# The Status of Virginia’s Public Oyster Resource 2017

MELISSA SOUTHWORTH
and ROGER MANN

Molluscan Ecology Program
Department of Fisheries Science
Virginia Institute of Marine Science
The College of William and Mary
Gloucester Point, VA 23062

April 2018

TABLE OF CONTENTS



Citation for this report:

Southworth, M. and R. Mann. 2018. The status of Virginia's public oyster resource, 2017. Molluscan Ecology Program, Virginia Institute of Marine Science, Gloucester Point, Virginia. 51 pp.

# Part I. OYSTER RECRUITMENT IN VIRGINIA DURING 2017

## *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 (settlement of larval oysters called 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 settlement 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), Shellfish Replenishment Division) 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 larvae 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 in 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. Settlement and subsequent survival of spat on bottom cultch are 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 settlement and survival of spat on the bottom. Therefore, settlement on shellstrings may not directly correspond with recruitment on bottom cultch at all times or places. Under most circumstances, however, the relationship between settlement on shellstrings and recruitment to bottom cultch is expected to be commensurate.

This report summarizes data collected during the 2017 settlement season in three tributaries in the Virginia portion of the Chesapeake Bay.

## *METHODS*

Settlement during 2017 was monitored in the James, Piankatank and Great Wicomico Rivers from the week of May 20 (Piankatank and Great Wicomico Rivers) and May 27 (James River) through the week of September 23 (Piankatank and Great Wicomico Rivers) and September 30

(James River). Settlement 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 twenty-five 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[1]. 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.

Oyster shellstrings were used to monitor oyster settlement. 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).

Although shellstring collectors at most sites were deployed for 7-day periods, there were some weather related deviations such that shellstring deployment periods during 2017 ranged from 7 to 14 days. These periods do not always coincide among the different rivers 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 settlement trends over the course of the season between various sites in a river as well as between data for different years.

The cumulative settlement 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 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

[1] http://www.vims.edu/research/units/labgroups/molluscan_ecology/restoration/va_restoration_atlas/index.php

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 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*

Settlement on shellstring collectors during 2017 is summarized in Table S1 and is discussed below for each river system monitored. Table S2 includes a summary of settlement over the past twenty-five years (1992-2017) at the historical sites in all three-river systems and over the past nineteen years (1998-2017) 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 settlement 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 2017 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 2017. Comparisons were made over the past nineteen years for the modern sites whereas the historical sites include twenty-five 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 Fleet Point, Glebe Point, Haynie Point, Hudnall and Whaley's East (labeled Cranes Creek in reports prior to 1997).

### James River

Oyster settlement in the James River was first observed during the week of June 10 at three out of the eight sites monitored (Table S1). Settlement occurred throughout the rest of the monitoring period, with at least one spat settling at seven out of the eight sites every week. Settlement during the first week of July accounted for approximately 54% of the total settlement observed in the river for the year (Figure S3). At both Day's Point and Swash, settlement during this week accounted for 65% of the total settlement observed in 2017. At every site except Deep Water Shoal, between 53% (Rock Wharf) and 83% (Swash) of the total recruitment observed in 2017 had occurred by the week of July 8. At Deep Water Shoal, the $50^{th}$ percentile of recruitment for the year had occurred by the end of July.

Cumulative settlement in the James River during 2017 was moderate at Deep Water Shoal, heavy at Horsehead, Point of Shoal, Swash, Rock Wharf and Wreck Shoal and extremely heavy at Dry Shoal and Day's Point. Settlement ranged from a low of 7.6 cumulative spat shell$^{-1}$ at Deep Water Shoal to a high of 139.3 cumulative spat shell$^{-1}$ at Day's Point (Table S1; Figure S4). Settlement during 2017 was higher than the previous year (2016) at Dry Shoal, Rock Wharf and Day's Point. Settlement in 2017 was higher than the five-year means at the five most downriver sites (see Fig. S1) and was higher than the ten-year means at Dry Shoal and Day's Point. Settlement in 2017 was higher than both the 20 and 25-yr means at every site except Deep Water Shoal. At the five most downriver sites (Swash, Dry Shoal, Rock Wharf, Wreck Shoal and Day's Point; see Fig S1), settlement in 2017 was in the upper range of that observed during the past twenty-five years of monitoring (the 91st and 92nd percentile at Swash and Wreck Shoal, respectively and the 88th percentile at Swash, Rock Wharf and Day's Point). The long-term means are primarily driven by a few exceptionally high settlement years (1991, 1993, 2002, 2008, 2010, 2012, and 2016).

Average river water temperature in the James River during the 2017 monitoring period ranged from a low of 22.4 to a high of 28.9°C (Figure S5A). Temperature steadily rose from the beginning of the monitoring period until reaching the season high during the second week of July (Figure S5A). This maximum occurred one to two weeks earlier than what is typical for the James River and temperature during this week was 1 to 2°C higher than the long-term (5, 10, 20 and 30-yr) means. After reaching the maximum for the year, temperature generally decreased before again increasing to 28.7°C in late August, at which time temperature in the system was again 1 to 2°C higher than the long-term means (Figure S5A). This second increase in temperature was followed by a relatively rapid decrease and a three-week period where temperature was 2 to 3°C lower than the long-term means.

Average salinities in the James River during 2017 ranged from 4.9 to 18.1, generally increasing from the first part of June into late July and then fluctuating between 13.4 and 17.2 throughout August and September (Figure S5B). From the last week of June through the middle of August, salinity in the James River was anywhere from 1 to 5.5 higher than the long-term (5, 10, 20 and 30-yr) means. From the end of July through the beginning of September, salinity fluctuated by 2 to 4 from one week to the next. Throughout the sampling period, the difference in salinity between the most upriver site (Deep Water Shoal) and the most downriver sites (Day's Point and/or Wreck Shoal; Figure 1) ranged between 5 and 12.

## Piankatank River

Settlement in the Piankatank River was first observed during the week of May 27 at Ginney Point, Cape Toon and Burton Point (Table S1; Figure S6). Settlement was relatively heavy and consistent from June 17 through July 15, accounting for 75% (Wilton Creek and Ginney Point) to 94% (Cape Toon) of the total spatfall for the year at the eight sites monitored. Settlement from mid-July through the end of the monitoring period was light and variable. At all eight sites, greater than 50% of the total spatfall for the year had occurred by the second week of July.

Cumulative spat shell$^{-1}$ for the year was extremely heavy at Cape Toon and heavy at the other seven sites, ranging from a low of 18.3 at Stove Point to a high of 112.0 at Cape Toon (Table S1). Settlement during 2017 was lower than that observed during 2016 at every site except Cape Toon. Settlement was also lower than the 5-yr means at all eight sites and lower than the 10-year means at every site except Cape Toon. Settlement at the three historical sites was also lower than the 20-yr means at all three sites and lower than the 25-yr means at Palace Bar and Burton Point (Table S2; Figure S7A). Settlement at Burton Point was the fifth highest observed over the past twenty-five years (84th percentile). At the modern sites, settlement was the fourth (Bland Point; 84th percentile) and fifth highest (Wilton Creek, Heron Rock and Cape Toon; 78th percentile) observed since monitoring began at those sites in 1998.

The average water temperature during the 2017 sampling period in the Piankatank River ranged from 20.1 to 30.1°C, reaching the maximum in the middle of July (Figure S8A). Water temperature in the Piankatank River was similar (within 1°C) to the long-term means (5, 10, 20 and 25-yr) from late May through mid-August (Figure S8A). The one exception to this occurred during the week of July 8 when the temperature was at its maximum, which was around 1.5°C higher than the 10, 20 and 25-yr means (Figure S8A). Water temperature decreased relatively sharply (3°C in one week) at the end of August and was 2 to 3°C lower than the long-term means during the first two weeks of September. Temperature then increased and became 1 to 2°C higher than the long-term means by the end of sampling period (Figure S8A).

Salinity in the Piankatank River during 2016 ranged from 14.7 to 18.2, generally increasing during the first five weeks of monitoring and then remaining relatively stable between 17 and 18 for the rest of the season (Figure S8B). Salinity in the Piankatank River typically increases over the shellstring sampling season, but this pattern was not observed during 2017. Instead, following a fairly sharp increase of 3 between June 10 and June 17, salinity was 2 to 4 higher than the long-term (5, 10, 20 and 25-yr) means from June 17 through the second week of July. From the third week of July through mid-August, salinity was 1 to 2 higher than the long-term means (Figure S8B). Salinity became similar to the long-term means in late August and remained similar throughout the rest of the monitoring period. In any given week, the difference recorded between the most upriver site (Wilton Creek) and the most down river site (Burton Point; see Figure S1) was less than 3.

**Great Wicomico River**

Settlement in the Great Wicomico River was first observed during the week of May 27 at Hilly Wash. Settlement was consistent and relatively heavy from June 10 through July 8 (Table S1; Figure S9). From July 29 through the end of the monitoring period settlement in the Great Wicomico River was light. Similar to the Piankatank River, the majority of settlement for the season occurred early in the monitoring period. Settlement during the four-week period from June 10 to July 1 accounted for 87 (Fleet Point) to 96% (Hudnall) of the settlement for the season (Table S1; Figure S9).

Cumulative spat shell$^{-1}$ for the year was extremely heavy at all nine sites, ranging from a low of 101.1 at Whaley's East to a high of 487.9 at Glebe Point (Table S1; Figure S10). Settlement in the Great Wicomico River in 2017 was lower than that observed in 2016 at all nine sites (Table S2; Figure S10). 2017 settlement was also lower than the 5-year means at every site except Fleet Point, but higher than the 10-year means at Glebe Point, Hilly Wash, Harcum Flats, Hudnall, Shell Bar and Fleet Point. Settlement in 2017 was higher than both the 20 and 25-year means at all five of the historic sites. When compared with the past twenty-five years, settlement in 2017, was the second highest recorded at Fleet Point (96th percentile), the third highest at Glebe Point, Hudnall and Whaley's East (92nd percentile) and the fifth highest at Haynie Point (84th percentile). At the modern sites, settlement in 2017 ranked the third (Harcum Flats; 89th percentile) and fourth highest (Rogue Point, Hilly Wash, and Shell Bar; 84th percentile) observed since monitoring began at those sites in 1998.

The average river water temperature in the Great Wicomico River during the 2017 sampling period ranged from 20.6 to 30.2°C, reaching the maxima during the week of July 17 (Figure S11A). The maxima occurred one to two weeks earlier than is typical for the system and water temperature was around 2°C higher than the long-term (5, 10 and 19-yr) means during that time. Following the temperature max in mid-July, water temperature steadily decreased, before experiencing a sharp 3°C decrease between the week of August 19 and August 26. Following this decrease, water temperature was 2 to 3°C lower than the long term means for several weeks before again increasing toward the end of the monitoring period when it was 1 to 2°C higher than the long term means.

