available for larval oysters to settle on).

Results from spatfall monitoring reflect the abundance of ready-to-settle oyster larvae in an area, and thus, provide an index of oyster population reproduction as well as development and survival of larvae to the settlement stage within an estuary. Environmental factors affecting these physiological activities may cause seasonal and annual fluctuations in spatfall, which are evident in the data.

Data from spatfall monitoring also serve as an indicator of potential oyster recruitment into a particular estuary. Survival of spat on bottom cultch is affected by many factors, including physical and chemical environmental conditions, the physiological condition of the larvae when they settle, predators, disease, and the timing of these various factors. Abundance and condition of bottom cultch also affects the settlement process and survival of spat on the bottom. Therefore, spatfall on shellstrings may not directly correspond with recruitment on bottom cultch at all times or places.

This report summarizes data collected during the 2022 settlement season in three tributaries in the Virginia portion of the Chesapeake Bay.

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[1] A number of terms are used to describe various stages of the settlement (behavior, larvae seeking the substrate), metamorphosis (irreversible change in morphology accompanying transition from larval to attached form), and subsequent growth to the juvenile (attached, small version of the adult) progression of oysters. Spat is commonly used to describe the early post metamorphic attached form. Spatfall "set" or "strike" is commonly used to describe the continuum resulting in spat. For the current report we use the common term spatfall to reflect the end point of settlement and metamorphosis on shellstrings, and recruitment to reflect survival of juvenile oysters on bottom substrate (cultch) in the following fall surveys.

METHODS

Spatfall during 2022 was monitored from the week of May 13 through the week of September 30 in the Piankatank and Great Wicomico River and from the week of May 27 through the week of September 30 in the James River. Spatfall sites included eight historical sites in the James River, three historical and five modern sites in the Piankatank River and five historical and four modern sites in the Great Wicomico River (Figure S1). In this report, "historical" sites refer to those that have been monitored annually for at least the past thirty years, whereas "modern" sites are sites that were added during 1998 to help monitor the effects of replenishment efforts by the Commonwealth of Virginia. The modern sites in both the Piankatank and Great Wicomico Rivers correspond to those sites that were considered "new" in the 1998 survey. From 1993 through the early 2000s, VMRC built numerous artificial oyster shell reefs in several tributaries of the western Chesapeake Bay as well as in both Pocomoke and Tangier Sounds on the eastern side of the Chesapeake Bay[2]. The change in the number and location of shellstring sites during 1998 was implemented to provide a means of monitoring oyster spatfall around some of these reefs. In particular, broodstock oysters were planted on a reef in the Great Wicomico River during winter 1996-97 and on reefs in the Piankatank and Great Wicomico Rivers during winter 1997-98. The increase in the number of shellstring sites during 1998 in the two rivers coincided with areas of new shell plantings in spring 1998 and provided a means of monitoring the reproductive activity of planted broodstock on the artificial oyster reefs. Since 1998, many of the reefs and bottom sites in the Piankatank and Great Wicomico Rivers have received shell plants on the bottom surrounding the reefs and these "new" sites have become permanent oyster spatfall monitoring sites.

Oyster shellstrings were used to monitor oyster spatfall. A shellstring consists of twelve oyster shells of similar size (about 76 mm, (3-in) in length) drilled through the center and strung (inside of shell facing the substrate) on heavy gauge wire (Figure S2). Throughout the monitoring period, shellstrings were deployed approximately 0.5 m (18-in) off the bottom at each site. Shellstrings were usually replaced after a one-week exposure and the number of spat that attached to the smooth underside of the middle ten shells was counted under a dissecting microscope. To obtain the mean number of spat shell^{-1} for the corresponding time interval, the total number of spat observed was divided by the number of shells examined (ten shells in most cases). A manual with a step-by-step description of the shellstring survey methods used can be found on the VIMS/Molluscan Ecology website[3].

Although shellstring collectors at most sites were deployed for 7-day periods, there were some deviations such that shellstring deployment periods during 2022 ranged from 7 to 21 days. These periods do not always coincide among the different rivers or sites monitored or in different years. Therefore, spat counts for different deployment dates and periods were standardized to correspond to the 7-day standard periods specified in Table 1 to allow for comparison among rivers and years. Standardized spat shell^{-1} (S) was computed using the formula: $S = \sum$ spat shell^{-1} / weeks (W) where W = number of days deployed / 7. Standardized weekly periods allow comparison of spatfall trends over the course of the season between various sites in a river as well as between data for different years.

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[2] https://www.vims.edu/research/units/labgroups/molluscan_ecology/archive/restoration/va_restoration_atlas/indexmap/index.php

[3] https://www.vims.edu/research/units/labgroups/molluscan_ecology/_docs/Shellstring_manual.pdf

The cumulative spatfall for each site was computed by adding the standardized weekly values of spat shell^{-1} for the entire sampling period. This value represents the average number of spat that would fall on any given shell if allowed to remain at that site for the entire sampling period. Note that this assumes that the shell would remain clean and relatively unfouled by other organisms, which is typically not the case when shells are planted on the bottom. Spat shell^{-1} values were categorized for comparison purposes as follows: 0.10-1.00, light; 1.01-10.00, moderate; 10.01 to 100.0, heavy; 100.01 or more, extremely heavy. Unqualified references to diseases in this text imply the two oyster diseases found in the Bay, *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (*Perkinsus*, or Dermo).

Water temperature (°C) and salinity (ppt) measurements were taken approximately 0.5 m off the bottom at all sites on a weekly basis using a handheld electronic probe (YSI Pro2030).

RESULTS

Spatfall on shellstring collectors during 2022 is summarized in Table S1 and is discussed below for each river system monitored. Table S2 includes a summary of spatfall compared with 2022 during the previous thirty years (1992-2021) at the historical sites in all three-river systems and during the previous twenty-four years (1998-2021) for the modern sites (as discussed in the methods) in the Piankatank and Great Wicomico Rivers. Unless otherwise specified, the information presented below refers to those two tables. In this report the term "peak" is used to define the period when there was a notable increase in spatfall at a particular site or area in the system compared with the other sites or when there was an increase at all sites throughout an entire river system.

When comparing 2022 data with historical data in the James River, all eight sites were used. All of the sites monitored in the James River are considered to be part of the traditional seed area. Historically seed oysters were transplanted from this area to other tributaries in the Chesapeake Bay where recruitment was typically low (Haven & Fritz 1985). Due to the addition of sites (modern) during 1998 in the Piankatank and Great Wicomico Rivers, any comparison made to historical data could not include data from all of the sites monitored during 2022. Comparisons were made over the past twenty-four years for the modern sites whereas the historical sites include thirty years of data. Historical sites in the Piankatank River are Burton Point, Ginney Point and Palace Bar. Historical sites in the Great Wicomico River include Glebe Point, Hudnall, Haynie Point, Whaley's East (labeled Cranes Creek in reports prior to 1997), and Fleet Point.

James River

Oyster spatfall in the James River was first observed during the week of June 10 at the six sites where shellstrings were collected that week (Table S1). From then through the end of the sampling period, there was at least one spat recorded every week at each site the shellstrings were collected. Spatfall was relatively steady and consistent throughout the course of the sampling season, with the three highest weeks being July 8 (14.7% of total), July 29 (13.1% of total) and August 26 (15.5% of total) (Figure S3). Approximately 92% of the total spatfall was recorded between the weeks of June 24 and September 9. Examining data for individual sites, at Day's Point, the week of July 8 accounted for around 28% of the total for the year and at Horsehead, the week of July 29 accounted for around 25% of the total for the year (Table S1, Figure S3).

Cumulative spatfall in the James River during 2022 was heavy at all eight sites monitored. Spatfall varied from a low of 26.2 cumulative spat shell^{-1} at Dry Shoal to a high of 58.8 cumulative spat shell^{-1} at Rock Wharf (Table S1; Figure S4). At Deep Water Shoal, spatfall during 2022 was higher than all previous reference points (2021, 5, 10, 20 and 30-yr means). Spatfall at Point of Shoal was similar to 2021, and higher than the 5, 10, 20 and 30-yr means. Spatfall at Swash, Dry Shoal and Wreck Shoal during 2022 was lower than all previous reference points (2021, 5, 10, 20 and 30-yr mean). Comparing 2022 to the previous thirty years, spatfall numbers at Rock Wharf, Point of Shoal and Deep Water Shoal were the sixth, fifth and third highest observed, respectively. Comparatively, spatfall at Dry Shoal ranked the lowest out of all of the sites monitored, with 2022 numbers falling in the 56th percentile. The long-term means are primarily driven by a few exceptionally high spatfall years (1993, 2008, 2010, 2012, 2016, 2018, and 2020). Since 2010, spatfall throughout the James River, has been consistently moderate to heavy (Table S2).

Average river water temperature in the James River during the 2022 monitoring period ranged from a low of 17.3 to a high of 28.8°C (Figure S5A). Water temperature was 1 to 2°C higher than the 10, 20 and 30-year means for the first three weeks of monitoring, but then decreased and was around 1°C lower than the 10, 20 and 30-year means for the last two weeks of June. Water temperature was similar to the long-term means throughout July, reaching the high for the year during the week of August 5. By the following week (August 12), average water temperature had decreased by almost 3°C, and for that one week, was around 2°C less than the long-term means (Figure S5A). Water temperature decreased relatively rapidly at the end of September into early October, ending the monitoring season around 6°C lower than the 5-yr mean, the only long-term mean that had enough data to calculate.

Average salinities in the James River during 2022 ranged from 5.9 to 18.2 ppt, generally increasing throughout the monitoring period (Figure S5B). Salinity in the James River was relatively variable from week to week, with average weekly values changing from one week to the next by 1 to 4 ppt (Figure S5B). During several of these large weekly fluctuations (July 1, July 29, August 12 and September 9), 2022 salinity was anywhere from 3 and 5 ppt higher than the long-term (5, 10, 20 and 30-yr) means. By the end of the monitoring period, salinity was approximately 6 ppt higher than the 5-yr mean, the only long-term mean that had enough data available to calculate. The difference in salinity between the most upriver site (Deep Water Shoal) and the two most downriver sites (Day's Point and/or Wreck Shoal; Figure S1) ranged between 5.7 and 11.6 ppt, with the difference most weeks ranging between 6 and 9 ppt.

Piankatank River

Spatfall in the Piankatank River was first observed during the week of June 10 at all eight sites monitored and was then consistent throughout the sampling period, with at least one spat recorded at each site every week (Table S1; Figure S6). Weekly spatfall frequency was highly variable ranging from 0.1 to 429 spat $shell^{-1}$. The largest overall peak in the system occurred during the weeks of July 1 and July 8, accounting for approximately 69% of the spatfall for the year (Figure S6A). There was a smaller peak observed later in the monitoring period, during the week of September 16, accounting for around 8% of the total spatfall for the year (Figure S6B). At the two most upriver sites, Wilton Creek and Ginney Point, approximately 43 and 48% of the spatfall respectively, were observed during the weeks of July 8 and July 15 (Figure S6B).

Cumulative spat $shell^{-1}$ for the year was extremely heavy at all eight sites monitored in the Piankatank River. Spatfall ranged from a low of 130.6 cumulative spat $shell^{-1}$ at Wilton Creek to a high of 916.5 cumulative spat $shell^{-1}$ at Bland Point (Table S1; Figure S7). With the exception of the 2021 reference point at Stove Point, spatfall during 2022 was higher than all previous reference points (2021, 5, 10, 20, and 30-yr means) at every site monitored. At the three historical sites, spatfall in 2022 was the highest recorded at Ginney Point and Burton Point and the second highest recorded at Palace Bar over the past thirty years (Figure S7A). At the modern sites, spatfall in 2022 was the highest recorded at Bland Point, Heron Rock and Cape Toon, the second highest at Stove Point and the third highest at Wilton Creek, since monitoring began at those sites in 1998.

The average water temperature in the Piankatank River during the 2022 monitoring period ranged from 17.3 to 29.7°C (Figure S8A), reaching the high for the season during the last week of July. Water temperature in the Piankatank River was typically less than 1°C different than the long-term (5, 10, 20, and 30-yr) means throughout most of the sampling period. The few exceptions occurred during the weeks of June 3 (around 2°C higher), August 12 (1 to 2°C lower), August 26 (1 to 2°C higher) and during final week of sampling, September 30, when water temperature was 5 to 6°C lower (Figure S8A). The decrease in water temperature during the week of August 12, was similar to that observed in the James River. The decrease in temperature observed in September was much faster than what is typically observed in the system, with an almost 9°C decrease between the weeks of September 9 (25.9 °C) and September 30 (17.3°C).

Salinity in the Piankatank River during 2022 ranged from 13.2 to 19.1 ppt, generally increasing over the monitoring period (Figure S8B). Salinity during 2022 was similar to the long-term (5, 10, 20 and 30-yr) means through the end of July (Figure S8B). Salinity generally increased throughout August and September, and was anywhere from 0.5 to 3.4 ppt higher than the long-term means during that time (Figure S8B). The largest difference was with the 5-yr mean, most likely due to the inclusion of data from 2018, an exceptionally wet, and therefore low salinity year throughout the Chesapeake Bay. The difference in salinity between the various sites monitored ranged between 0.9 and 2.8 ppt, with the difference most weeks ranging between 1 and 2 ppt.

Great Wicomico River

Spatfall in the Great Wicomico River was first observed during the week of June 3 at Harcum Flats and at all nine sites monitored during the week of June 10. Settlement from then through the rest of the monitoring period was consistent, with at least one spat settling at the majority of the sites each week. There was a very large pulse in spatfall during the three-week period between June 24 and July 8. Settlement during these three weeks accounted for 88 to 96% of the total for the year at every site (Table S1; Figure S9A). Approximately 3 to 7% of the additional spatfall for the year occurred during the weeks of June 17 and September 16 (Figure S9B). At Glebe Point, around 83% of the total spatfall for the year was observed during the week of June 24.

Cumulative spat shell^{-1} for the year was extremely heavy at all nine sites monitored, varying across the sites from a low of 235.2 cumulative spat shell^{-1} at Glebe Point to a high of 1,121.7 cumulative spat shell^{-1} at Shell Bar. With the exception of the 5, 10 and 20-yr means at Glebe Point, spatfall in the Great Wicomico River in 2022 was higher than all previous reference points at all nine sites monitored. When compared with the previous thirty years, spatfall in 2022 was in the 76th percentile or greater at all five historical sites. Spatfall in 2022 was the highest observed over the past thirty years at Haynie Point, the second highest (96th percentile) at Whaley's East and Fleet Point and the third highest (93rd percentile) at Hudnall (Figure S10A). When compared to the previous twenty-four years, spatfall in 2022 at the four modern sites ranked the highest at Shell Bar and the third highest (91st percentile) at Rogue Point, Hilly Wash and Harcum Flats (Figure D10B). Spatfall on the shellstring collectors in the Great Wicomico River has been consistent and heavy in almost every year since 2006 (Table S2).

The average river water temperature in the Great Wicomico River during the 2022 monitoring period ranged from 17.1 to 29.3°C (Figure S11A). Water temperature throughout the monitoring period was typically within 1°C of the long-term means (5, 10, and 20-year) for the river system (Figure S11A). The most notable exceptions occurred during the week of June 3 (2022 around 2°C higher), June 17 (2022 around 2°C lower), August 12 (2022 between 1 and 2°C lower) and the week September 30 (2022 around 6°C lower). The decrease in temperature observed during the week of August 12 as well as the one in mid-September was similar to what was observed in the James and Piankatank Rivers. The decrease in September was much faster than what is typically observed in the system, with an almost 9°C decrease between the weeks of September 16 (25.9 °C) and September 30 (17.1°C).

Salinity in the Great Wicomico River during 2022 ranged from 12.4 to 17.9 ppt, generally increasing throughout the monitoring period (Figure S11B). During the first few weeks of monitoring, at the end of May, salinity was 1 to 2 ppt lower than the long-term (5, 10 and 20-yr) means. Salinity was similar (less than 1 ppt difference) to the long-term means (5, 10, and 20-year) throughout June and July (Figure S11B). For much of August and September, salinity was 1 to 2 ppt higher than the long-terms means. The difference in salinity in any given week between all of the sites monitored, was typically less than 2 ppt.

DISCUSSION

During the sixteen-year period between 1992 and 2007, spatfall on the shellstrings was light to moderate; with 80% of all of the year/site combinations having a seasonal cumulative total of less than 10 spat shell^{-1}. However, spatfall on the shellstrings over the past fifteen years (2008-2022) has been on the rise such that 87% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat shell^{-1}) and 37% of all of the year/site combinations had extremely heavy spatfall (seasonal cumulative total of > 100 spat shell^{-1}; Table S2). Light settlement (seasonal cumulative total of < 1.0 spat shell^{-1}) has not been observed at any of the twenty-five sites monitored since 2005. This trend of increased spat set has been especially notable in the Great Wicomico River, where from 2006 through 2022, 89% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat shell^{-1}) and 42% of the total year/site combinations had extremely heavy spatfall (seasonal cumulative total of > 100 spat shell^{-1}; Table S2).

During 2022, water temperature in all three river systems, decreased by a notable amount during the week of August 12, around a 2°C decrease in one week. A relatively rapid temperature decrease was also observed in all three river systems at the end of September into early October (during the last few weeks of monitoring). In all three river systems, water temperature was around 26°C in early to mid-September, but had decreased to around 17°C by the first week of October. Water temperatures at this time of year are typically higher, ranging between 22 and 24°C. Changes in water temperature (both increases and decreases) have been indicated in stimulating oysters to spawn (Nelson 1928) and may have contributed to a late spawn that would not have been observed during the regular shellstring monitoring period.

Overall, spatfall on shellstrings in the James River during 2022 was heavy. Since 2008, the James River has had several very strong year classes on the shellstrings; 2008, 2010 and 2012, with 2016 through 2018, 2020 and 2021 being notable as well. The mean cumulative spat shell^{-1} over all eight sites from 1992 to 2007 was 9.4, whereas the mean for all eight sites over the past fifteen years (2008 to 2022) was 73.6. This translates to around an eight-fold increase in spatfall over the past fifteen years compared with the previous sixteen years. Since 2008, at least three out of the eight sites experienced heavy to extremely heavy spatfall each year, with heavy or extremely heavy spatfall during 83% (99/120) of the year/site combinations and moderate spatfall during the remaining year/site combinations (21/120). The one exception was during 2009, when all eight sites monitored had moderate spatfall (Table S2). From 1992 to 2007 on the other hand, only 19% (24/127) of the year/site combinations had heavy or extremely heavy spatfall, with 15% (19/127) during that time period experiencing light spatfall.

Overall, spatfall in 2022 on the shellstrings in the Piankatank River was extremely heavy. Similar to the James River, the Piankatank River has had several very strong year classes on the shellstrings in recent years; 2012, 2015, 2016, 2021 and now 2022, with 2014 being notable as well. From 1992 to 2006 (historical sites) and 1998 to 2006 (modern sites), spatfall in the Piankatank River was consistently low to moderate at most of the sites monitored. Spatfall began to improve beginning around 2007 and has been consistently good since 2010. From 1992 to 2009, only 17% (19/114) of the year/site combinations experienced heavy spatfall and 38% (43/114) experienced light spatfall. However, since 2010, no year/site combinations have experienced light spatfall and only four year/site combinations have had moderate spatfall, with extremely heavy spatfall occurring at 36% (37/104) of the year/site combinations and heavy spatfall during the remaining year/site combinations. At the three historical sites the mean from 1992 to 2009 was 4.1 cumulative spat shell^{-1}, whereas from 2010 to 2022 the mean at those three sites was 111.2 cumulative spat shell^{-1}, a 27-fold increase over the previous eighteen-year mean. Since the addition of the modern sites in 1998, the mean across the river increased from 5.5 cumulative spat shell^{-1} (1998 to 2009) to 133.6 cumulative spat shell^{-1} (2010 to 2022), a 24-fold increase.

With the exception of 2018, spatfall on the shellstrings in the Great Wicomico River has been especially good since 2006. Four out of the last seven years (2016, 2017, 2019 and 2022) saw extremely heavy spatfall at all nine sites monitored in the Great Wicomico River. In eight out of the eleven years between 2012 and 2022, at least seven out of the nine sites monitored in the Great Wicomico had extremely heavy spatfall. During that time only 8% (9/117) of the year/site combinations had moderate spatfall, with the remaining year/site combinations having either heavy (56/117) or extremely heavy spatfall (52/117). As has been typical in recent years (Southworth & Mann 2004), spatfall in the Great Wicomico River has been getting progressively earlier, with the majority (greater than 96%) of spat settling on the shellstrings in 2022, having set by early July.

Table S1: Average number of spat shell^{-1} for standardized week beginning on the date shown. "D" indicates the date deployed and "-" denotes a week when a shellstring was not collected.

STATION	5/13	5/20	5/27	6/3	6/10	6/17	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/2	9/9	9/16	9/23	9/30	YEAR
	133	140	147	154	161	168	175	182	189	196	203	210	217	224	231	238	245	252	259	266	273	TOTAL
JAMES RIVER																						
Deep Water Shoal			D	0	-	-	0.1	1.1	4.2	-	0.9	5.8	3.8	0.9	1.8	5.2	1.6	6.7	-	-	0.8	32.9
Horsehead			D	0	0.3	-	1.2	4.0	3.5	-	1.4	11.8	3.9	1.6	1.7	7.4	3.4	5.5	-	-	1.4	47.1
Point of Shoal			D	0	0.3	-	1.0	1.8	7.1	-	1.2	6.5	6.1	2.0	2.4	6.6	3.3	5.8	-	-	1.1	45.2
Swash			D	0	0.6	-	1.0	4.0	1.7	-	1.4	4.0	3.7	1.7	0.8	6.2	2.8	2.9	-	-	-	30.8
Dry Shoal			D	0	0.4	2.4	3.4	3.2	5.0	-	1.6	3.7	0.5	0.3	1.1	2.0	1.4	1.0	-	-	0.2	26.2
Rock Wharf			D	0	0.5	2.5	2.0	3.1	7.0	-	3.6	4.2	2.1	1.3	2.6	14.1	8.4	6.6	-	-	0.8	58.8
Wreck Shoal			D	0	-	-	0.9	7.0	5.4	-	2.5	2.9	2.3	0.5	1.3	1.9	2.5	3.1	-	-	1.2	31.5
Day's Point			D	0	0.5	1.1	5.6	1.8	13.1	-	2.1	2.9	1.7	0.7	2.9	5.9	4.0	2.7	-	-	1.4	46.4
PIANKATANK RIVER																						
Wilton Creek	D	-	0	0	0.4	1.3	12.4	8.3	27.1	28.6	2.4	0.8	0.1	0.9	2.5	0.6	0.7	3.7	36.3	-	4.5	130.6
Ginney Point	D	-	0	0	0.3	1.1	19.7	25.0	80.1	53.8	6.7	0.8	0.7	1.8	3.9	2.1	3.7	10.4	47.1	18.1	3.1	278.4
Palace Bar	D	-	0	0	0.1	1.7	18.5	50.4	41.1	6.6	1.0	0.9	0.1	0.3	3.5	3.4	1.2	1.2	10.7	4.4	0.5	145.6
Bland Point	D	-	0	0	1.2	2.7	67.5	257.0	337.0	9.0	0.7	0.6	0.3	1.4	12.2	20.8	55.5	26.8	90.8	27.2	5.8	916.5
Heron Rock	D	-	0	0	0.2	1.4	23.5	162.6	100.5	9.4	0.9	0.7	0.1	1.1	3.6	9.4	13.3	19.1	27.3	15.4	1.0	389.5
Cape Toon	D	-	0	0	0.3	1.2	29.8	315.7	77.7	12.0	0.2	0.8	0.3	1.8	0.7	3.9	7.0	9.7	26.8	10.9	0.2	499.0
Stove Point	D	-	0	0	0.2	0.6	24.6	373.3	169.3	4.4	0.3	0.4	0.1	0.2	2.3	46.2	12.0	12.7	36.6	-	2.7	685.9
Burton Point	D	-	0	0	0.8	1.2	40.8	429.0	272.1	7.6	1.8	0.3	0.9	0.8	9.1	13.4	12.7	23.7	42.3	27.0	1.3	884.8
GREAT WICOMICO																						
Glebe Point	D	-	-	0	0	7.9	194.3	3.6	17.3	7.8	0	0.1	0.9	0	0.3	1.3	0.1	0.7	0.5	-	0.4	235.2
Rogue Point	D	-	0	0	3.3	18.0	449.6	259.4	60.9	7.3	0.3	0.1	0.2	0.2	0.8	1.7	0.3	0.9	13.6	-	0.6	817.2
Hilly Wash	D	-	0	0	3.2	14.4	331.7	96.0	198.0	3.1	0.8	0.5	0.2	0.2	0.6	0.6	0.3	0.5	3.7	-	1.1	654.9
Harcum Flats	D	-	0	0.1	3.6	25.0	373.7	308.8	138.5	3.7	0.3	0.2	0.4	0.3	0.4	1.1	1.1	1.2	8.7	-	3.2	870.3
Hudnall	D	-	0	0	3.1	15.4	200.3	105.8	156.9	5.5	0	0	0	0.3	0.2	1.3	0.5	1.6	8.1	-	1.3	500.3
Shell Bar	D	-	0	0	7.2	18.9	362.2	378.9	319.5	4.4	0.2	0.3	0.2	0.2	0.9	2.9	2.1	4.3	16.7	-	2.8	1121.7
Haynie Point	D	-	0	0	0.1	11.8	149.3	418.8	211.3	4.3	0.1	0.1	0	0.2	0.1	1.1	1.1	3.4	13.8	-	1.4	816.9
Whaley's East	D	-	0	0	2.9	6.0	35.9	134.5	143.5	2.3	0.2	0.3	0	0	0.2	2.4	1.8	1.7	13.7	-	2.1	347.5
Fleet Point	D	-	0	0	0.5	14.4	36.4	162.7	87.2	5.4	0.9	0.1	0.1	0.4	0.2	1.9	1.0	6.7	7.3	-	1.2	326.4

Table S2: Spatfall totals for historical sites (1992-2022) and modern sites (1998-2022) as defined in the text. Values presented are the cumulative sum of spat shell^{-1} values for each year. "+" and "-" indicate the direction of change in 2022 in reference to 2021 and to the five, ten, twenty, and thirty year means. Blank cells for a site indicate years where data are not available.

STATION	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Mean 17-21	Mean 12-21	Mean 02-21	Mean 92-21	Ref. 2021	Ref. 5-yr	Ref. 10-yr	Ref. 20-yr	Ref. 30-yr
JAMES																																								
Deep Water Shoal	0.7	15.7	0.7	1.7	0.5	1.6	1.2	5.7	0.7	2.0	33.8	0.1	1.6	1.0	2.1	5.3	252.3	1.7	19.7	7.0	13.6	2.8	2.3	18.0	19.5	7.6	4.3	20.2	9.7	15.8	32.9	11.5	11.4	21.9	15.6	+	+	+	+	+
Horsehead	3.6	43.7	3.7	2.8	3.6	2.8	1.1	3.8	2.3	4.0	24.4	0.0	3.6	1.3	2.2	4.2	227.6	4.2	115.0	15.0	86.3	4.7	6.1	46.4	87.1	42.0	26.8	47.8	60.9	66.4	47.1	48.8	47.5	43.6	31.4	-	-	NC	+	+
Point of Shoal	5.4	73.8	17.2	5.5	2.6	2.9	1.5	3.5	0.7	4.0	31.3	0.1	3.1	1.1	2.2	8.6	293.6	2.9	65.0	8.0	64.9	3.2	5.5	36.7	37.3	29.9	22.3	43.5	29.0	45.0	45.2	33.9	31.7	36.7	28.3	NC	+	+	+	+
Swash		46.2	5.5	0.3	2.4	2.0	1.6	6.8	2.6	3.5	26.0	0.5	11.9	1.4	1.8	6.3	481.5	5.2	52.5	14.1	56.8	4.0	12.8	32.5	111.6	60.2	72.2	38.6	41.6	69.3	30.8	56.4	50.0	55.0	40.4	-	-	-	-	-
Dry Shoal	14.2	119.1	30.4	1.8	12.3	1.4	1.1	6.1	3.7	2.1	16.5	0.6	8.7	3.1	8.5	4.9	269.6	8.9	240.2	33.8	151.1	20.4	21.7	63.6	106.2	133.3	188.7	63.0	170.2	63.2	26.2	123.7	98.1	78.8	58.9	-	-	-	-	-
Rock Wharf	11.4	34.3	12.0	2.6	2.8	5.4	2.1	8.0	1.0	8.5	22.7	0.1	10.0	4.4	1.9	19.8	347.5	5.0	272.4	33.8	106.5	10.9	11.5	52.3	48.0	77.2	58.3	82.7	28.9	53.9	58.8	60.2	53.0	62.4	44.5	+	-	+	-	+
Wreck Shoal	3.3	15.5	2.2	0.2	11.0	0.8	0.7	3.1	0.9	3.2	8.3	1.3	21.6	3.1	4.1	4.1	584.3	7.1	64.1	17.5	66.4	3.3	12.3	30.4	149.3	87.7	223.2	61.3	130.5	167.9	31.5	134.1	93.2	82.4	56.3	-	-	-	-	-
Day's Point	14.3	131.5	49.1	3.4	5.2	6.0	0.4	7.3	4.3	1.6	10.5	0.1	3.6	1.6	1.9	30.8	249.2	3.0	335.0	25.6	182.9	11.1	13.3	93.1	28.1	139.3	38.6	53.5	30.5	14.9	46.4	55.4	60.5	63.3	49.7	+	-	-	-	-
PIANKATANK																																								
Wilton Creek							1.9	5.9	3.6	0.2	6.5	0.1	0.2	0.4	3.9	2.9	12.1	4.1	20.9	18.4	235.6	23.3	29.7	31.4	209.5	27.2	18.7	17.8	8.9	63.2	130.6	27.2	66.5	36.7	31.1	+	+	+	+	+
Ginney Point	11.7	1.7	0.0	0.5	1.3	0.0	2.2	6.4	6.8	1.2	5.9	0.2	0.2	0.3	3.9	7.1	18.3	4.5	63.7	32.0	232.0	29.3	70.5	70.4	64.1	27.9	35.8	24.3	25.9	134.4	278.4	49.7	71.5	42.5	29.4	+	+	+	+	+
Palace Bar	25.0	5.0	0.9	1.0	1.6	0.0	5.5	10.1	3.9	0.2	3.1	0.1	0.5	0.2	2.1	4.6	7.5	5.9	30.3	14.1	155.7	16.6	24.8	56.7	142.0	18.6	14.5	14.4	9.3	101.4	145.6	31.6	55.4	31.1	22.5	+	+	+	+	+
Bland Point							2.3	44.1	2.7	1.3	6.7	0.2	0.4	1.0	3.7	11.0	11.1	4.7	34.7	22.5	224.5	41.5	29.6	390.9	815.0	62.1	39.3	92.0	27.1	315.7	916.5	107.2	203.8	106.7	91.0	+	+	+	+	+
Heron Rock							10.1	9.3	3.2	0.6	5.1	0.2	0.7	0.4	1.1	9.9	7.4	5.4	28.2	22.5	73.1	4.3	50.8	105.1	159.4	31.3	36.1	35.3	8.8	145.8	389.5	51.5	65.0	36.5	31.4	+	+	+	+	+
Cape Toon							4.5	12.3	1.2	1.8	9.1	0.1	2.0	2.6	8.2	23.5	23.4	9.9	193.2	33.1	191.2	62.9	271.0	167.5	104.3	112.0	75.9	88.4	11.2	410.2	499.0	139.5	149.5	90.0	75.8	+	+	+	+	+
Stove Point							1.0	7.1	1.8	1.6	31.0	0.1	0.7	1.7	7.0	19.9	14.1	6.0	23.2	26.0	121.0	42.3	31.4	304.1	335.8	18.3	28.7	63.5	14.1	704.3	685.9	165.8	166.4	89.7	75.2	-	+	+	+	+
Burton Point	11.8	6.5	0.1	1.0	1.0	0.7	1.3	14.9	2.7	0.8	4.9	0.2	1.9	0.9	2.9	10.6	7.1	3.0	19.0	17.5	172.0	21.3	58.4	379.5	474.5	43.7	34.6	54.2	19.8	323.0	884.8	95.1	158.1	82.4	56.3	+	+	+	+	+
GREAT WICOMICO																																								
Glebe Point	1.0	0.2	0.0	2.1	0.6	42.7	0.6	2.4	4.2	1.1	283.3	4.9	1.6	2.0	150.3	132.9	140.6	405.6	39.5	134.0	2122.5	49.4	251.4	234.8	1117.3	487.9	10.0	169.2	626.7	13.0	235.2	261.4	508.2	318.8	214.4	+	-	-	-	+
Rogue Point							0.9	2.0	2.6	0.7	16.6	7.0	0.5	2.6	88.1	112.0	126.2	92.9	82.9	33.5	1136.2	79.5	442.5	102.7	618.9	141.1	11.1	188.5	1177.7	61.4	817.2	316.0	396.0	226.1	188.7	+	+	+	+	+
Hilly Wash							0.6	1.6	3.2	0.8	24.1	2.9	0.5	1.9	43.9	126.9	137.7	81.7	27.6	43.3	1198.8	73.2	283.0	151.4	525.6	281.6	9.9	113.2	918.5	59.0	654.9	276.4	361.4	205.2	171.3	+	+	+	+	+
Harcum Flats							0.1	1.3	0.8	1.1	33.7	3.7	0.7	1.5	110.7	135.3	273.3	112.3	31.3	51.0	1128.3	38.6	156.6	260.9	601.9	333.6	14.5	229.1	884.9	87.3	870.3	309.9	373.6	224.5	187.2	+	+	+	+	+
Hudnall	1.0	0.9	0.0	0.3	0.4	78.6	0.5	0.9	1.0	1.4	12.7	3.1	0.6	0.9	37.4	51.7	83.0	44.3	32.5	44.5	287.0	37.8	150.5	136.4	601.9	200.7	9.7	186.1	966.7	56.9	500.3	284.0	263.4	147.2	101.0	+	+	+	+	+
Shell Bar							0.0	2.9	0.8	0.8	17.8	1.9	0.3	0.9	29.6	30.3	78.1	18.5	46.2	40.2	472.7	51.2	295.0	437.7	991.1	336.7	12.8	298.8	542.1	194.0	1121.7	276.9	363.2	194.8	162.5	+	+	+	+	+
Haynie Point	1.5	1.6	0.0	0.3	5.4	8.7	0.7	1.1	1.1	0.9	15.4	1.6	0.3	0.8	17.1	24.8	43.1	8.6	17.8	22.7	213.5	16.1	220.4	261.9	575.7	106.9	8.8	273.6	428.0	142.7	816.9	192.0	224.8	120.0	80.7	+	+	+	+	+
Whaley's East	0.3	0.2	0.0	0.6	3.5	2.0	0.4	1.8	0.2	0.7	2.4	0.9	0.1	0.4	6.0	21.6	1.9	2.3	16.4	5.5	144.7	4.1	83.0	82.5	747.8	101.1	7.5	165.3	280.7	125.2	347.5	136.0	174.2	90.0	60.3	+	+	+	+	+
Fleet Point	7.5	2.3	0.0	2.8	4.2	6.9	0.3	0.5	0.6	1.0	3.9	0.4	0.3	0.4	4.9	8.6	8.4	1.3	10.2	6.5	79.3	8.4	77.5	36.8	595.7	224.1	21.9	239.1	23.9	43.5	326.4	110.5	135.0	69.8	47.4	+	+	+	+	+

Light settlement (0.0 - 1.0 spat/shell)
Moderate settlement (1.01-10.0 spat/shell)
Heavy settlement (10.1-100.0 spat/shell)
Extremely heavy settlement (>100.0 spat/shell)

Figure S1: Map showing the location of the 2022 shellstring deployment sites. An M following the site name indicates a modern site as specified in the text; all other sites are historical. James River: 1) Deep Water Shoal, 2) Horsehead, 3) Point of Shoal, 4) Swash, 5) Dry Shoal, 6) Rock Wharf, 7) Wreck Shoal, 8) Day's Point. Piankatank River: 9) Wilton Creek (M), 10) Ginney Point, 11) Palace Bar, 12) Bland Point (M), 13) Heron Rock (M), 14) Cape Toon (M), 15) Stove Point (M), 16) Burton Point. Great Wicomico River: 17) Glebe Point, 18) Rogue Point (M), 19) Hilly Wash (M), 20) Harcum Flats (M), 21) Hudnall, 22) Shell Bar (M), 23) Haynie Point, 24) Whaley's East, 25) Fleet Point.

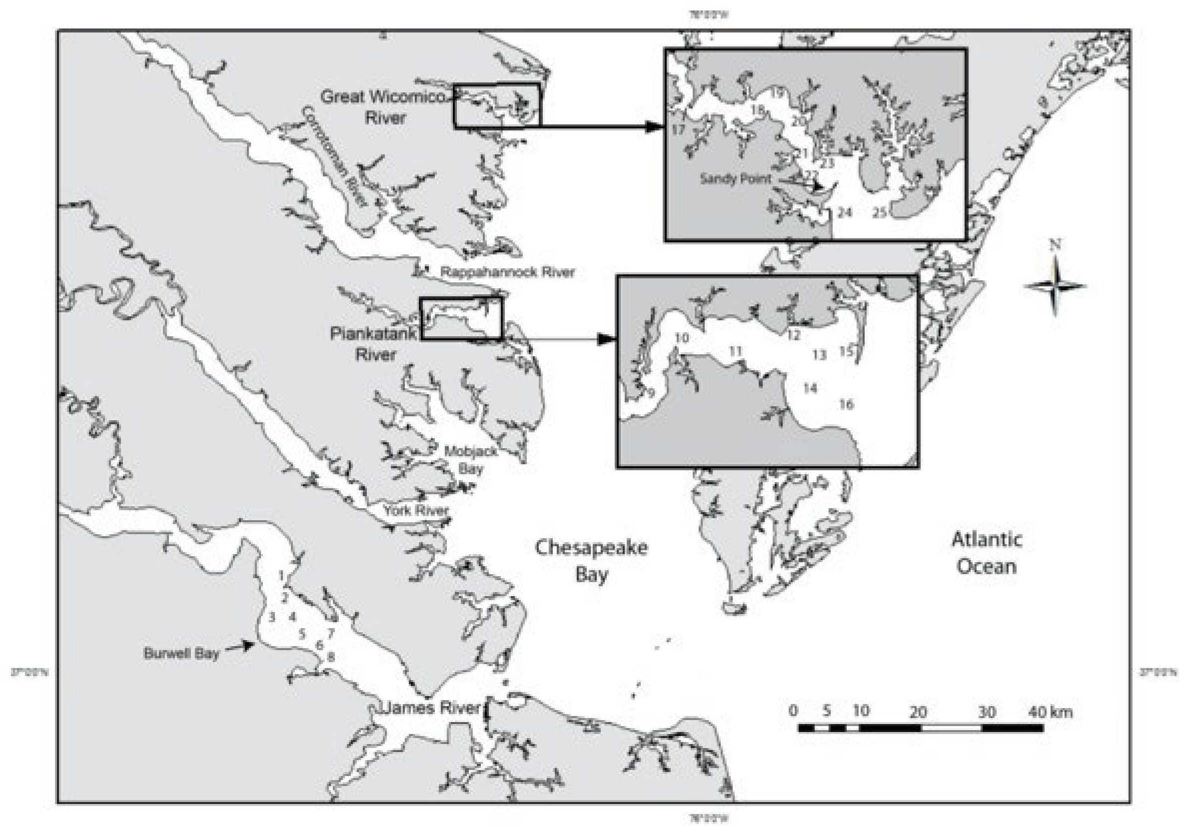


Figure S2: Diagram of the shellstring setup on buoys with pictures laying out each step (see https://www.vims.edu/research/units/labgroups/molluscan_ecology/_docs/Shellstring_manual.pdf for a detailed description of the shellstring survey methods).

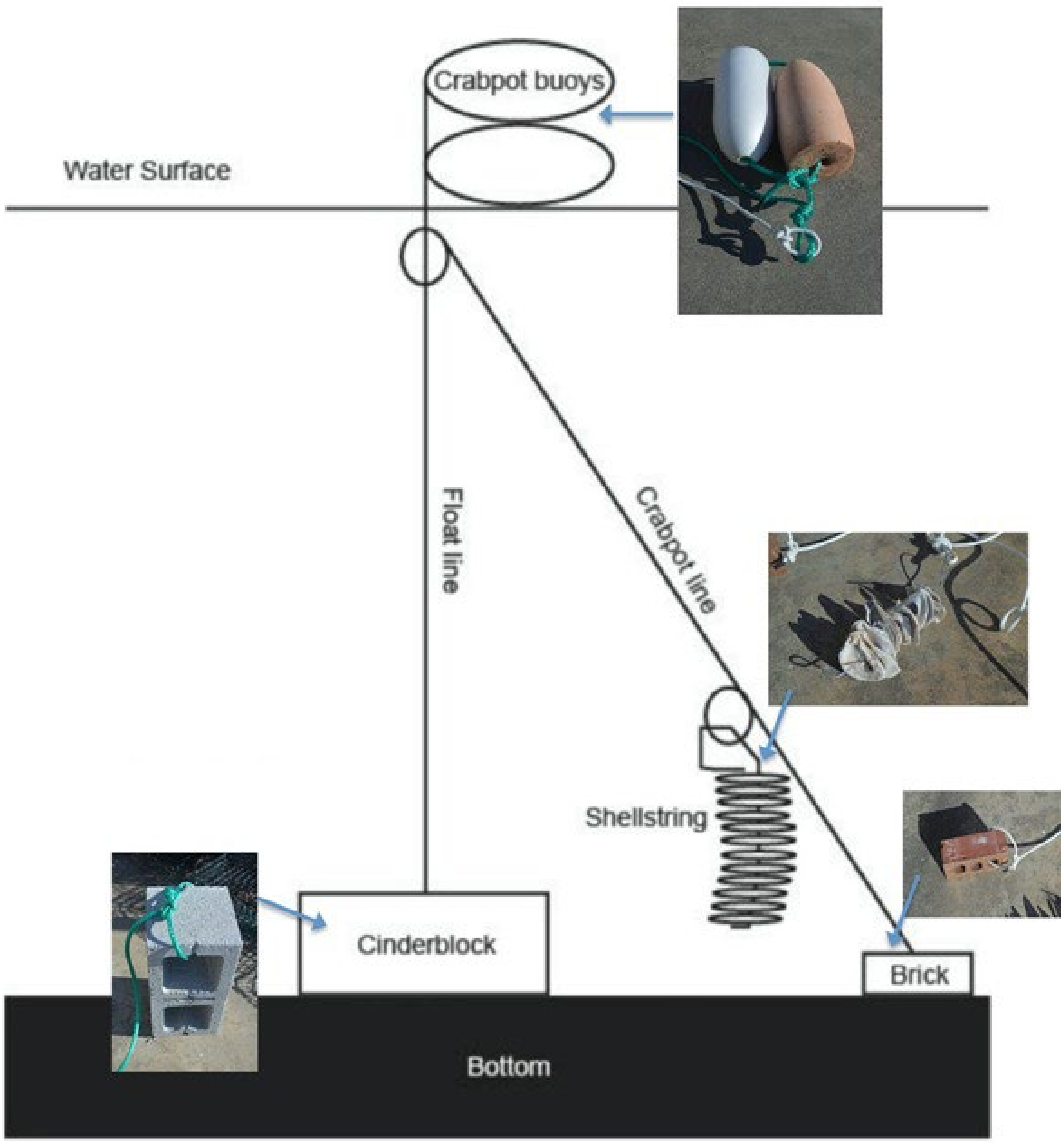


FIGURE S3: JAMES RIVER (2022) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}
(H = historical station: M = modern station as described in text)
See Table S1 for weeks when data for individual sites are missing.