Salinity in the Great Wicomico River during the 2017 sampling period ranged from 13.2 to 16.6, remaining generally stable around 16 from June 17 onward (Figure S11B). From June 17 to July 8, salinity was around 1 to 2 higher than the long-term (5, 10 and 19-yr) means (Figure S11B). Salinity became similar (less than 1 difference) to the long-term means beginning in mid-July and remained similar for the rest of the monitoring period. There was typically a 1 to 2 difference in salinity between the most upriver site (Glebe Point) and the most downriver site (Fleet Point: Figure S1) throughout the monitoring period.

## *DISCUSSION*

During the fourteen-year period between 1994 and 2007, settlement on the shellstrings was light to moderate; with 83% of all of the year/site combinations having a seasonal cumulative total of less than 10 spat shell$^{-1}$. However, settlement on the shellstrings over the past ten years (2008-2017) has been on the rise such that 84% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat shell$^{-1}$) and 36% of all of the year/site combinations had extremely heavy spatfall (seasonal cumulative total of > 100 spat shell$^{-1}$; Table S2). This trend of increased spat set has been especially notable in the Great Wicomico River, where since 2006, 89% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat shell$^{-1}$) and 49% of the total year/site combinations had extremely heavy spatfall (seasonal cumulative total of > 100 spat shell$^{-1}$; Table S2). For the second year in a row, settlement was extremely heavy on all of the sites monitored in the Great Wicomico River, including the two most downriver sites (Fleet Point and Whaley's East), which have historically experienced much lower settlement than the sites upriver of Sandy Point (see Figure S1 for reference).

With the exception of Deep Water Shoal, overall settlement on shellstrings in the James River during 2017 was heavy (five sites) to extremely heavy (two sites). Since 2008, the James River has had several very strong year classes (2008, 2010, 2012 and 2016). The mean cumulative spat shell$^{-1}$ over all eight sites from 1992 to 2007 was 9.3, whereas the mean for all eight sites over the past ten years (2008 to 2016) was 80.9. This translates to almost a nine-fold increase in settlement over the past ten years compared with the previous sixteen years. Since 2008, at least three out of the eight sites experienced heavy to extremely heavy settlement each year. The one exception was during 2009, when all eight sites monitored had moderate settlement (Table S2). In recent years, the timing of settlement in the James River has been getting progressively earlier (Southworth & Mann 2004). Once settlement began in late-June, at least some settlement occurred each week throughout the rest of the 2017 monitoring period. However, similar to what Southworth and Mann (2004) observed, the majority of this settlement occurred in the first half of the season, such that at seven out of the eight sites monitored, at least 55% of the total settlement for the season had occurred by the week of July 8. The one exception to this was Deep Water Shoal. This may have been due to Deep Water Shoal being especially vulnerable to low salinity early in the spawning season. Overall, settlement at the three most upriver sites (Deep Water Shoal, Horsehead and Point of Shoal) was considerably lower than at the five more downriver sites.

Overall, settlement in 2017 on the shellstrings in the Piankatank River was heavy (seven sites) to extremely heavy (one site). Similar to the James River, the Piankatank River has had several very strong year classes in recent years (2012, 2015 and 2016). From 1993 to 2006 (historical sites) and 1998 to 2006 (modern sites), settlement in the Piankatank River was consistently low to moderate at most of the sites monitored. At the three historical sites the mean from 1993 to 2006 was 2.5 cumulative spat shell$^{-1}$, whereas from 2007 to 2017 the mean at those three sites was 69.8 cumulative spat shell$^{-1}$, a 28-fold increase over the previous fourteen-year mean. Since the addition of the modern sites in 1998, the mean across the river increased from 4.1 cumulative spat shell$^{-1}$ (1998 to 2006) to 81.8 cumulative spat shell$^{-1}$ (2007 to 2017), a 23-fold increase. For the past several years potential broodstock (small plus market) in the system has been on the rise. At the three Piankatank River sites monitored during the fall dredge survey, the total number of small and market oysters combined in the system overall was lower than that observed over the past few years, but was still higher than what was observed in the late 1990s through early 2000s when settlement on the shellstrings tended to be lower (Part II of this report). Density and abundance of broodstock is an important factor in determining fertilization success (Mann & Evans 1998) and the increase in small and market oysters in the system over the past few years may help to explain at least some of the spawning success observed in the system during that time.

Settlement on the shellstrings in the Great Wicomico has been especially good for the past eleven years, with 2017 marking the second year in a row with extremely heavy (>100 cumulative spat shell$^{-1}$) settlement recorded at all nine sites monitored. Settlement at the two most downriver sites (Whaley's East and Fleet Point; Figure S1) was the second and third highest recorded at those two sites since regular monitoring began in 1970 (http://www.vims.edu/research/units/labgroups/molluscan_ecology/publications/topic/shellstring/index.php). In contrast to what was observed during most of the 1990s and the early 2000s, settlement in the Great Wicomico River over the past twelve years has been especially good. At the five historical sites the mean from 1992 to 2005 was 6.4 cumulative spat $shell^{-1}$, whereas from 2006 to 2017 the mean at those five sites was 179.7 cumulative spat $shell^{-1}$, a 28-fold increase over the previous fourteen-year mean. Since the addition of the modern sites in 1998, the mean across the river increased from 6.9 cumulative spat $shell^{-1}$ (1998 to 2005) to 211.8 cumulative spat $shell^{-1}$ (2006 to 2017), a 31-fold increase.

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 | 5/20<br>140 | 5/27<br>147 | 6/3<br>154 | 6/10<br>161 | 6/17<br>168 | 6/24<br>175 | 7/1<br>182 | 7/8<br>189 | 7/15<br>196 | 7/22<br>203 | 7/29<br>210 | 8/5<br>217 | 8/12<br>224 | 8/19<br>231 | 8/26<br>238 | 9/2<br>245 | 9/9<br>252 | 9/16<br>259 | 9/23<br>266 | 9/30<br>273 | YEAR TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAMES RIVER | | | | | | | | | | | | | | | | | | | | | |
| Deep Water Shoal | | D | 0 | 0 | - | 0.3 | 1.8 | 0.5 | 0.2 | 0.4 | 1.1 | 1.0 | 1.1 | 0.4 | 0.3 | 0.2 | 0 | 0.1 | - | 0.2 | 7.6 |
| Horsehead | | D | 0 | 0 | - | 7.1 | 22.9 | 3.8 | 1.8 | 0.5 | 1.0 | 0.9 | 1.0 | 0.4 | 1.5 | 0.4 | - | 0.4 | - | 0.3 | 42.0 |
| Point of Shoal | | D | 0 | 0 | - | 2.9 | 13.8 | 2.8 | 0.5 | 1.2 | 3.1 | 1.3 | 0.9 | 0.8 | 1.0 | 0.9 | 0.3 | 0.2 | - | 0.2 | 29.9 |
| Swash | | D | 0 | 0.1 | - | 5.4 | 39.4 | 4.9 | 2.0 | - | 3.7 | 1.1 | 0.9 | 0.1 | 1.0 | 0.6 | 0.5 | 0.5 | - | 0 | 60.2 |
| Dry Shoal | | D | 0 | 0.1 | - | 7.8 | 71.7 | 4.6 | 7.0 | 5.0 | 10.1 | 1.5 | 7.9 | 1.9 | 5.4 | 1.9 | 1.7 | 5.7 | - | 1.0 | 133.3 |
| Rock Wharf | | D | 0 | 0 | - | 4.0 | 33.8 | 3.3 | 8.1 | 5.8 | 8.7 | 0.6 | 4.4 | 0.9 | 4.0 | 1.6 | 1.9 | - | - | 0.1 | 77.2 |
| Wreck Shoal | | D | 0 | 0.4 | - | 17.1 | 38.5 | 9.7 | 4.7 | 3.7 | 5.4 | 0.9 | 3.3 | 0 | 1.2 | 1.4 | 1.4 | - | - | - | 87.7 |
| Day's Point | | D | 0 | 0 | - | 7.2 | 91.1 | 1.7 | 12.5 | - | 6.9 | 0 | 6.5 | 2.4 | 9.4 | 0.8 | 0.4 | 0.4 | - | - | 139.3 |
| PIANKATANK RIVER | | | | | | | | | | | | | | | | | | | | | |
| Wilton Creek | D | 0 | 0.2 | 0.8 | 2.9 | 1.9 | 4.1 | 5.3 | 6.1 | 0.5 | 0.8 | 0 | 1.9 | 0.8 | 1.5 | 0.1 | 0.3 | 0 | 0 | | 27.2 |
| Ginney Point | D | 0.1 | 0.2 | 0.2 | 2.1 | 2.8 | 3.7 | 6.8 | 5.4 | 1.5 | 0.5 | 0.4 | 2.2 | - | 1.5 | 0.3 | 0.1 | 0.1 | 0 | | 27.9 |
| Palace Bar | D | 0 | 0.2 | 0.6 | 4.2 | 3.3 | 1.8 | 4.4 | 1.5 | 0.2 | 0.3 | 0.1 | 0.3 | 0.3 | 1.2 | 0.0 | 0.1 | 0.1 | 0 | | 18.6 |
| Bland Point | D | 0 | 0.1 | 1.4 | 12.8 | 18.3 | 15.1 | 9.2 | 2.1 | 0.3 | 0.1 | 0.1 | 0.2 | 0.2 | 1.0 | 0.2 | 0.5 | 0.4 | 0.1 | | 62.1 |
| Heron Rock | D | 0 | 0.1 | 0.6 | 2.6 | 6.5 | 11.1 | 6.8 | 1.2 | 0.3 | 0.2 | 0.3 | - | 0.1 | 0.5 | 0 | 0.5 | 0.4 | 0.1 | | 31.3 |
| Cape Toon | D | 0.1 | - | 0.6 | 8.7 | 15.2 | 52.5 | 23.7 | 5.6 | 0.5 | 0.6 | 0.1 | 1.7 | 0.7 | - | 0.9 | 0.4 | 0.2 | 0.5 | | 112.0 |
| Stove Point | D | 0 | 0 | 0.3 | 4.2 | 3.6 | 3.5 | 3.2 | 1.1 | 0 | 0 | 0 | 0.4 | 0.1 | 0.9 | 0.4 | 0.2 | 0.2 | 0.2 | | 18.3 |
| Burton Point | D | 0.1 | - | 0.1 | 5.2 | 10.4 | 15.2 | 9.7 | 0.2 | 0.2 | 0 | 0.2 | 0.4 | 0.5 | 0.5 | 0.4 | 0.1 | 0.2 | 0.3 | | 43.7 |
| GREAT WICOMICO | | | | | | | | | | | | | | | | | | | | | |
| Glebe Point | D | 0 | 4.5 | 73.3 | 87.8 | 49.4 | 234.6 | 35.2 | 0.4 | 0 | 0.2 | 0 | 0.1 | 1.3 | 0.2 | 0.8 | 0 | 0.1 | 0 | | 487.9 |
| Rogue Point | D | 0 | 1.4 | 10.3 | 90.3 | 19.1 | 7.7 | 2.1 | 0.1 | 0 | 0.6 | 0.5 | 1.6 | 3.3 | 1.7 | 0.8 | 0.1 | 0.3 | 1.2 | | 141.1 |
| Hilly Wash | D | 0.1 | 0.9 | 30.4 | 96.1 | 94.6 | 45.0 | 10.2 | 0.2 | 0 | 0.2 | 0.1 | 0.7 | 2.0 | 0.3 | 0.2 | 0 | 0.3 | 0.3 | | 281.6 |
| Harcum Flats | D | 0 | 1.8 | 28.7 | 96.0 | 85.5 | 103.2 | 12.1 | 0 | 0 | 0.3 | 0.2 | 1.6 | 1.8 | 0.9 | 0.6 | 0.5 | 0.1 | 0.3 | | 333.6 |
| Hudnall | D | 0 | 0.6 | 15.5 | 68.5 | 63.1 | 45.1 | 3.6 | 0.1 | 0 | 0.1 | 0.3 | 1.1 | 0.4 | 0.7 | 0.3 | 0.2 | 0.2 | 0.9 | | 200.7 |
| Shell Bar | D | 0 | 1.2 | 28.7 | 131.6 | 76.6 | 82.0 | 8.8 | 0.2 | 0 | 0.7 | 1.3 | 1.1 | 1.0 | 0.8 | 0.3 | 0.5 | 0.3 | 1.6 | | 336.7 |
| Haynie Point | D | 0 | 0.2 | 18.8 | 59.2 | 12.8 | 10.7 | 2.1 | 0.1 | 0 | 0.1 | 0.2 | 0.5 | 0.1 | 0.5 | 0.2 | 0.1 | 0.4 | 0.9 | | 106.9 |
| Whaley's East | D | 0 | 0.1 | 6.4 | 20.8 | 57.0 | 10.5 | 4.0 | 0.1 | 0 | 0.1 | 0.3 | 0.4 | 0.7 | 0.1 | 0 | 0.2 | 0.1 | 0.3 | | 101.1 |
| Fleet Point | D | 0 | 0 | 1.8 | 78.3 | 64.8 | 49.4 | 22.3 | 0.4 | 0 | 0.1 | 0.8 | 0.2 | 0.1 | 0.9 | 2.4 | 1.5 | 0.4 | 0.7 | | 224.1 |