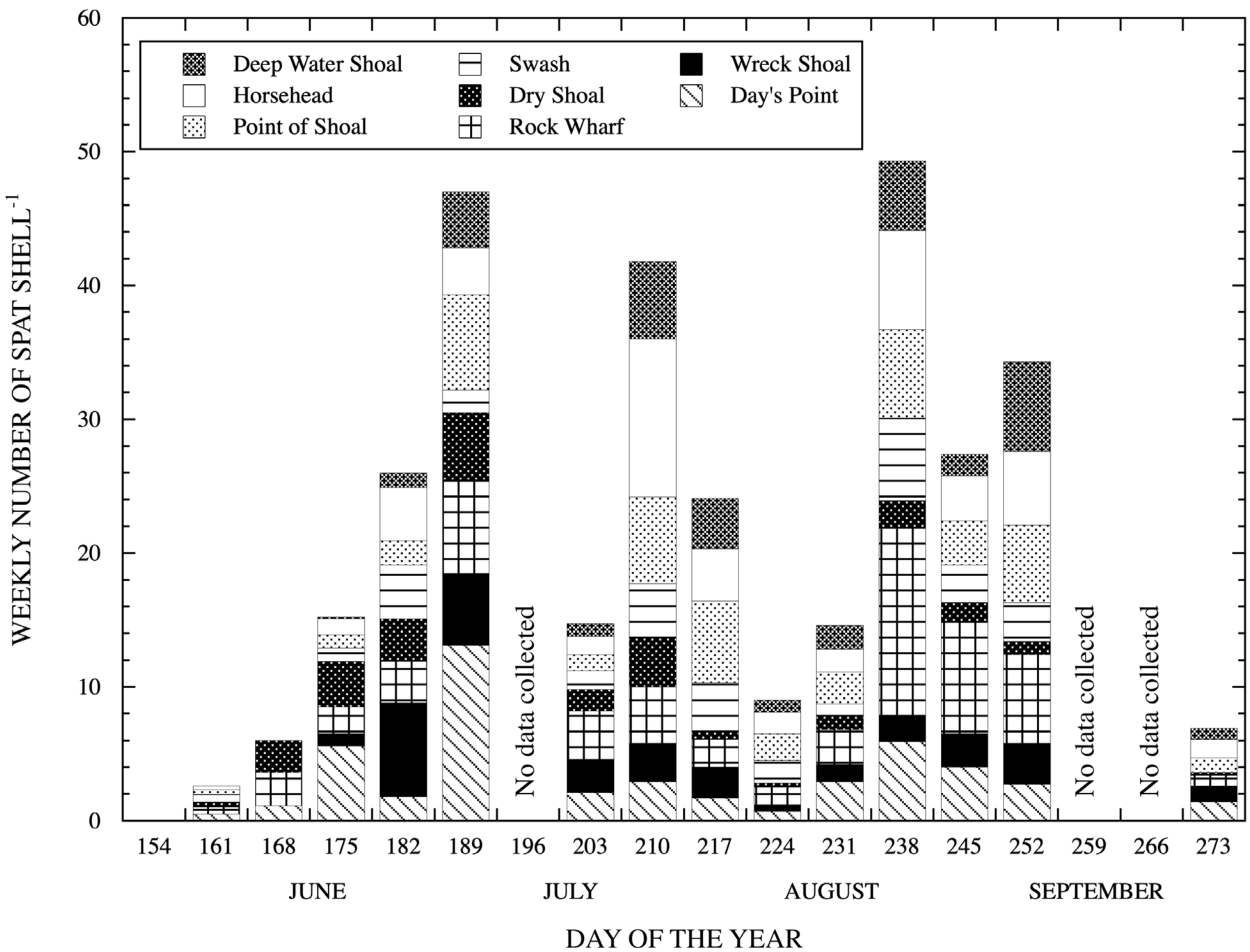


FIGURE S4: SPATFALL TRENDS FROM 1992 TO 2022 AT ALL EIGHT SITES IN THE JAMES RIVER (upriver sites in panel A; downriver sites in panel B) (expressed as cumulative weekly spatfall; solid line > 100 spat/shell, dashed line > 10 spat/shell)

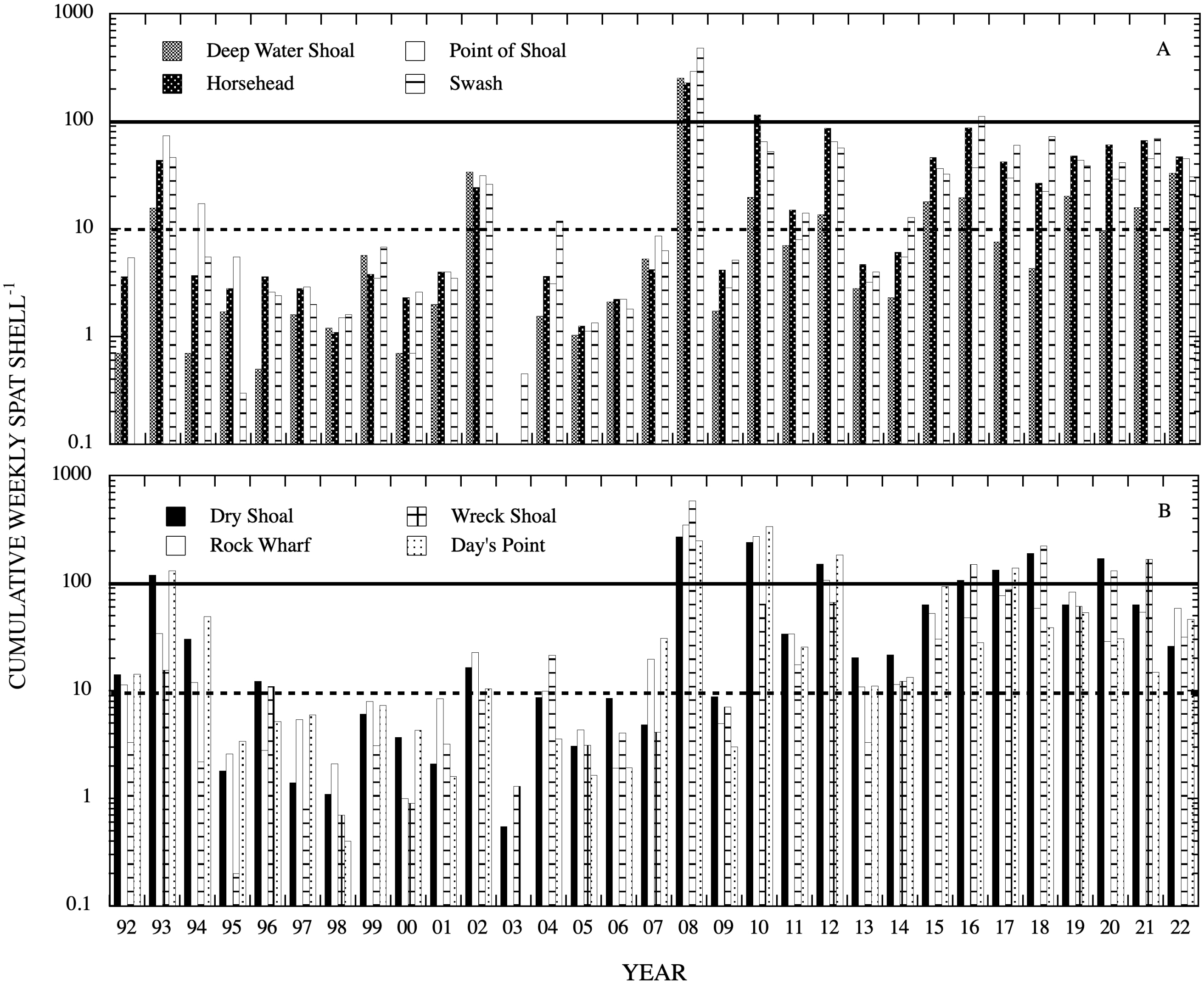


FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE MONITORING PERIOD: 5, 10, 20 AND 30-YEAR MEANS COMPARED WITH 2022
(Error bars represent standard error of the mean; greater than 92% of spatfall for the year occurred during the period that is shaded)

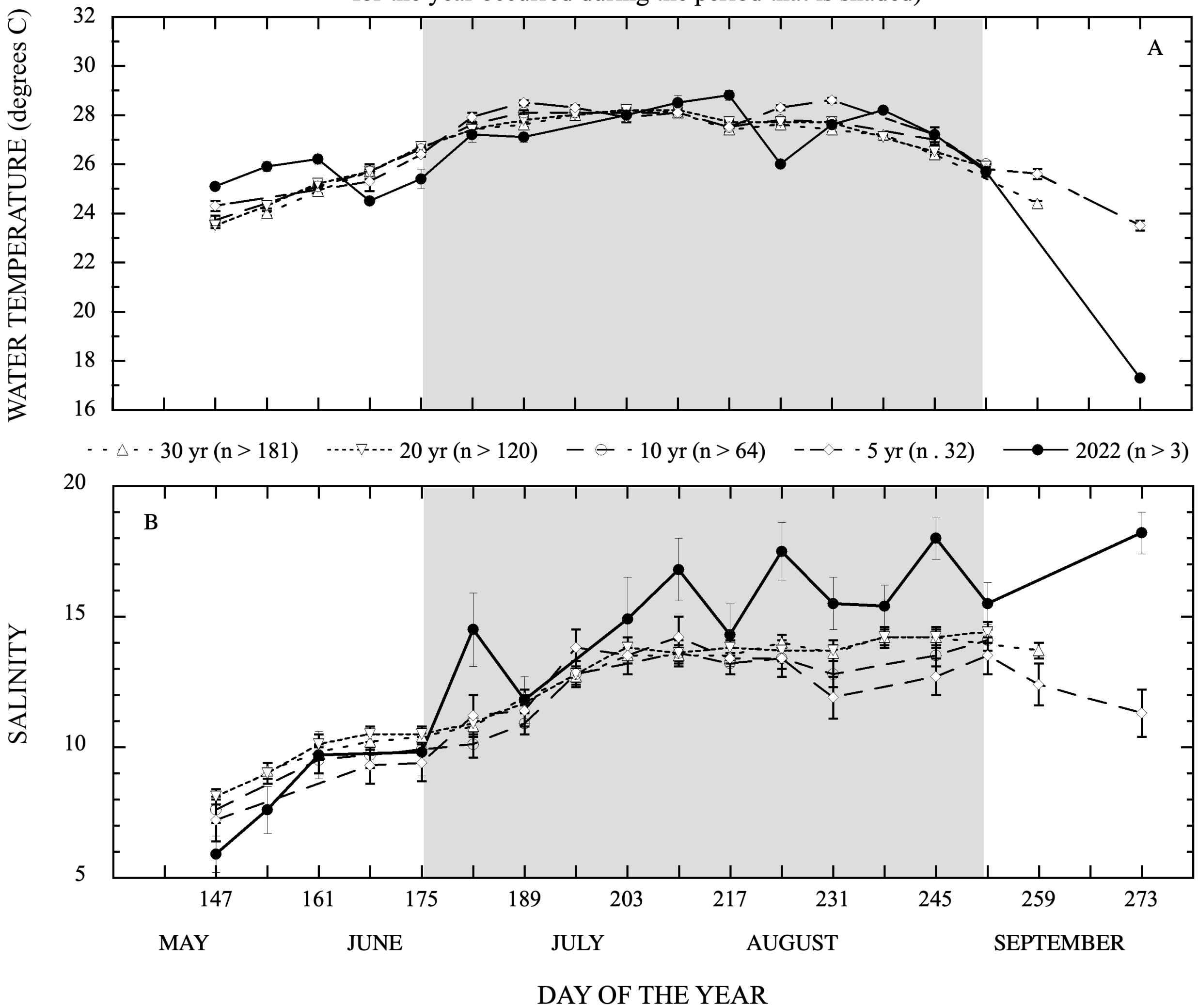


FIGURE S6: PIANKATANK RIVER (2022) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}
(H = historical station: M = modern station as described in text)
Panel A includes all weeks, Panel B has the major peak weeks (DOY 182 & 189) removed

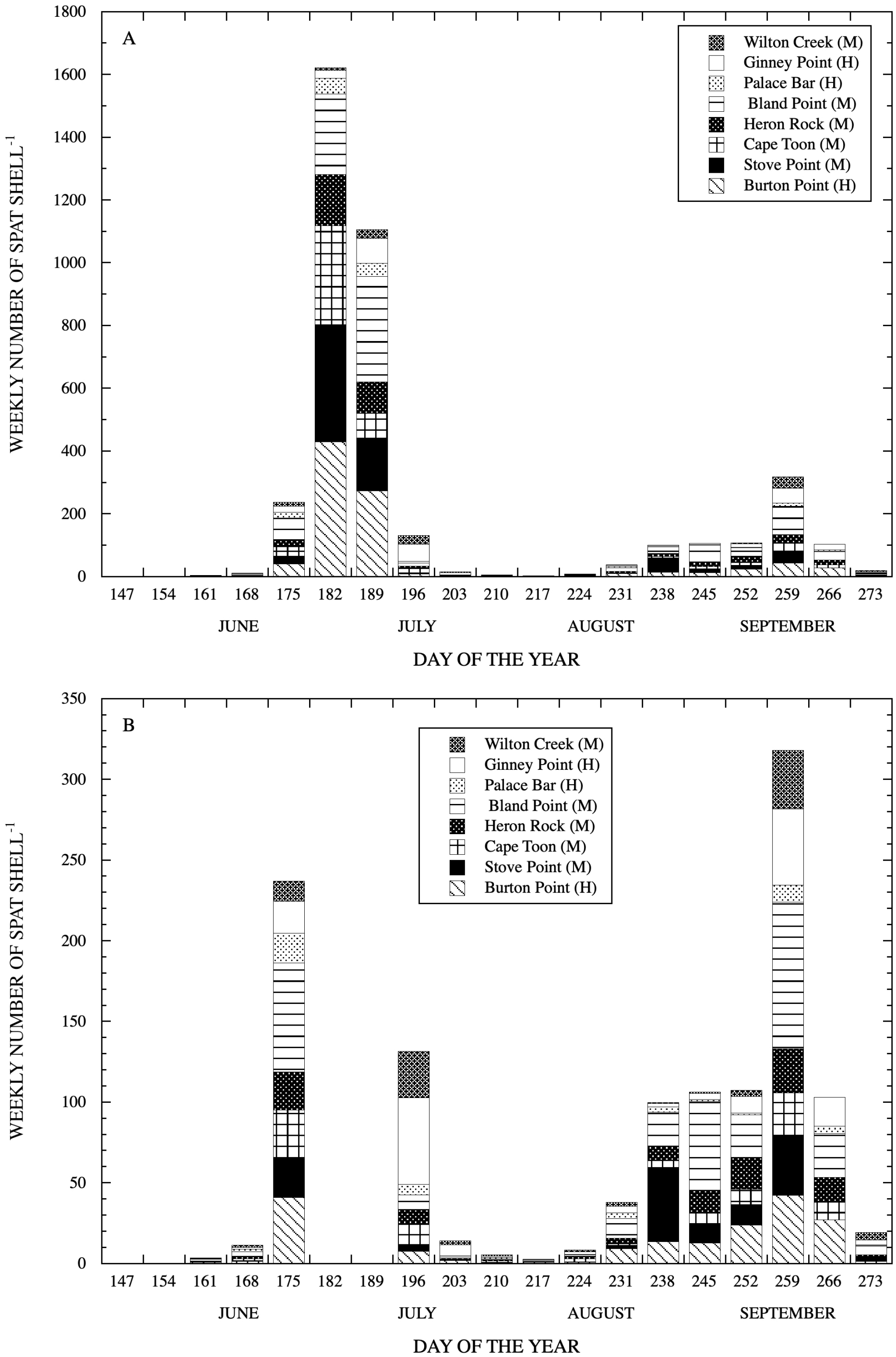


FIGURE S7: SPATFALL TRENDS IN THE PIANKATANK RIVER AT THE THREE HISTORICAL SITES (panel A: 1992 to 2022) AND THE FIVE MODERN SITES (panel B: 1998 to 2022)
(expressed as cumulative weekly spatfall; solid line > 100 spat/shell, dashed line > 10 spat/shell)

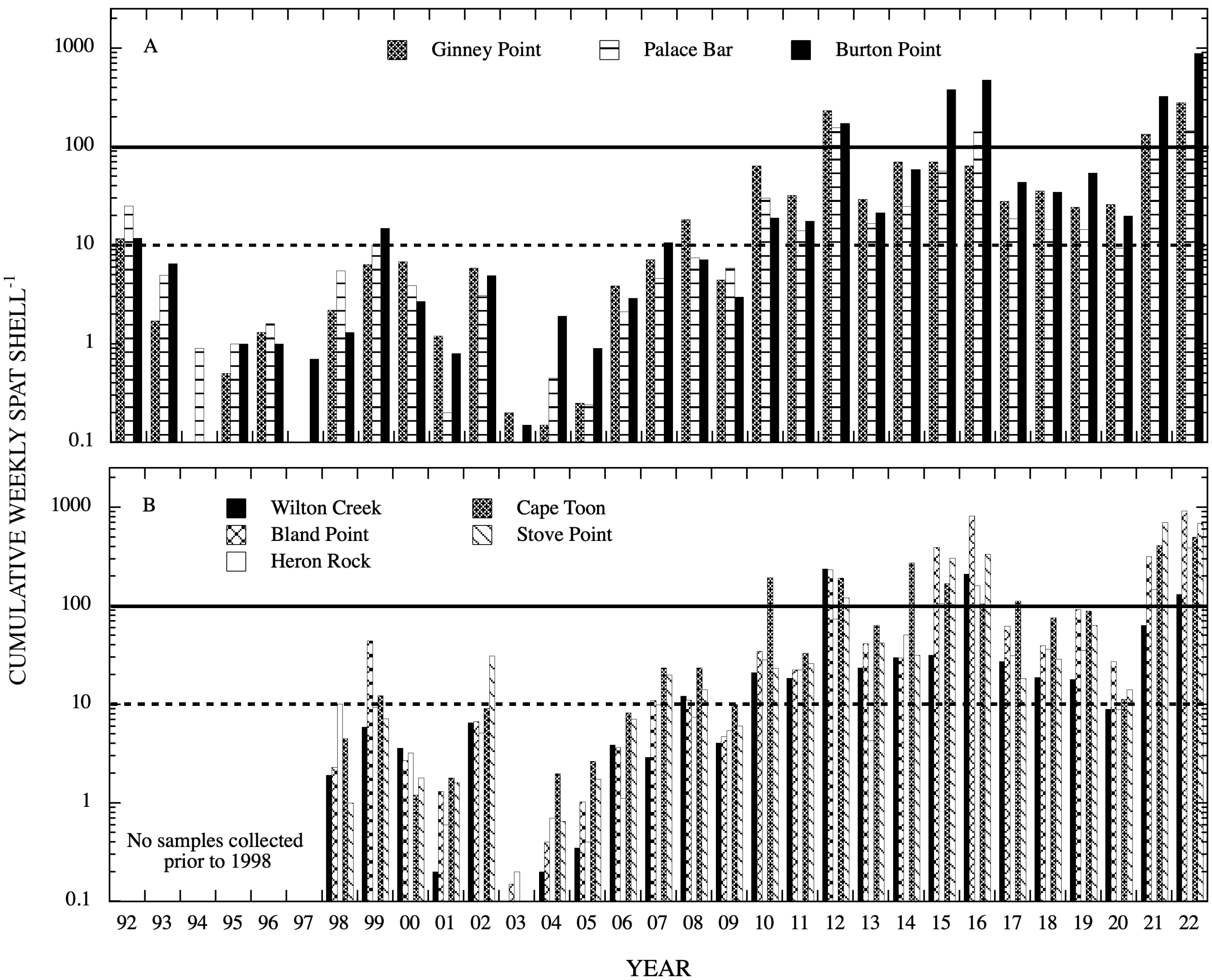


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE MONITORING PERIOD: 5, 10, 20 AND 30-YEAR MEANS COMPARED WITH 2022
(Error bars represent standard error of the mean; darker shading represents 69% of spatfall for the year, with an additional 25% occurring during the weeks with lighter shading)

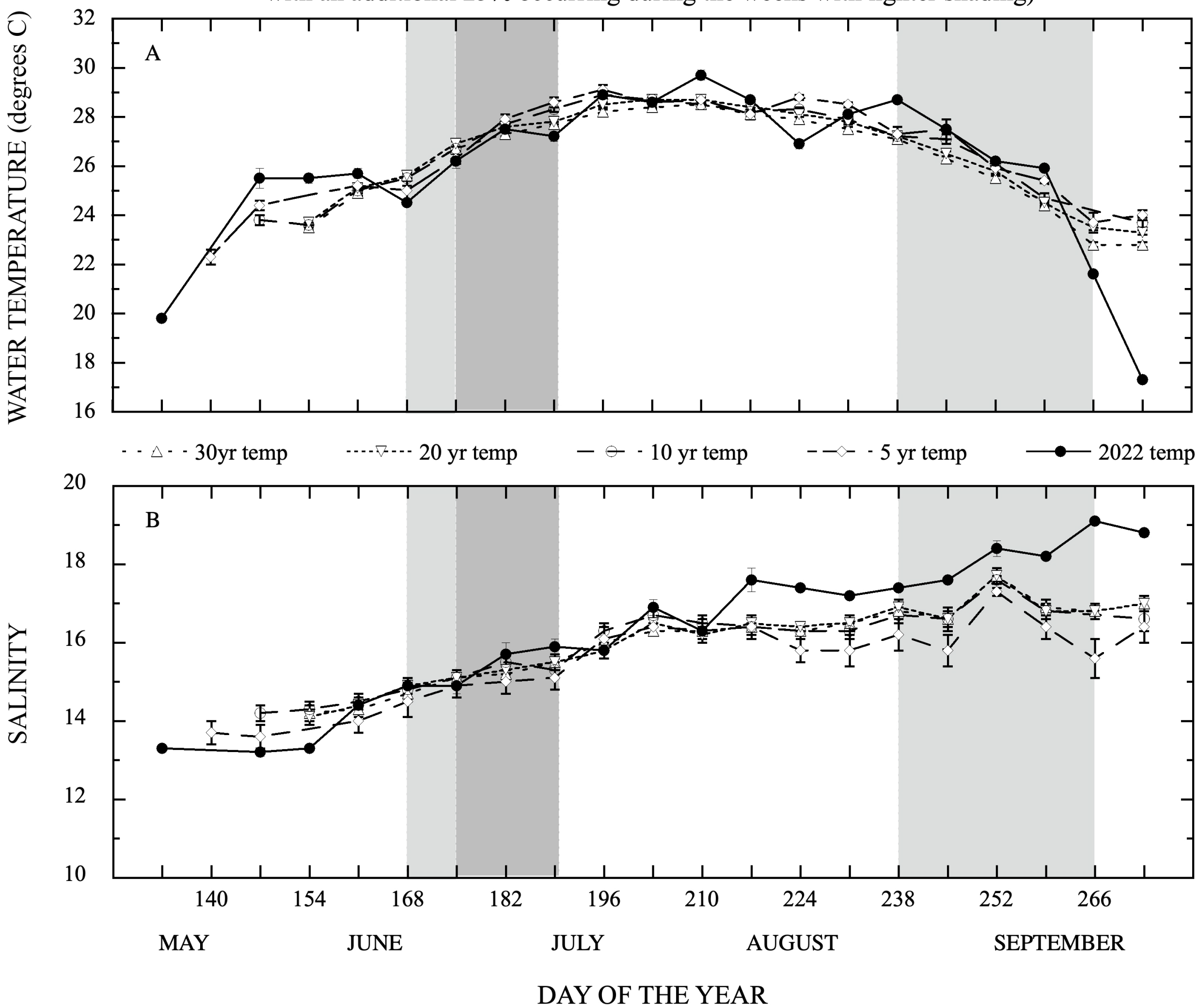


FIGURE S9: GREAT WICOMICO RIVER (2022) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}
(H = historical station: M = modern station as described in text)
Panel A includes all weeks, Panel B has the major peak weeks (DOY 175, 182 & 189) removed

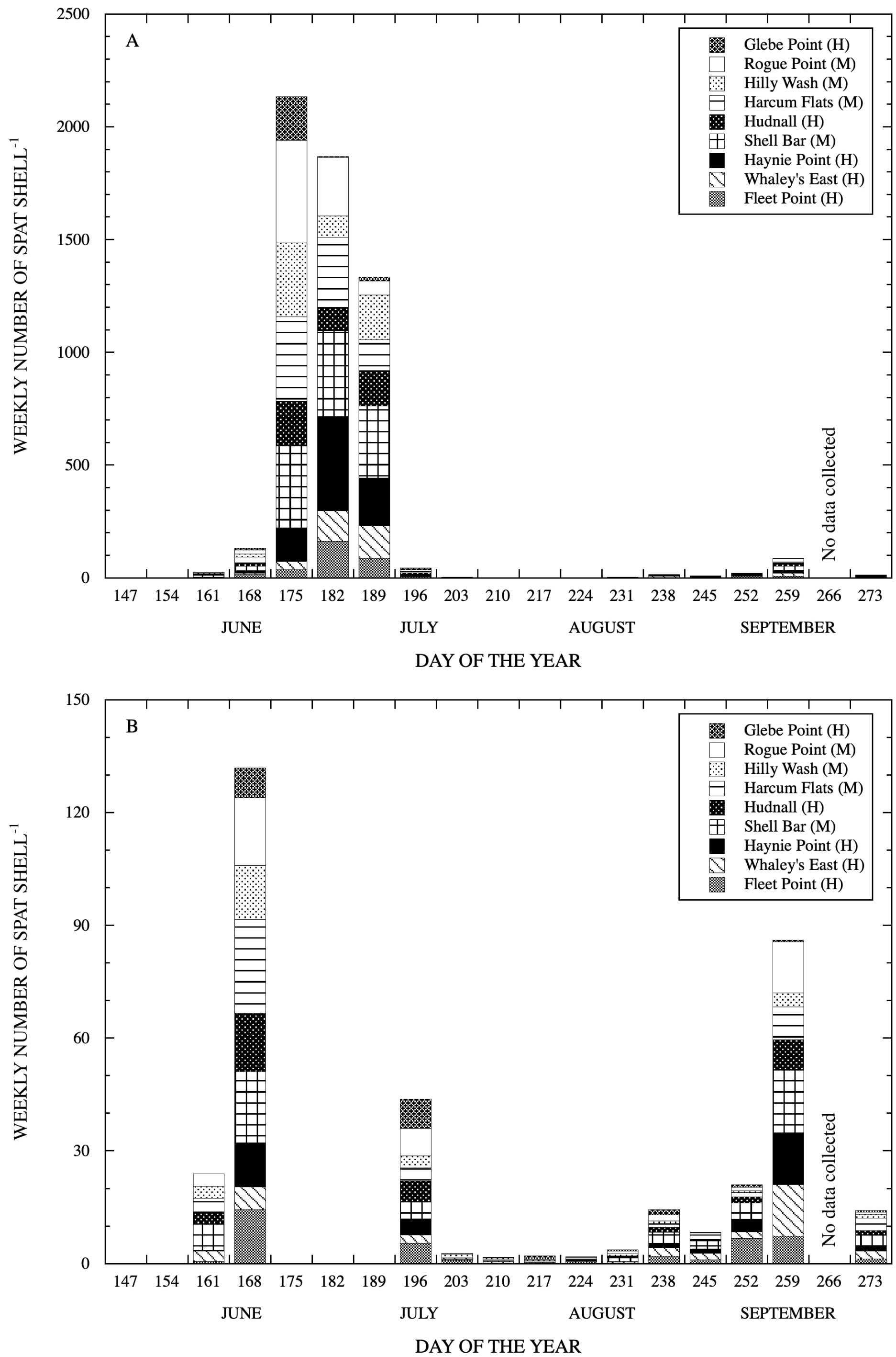


FIGURE S10: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER AT THE THREE HISTORICAL SITES (panel A: 1992 to 2022) AND THE FIVE MODERN SITES (panel B: 1998 to 2022)
(expressed as cumulative weekly spatfall; solid line > 100 spat/shell, dashed line > 10 spat/shell)

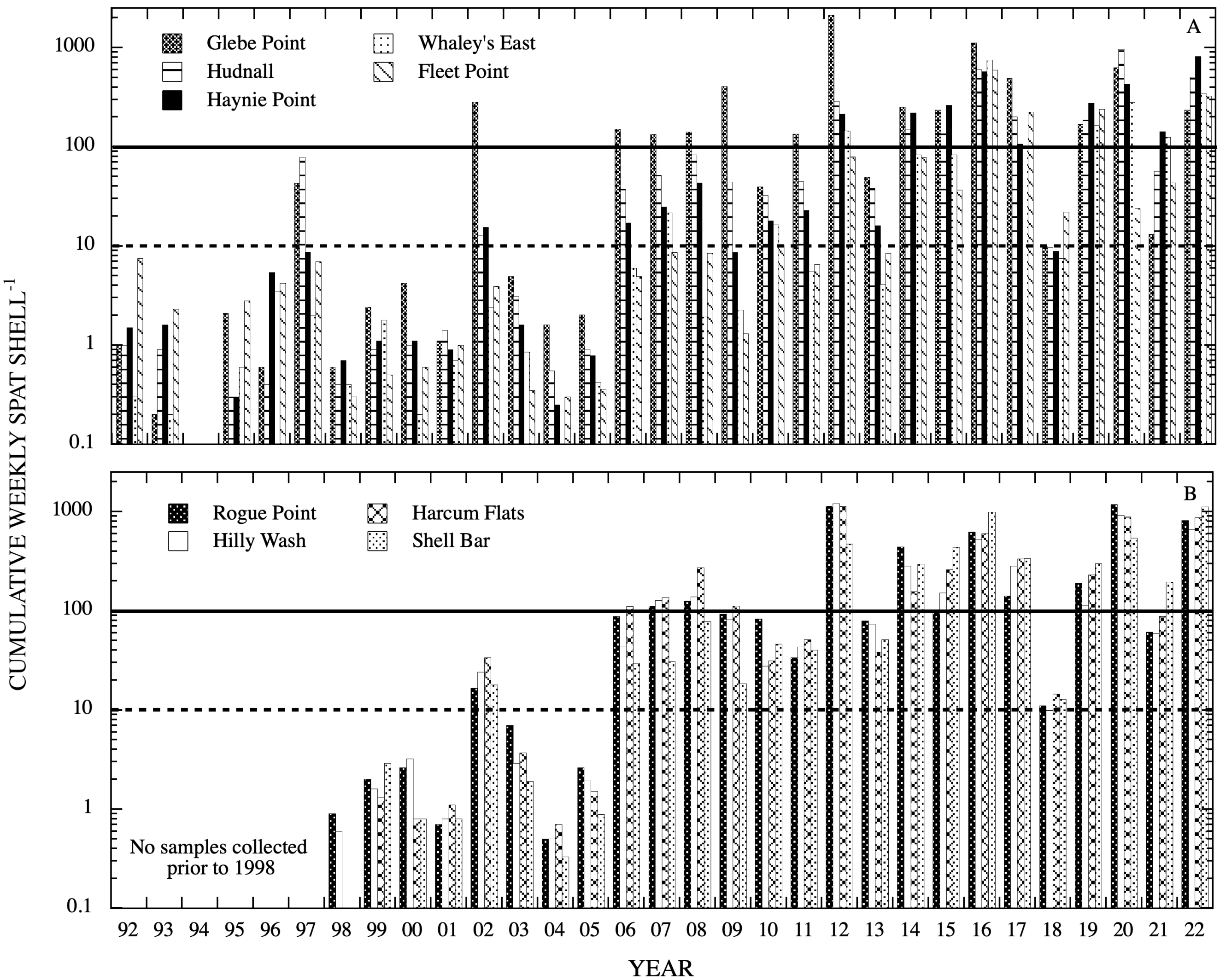
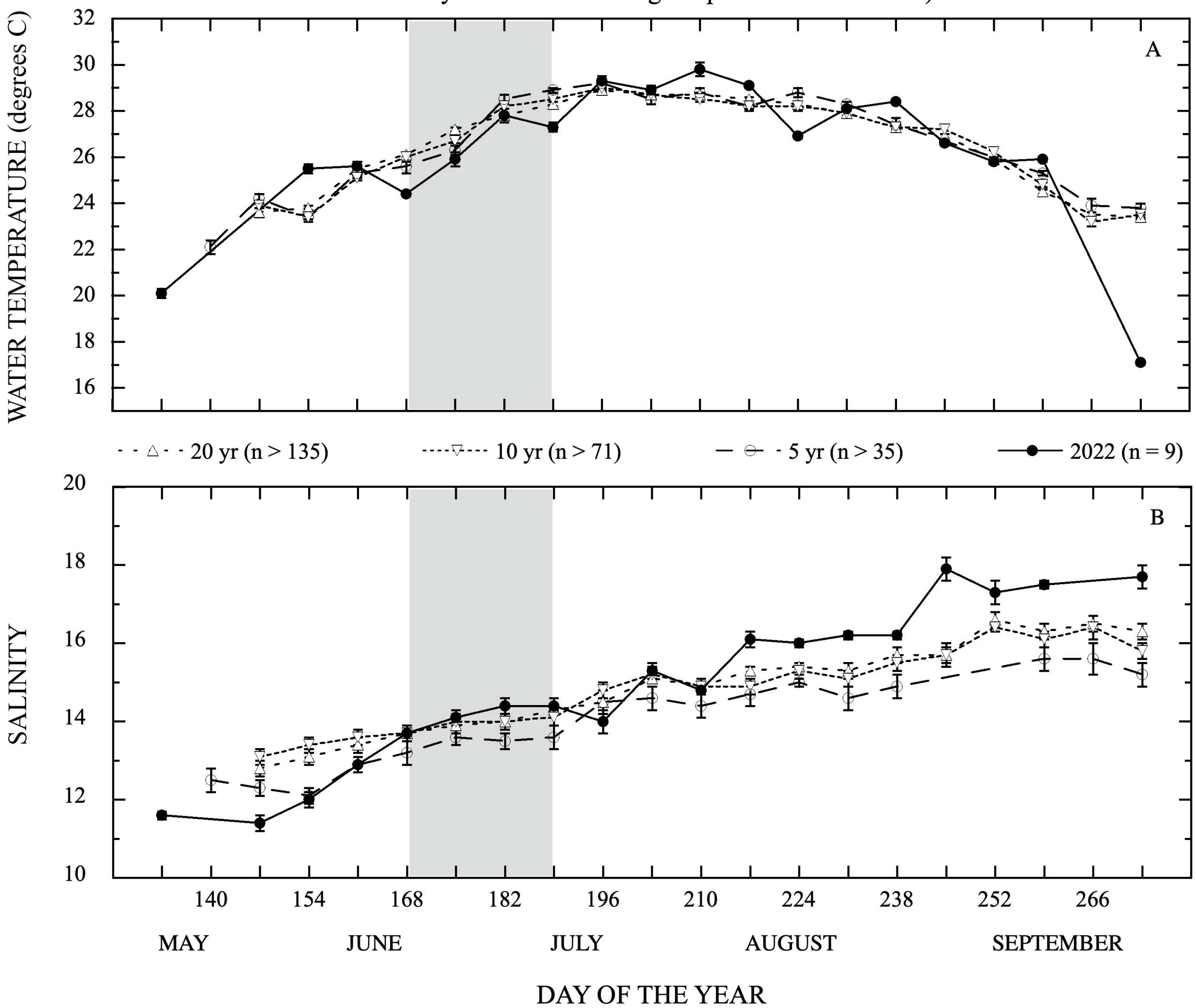


FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE MONITORING PERIOD: 5, 10 AND 20-YEAR MEANS COMPARED WITH 2022
(Error bars represent standard error of the mean; greater than 93% of spatfall for the year occurred during the period that is shaded)



Part II. DREDGE SURVEY OF SELECTED OYSTER BARS IN VIRGINIA DURING 2022

INTRODUCTION

The Eastern oyster, *Crassostrea virginica* (Gmelin, 1791), has been harvested from Virginia waters as long as humans have inhabited the area. Accelerating depletion of natural stocks during the late 1880s led to the establishment of oyster harvesting regulations by public fisheries agencies. A survey of bottom areas in which oysters grew naturally was completed in 1896 under the direction of Lt. J. B. Baylor, U.S. Coast and Geodetic Survey (Baylor 1896) and was later updated by Haven et al. (1981). These areas (over 243,000 acres) were set aside by legislative action for public use and have come to be known as the Baylor Survey Grounds or Public Oyster Grounds of Virginia[4]. These areas are currently under management by the Virginia Marine Resources Commission (VMRC).

Every year the Virginia Institute of Marine Science (VIMS) in collaboration with the Conservation and Replenishment Department of the Shellfish Management Division (SMD) at VMRC conducts a dredge survey of selected public oyster bars in Virginia tributaries of the western Chesapeake Bay to assess the status of the existing oyster resource. These surveys provide information about oyster recruitment, mortality, and relative changes in abundance of seed and market-size oysters from one year to the next. This section summarizes data collected during oyster bar surveys conducted during September and October 2022.

Spatial variability in the distribution of oysters over the bottom can result in wide differences among dredge samples. Large differences among samples collected on the same day from one bar are an indication that distribution of oysters over the bottom is highly variable. An extreme example of that variability can be found in Figure D2 of the 2015 annual report (Southworth & Mann 2016) by the width of the confidence interval around the average count of spat (average spat count = 1033.5, CI = 524.0) at Deep Water Shoal (James River, VA). Dredges provide semi-quantitative data, have been used with consistency over extended periods of time (decades) in Virginia, and provide data on population trends. However, absolute quantification of dredge data is difficult in that dredges accumulate organisms as they move over the bottom, may not sample with constancy throughout a single dredge haul, and may fill before completion of the haul, thereby providing biased sampling (Mann et al. 2004). Therefore, in the context of the present sampling protocol, differences in average counts found at a particular bar in different years may be the result of sampling variation rather than actual short-term changes in abundance. If the observed changes persist for several years and/or can be attributed to well-documented physiological or environmental factors, then they may be considered a reflection of actual changes in abundance with time.

[4] https://webapps.mrc.virginia.gov/public/maps/chesapeakebay_map.php

METHODS

Locations of the oyster bars sampled during Fall 2022 are shown in Figure D1. Geographic coordinates of the bars are given in Table D1. It should be noted that similar to 2020 and 2021, the 2022 dredge survey was conducted approximately 2 to 3 weeks earlier (mid to late September versus early to mid-October) than it usually is and by all indications observed during the shellstring survey (Part I of this report), spatfall was still occurring at that time.

Samples of bottom material were collected on each bar using an oyster scrape/dredge. In all surveys in the York River and Mobjack Bay (through 2022) and in the Great Wicomico River in 2015 and 2022, samples were collected using a 2-ft wide oyster scrape with 4-in teeth towed from a 21-ft boat; volume collected in the scrape bag was 1.5 bushels. For clarification, all bushels mentioned in this report refer to a Virginia bushel (3003.9 $inches^3$), which differs from a US bushel (2150.4 $inches^3$) and a Maryland bushel (2800.7 $inches^3$). In the James, Piankatank, Rappahannock, and Great Wicomico River, samples (with the exception of 2015 and 2022 in the Great Wicomico River as previously mentioned) were collected using a 4-ft oyster dredge with 4-in teeth towed from the 43-ft long VMRC research vessel *J. B. Baylor*; volume collected in the bag of that dredge was 3 bushels. In all surveys a half-bushel (25 liters) subsample was taken from each tow for examination. Data presented give the average of the samples collected at each bar for live oysters and box counts after conversion to a full bushel. In most years, four samples (n = 4) were collected and processed at each sampling site, however, some deviation did occur such that fewer samples were collected. The number of samples collected in 2022 was reduced to three at all of the oyster bars sampled in the survey.

From each half-bushel sample, the number of market oysters (76 mm = 3-in. in length or larger), small oysters (< 76 mm, excluding spat), spat (recent 2022 recruits), new boxes[5] (inside of shells perfectly clean; presumed dead for approximately < 1 week), old boxes, spat boxes and drill boxes (spat box with a drill hole, indicative of predation by one of the two native oyster drills, *Eupleura caudata* and *Urosalpinx cinerea*, both of which are found in the Chesapeake Bay) were counted. The presumed time period since death of an oyster associated with the new and old box categories is a qualitative description based on visual observations. Water temperature (°C) and salinity (ppt) were recorded approximately 0.5 meters off the bottom on the day of sampling at each of the oyster bars using a handheld electronic probe (YSI 30).

RESULTS

Thirty oyster bars were sampled between September 20 and October 10, in six of the major Virginia tributaries on the western shore of the Chesapeake Bay. Bar locations and geographic

[5] The term box is commonly used to describe the articulated valves of a dead oyster. A "new" box may contain tissue from a recent mortality or simply be a set of valves with clean interior. An "old" box" is typically fouled internally. Boxes are a proxy of recent mortality, but the rates at which paired shells disarticulate is poorly understood and probably varies with size and time of year.

coordinates are shown in Figure D1 and Table D1, respectively. It should be noted that Bell Rock in the York River is located on a private lease and is included in this report for historical reasons. Results of this survey are summarized in Table D2 and, unless otherwise indicated, the numbers presented below refer to that table. In years where data was not collected for a specific site, it has been indicated on the graph for that particular site/system. All other blanks on the graphs are where the population levels for a particular site/oyster category were zero.

James River

Ten bars were sampled in the James River, between Nansemond Ridge at the lower end of the river and Deep Water Shoal near the uppermost limit of oyster distribution in the system. The average number of live oysters ranged from a low of 544.0 bushel^{-1} at Nansemond Ridge to a high of 1,688.7 bushel^{-1} at Mulberry Point (Figure D2). The total number of live oysters was the fourth highest observed over the past thirty years of monitoring at Thomas Rock and Nansemond Ridge, the seventh highest at Point of Shoal and the eighth highest at Wreck Shoal (Figures D2B and D2C). When spat are excluded, the total number of small and market oysters combined was the highest (Nansemond Ridge), second highest (Thomas Rock) and fifth highest (Deep Water Shoal and Point of Shoal) observed over the past thirty years. The numbers at Wreck Shoal were the sixth highest observed over the past thirty years of monitoring, but it should be noted that 2022 was the second year in a row that saw an overall decrease in the numbers of small and market oysters combined on that oyster bar.

Overall, the average number of market oysters in the James River remains low when compared with historical numbers. The number of market oysters in 2022 ranged from a low of 2.7 bushel^{-1} at Swash to a high of 238.7 bushel^{-1} at Point of Shoal. When compared with 2021 numbers, there was a fairly large increase in the number of market oysters observed at Deep Water Shoal, Horsehead, Point of Shoal and Long Shoal and a smaller, but still notable increase at Dry Shoal and Nansemond Ridge (Figure D3). The number of market oysters at Horsehead was the highest observed over the past thirty years of monitoring, the first relatively large increase observed at that site over the past decade or so. The number of market oysters at Point of Shoal has fluctuated from one year to the next for the past several years, it was up in 2015, down in 2016 and 2017, then back up in 2018, down in 2019 up in 2020 and up again in 2022. This reef has been heavily targeted for seed harvest over the past few years and this fluctuation may reflect that activity. The number of market oysters on Point of Shoal in 2022, was almost double the next highest (2010) observed over the past thirty years. The number of market oysters at Wreck Shoal steadily increased between 2009 and 2014, then remained relatively stable (between 90 and 100 bushel^{-1}) from 2014 to 2016 (Figure D2C). From 2017 to 2020, market oysters at Wreck Shoal again steadily increased, from 42.7 bushel^{-1} in 2017 to 63.3 bushel^{-1} by 2020, but then showed a notable decrease in 2021 (40 bushel^{-1}), and remained at similar levels (36.7 bushel^{-1}) in 2022 (Figure D2C). The number of market oysters on Thomas Rock remained relatively stable from 2016 to 2020, ranging between 51 and 66 bushel^{-1} (Figure D2C), but then showed a notable increase to 104.7 bushel^{-1} in 2021, remaining at similar levels in 2022. For the sixth year in a row, the number of market oysters at Swash was among the lowest observed (second lowest) since monitoring began at that site in the early 1990s (Figure D2B). The number of market oysters at Long Shoal increased in 2022 after reaching a thirty-year low in 2021. For the second year in a row, the number of market oysters on

Deep Water Shoal increased, since the 2018 low salinity mortality event occurred on that reef, such that numbers in 2022 were the highest observed over the past thirty years. At Thomas Rock and Nansemond Ridge, the two most down river reefs in the system, the number of market oysters have generally been increasing for the past five (Nansemond Ridge) to nine (Thomas Rock) years, such that numbers in the 2022 were the highest observed over the past thirty years of monitoring (Figure D2C).

The average number of small oysters bushel^{-1} ranged from a low of 232.7 at Nansemond Ridge to a high of 1,180.7 at Mulberry Point. When compared with 2021, there was a small, but notable increase in the number of small oysters at Thomas Rock and Nansemond Ridge and a decrease in the number of small oysters at Swash and Long Shoal (Figure D2B, D2C and D3). With the increases at Thomas and Nansemond Ridge, 2022 had the second highest and highest number of small oysters over the past thirty years at the two reefs, respectively. While the number of small oysters observed at Nansemond Ridge was the lowest of the ten sites monitored, the number of small oysters at that site have generally been increasing since about 2016 (Figure D2C). The number of small oysters was the sixth highest observed over the past thirty years at Wreck Shoal, but numbers in 2022 were around half what they were when they were at a high in 2019/2020 (Figure D2C).