Table S2: Spatfall totals for historical sites (1992-2016) and modern sites (1998-2016) as defined in the text. Values presented as the cumulative sum of spat $shell^{-1}$ values for each year. "+" and "-" indicate the direction of change in 2017 in reference to 2016 and to the five, ten, twenty and twenty-five year means. Blank cells for a site indicate years where data are not available. NC indicates a change of less than 1 spat $shell^{-1}$ in either direction.

| 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 | Mean 12-16 | Mean 07-16 | Mean 97-16 | Mean 92-16 | Ref. 2016 | Ref. 5-yr | Ref. 10-yr | Ref. 20-yr | Ref. 25-yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JAMES | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Deep Water Shoal | 0.7 | 15.7 | 0.6 | 1.7 | 0.5 | 1.3 | 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 | 11.2 | 34.2 | 19.6 | 16.4 | - | - | - | - | - |
| Horsehead | 3.6 | 43.7 | 3.2 | 0.3 | 3.6 | 2.4 | 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 | 46.1 | 59.7 | 32.1 | 27.8 | - | - | - | + | + |
| Point of Shoal | 5.4 | 73.7 | 15.0 | 4.8 | 2.3 | 2.3 | 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 | 29.5 | 52.6 | 28.8 | 27.1 | - | NC | - | + | + |
| Swash | | 46.2 | 4.8 | 1.8 | 2.2 | 1.7 | 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 | 43.5 | 77.7 | 41.7 | 37.1 | - | + | - | + | + |
| Dry Shoal | 14.2 | 119.0 | 25.8 | 2.8 | 11.0 | 1.1 | 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 | 72.6 | 92.0 | 48.6 | 45.8 | + | + | + | + | + |
| Rock Wharf | 11.4 | 34.3 | 10.7 | 0.2 | 2.4 | 5.6 | 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 | 45.8 | 90.8 | 48.6 | 41.2 | + | + | - | + | + |
| Wreck Shoal | 3.3 | 15.5 | 2.2 | 2.6 | 10.0 | 0.7 | 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 | 52.3 | 93.9 | 49.3 | 40.8 | - | + | - | + | + |
| Day's Point | 14.2 | 131.5 | 42.2 | 3.0 | 4.6 | 5.6 | 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 | 65.7 | 97.2 | 50.4 | 48.2 | + | + | + | + | + |
| 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 | 105.9 | 58.8 | | | - | - | - | | |
| Ginney Point | 11.4 | 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 | 93.3 | 59.2 | 30.9 | 25.3 | - | - | - | - | + |
| Palace Bar | 24.9 | 5.0 | 0.8 | 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 | 79.2 | 45.8 | 24.2 | 20.7 | - | - | - | - | - |
| 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 | 300.3 | 158.5 | | | - | - | - | | |
| 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 | 78.5 | 46.6 | | | - | - | - | | |
| 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 | 159.4 | 108.0 | | | + | - | + | | |
| 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 | 166.9 | 92.4 | | | - | - | - | | |
| Burton Point | 11.7 | 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 | 221.1 | 116.3 | 59.7 | 48.6 | - | - | - | - | - |
| GREAT WICOMICO | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Glebe Point | 0.5 | 0.2 | 0.0 | 1.5 | 0.6 | 21.2 | 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 | 755.1 | 462.8 | 255.0 | 204.1 | - | - | + | + | + |
| 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 | 476.0 | 282.7 | | | - | - | - | | |
| 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 | 446.4 | 264.9 | | | - | - | + | | |
| 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 | 437.3 | 278.9 | | | - | - | + | | |
| Hudnall | 0.5 | 0.8 | 0.0 | 0.1 | 0.2 | 39.1 | 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 | 242.7 | 147.0 | 78.4 | 62.7 | - | - | + | + | + |
| 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 | 449.5 | 246.1 | | | - | - | + | | |
| Haynie Point | 0.6 | 1.4 | 0.0 | 1.0 | 3.7 | 4.4 | 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 | 257.5 | 140.5 | 72.4 | 58.2 | - | - | - | + | + |
| Whaley's East | 0.1 | 0.2 | 0.0 | 0.3 | 2.1 | 1.0 | 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 | 212.4 | 111.0 | 56.2 | 45.0 | - | - | - | + | + |
| Fleet Point | 2.9 | 2.0 | 0.0 | 0.3 | 2.6 | 3.4 | 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 | 159.5 | 83.3 | 42.4 | 34.2 | - | + | + | + | + |

Light settlement (0.1 - 1.0 spat/shell)
Moderate settlement (1.01-10.0 spat/shell)
Heavy settlement (10.0-100.0 spat/shell)
Extremely heavy settlement (>100.0 spat/shell)

Figure S1: Map showing the location of the 2017 shellstring 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.

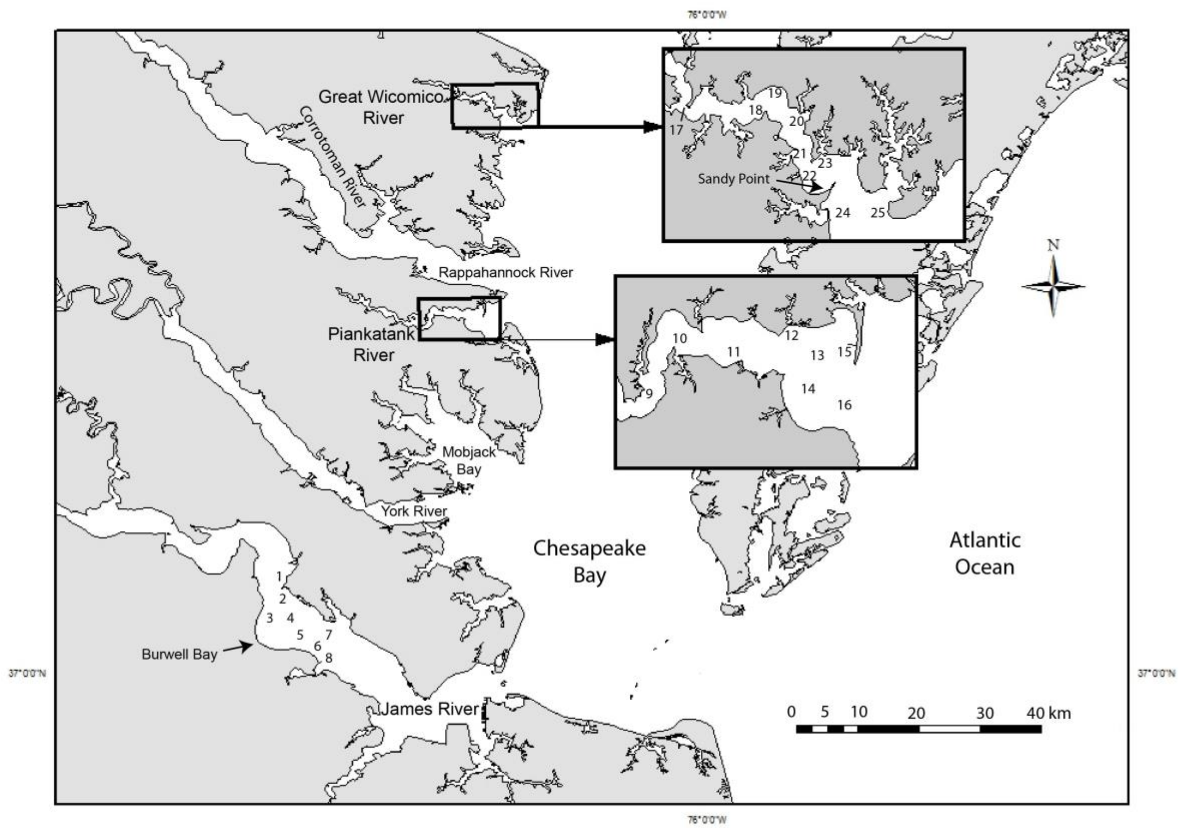


Figure S2: Diagram of shellstring setup on buoys with picture of a shellstring embedded (see http://www.vims.edu/research/units/labgroups/molluscan_ecology/_docs/Shellstring_manual.pdf for more detailed information).