Overall, recruitment in the James River in 2022 was moderate, and generally lower than that observed in the system in more recent years (Figure D2), falling in the 66th percentile over the past thirty years. Eleven out of the twelve highest recruitments over the past thirty years have occurred since 2008. Overall recruitment in 2022 was similar to that observed in 2021, with the exception of Swash, where there was a small, but notable decrease (Figure D2B and D3). The average number of spat bushel^{-1} ranged from a low of 168.7 at Thomas Rock to a high of 539.3 at Horsehead. Since 2008, recruitment in the James River has had several strong year classes; 2010, 2012, 2015, 2016, 2018 and 2019. This is in contrast to what was observed on the shellstrings (Part I of this report), where 2015 and 2019 were moderate years, but 2017, 2020 and 2021 were good years.

The average number of boxes bushel^{-1} was low to moderate, ranging from 31.9 at Point of Shoal to 102.7 at Swash, and was generally higher at the more down-river sites. Boxes accounted for less than 5% of the total (live oysters plus boxes) at the five most upriver sites, with the majority of those being old boxes. At the five most downriver sites, boxes accounted for 6.6 (Long Shoal) to 11.1% (Dry Shoal) of the total (live oysters plus boxes). At Thomas Rock and Nansemond Ridge, 21 to 22% of the boxes were new boxes, indicating some recent mortality at those sites. Approximately 27% of the boxes at Horsehead were spat boxes.

Water temperature during the two days of sampling ranged between 17.5 and 18.4°C (Table D2). This was several degrees cooler than what is typical for this time of year as well as cooler than what it was in the other river systems sampled just one to two weeks earlier. Salinity generally increased in a downriver direction (see Figure D1), from a low of 15.2 ppt at Deep Water Shoal to a high of 21.0 ppt at Thomas Rock and 22.8 ppt at Nansemond Ridge.

York River

In the York River, the average total number of live oysters bushel^{-1} was 159.4 at Bell Rock and 283.4 at Aberdeen Rock. When compared with 2021, there was a notable increase in the number of market oysters at Aberdeen Rock and a decrease in the number of small oysters at both sites (Figures D4 and D5). The number of market oysters at Aberdeen Rock steadily increased between 2014 and 2020, but there was a notable decrease observed in 2021 (Figure D5). However, market oysters again increased in 2022, with numbers being similar to those observed in 2020. This was either an aberration in the data or more likely a result of harvesting. Overall, the number of market oysters on Aberdeen Rock over the past few years has been among the highest observed over the past thirty years of monitoring. Recruitment in 2022 was light at both sites in the York River, but still ranked in the 75th and 78th percentile over the past thirty years at Bell Rock and Aberdeen Rock, respectively. The average number of boxes bushel^{-1} was light at Bell Rock and moderate at Aberdeen Rock, accounting for 6 and 15% of the total (live oysters plus boxes) at the two sites, respectively. Water temperature on the day of sampling was around 26.0°C at both sites. Salinity was 18.2 ppt at Bell Rock and 21.5 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters at Tow Stake and Pultz Bar were 321.4 and 489.3 oysters bushel^{-1}, respectively. When compared with 2021, there was a notable increase in the numbers of both market oysters and spat observed at Pultz Bar and for a second year in a row, there was a decrease in the number of small oysters observed at both Mobjack Bay sites (Figure D4). At Tow Stake, the number of market oysters was the second highest over the past thirty years and the number of small and market oysters combined was the third highest over that time period (Figure D5). The number of market oysters at Pultz Bar was in the 93rd percentile over the past thirty years of monitoring. The total number of boxes observed in the system was low, accounting for 6 and 7% of the total (live oysters plus boxes) at Tow Stake and Pultz Bar, respectively. Approximately 18% of the boxes at Pultz Bar were new, indicating some recent mortality at that site. On the day of sampling, water temperature was around 25°C at both sites. Salinity was around 24.6 ppt at Tow Stake and 23.6 ppt at Pultz Bar. The only spat box observed at Tow Stake and one of the three spat boxes observed at Pultz Bar each contained a drill hole, indicative of mortality caused by one of the two oyster drills (*Urosalpinx cinerea* or *Eupleura caudata*) found in the bay.

Piankatank River

In the Piankatank River, the average total number of live oysters bushel^{-1} ranged from a low of 444.0 at Ginney Point to a high of 928.0 at Palace Bar. When compared with 2021, there was a notable increase in the number of market oysters at Ginney Point and Burton Point and a decrease in the number of small oysters at Ginney Point (Figures D7 and D8). Overall, the number of market oysters in the river was low from 1993 through 2007, but generally increased between 2008 and

2014. Since 2014, there have generally been more market oysters in the Piankatank River but numbers from one year to the next have been more variable. The same is true for small oysters. The average number of market oysters across all three sites from 1992 to 2007 ranged from 0 to 12.7 bushel^{-1}, whereas from 2008 to 2022 the average across all three sites ranged from 22.2 to 116.2 bushel^{-1}, with 2022 being the highest over the past thirty years. For small and market oysters combined the average across all three sites from 1991 to 2007 ranged from 9.8 to 171.0 bushel^{-1}, whereas from 2008 to 2021, the average ranged from 171.3 to 623.7 bushel^{-1}, with 2022 being the fifth highest over the past thirty years of monitoring. Recruitment in 2022 was moderate to high at all three sites, with the overall average across the three sites ranking in the 80th percentile over the past thirty years. This was an increase at all three sites when compared with 2021 (Figure D8). The number of boxes observed was low at all three sites ranging between 4 (Palace Bar and Burton Point) and 9% (Ginney Point) of the total (live plus boxes), with the majority of boxes being old. On the day of sampling, water temperature was between 21 and 22ºC at all three sites and salinity was between 18.6 (Ginney Point) and 19.3 ppt (Burton Point). There were no drill boxes observed at any of the sites in the Piankatank River.

Rappahannock River

In the Rappahannock River, the average total number of live oysters bushel^{-1} ranged from a low of 275.9 at Long Rock to a high of 804.0 at Drumming Ground. As is typical for the Rappahannock River system, there appeared to be no relationship between the total number of live oysters and location in the river (i.e., upriver vs. downriver: Figure D1), temperature or salinity (Table D2). Typically, most of the oysters in the Rappahannock River system are found in the Corrotoman River (Middle Ground), just outside the mouth of the Corrotoman (Drumming Ground) and at the more downriver sites. Due to a much larger than normal spatfall at the more upriver sites, this pattern did not hold true in 2022. At Ross Rock, the oyster population had been steadily increasing since about 2009, but following a freshet event in 2018, all of the oysters at Ross Rock died. The total number of oysters at Middle Ground showed a relatively large decrease in 2011, following several good years of growth between 2008 and 2010. Since then, the total number of oysters at Middle Ground has increased, such that numbers over the past few years have been greater than or similar to those observed prior to the decrease in 2011. The total number of oysters on Middle Ground in 2022 was the second highest observed over the past thirty years of monitoring, slightly higher than what was observed the previous year.

The average number of market oysters bushel^{-1} ranged from a low of 0.0 at Ross Rock to a high of 146.0 at Drumming Ground. When compared with 2021, there was a small, but notable increase in the number of market oysters observed at Parrot Rock and a decrease at Hog House (Figure D9, D10B and D10C). The number of market oysters in 2022 were in the 80th percentile or higher over the past thirty years at every site except Bowler's Rock (63rd percentile) and Ross Rock (no market oysters observed; Figure D10). Overall, the number of market oysters in the Rappahannock River has been higher since about 2008 (Figure D10). From 1992 to 2007, the average over all ten sites in any given year was less than 20 market oysters bushel^{-1}, whereas from 2008 to 2022 the average over all ten sites ranged between 22 (2008) and 73 (2022) market oysters bushel^{-1} (Figure D10).

The number of small oysters bushel^{-1} ranged from a low of 58.7 at Smokey Point to a high of 274.7 at Drumming Ground (Figures D9 and D10). When compared with 2021, there were relatively large increases in the number of small oysters at Ross Rock and Bowler's Rock (Figure D9 and D10A). This was not unexpected given the larger than normal recruitment observed at both of these sites in 2021 and the increase was such that 2022 had the highest numbers observed over the past thirty years. There was a small, but notable decrease in the number of small oysters at Smokey Point, Middle Ground and Broad Creek when compared with 2021 (Figures D9B, D9C and D10). At every site except Smokey Point, the number of small oysters observed in 2022 ranked in the 76th percentile or higher observed over the past thirty years.

For the second year in a row, recruitment in the Rappahannock River was higher than what is typical for the river, ranging from 83.3 spat bushel^{-1} at Long Rock to 616.7 spat bushel^{-1} at Hog House. In recent years, recruitment has become more common at the more upriver sites (Figures D9 and D10) with at least one spat at each of the sites in the river, but the largest recruitment still typically occurred at the more downriver sites. Recruitment in both 2021 and 2022 however, was highest at the more upriver sites. Recruitment at Bowler's Rock in 2022 was similar to that observed in 2021, which was around twenty times higher than the next highest observed over the previous thirty years. Looking back even further, the highest single spat count at Bowler's Rock since that site was first samples in 1947 was 64 spat bushel^{-1} (1987), with an average over the 3 samples taken that year of 34.7 spat bushel^{-1} (recruitment at Bowler's Rock was an average of 134.0 and 114.7 spat bushel^{-1} in 2021 and 2022, respectively). Settlement in 2022 at Ross Rock was around two and a half times larger than 2021, and compared with the previous thirty years was around 53 times higher than the next highest year (after 2021). The highest recruitment recorded at Ross Rock since monitoring began at that site in 1969 was an average of 9.0 bushel^{-1} (recruitment at Ross Rock was 195.3 and 494.0 spat bushel^{-1} in 2021 and 2022, respectively). Other sites that had exceptionally high settlement in 2022 include Long Rock (93.3 spat bushel^{-1}), Morattico Bar (166.7 spat bushel^{-1}), Smokey Point (407.3 spat bushel^{-1}) and Hog House (616.7 spat bushel^{-1}). Recruitment at these four sites were around 4, 4, 6 and 8 times higher than the next highest recruitment observed, respectively at each site over the past thirty years of monitoring. In general, since 2010, higher recruitment has become more common in the Rappahannock River. In the eighteen-year period from 1992 to 2009, there were only four years (1995, 1999, 2002 and 2006) with an overall average recruitment greater than 50 spat bushel^{-1}, whereas in the thirteen-year period from 2010 to 2022 there were six years (2010, 2012, 2015, 2017, 2019, 2021 and 2022) with an overall average recruitment greater than 50 spat bushel^{-1}, and two (2015 and 2022) years with greater than 100 spat bushel^{-1}.

The average total number of boxes bushel^{-1} was low to moderate, accounting for less than 1 (Ross Rock) to 16% (Middle Ground) of the total (live oysters plus dead). Around 22% of the total boxes at Broad Creek were new boxes, indicating some recent mortality at that site. The number of new and old boxes combined observed at Hog House, Middle Ground and Broad Creek, was relatively large when compared with the number of small and market oysters at those sites, accounting for approximately 37%, 25% and 17% of the total (small and market oysters plus new and old boxes) at each site, respectively. There were no drill boxes observed at any of the sites in the Rappahannock River.

Water temperature on the day of sampling ranged from 21.1 to 22.9°C. Salinity generally increased as one moved from the most upriver site (Ross Rock: 11.1 ppt) toward the mouth (Broad Creek: 20.0 ppt).

Great Wicomico River

In the Great Wicomico River, the average total number of live oysters bushel^{-1} ranged from a low of 1,407.3 at Haynie Point to a high of 2,024.7 at Fleet Point. When compared with 2021, there were notable decreases in the number of small oysters as well as large increases in the number spat at all three sites (Figure D11 and D12). The number of market oysters has remained relatively stable at Haynie Point and Whaley's East for the past three years, ranging between 100 and 120 bushel^{-1} at Haynie Point and between 75 and 100 bushel^{-1} at Whaley's East. In 2022, market oysters ranked among the highest (93rd percentile or higher) observed over the past thirty years at all three sites monitored. Recruitment in the Great Wicomico River in 2022 was heavy, with an average over all three sites being the highest observed over the past thirty years. Recruitment in the Great Wicomico River is typically highest at Haynie Point, and at other sites upriver of Sandy Point (sites not sampled as part of the regular dredge survey), but during 2022, recruitment was highest at the most downriver site in the river, Fleet Point (see Figure D1 for station location). Recruitment at Fleet Point was around four times higher than the next highest year (Figure D12). The total number of boxes bushel^{-1} was low at all three sites, accounting for less than 3% of the total (live oysters plus boxes). Between 17 (Whaley's East) and 33% (Haynie Point) of the boxes were new, indicating some recent morality at all three sites in the river. Water temperature on the day of sampling was between 25.4 and 26.1°C and salinity was between 18.0 and 18.5 ppt.

DISCUSSION

The abundance of market oysters throughout the Chesapeake Bay region has been in serious decline since the beginning of the 20th century (Hargis & Haven 1995, Rothschild et al. 1994). For the past several decades, the greatest concentration of market oysters on Virginia's public oyster grounds has been found at the upper limits of oyster distribution (lower salinity areas) in the James and Rappahannock Rivers, with the exclusion of Broad Creek in the mouth of the Rappahannock River. Presently, the abundance of market oysters in the Virginia tributaries of the Chesapeake remains low (average of 85.0 market oysters bushel^{-1}). From 1992 through 2007, the number of market oysters averaged over the thirty bars that are sampled annually, ranged between 4.1 and 20.8 bushel^{-1}. From 2008 through 2022, the number of market oysters on the thirty bars has generally been higher with the annual average ranging between 27.9 and 85.0 bushel^{-1}.

For the past several decades, the bulk of Virginia's oyster population has been composed primarily of small oysters and spat. During 2022, the overall oyster population was composed of 45% spat, 45% small oysters and 10% market oysters. At twelve out of the thirty sites monitored, small oysters accounted for greater than 50% of the live oysters present, with spat dominating at seven out of the thirty sites (Palace Bar in the Piankatank River, Ross Rock, Smokey Point and Hog

House in the Rappahannock River and all three sites in the Great Wicomico River). There was a large die-off of broodstock oysters that occurred in the Piankatank River in late 2003/early 2004 (Southworth et al. 2005). Following that die-off, the oyster population in the river started to increase and remained at higher levels from 2010 through 2017; the average number of small and market oysters combined over the three sites monitored in the Piankatank River consistently remained above 300 bushel^{-1} from 2013 to 2017. Levels dipped below 300 bushel^{-1} in 2018 and 2019, but have been back up for the past three years.

Recruitment during 2022 varied considerably from one site and river to the next throughout the Virginia portion of the Bay. There were less than 50 spat bushel^{-1} at only two out of the thirty sites (Bell Rock in the York River and Tow Stake in Mobjack Bay) monitored. There were greater than 100 spat bushel^{-1} at twenty-six out of the thirty sites, with greater than 500 spat bushel^{-1} at six sites (Deep Water Shoal and Horsehead in the James River, Hog House in the Rappahannock River and all three sites in the Great Wicomico River). Historically, recruitment in the Rappahannock River tended to be highest at the more downriver sites (see Figure D1 for locations), with often no recruitment at the upriver sites. In both 2021 and 2022, the highest recruitment was observed at the more upriver sites and recruitment at these sites was many times higher than any in the recorded history for the river (Figure D13), although it should be noted that the historical record is missing years at many of the sites. For example, at Ross Rock, data was collected in 1969, 1970 and 1989 through 2022. The highest recruitment recorded at that site prior to 2021 was 9 spat bushel^{-1} in 1992. Ross Rock had an average of 195 spat bushel^{-1} in 2021 and 494 spat bushel^{-1} in 2022 (Figure D13A). At Bowler's Rock, data was collected relatively consistently from 1947 to 2022 (missing ten years between 1952 and 1974). The highest recruitment recorded at that site prior to 2021 was 22 spat bushel^{-1} in 1985. Bowler's Rock had an average of 134 spat bushel^{-1} in 2021 and 115 spat bushel^{-1} in 2022 (Figure D13A). Long Rock (1994 to 2022), Morattico Bar (1948 to 2022), Smokey Point (1969 to 2022) and Hog House (1947 to 2022) were all similar, with 2022 being the highest in the recorded history of the reef at Long Rock, Smokey Point and Hog House and the second highest at Morattico Bar (Figure D13). When you compare the average recruitment across all of the sites sampled in any given year (1947 to 2022), 2022 was the second highest recorded (273 spat bushel^{-1}), second only to 291 spat bushel^{-1} in 1981.

The average total number of boxes observed during 2022 was low to moderate, accounting for less than 15% of the total (live oysters plus boxes) at all thirty sites monitored. Over the past few years several sites have had a large number of small and market boxes, indicating some increased mortality caused by disease. In 2022, eight out of the thirty sites (Dry Shoal, Wreck Shoal and Nansemond Ridge in the James River, Aberdeen Rock in the York River, Smokey Point and Hog House, Middle Ground and Broad Creek in the Rappahannock River) had a relatively large number of small and market size boxes (greater than 12% of the total, live small and market oysters plus new and old boxes, respectively). At these eight sites, the percentage ranged from 12% of the total at Smokey Point to 37% at Hog House.

In general, drill holes have become more prevalent in spat boxes since the early 2000s. During 2022, there were drill holes present spat boxes at both sites in Mobjack Bay. The presence of a drill hole is indicative of predation by one of the two oyster drill species, *Urosalpinx cinerea* or *Eupleura caudata,* which are found in the lower Chesapeake Bay. Both of these species have been shown to be voracious predators of oyster spat causing mortality throughout most of the

Chesapeake Bay (Carriker 1955) until Hurricane Agnes (1972) eradicated them from all but the lower reaches of the James River and mainstem Bay (Haven 1974). However, individuals of both of these species and their corresponding egg masses have become more common since the mid-2000s in the lower James River, in the lower York River, in the mouths of the Piankatank and Rappahannock Rivers, and in Mobjack Bay. In addition, both species of oyster drills, as well as evidence of their predation, were observed on various reefs in the James and York Rivers, in Mobjack Bay and in both Pocomoke and Tangier Sounds (Southworth, unpublished data).

Table D1: Station locations for the 2022 VIMS/VMRC fall dredge survey

Station	Latitude	Longitude
James River		
Deep Water Shoal	37 08.933	76 38.133
Mulberry Point	37 07.150	76 37.917
Horsehead	37 06.413	76 38.056
Point of Shoal	37 04.617	76 38.600
Swash	37 05.533	76 36.733
Long Shoal	37 04.581	76 37.028
Dry Shoal	37 03.551	76 36.168
Wreck Shoal	37 03.617	76 34.333
Thomas Rock	37 01.766	76 29.597
Nansemond Ridge	36 55.557	76 27.097
York River		
Bell Rock	37 29.050	76 44.983
Aberdeen Rock	37 20.117	76 36.033
Mobjack Bay		
Tow Stake	37 20.333	76 23.167
Pultz Bar	37 21.183	76 21.167
Piankatank River		
Ginney Point	37 32.000	76 24.200
Palace Bar	37 31.600	76 22.200
Burton Point	37 30.900	76 19.700
Rappahannock River		
Ross Rock	37 54.067	76 47.350
Bowler's Rock	37 49.642	76 44.180
Long Rock	37 48.810	76 42.504
Morattico Bar	37 46.832	76 39.491
Smokey Point	37 43.150	76 34.933
Hog House	37 38.171	76 32.553
Middle Ground	37 41.000	76 28.400
Drumming Ground	37 38.633	76 27.983
Parrot Rock	37 36.350	76 25.333
Broad Creek	37 34.617	76 18.050
Great Wicomico River		
Haynie Point	37 49.783	76 18.550
Whaley's East	37 48.517	76 18.000
Fleet Point	37 48.583	76 17.317

Table D2: Results of the Virginia Public oyster grounds survey, Fall 2022. Note that the bushel measure used is a VA bushel which is equivalent to 3003.9 in^{-3} (50 liters). A VA bushel differs in volume from both a U.S. bushel (2150.4 in^{-3}, 35 liters) and a MD bushel (2800.7 in^{-3}, 46 liters). "*" indicates a private bar. Middle Ground (#) is located in the Corrotoman River, a sub-estuary of the Rappahannock River system.