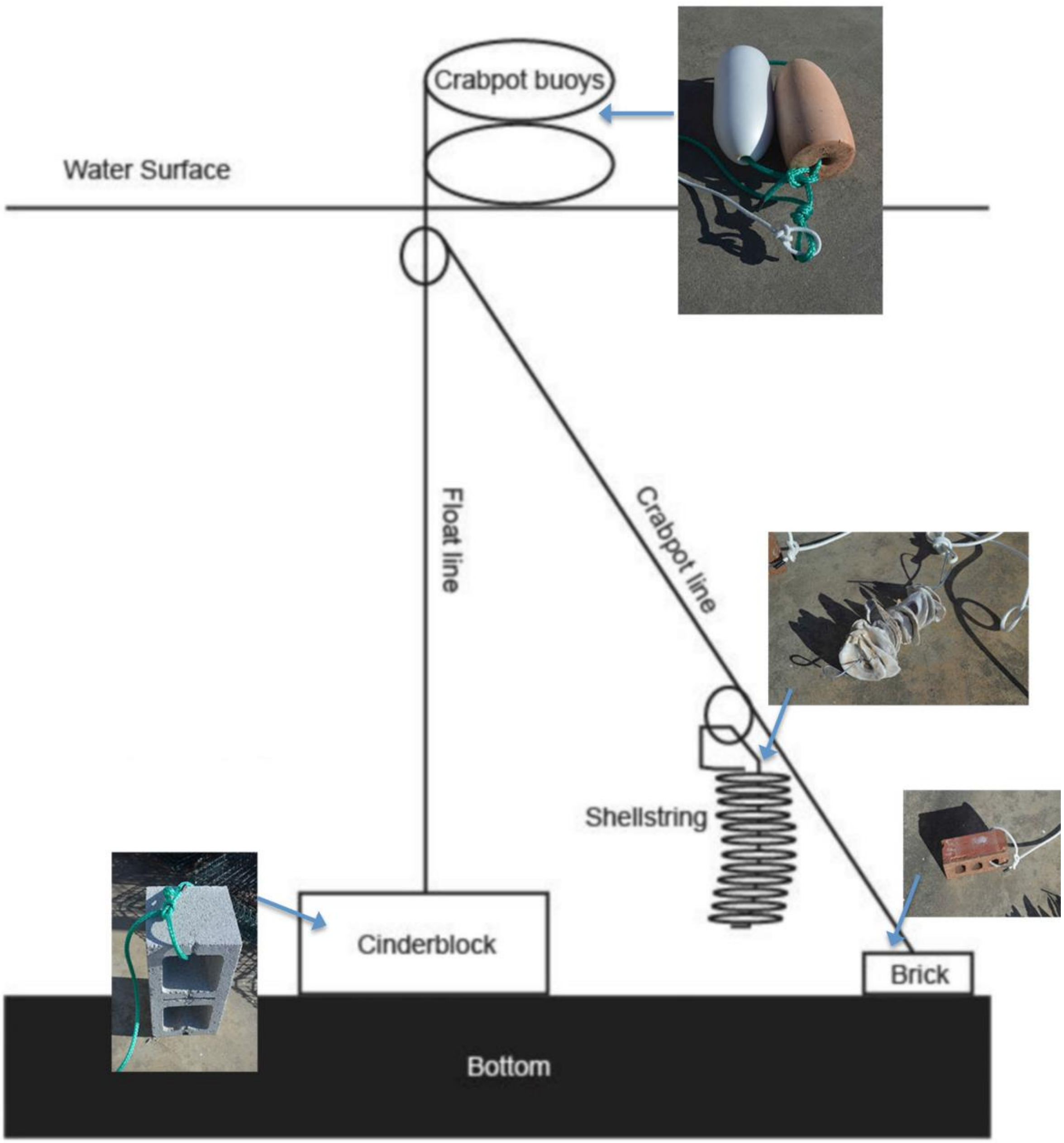


FIGURE S3: JAMES RIVER (2017) WEEKLY RECRUITMENT INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$

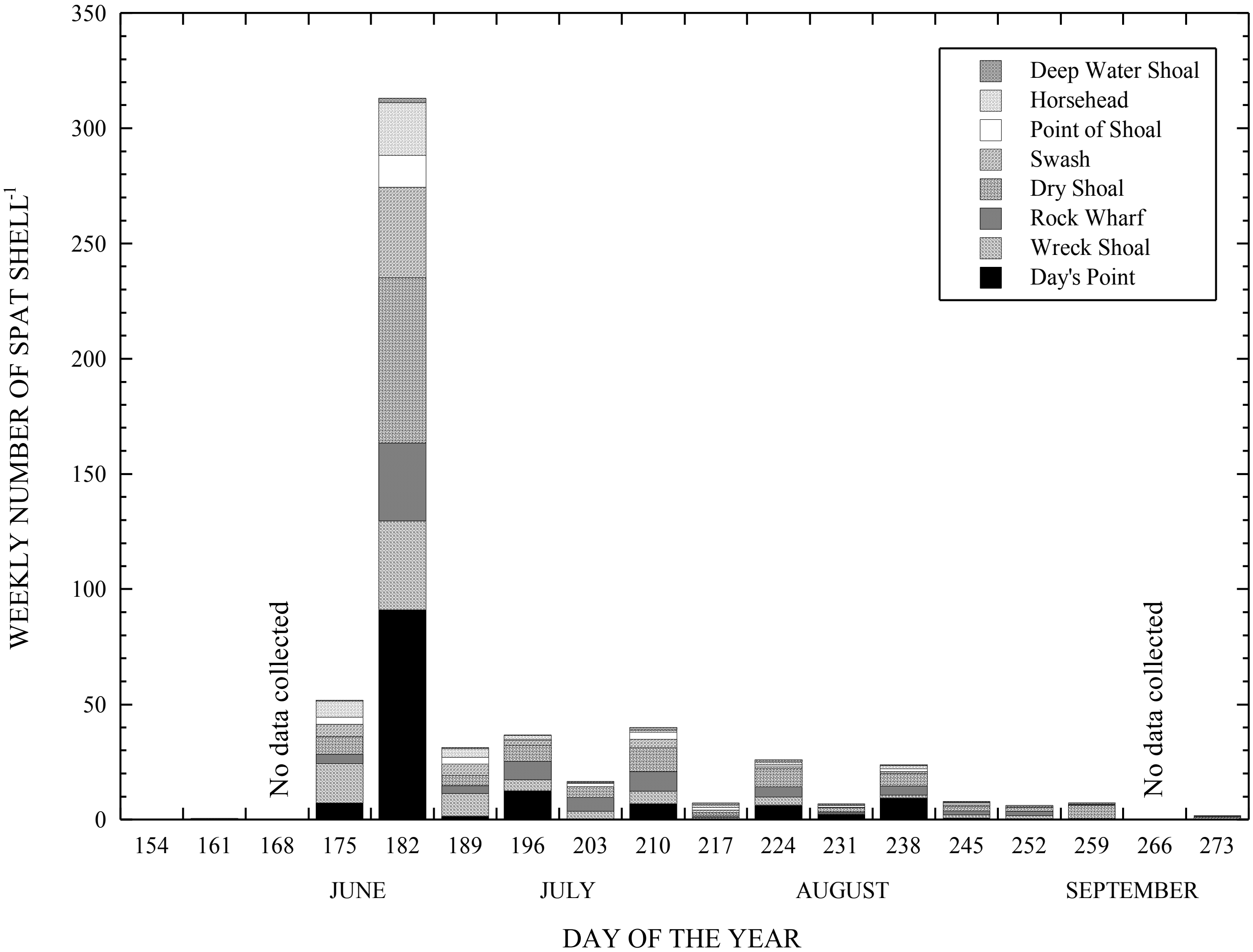


FIGURE S4: RECRUITMENT TRENDS OVER THE PAST 25 YEARS AT ALL EIGHT SITES IN THE JAMES RIVER (upriver sites in panel A; downriver sites in panel B) (expressed as cumulative weekly spatfall)

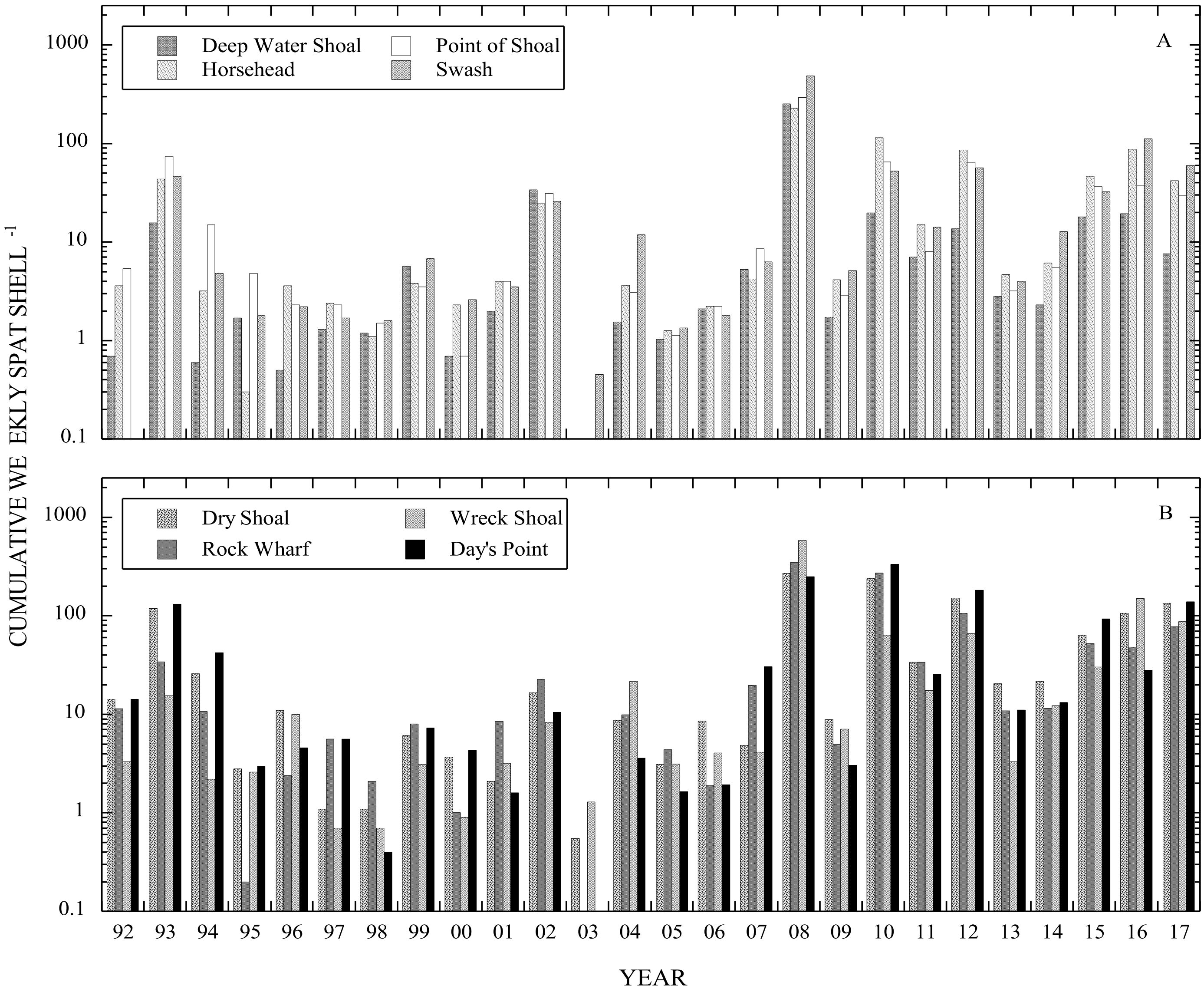


FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE RECRUITMENT PERIOD: 5, 10, 20 AND 30-YEAR MEANS COMPARED WITH 2017