Station	Date	Temp (°C)	Sal (ppt)	Average number of oysters per bushel				Average number of boxes per bushel			
				Market	Small	Spat	Total	New	Old	Spat	Total
James River											
Deep Water Shoal	10/7	18.2	15.2	176.7	662.7	512.7	1352.1	4.7	22.0	6.7	33.4
Mulberry Point	10/7	17.9	16.2	23.3	1180.7	484.7	1688.7	5.3	30.0	4.7	40.0
Horsehead	10/7	18.0	18.1	120.7	1015.3	539.3	1675.3	1.3	32.0	12.0	45.3
Point of Shoal	10/7	18.0	17.4	238.7	838.7	480.0	1557.4	1.3	29.3	1.3	31.9
Swash	10/7	17.9	18.3	2.7	1050.0	232.7	1285.4	7.3	39.3	4.7	51.3
Long Shoal	10/7	18.4	18.6	24.0	1092.0	240.7	1356.7	6.7	88.0	0.7	95.4
Dry Shoal	10/10	17.8	18.4	40.7	558.0	225.3	824.0	6.7	95.3	0.7	102.7
Wreck Shoal	10/10	17.5	19.2	36.7	503.3	320.7	860.7	3.3	75.3	0.0	78.6
Thomas Rock	10/7	17.6	21.9	110.0	467.3	168.7	746.0	5.3	50.0	2.7	58.0
Nansemond Ridge	10/10	17.8	22.8	89.3	232.7	222.0	544.0	4.7	42.7	0.0	47.4
York River											
Bell Rock *	9/20	26.0	18.2	42.7	90.7	26.0	159.4	1.3	7.3	0.7	9.3
Aberdeen Rock	9/20	26.0	21.5	92.7	118.0	72.7	283.4	4.7	43.3	1.3	49.3
Mobjack Bay											
Tow Stake	9/20	25.4	24.6	100.0	174.7	46.7	321.4	2.7	18.0	0.7	21.4
Pultz Bar	9/20	25.7	23.6	87.3	245.3	156.7	489.3	6.7	29.3	2.0	38.0
Piankatank River											
Ginney Point	9/29	21.2	18.6	167.3	174.7	102.0	444.0	4.0	39.3	0.0	43.3
Palace Bar	9/29	21.7	19.0	48.0	394.0	486.0	928.0	4.0	28.7	0.7	33.4
Burton Point	9/29	21.7	19.3	133.3	304.7	271.3	709.3	2.0	26.7	2.7	31.4
Rappahannock River											
Ross Rock	9/28	21.1	11.1	0.0	139.0	494.0	633.0	0.0	0.0	2.0	2.0
Bowler's Rock	9/28	21.2	13.5	34.7	219.3	114.7	368.7	0.0	2.7	2.7	5.4
Long Rock	9/28	22.3	14.4	99.3	93.3	83.3	275.9	0.0	2.7	3.3	6.0
Morattico Bar	9/28	21.6	16.2	73.3	166.7	125.3	365.3	1.3	17.3	0.0	18.6
Smokey Point	9/28	22.0	17.5	62.7	58.7	407.3	528.7	0.7	16.0	0.0	16.7
Hog House	9/28	22.1	18.0	30.0	144.0	616.7	790.7	2.0	98.0	1.3	101.3
Middle Ground #	9/28	22.8	18.3	46.7	224.7	196.7	468.1	6.7	83.3	0.0	90.0
Drumming Ground	9/28	22.9	19.2	146.0	274.7	383.3	804.0	3.3	36.7	0.7	40.7
Parrot Rock	9/28	22.3	18.8	104.7	150.0	190.7	445.4	2.0	23.3	0.0	25.3
Broad Creek	9/28	22.9	20.0	136.7	152.7	122.0	411.4	12.7	44.7	0.0	57.4
Great Wicomico River											
Haynie Point	9/21	26.0	18.5	119.3	302.7	985.3	1407.3	2.0	33.3	9.3	44.6
Whaley's East	9/21	26.1	18.2	74.7	264.0	1374.7	1713.4	2.0	17.3	8.0	27.3
Fleet Point	9/21	25.4	18.0	87.3	162.7	1774.7	2024.7	4.0	20.0	22.7	46.7

Figure D1: Map showing the location of the oyster bars sampled during the 2022 dredge survey. James River: 1) Deep Water Shoal, 2) Mulberry Point, 3) Horsehead, 4) Point of Shoal, 5) Swash, 6) Long Shoal, 7) Dry Shoal, 8) Wreck Shoal, 9) Thomas Rock, 10) Nansemond Ridge. York River: 11) Bell Rock, 12) Aberdeen Rock. Mobjack Bay: 13) Tow Stake, 14) Pultz Bar. Piankatank River: 15) Ginney Point, 16) Palace Bar, 17) Burton Point. Rappahannock River: 18) Ross Rock, 19) Bowler's Rock, 20) Long Rock, 21) Morattico Bar, 22) Smokey Point, 23) Hog House, 24) Middle Ground, 25) Drumming Ground, 26) Parrot Rock, 27) Broad Creek. Great Wicomico River: 28) Haynie Point, 29) Whaley's East, 30) Fleet Point.

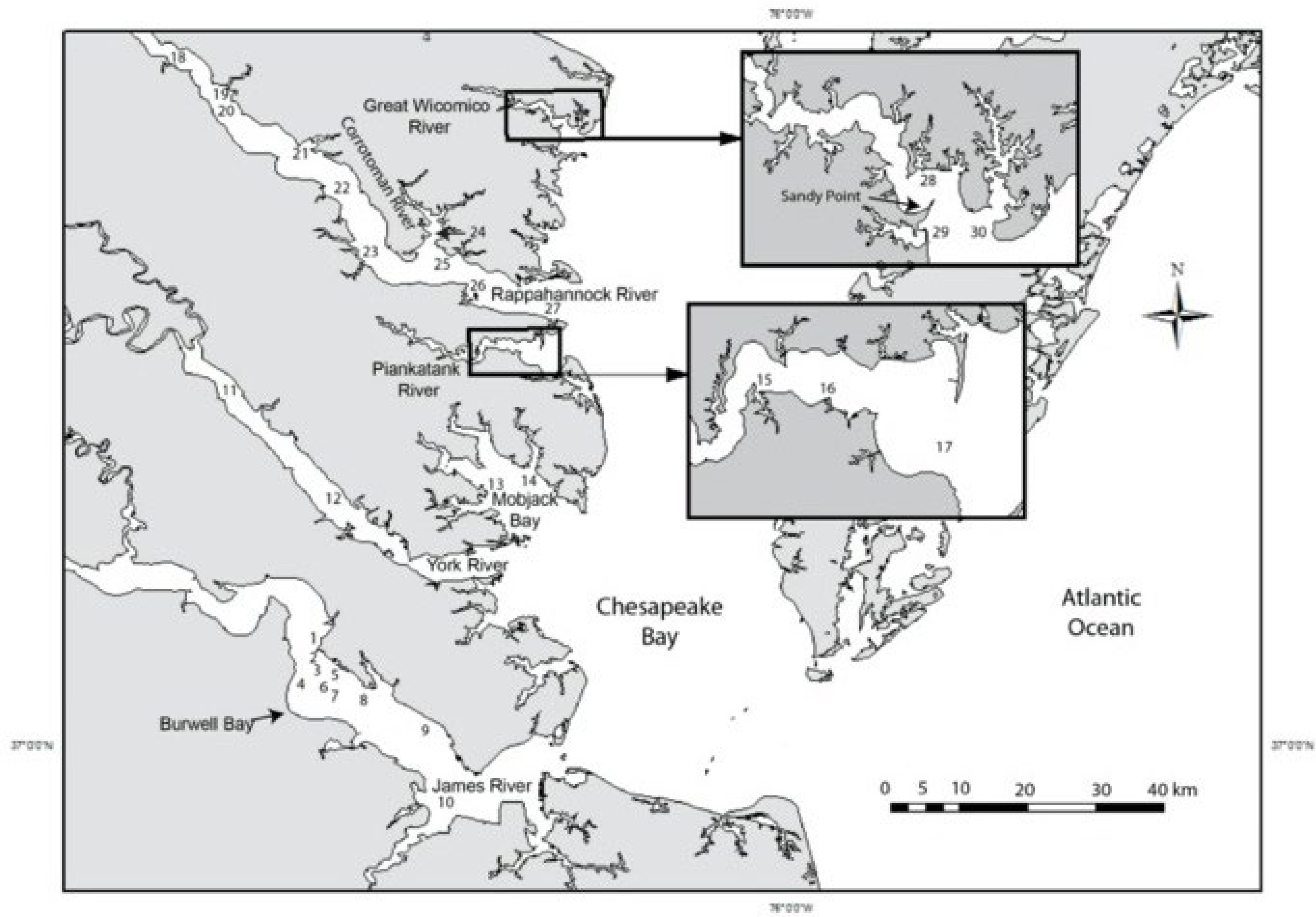
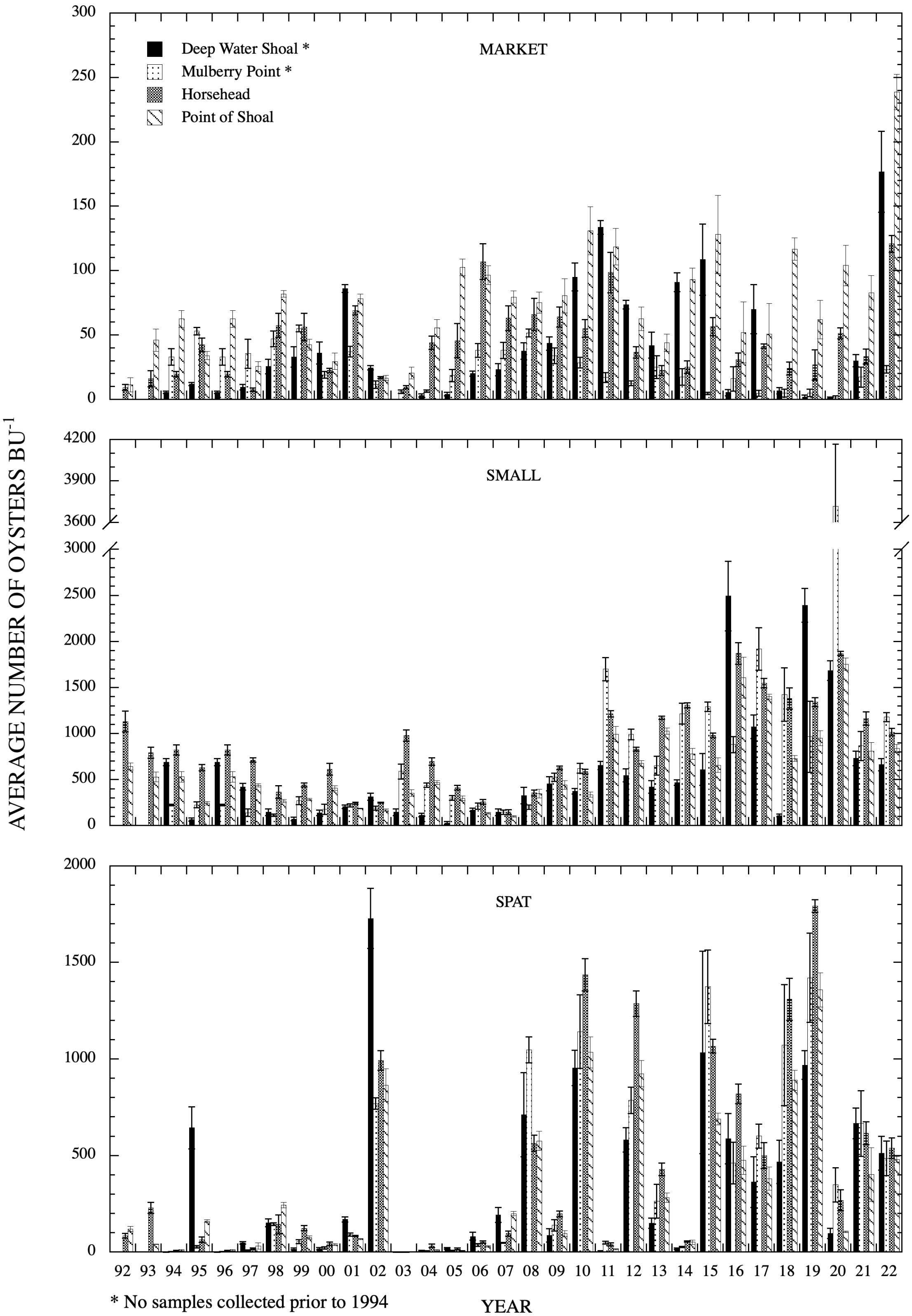


FIGURE D2A: JAMES RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)



* No samples collected prior to 1994

FIGURE D2B: JAMES RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)

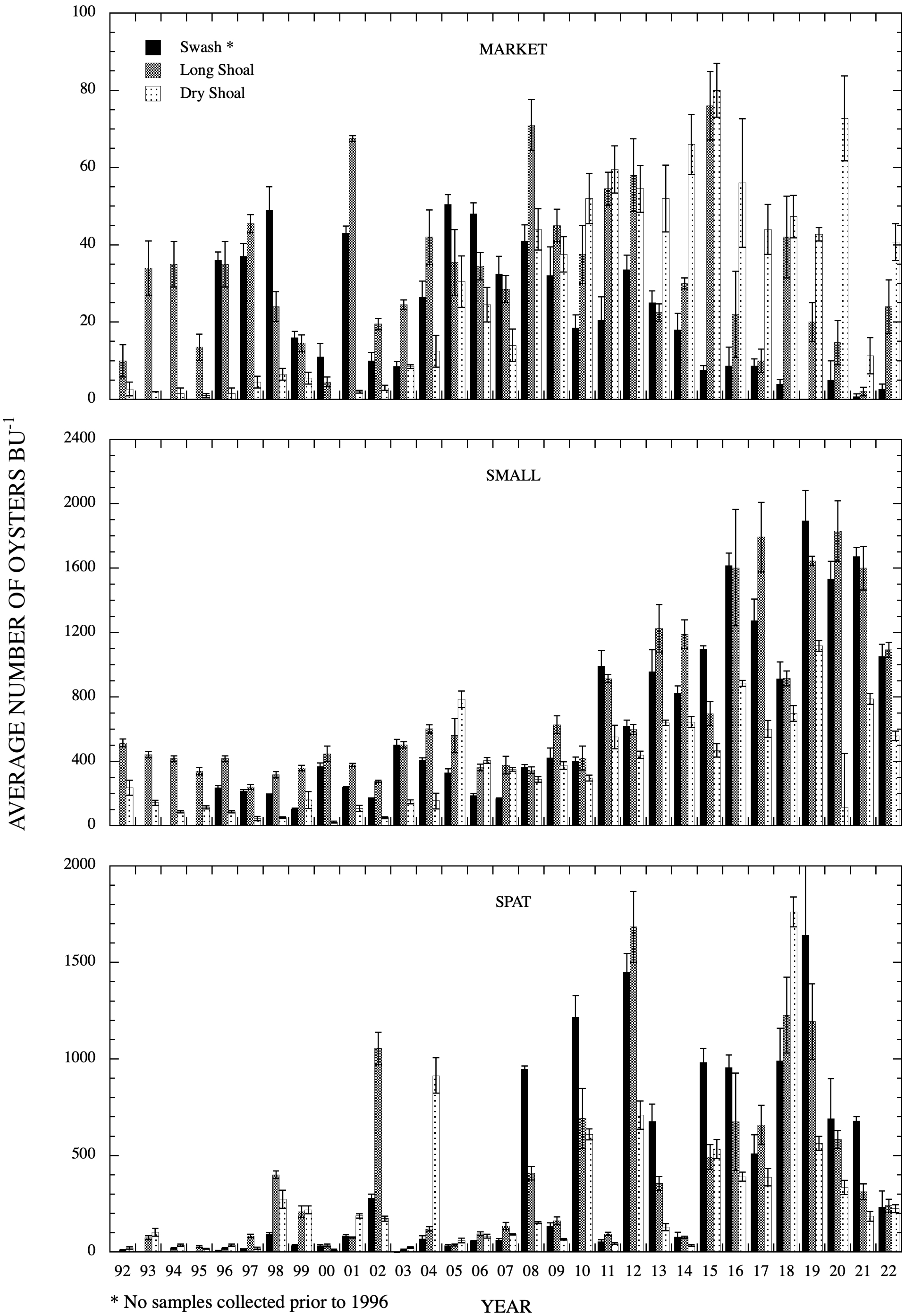


FIGURE D2C: JAMES RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)

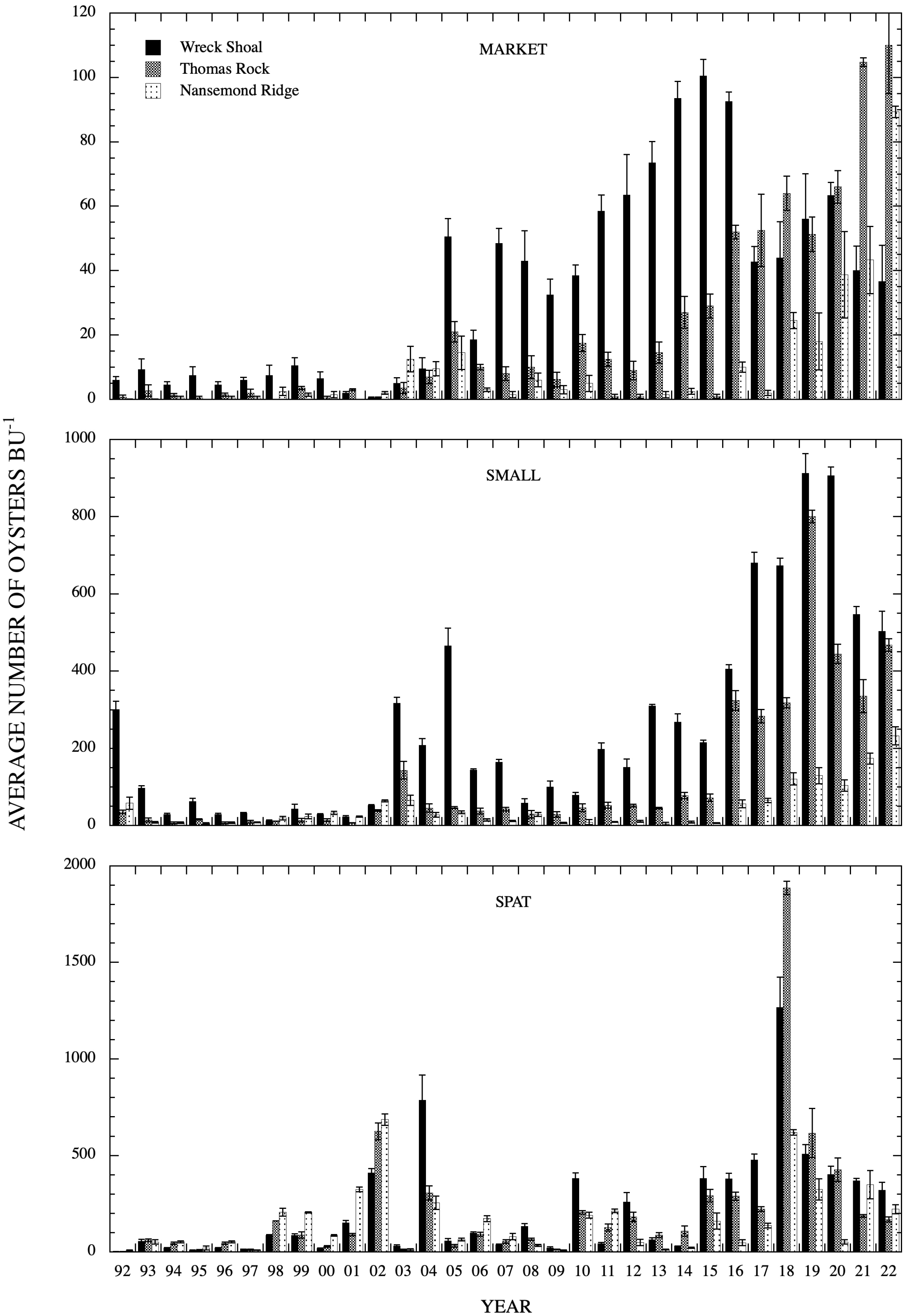


FIGURE D3: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE JAMES RIVER (2020-2021)
(Error bars represent standard error of the mean)

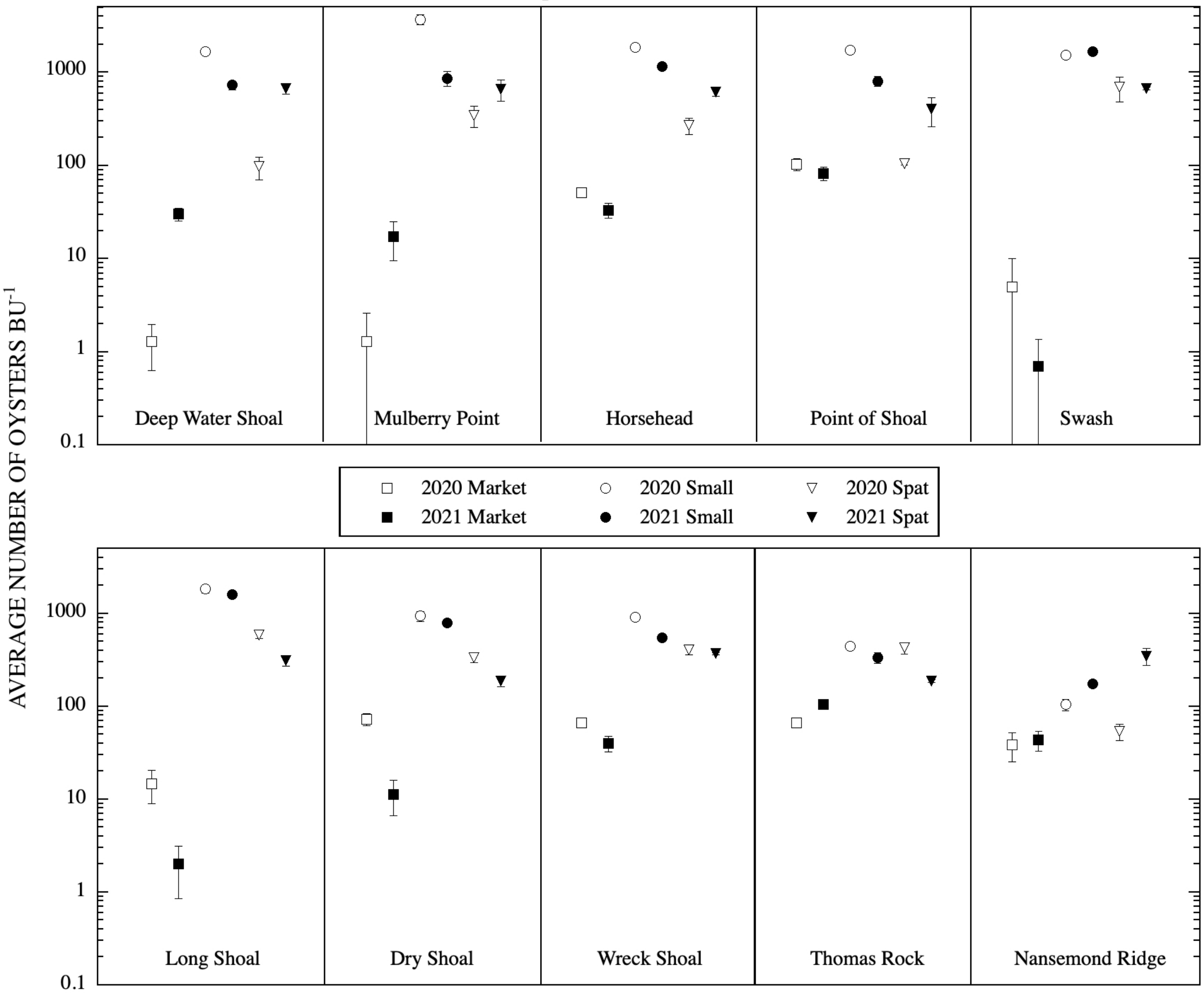


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE YORK RIVER AND MOBJACK BAY (2021-2022)
(Error bars represent standard error of the mean)