(Error bars represent standard error of the mean; darker shaded area = period of heaviest recruitment; lighter shade area = period of light recruitment; n is the number of data points used to calculate the mean)

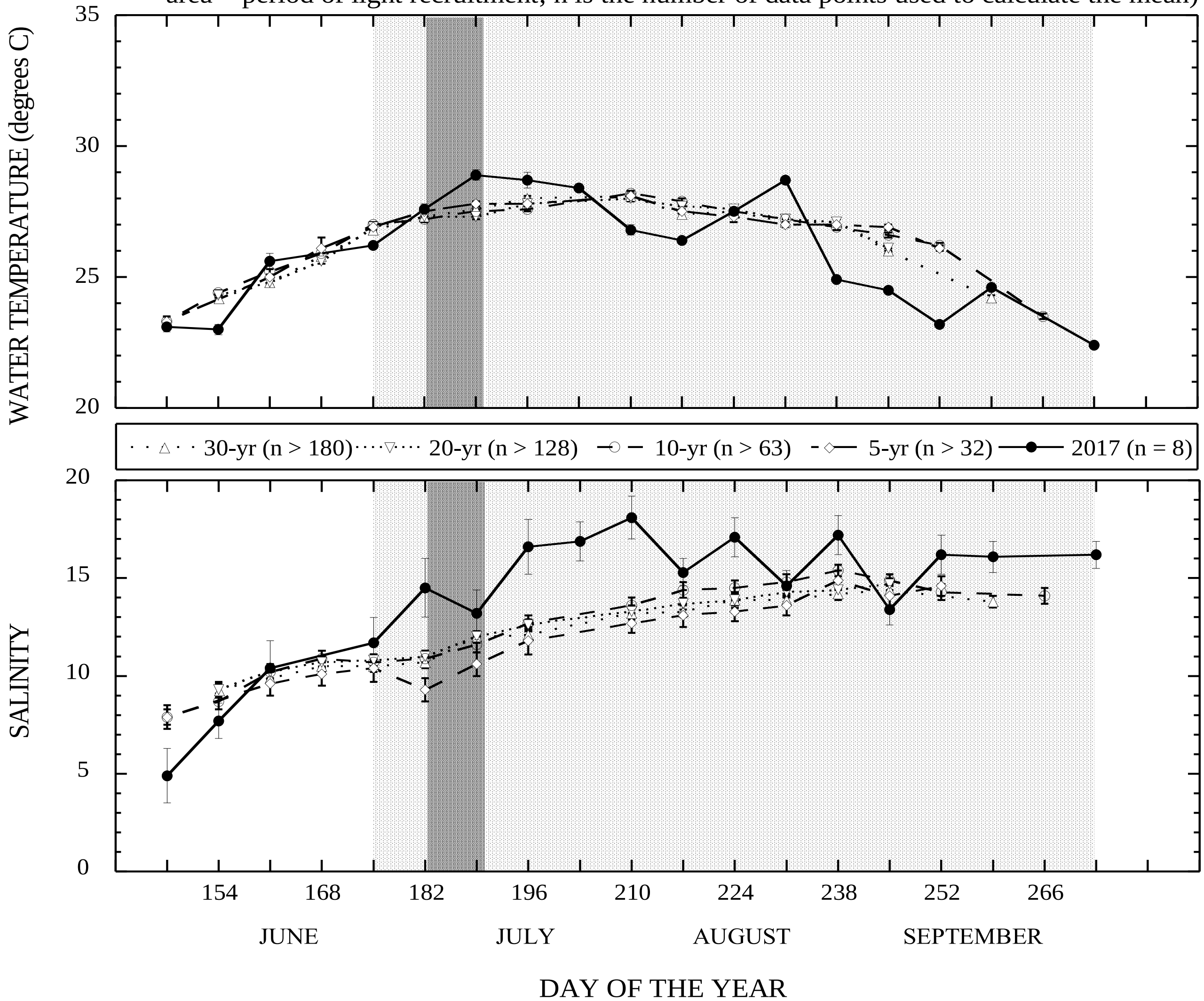


FIGURE S6: PIANKATANK RIVER (2017) WEEKLY RECRUITMENT INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: M = modern station as described in text)

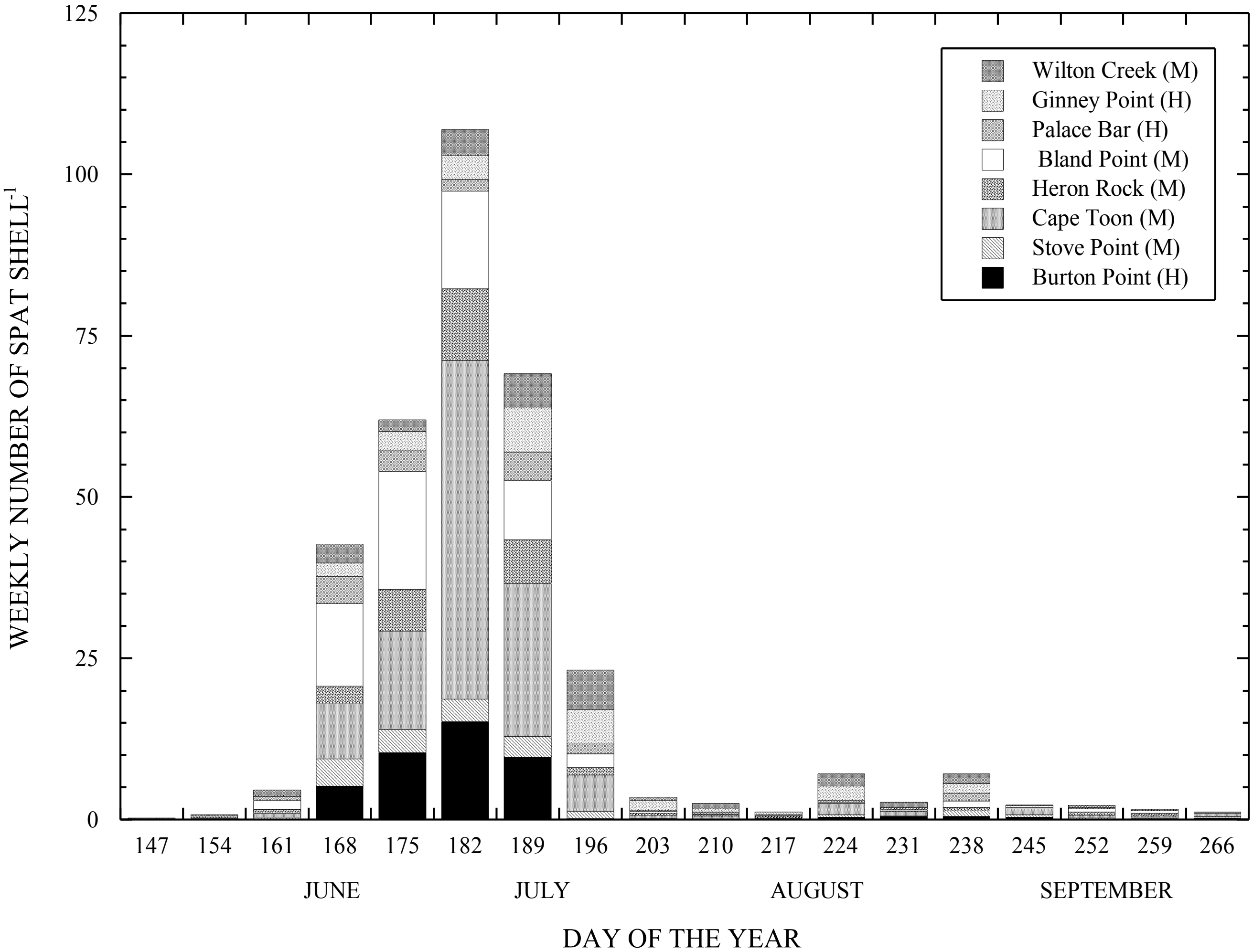


FIGURE S7: RECRUITMENT TRENDS IN THE PIANKATANK RIVER AT THE THREE HISTORICAL SITES (panel A: 25 years) AND THE FIVE MODERN SITES (panel B: 19 years)
(Expressed as cumulative weekly spatfall)

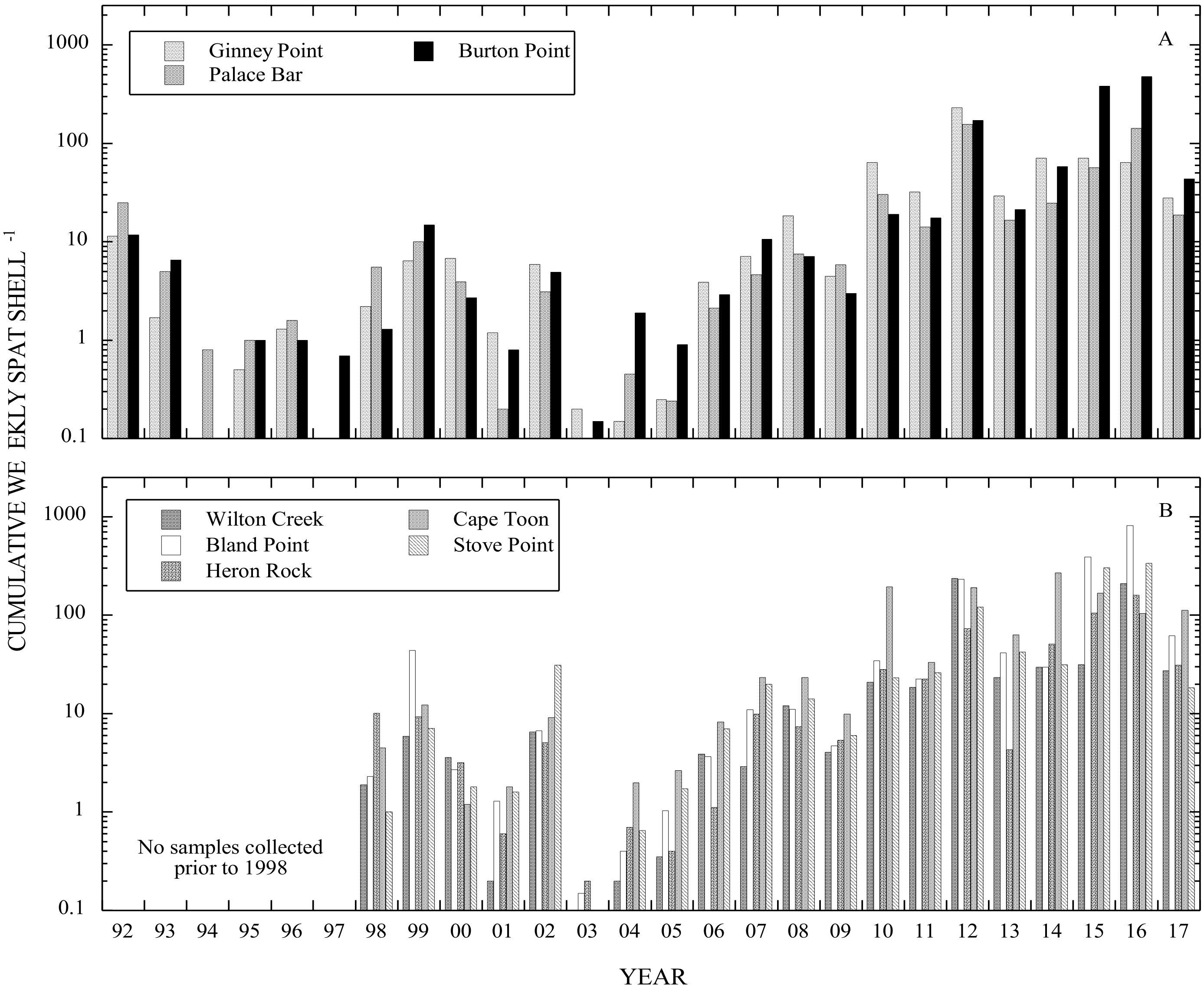


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE RECRUITMENT PERIOD: 5, 10, 20 AND 25-YEAR MEANS COMPARED WITH 2017
(Error bars represent standard error of the mean; darker shaded area = period of heavier recruitment; lighter shade area = period of light recruitment; n is the number of data points used to calculate the mean)

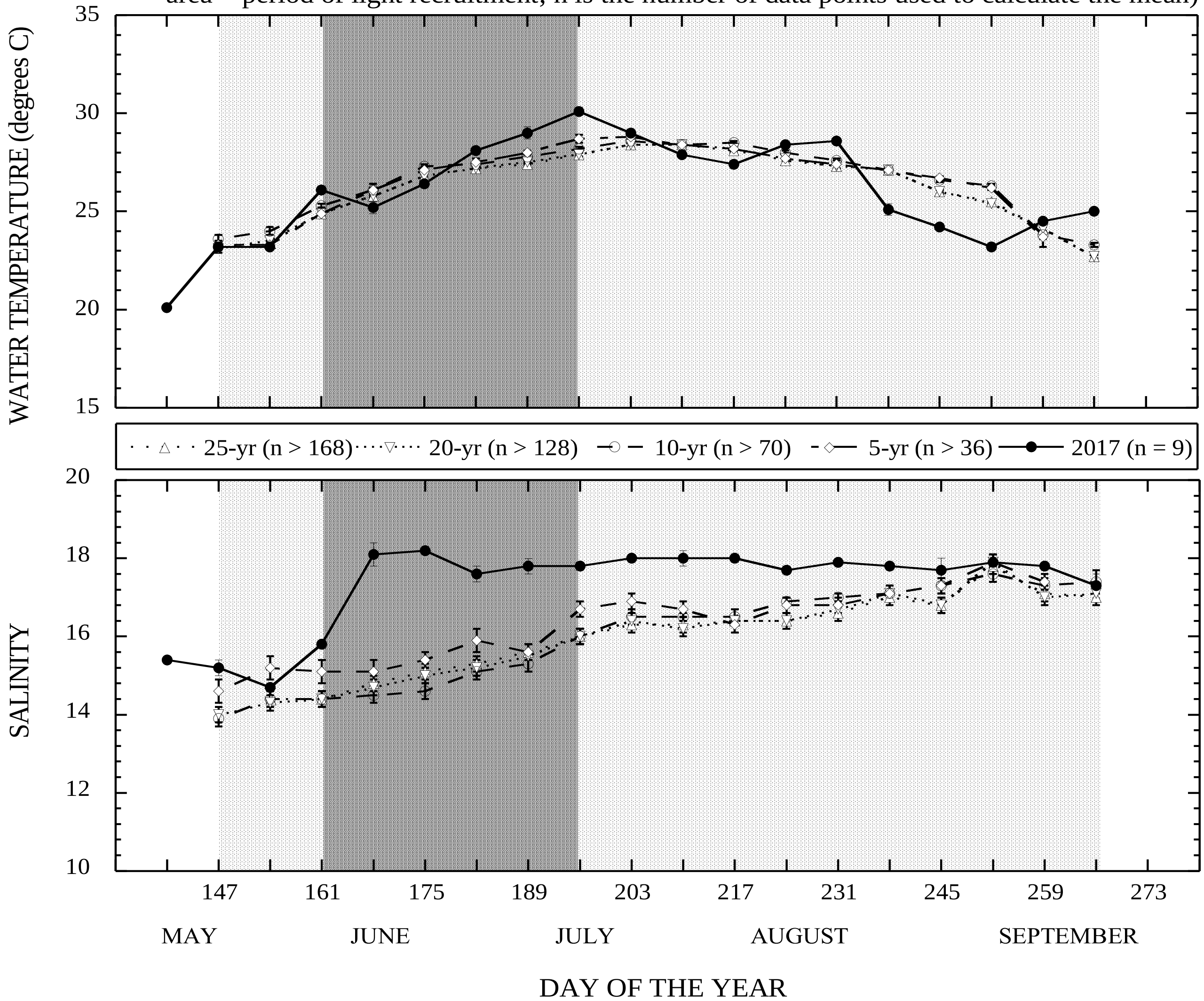


FIGURE S9: GREAT WICOMICO RIVER (2017) WEEKLY RECRUITMENT INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: M = modern station as described in text)

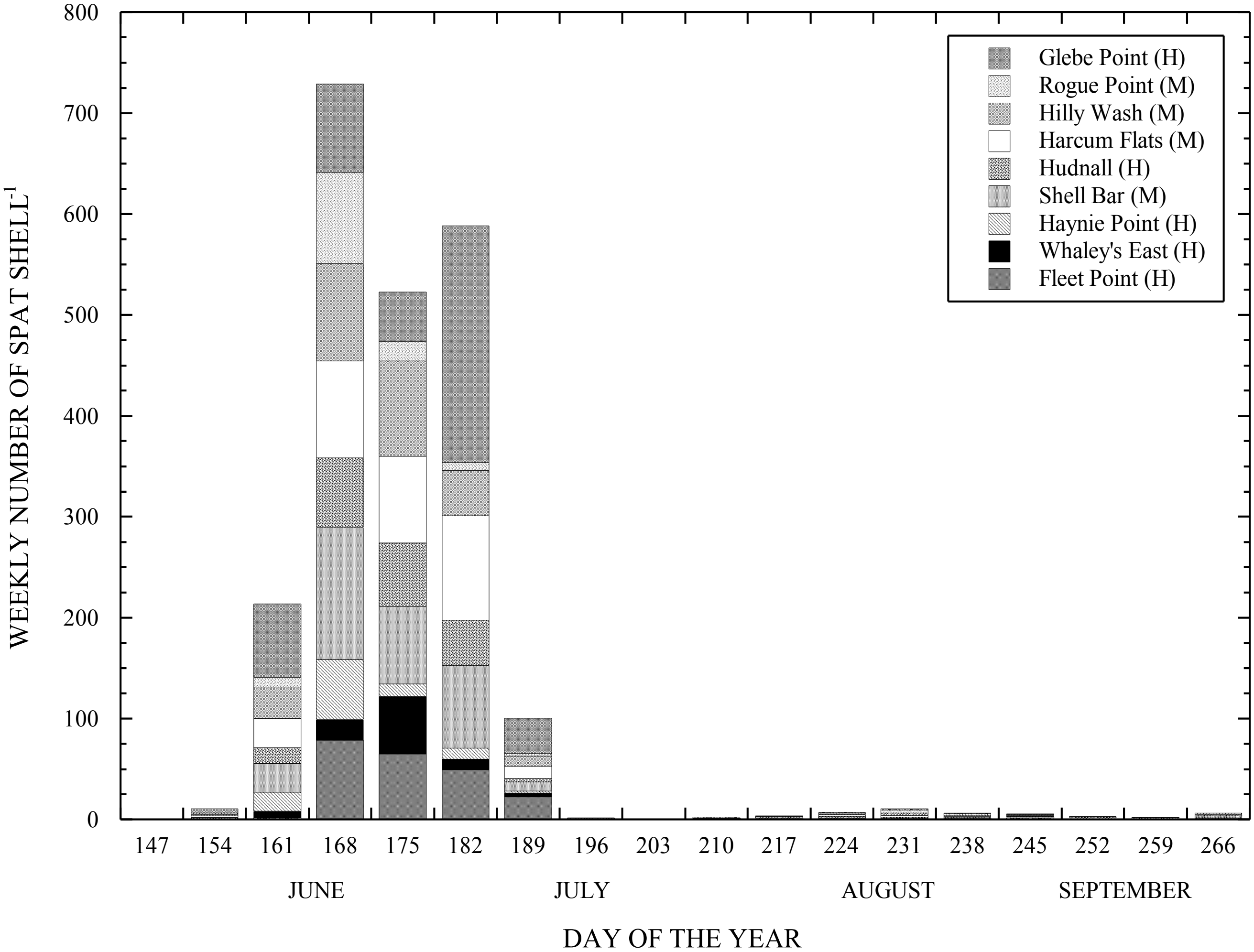


FIGURE S10: RECRUITMENT TRENDS IN THE GREAT WICOMICO RIVER AT THE FIVE HISTORICAL SITES (panel A: 25 years) AND THE FOUR MODERN SITES (panel B: 19 years) (Expressed as cumulative weekly spatfall)