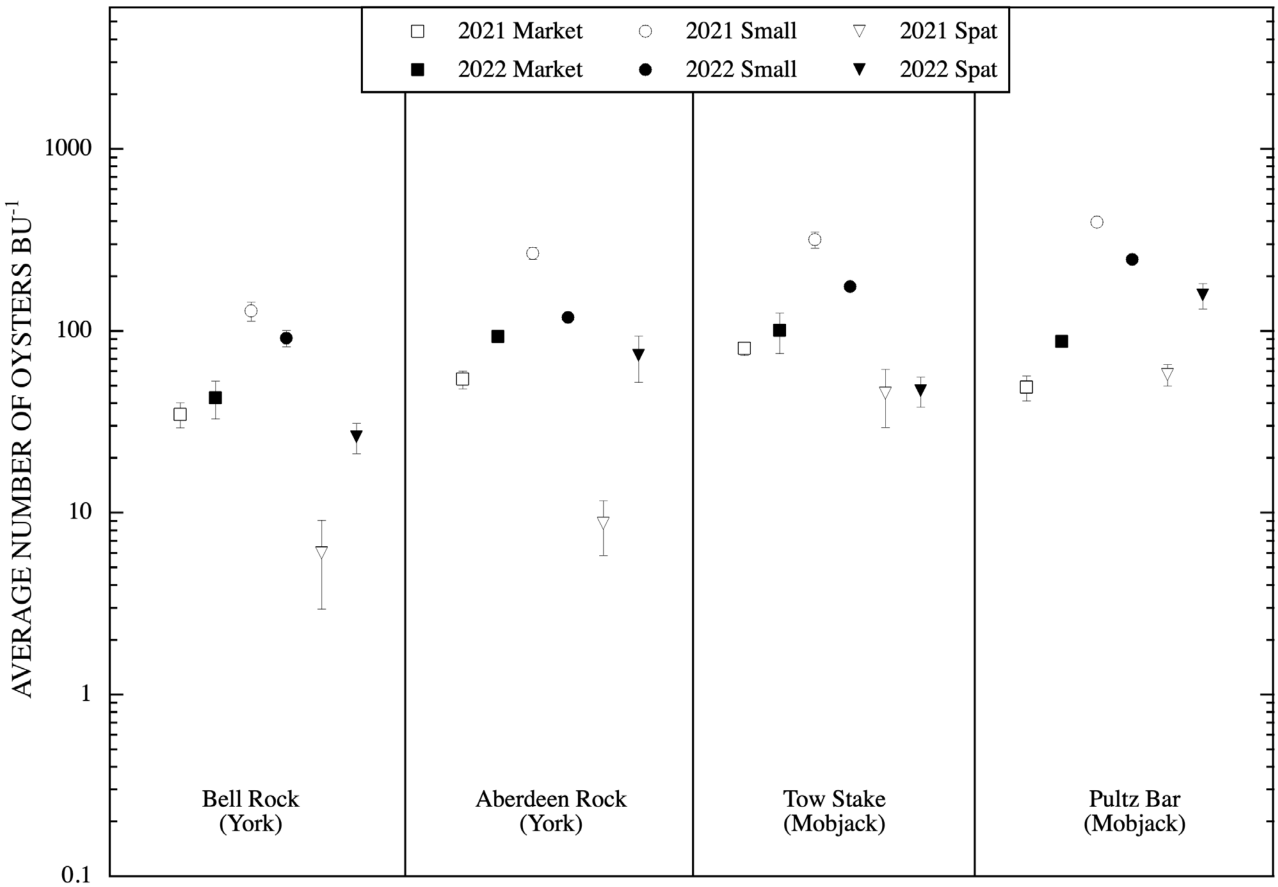


FIGURE D5: YORK RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)

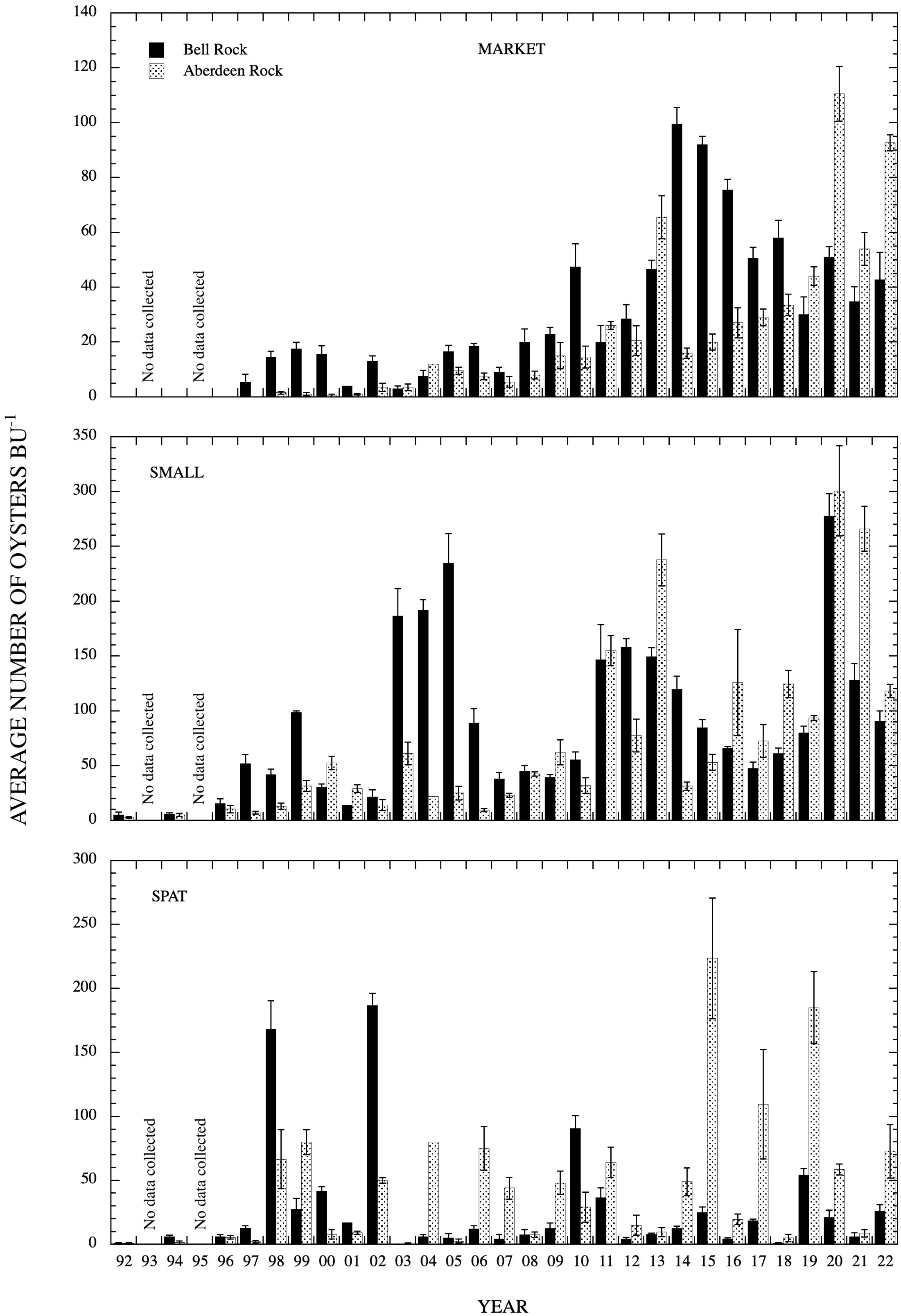


FIGURE D6: MOBJACK BAY OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)

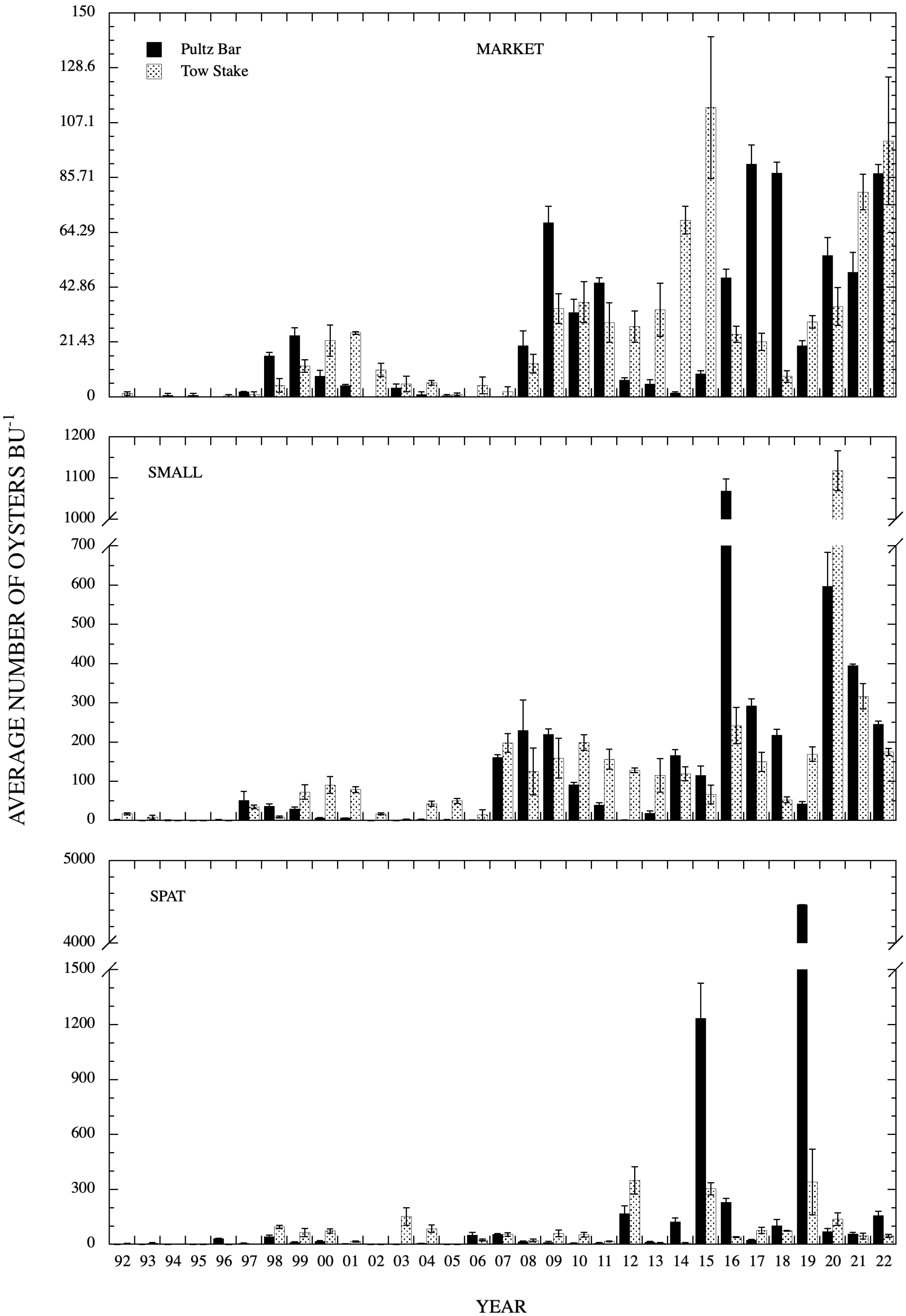


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE PIANKATANK RIVER (2021-2022)
(Error bars represent standard error of the mean)

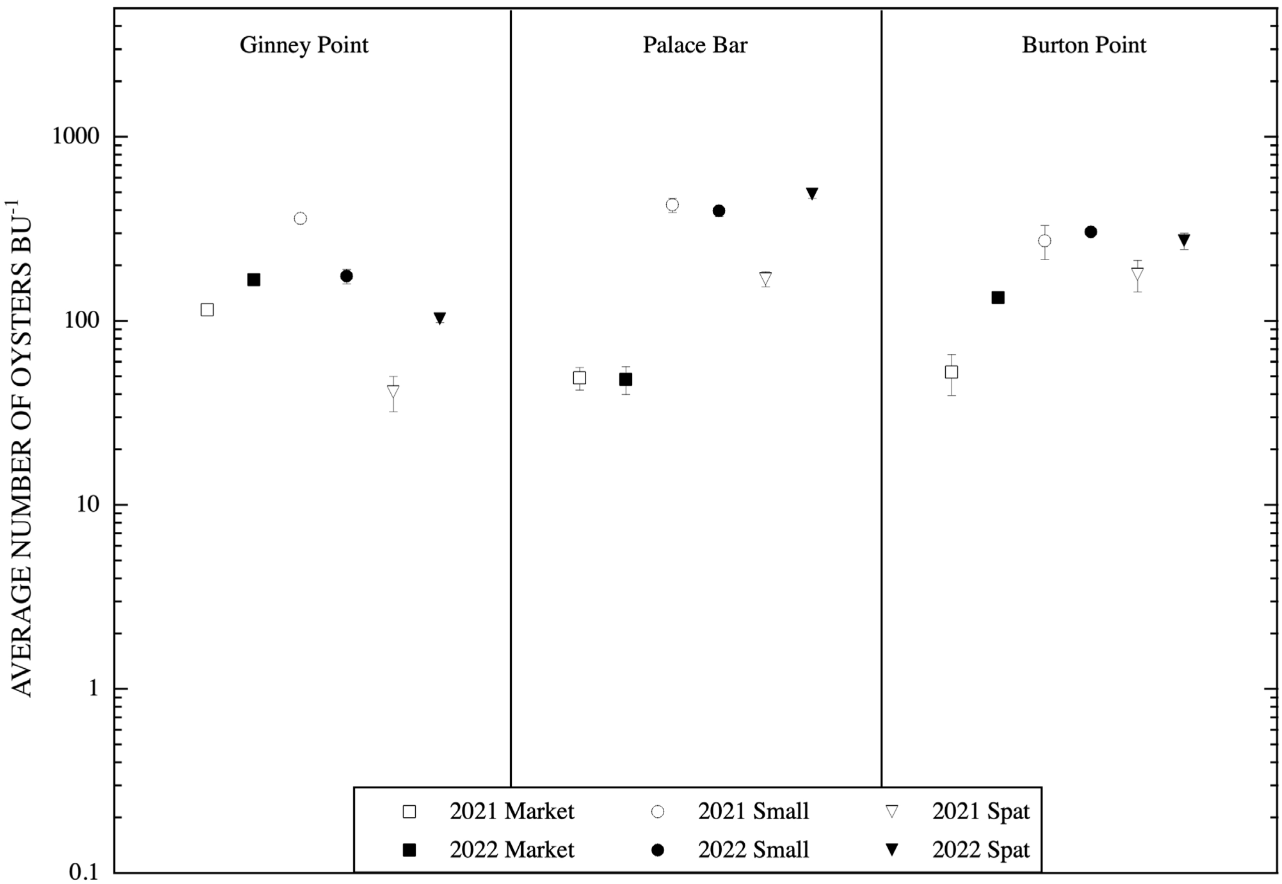
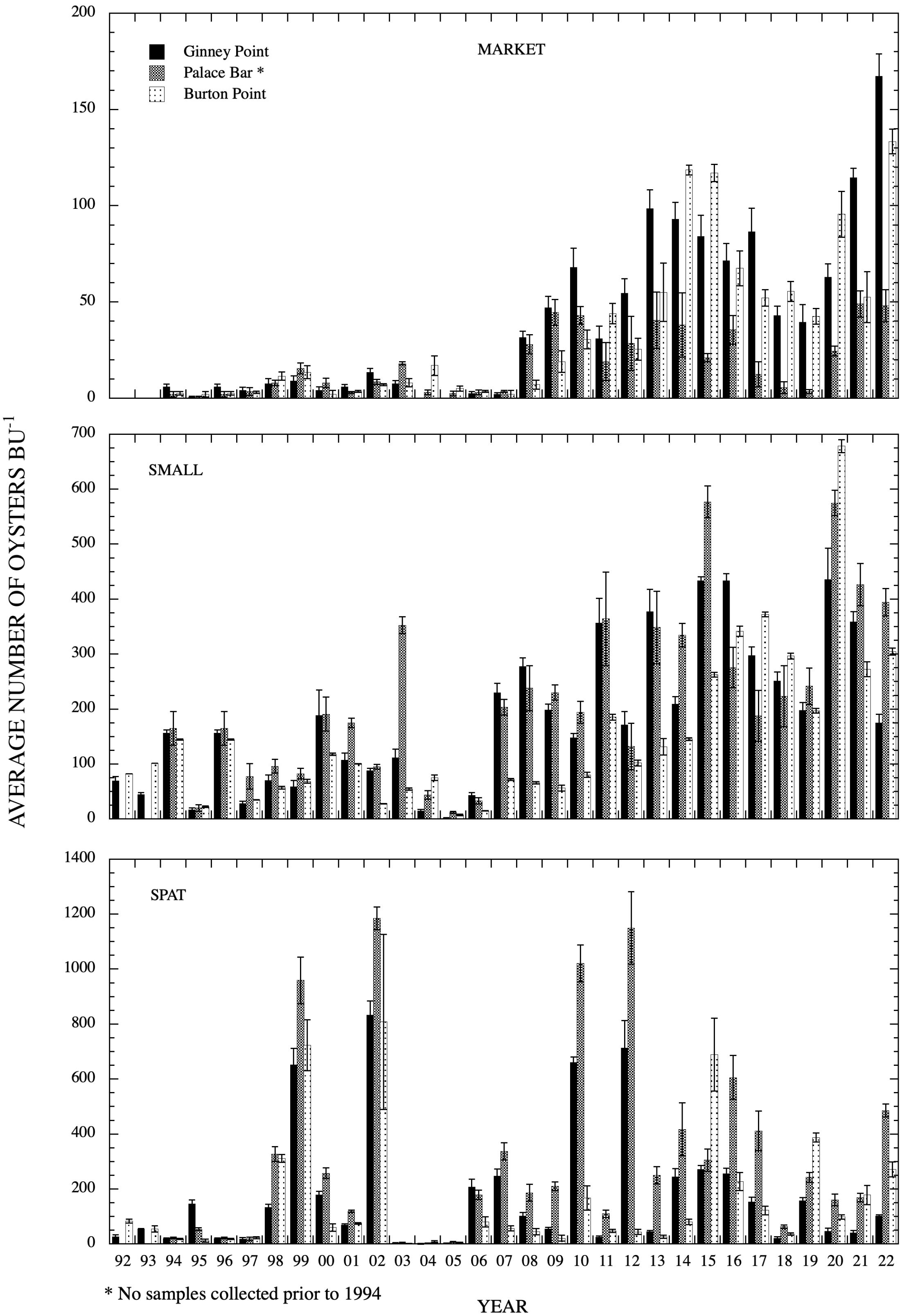


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)



* No samples collected prior to 1994

FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE RAPPAHANNOCK RIVER (2021-2022)
(Error bars represent standard error of the mean)