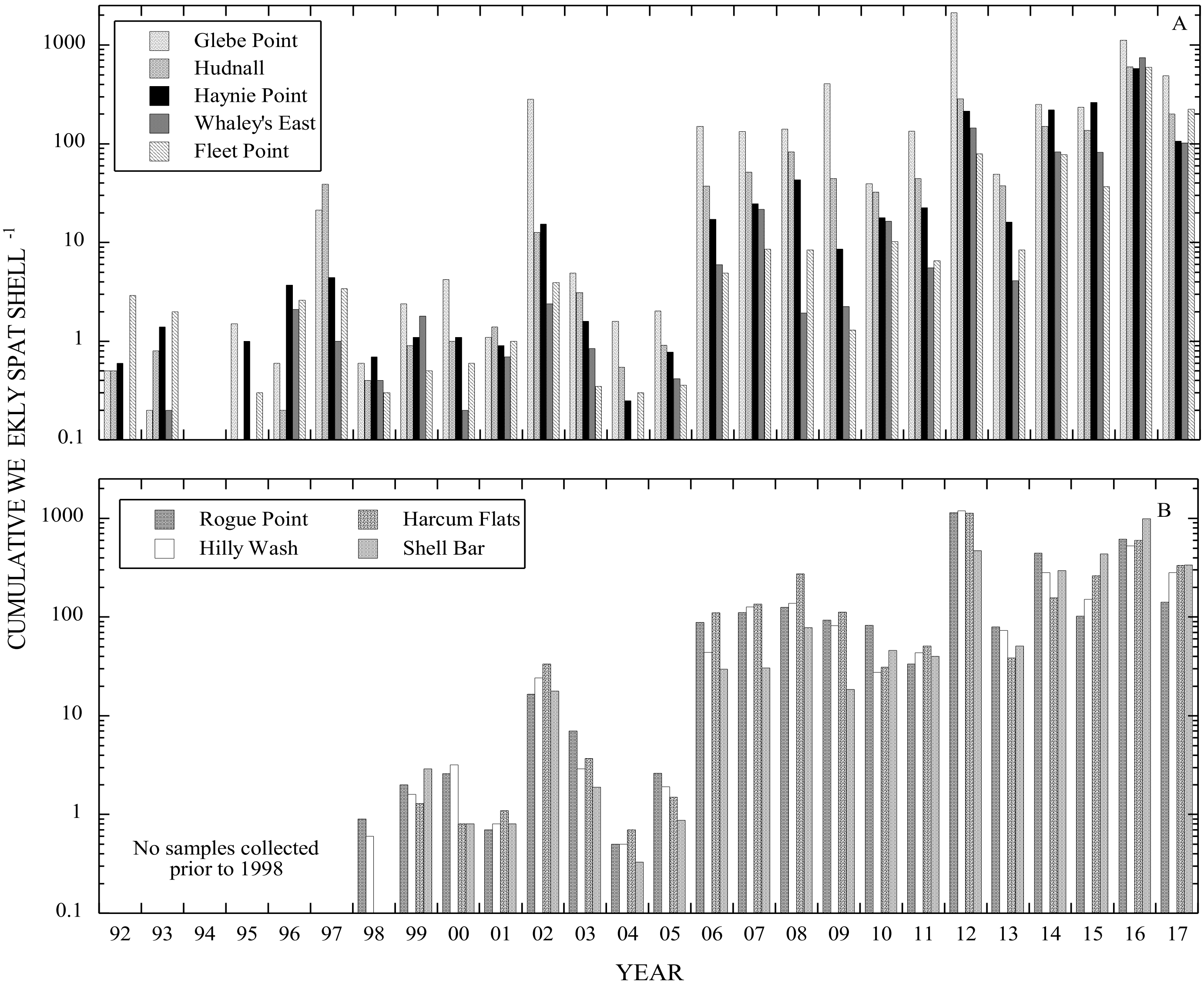
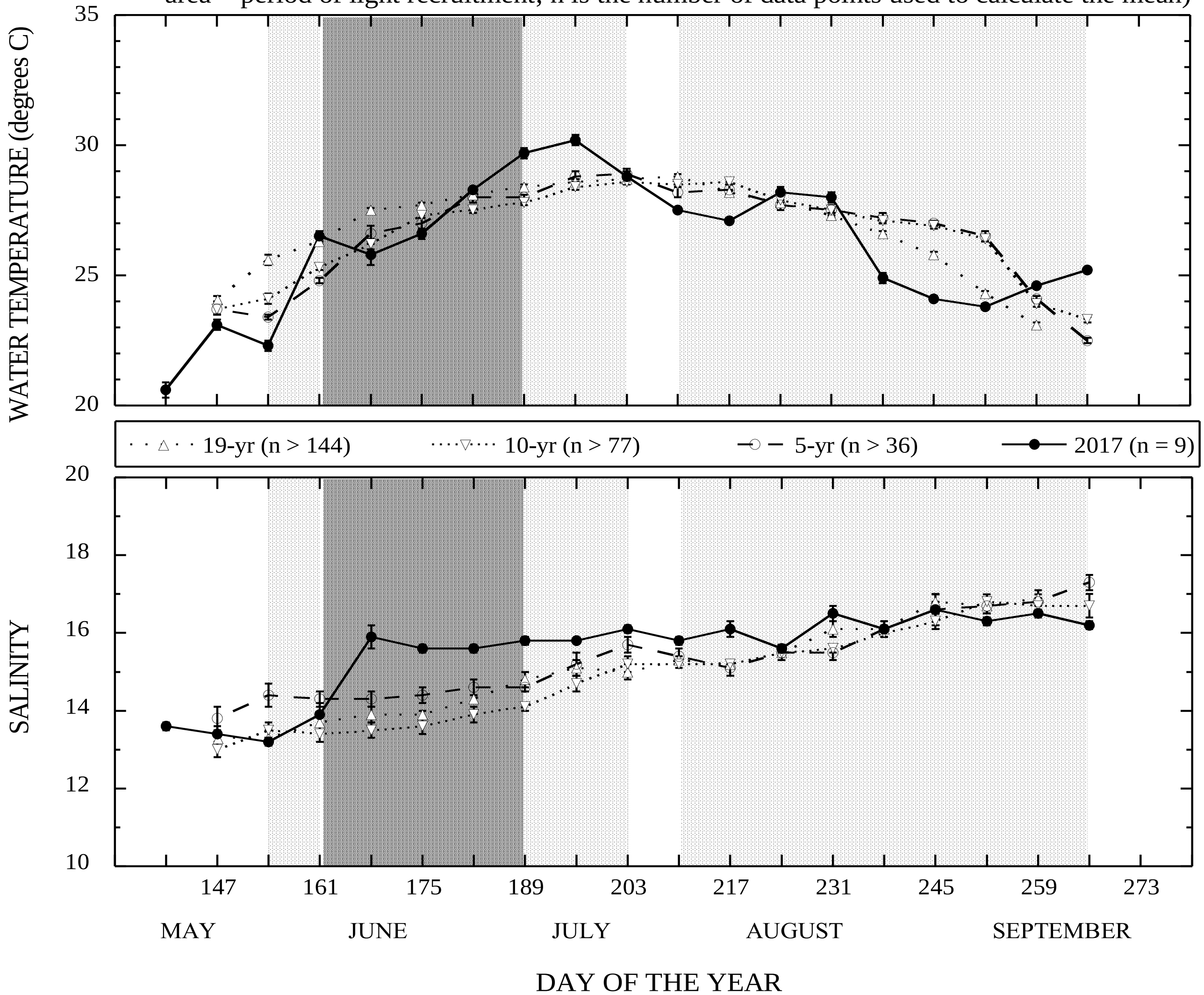


FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE RECRUITMENT PERIOD: 5, 10 AND 19-YEAR MEANS COMPARED WITH 2017

(Error bars represent standard error of the mean; darker shaded area = period of heaviest recruitment; lighter shade area = period of light recruitment; n is the number of data points used to calculate the mean)



## Part II. DREDGE SURVEY OF SELECTED OYSTER BARS IN VIRGINIA DURING 2017

### *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[2]. These areas are presently under management by the Virginia Marine Resources Commission (VMRC).

Every year the Virginia Institute of Marine Science (VIMS) in collaboration with 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 settlement and 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 2017.

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 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.

[2] http://www.vims.edu/research/units/labgroups/molluscan_ecology/restoration/va_restoration_atlas/index.php or https://webapps.mrc.virginia.gov/public/maps/chesapeakebay_map.php

***METHODS***

Locations of the oyster bars sampled during Fall 2017 are shown in Figure D1. Geographic coordinates of the bars are given in Table D1.

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 2017), in surveys in the James, Piankatank, Rappahannock and Great Wicomico Rivers in 1991 to 1994 and in the Great Wicomico River in 2015, sampling was effected 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$^3$). Beginning in 1995, James, Piankatank, Rappahannock, and Great Wicomico River samples (with the exception of 2015 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 derivation did occur such that fewer samples (n = 3) were collected. Due to the large number of oysters observed in the 2017 samples in the upper James River, the number of samples was reduced (n = 3) at the eight most upriver sites (see Figure D1) to facilitate sample processing in a timelier manner.

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 (recently settled, 2017 recruits), new boxes (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 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 29 and October 23, in six of the major Virginia tributaries on the western shore of the Chesapeake Bay. Bar locations are shown in Figure D1 and Table D1. 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 205 bushel$^{-1}$ at Nansemond Ridge to a high of 2,526.1 bushel$^{-1}$ at Mulberry Point. The total number of live oysters was the highest observed over the past twenty-five years of monitoring at Long Shoal and Wreck Shoal, the second highest observed at Mulberry Point and Point of Shoal (96th percentile) and the third highest at Thomas Rock (92nd percentile). When spat are excluded, the total number of small and market oysters combined was the highest (Mulberry Point, Long Shoal and Wreck Shoal) and second highest (Deep Water Shoal, Horsehead, Point of Shoal, Thomas Rock and Nansemond Ridge) observed over the past twenty-five years. The number of oysters at Nansemond Ridge had been at fairly low levels for several years and while the total number of oysters on Nansemond Ridge during 2017 was in 72nd percentile of that observed over the past twenty-five years of monitoring, the number of small and market oysters combined was among the highest (96th percentile) observed since prior to 1992 and has been on the rise over the past two years.