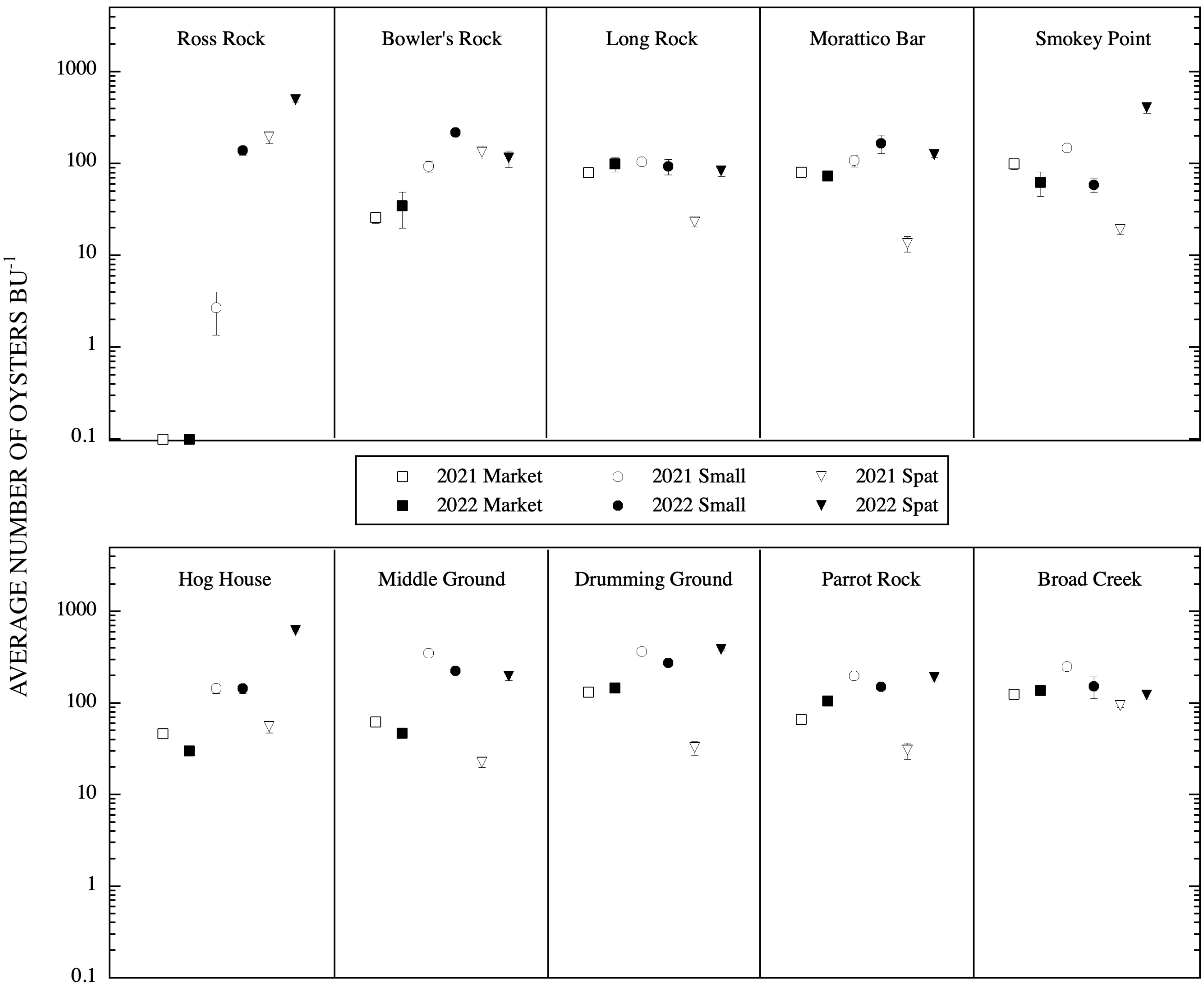
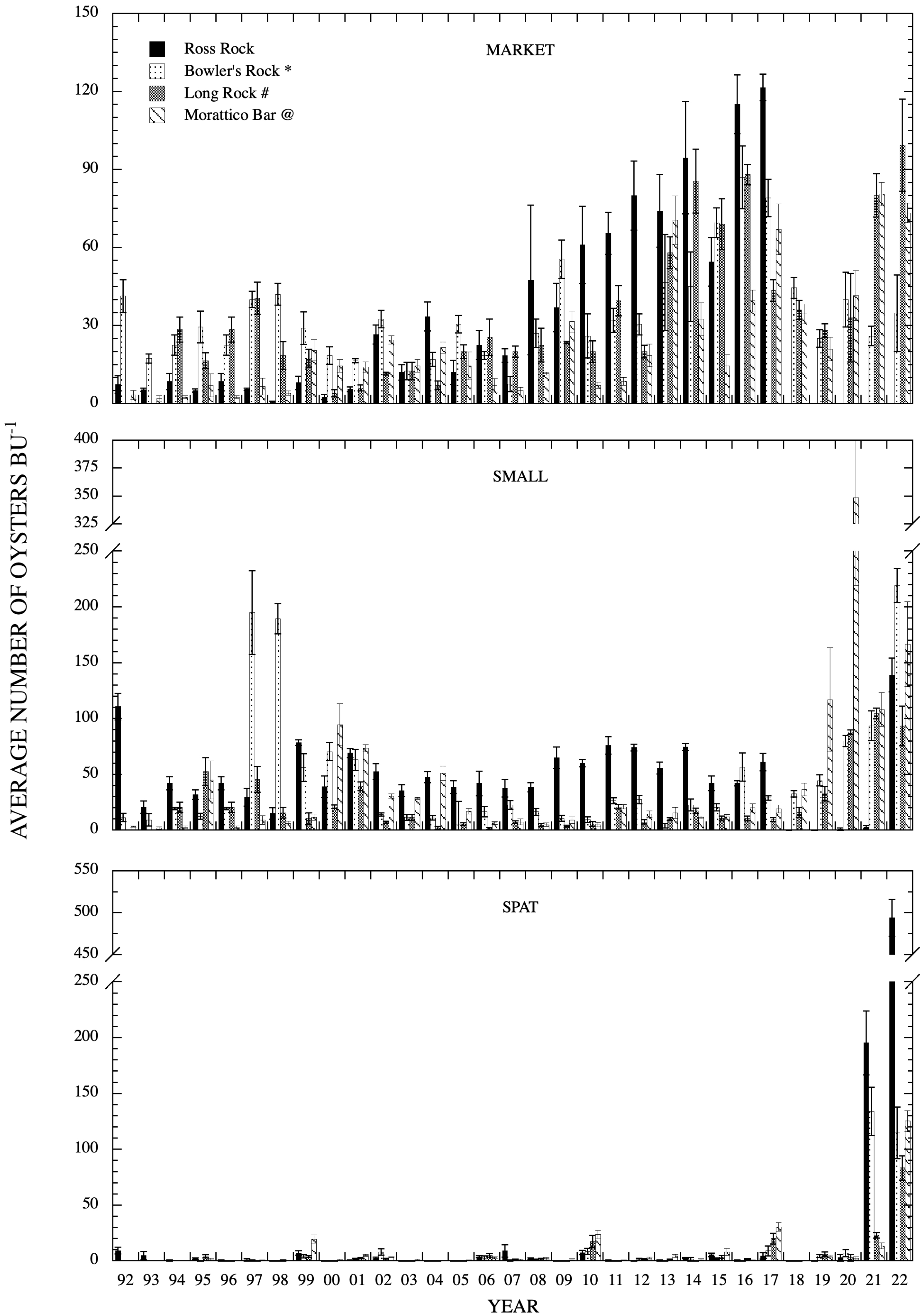
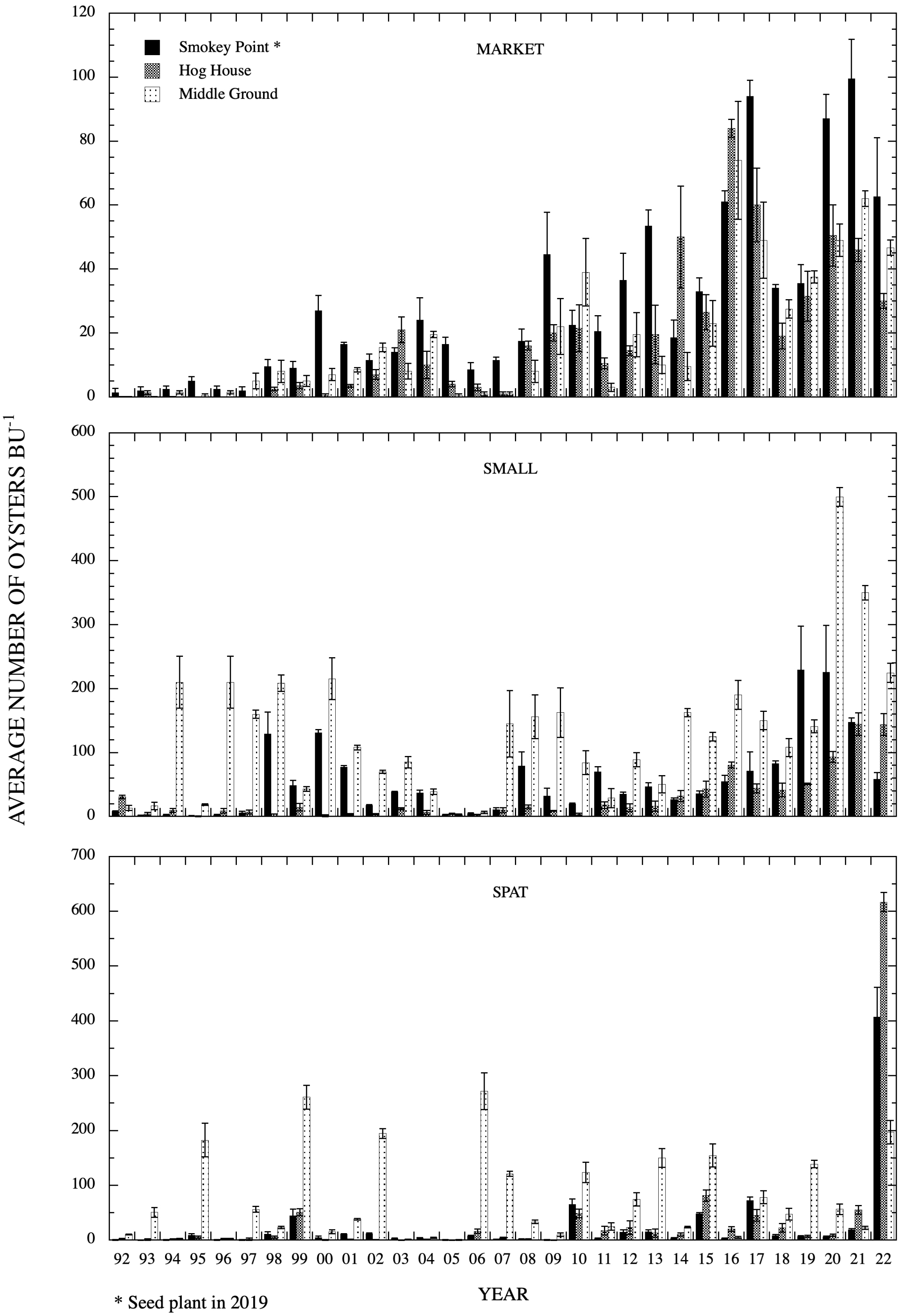


FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)



* = seed plant in 1997: # = no data prior to 1994: @ = seed plant in 2019 & 2020

FIGURE D10B: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)



* Seed plant in 2019

FIGURE D10C: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)

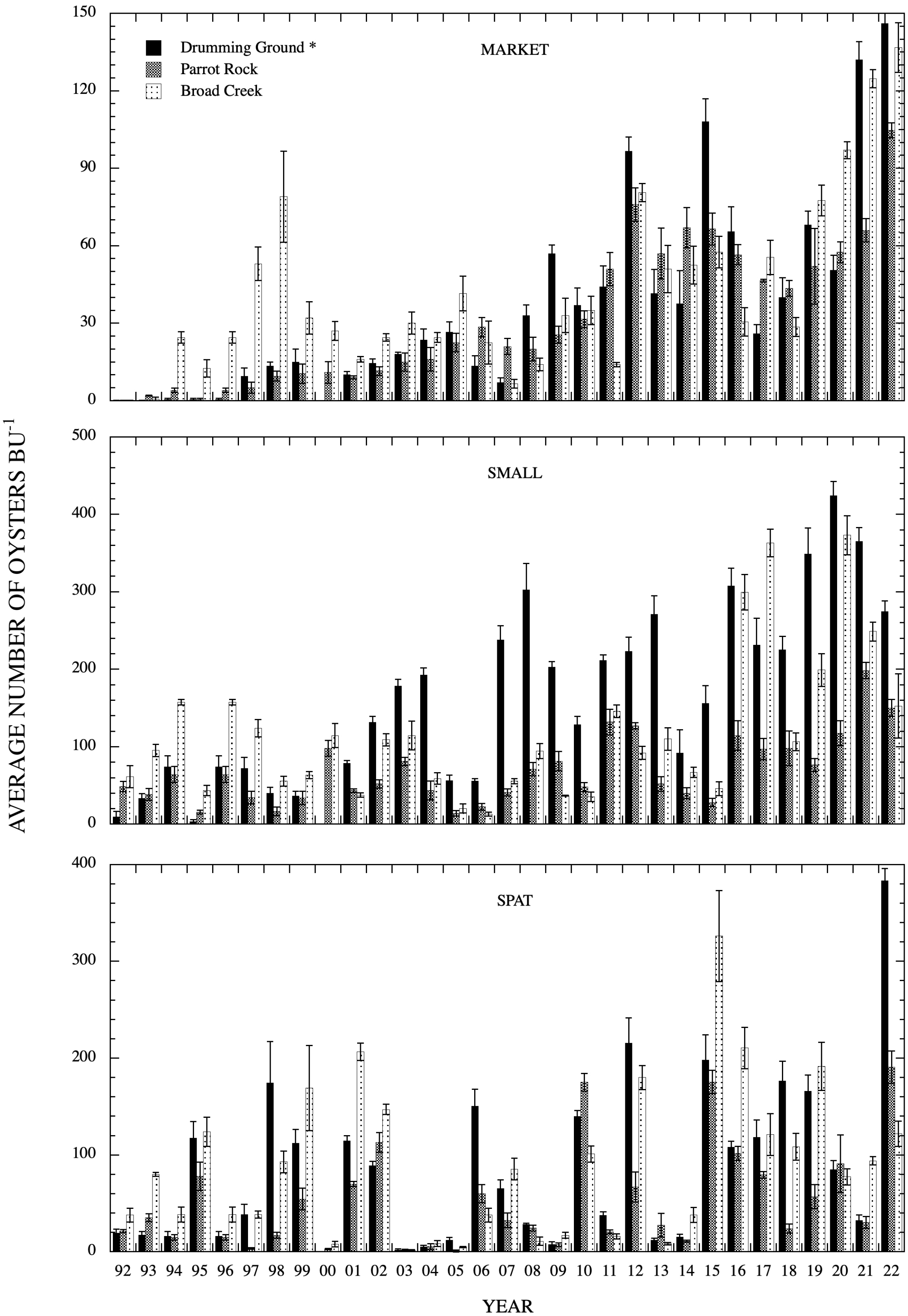


FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE GREAT WICOMICO RIVER (2021-2022)
(Error bars represent standard error of the mean)

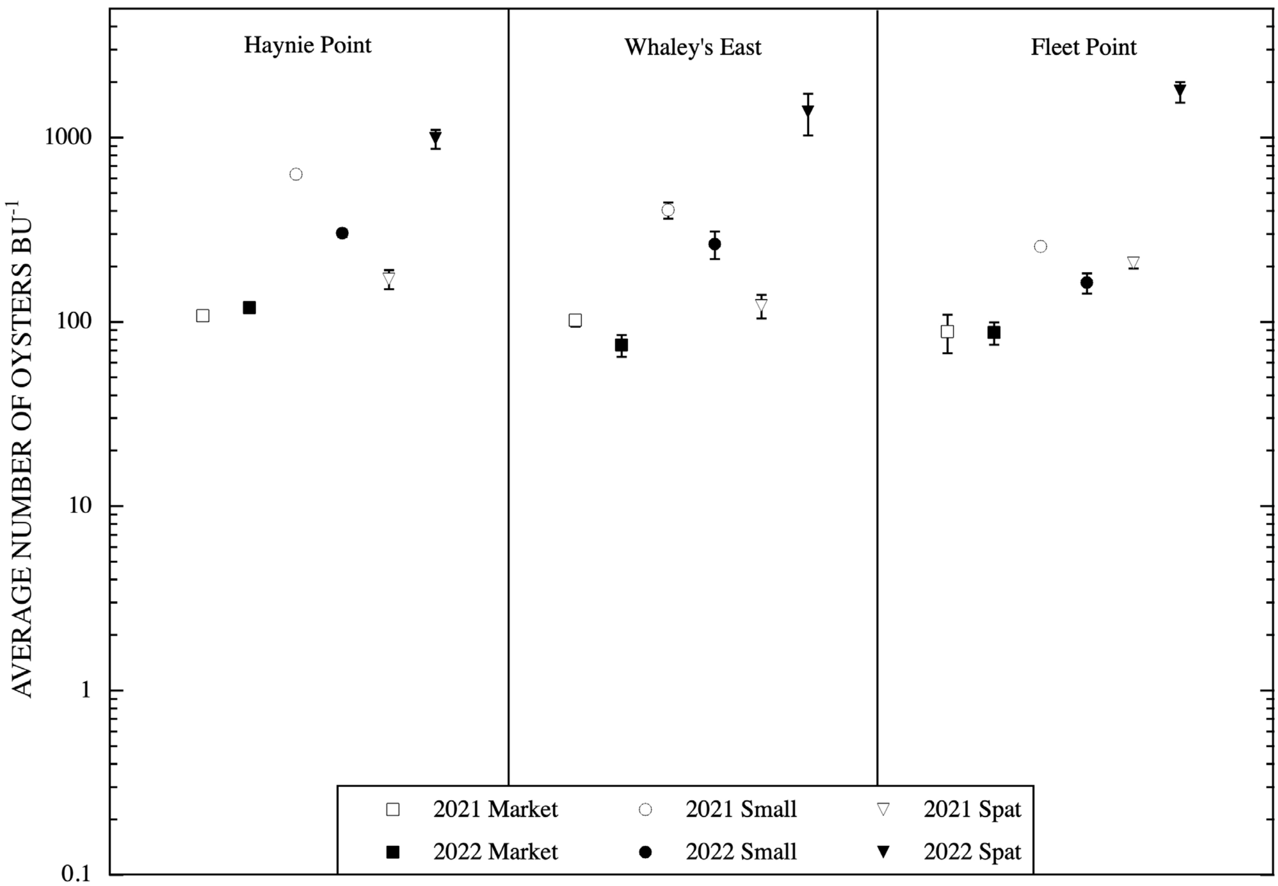


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS OVER THE PAST 30 YEARS
(Error bars represent standard error of the mean)

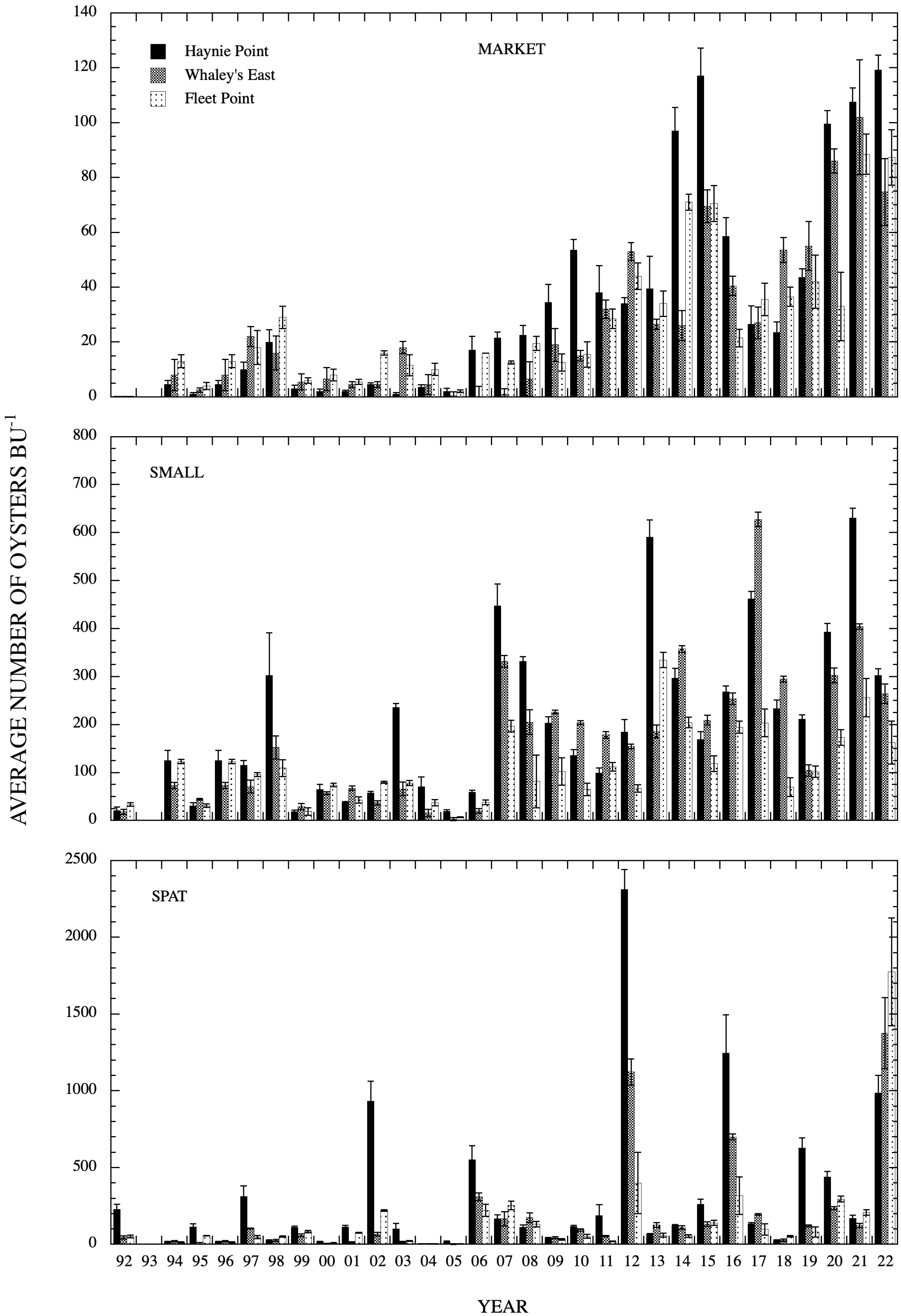
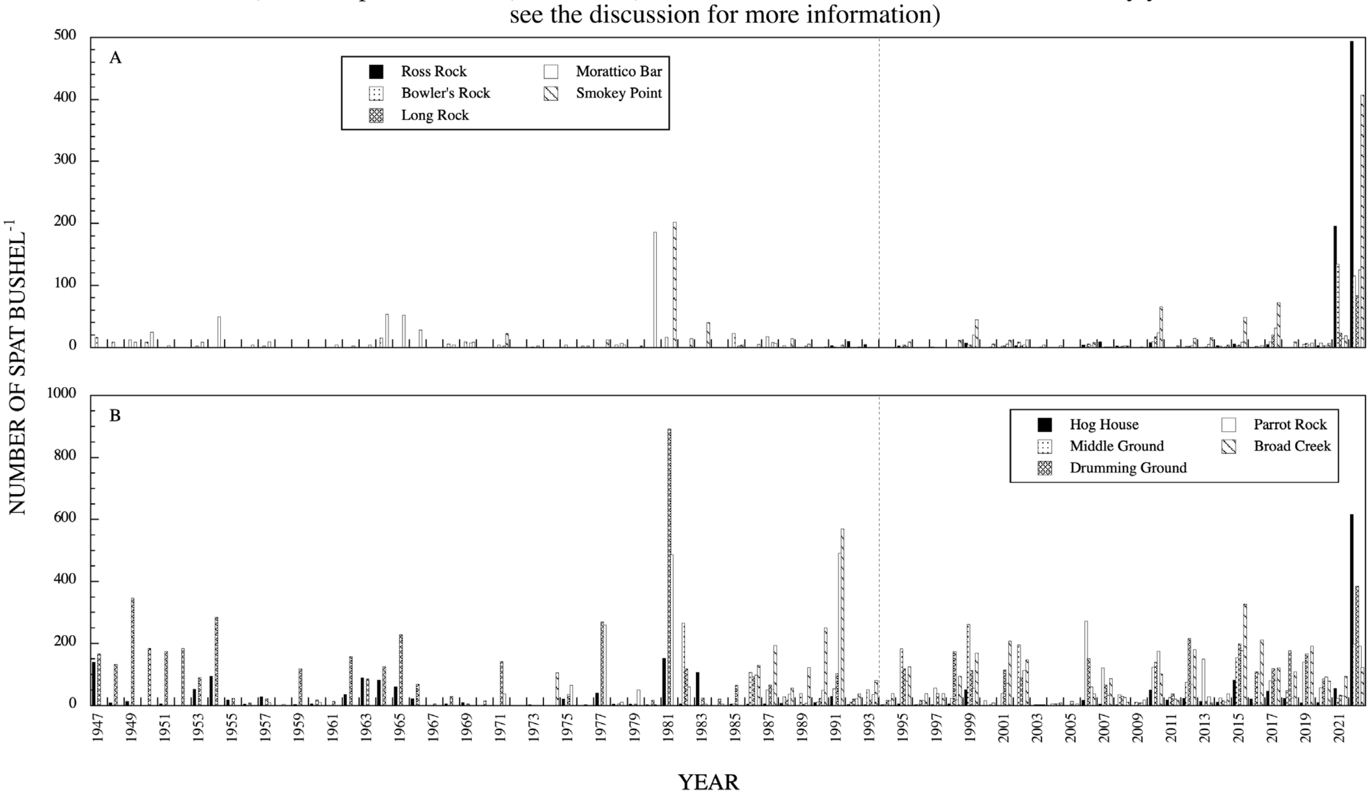


FIGURE D13: RECRUITMENT TRENDS IN THE RAPPAHANNOCK RIVER FROM 1947 TO 2022
(note that prior to 1994 (dashed line), data was not collected at all of the sites every year;
see the discussion for more information)



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