The average number of market oysters in the James River remains low when compared with historical numbers, but in recent years has been on the rise at the more downriver sites in the system. All of the sites monitored had low to moderate numbers of market oysters, ranging from a low of 2.0 bushel$^{-1}$ at Nansemond Ridge to a high of 70.0 bushel$^{-1}$ at Deep Water Shoal. There was a notable increase (Figure D2) in the number of market oysters at Deep Water Shoal when compared with 2016, and a notable decrease at Wreck Shoal and Nansemond Ridge (Figure D3C). 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 D3C). There were around 43 market oysters bushel$^{-1}$ on Wreck Shoal in 2017. For the second year in a row, the number of market oysters at Mulberry Point, Long Shoal and Swash were among the lowest observed (the 4th, 4th and 9th percentile, respectively) since monitoring began at those sites in the early 1990s (Figure D3A and D3B).

The average number of small oysters bushel$^{-1}$ ranged from a low of 65.5 at Nansemond Ridge to a high of 1,902.7 at Mulberry Point. When compared with 2016, there was a notable increase in the number of small oysters at Mulberry Point and Wreck Shoal and a notable decrease at Deep Water Shoal (Figures D2 and D3). The number of small oysters in 2017 was the highest observed over the past twenty-five years of monitoring at Mulberry Point, Long Shoal, Wreck Shoal and Nansemond Ridge (tied with 2016) and the second highest at Deep Water Shoal, Horsehead, Point of Shoal, Swash and Thomas Rock (96th percentile).

Overall, settlement in the James River in 2017 was moderately high, comparable to the past few years (Figure D2 and D3). While there was a notable decrease observed when compared to 2016 at Mulberry Point and Horsehead (Figure D2 and D3), overall settlement at these sites was still relatively high (fourth and seventh highest, respectively) when compared with the past twenty-five years. The average number of spat bushel$^{-1}$ ranged from a low of 137.5 at Nansemond Ridge to a high of 659.3 at Long Shoal. Since 2008, settlement in the James River has had several strong year classes (2008, 2010, 2012 and 2016). Settlement patterns in the James River historically showed a trend of an increasing percentage of small oysters combined with a decreasing percentage of spat as one moved from the most downriver site (Nansemond Ridge) to the most upriver site (Deep Water Shoal). In general, this pattern was again observed in 2017, with an increase in the percentage of small oysters and a decrease in the percentage of spat when moving from downriver to upriver (Figure D1 and D3), although overall greater than 50% of the oysters were small at every site except Nansemond Ridge.

The average number of boxes bushel$^{-1}$ was low to moderate, ranging from 13.0 at Nansemond Ridge to 124.0 at Dry Shoal. Boxes accounted for less than 10% of the total (live oysters plus boxes) at every site except Dry Shoal. At Dry Shoal, 16% of the boxes were new boxes, indicating some recent mortality at that site. At Nansemond Ridge 69% of the boxes were spat boxes, which is not surprising given that 67% of the live oysters were spat.

Water temperature during the two days of sampling ranged between 19.7 and 21.1°C (Table D2). Salinity was variable depending on location in the river, generally increasing in a downriver direction, from 10.7 at Deep Water Shoal to 18.2 at both Thomas Rock and Nansemond Ridge.

**York River**

In the York River, the average total number of live oysters bushel$^{-1}$ was 116.5 at Bell Rock and 211.0 at Aberdeen Rock. When compared with 2016, there was a notable increase in the number of spat observed at both (Figures D4 and D5) sites. Overall the number of oysters at Aberdeen Rock ranked among the highest observed over the past twenty-five years of monitoring, with the second highest number of market oysters (95th percentile) and the fifth highest number of small oysters (82nd percentile; Figure D5). Settlement on Aberdeen Rock was the second highest observed since the early 1990s. In 2014, the number of market oysters on Bell Rock, was at its highest (99 bushel$^{-1}$) observed in twenty-five years, but market oysters have been steadily decreasing over the past few years and there was around 50.5 bushel$^{-1}$ in 2017. For the second year in a row, the average number of boxes bushel$^{-1}$ was moderate (45.0 bushel$^{-1}$) at Bell Rock and low (23.0 bushel$^{-1}$) at Aberdeen Rock, accounting for approximately 28 and 10% of the total oysters (live oysters plus boxes) at Bell Rock and Aberdeen Rock respectively. The majority (>83%) of the boxes at both sites were old. Water temperature on the day of sampling was between 24 and 25°C. The difference in salinity between the two sites was 3.8: 13.5 at Bell Rock and 17.3 at Aberdeen Rock.

**Mobjack Bay**

The average total number of live oysters at Tow Stake and Pultz Bar were 247.0 and 407.0 oysters bushel$^{-1}$ respectively. When compared with 2016, there was a notable increase in the number of market oysters observed at Pultz Bar with 2017 having the highest number of market oysters observed over the past twenty-five years of monitoring. At the same time there was a notably large decrease (1,068.5 bushel$^{-1}$ in 2016 compared with 293.0 bushel$^{-1}$ in 2017) in the number of small oysters at Pultz Bar. Despite this, the number of small and market oysters combined at Pultz Bar in 2017 was the second highest observed since the early 1990s. At Tow Stake, 2016 had the highest number of small oysters observed since the early 1990s, but this did not result in an increase in the number of market oysters in 2017 (Figure D6). The total number of boxes observed in the system was low, accounting for 5 (Pultz Bar) and 8% (Tow Stake) of the total (live oysters plus boxes). At Tow Stake around 14% of the total boxes were spat boxes. One out of the six spat boxes observed at Tow Stake contained a drill hole. The presence of a drill hole is 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. On the day of sampling, water temperature was 23.7°C and salinity was around 18 (Table D2) at both sites.

**Piankatank River**

In the Piankatank River, the average total number of live oysters bushel$^{-1}$ ranged from a low of 537.0 at Ginney Point to a high of 611.5 at Palace Bar. When compared with 2016, there was a notable decrease in the number of small oysters at Ginney Point and in the number of market oysters at Palace Bar (Figures D7 and D8). Since reaching a twenty-five year high in 2014/2015, the number of market oysters at Burton Point has been in decline for the past several years (Figure D8). The number of market oysters at Ginney Point has remained relatively high and stable (between 72 and 99 bushel$^{-1}$) for the past five years. The number of market oysters throughout the river increased in 2008 and has remained at higher levels since. From 1992 to 2007, the average over the three sites ranged from less than 1 to 13 market oysters bushel$^{-1}$, whereas from 2008 to 2017 there were between 22 and 83 market oysters bushel$^{-1}$ (Figure D8). The average over the three sites in the Piankatank River in 2017 was 50 market oysters bushel$^{-1}$, a slight decrease from 2016. The number of boxes observed was low, accounting for 4 (Palace Bar) to 8% (Burton Point) of the total (live oysters plus boxes). The majority (>84%) of boxes at all three sites were old. On the day of sampling, water temperature was around 24ºC at all three sites and salinity was between 15.2 (Ginney Point) and 16.9 (Burton Point).

**Rappahannock River**

In the Rappahannock River, the average total number of live oysters bushel$^{-1}$ ranged from a low of 73.0 at Long Rock to a high of 539.5 at Broad Creek. 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. This pattern again held true during 2017, although it should be noted that the oyster population at Ross Rock, the most upriver site, has generally been higher for the past nine years, compared to the previous sixteen. From 1993 to 2008, the average total number of oysters at Ross Rock ranged between 31 and 94 bushel$^{-1}$, whereas from 2009 to 2017, the average ranged between 102 and 187 bushel$^{-1}$. 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 similar to those observed prior to the decrease in 2011.

The average number of market oysters bushel$^{-1}$ ranged from a low of 26.0 at Drumming Ground to a high of 121.5 at Ross Rock. When compared with 2016, there was a notable increase in the number of market oysters at Morattico Bar and Broad Creek and a decrease observed at Long Rock and Drumming Ground (Figure D9 and D10). Market oysters at Drumming Ground have been decreasing for the past two years, since reaching a twenty-five year high in 2015. However, overall the number of market oysters in the Rappahannock River in recent years (since 2008) has been on the rise and 2017 ranked among the highest to fourth highest over the past twenty-five years at seven out of the ten sites monitored. 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 2017 the average over all ten sites ranged between 21 (2008) and 70 (2016) market oysters bushel$^{-1}$ (Figure D10). The average over all ten sites in 2017 was 64.2 market oysters bushel$^{-1}$. At the four most upriver sites (Ross Rock, Bowler's Rock, Long Rock and Morattico Bar) market oysters accounted for greater than 58% of the live oysters observed.

Broad Creek had the highest number of small oysters, with 363.0 bushel$^{-1}$ (Figure D9 and D10). This was the highest number observed at Broad Creek over the past twenty-five years of monitoring. When compared with 2016, there was a notable decrease in the number of small oysters observed at Bowler's Rock and Hog House (Figure D9 and D10). Despite the decrease in small oysters at Hog House, 2017 had the second highest number of small oysters at that site since the early 1990s. The number of small oysters at Morattico Bar continues to be low with 2017 having among the lowest observed at that site since prior to 1992 (Figure D10A).

Overall, settlement in the Rappahannock River in 2016 was moderate, ranging from 4.5 spat bushel$^{-1}$ at Ross Rock to 121.0 spat bushel$^{-1}$ at Broad Creek. There was at least one spat found at all ten of the sites monitored. When compared to 2016, there was a notable increase in the number of spat observed at the seven most upriver sites (Ross Rock, Bowler's Rock, Long Rock, Morattico Bar, Smokey Point, Hog House and Middle Ground) and a notable decrease at Broad Creek (Figure D9). Settlement at Bowler's Rock, Long Rock, Morattico Bar and Smokey Point was the highest observed since prior to 1992 (Figures D10A and D10B).

The average total number of boxes bushel$^{-1}$ was low to moderate, accounting for 3 (Ross Rock) to 19% (Hog House) of the total (live oysters plus dead). Greater than 20% of the total boxes at Bowler's Rock and Broad Creek were new boxes, indicating some recent mortality at those sites. At the other eight sites, greater than 80% of the total boxes were old. There were no boxes with drill holes, indicative of predation by one of the two native oyster drills, *Eupleura caudata* and *Urosalpinx cinerea*, observed at any of the sites.

Water temperature on the two days of sampling ranged from 22.0 to 24.6°C. Salinity generally increased as one moved from the most upriver site (Ross Rock: 10.2) toward the mouth (Broad Creek: 15.3).

**Great Wicomico River**

In the Great Wicomico River, the average total number of live oysters bushel$^{-1}$ ranged from a low of 337.0 at Fleet Point to a high of 850.5 at Whaley's East. When compared with 2016, there was a notable decrease in the number of market oysters observed at Haynie Point and a notable increase in the number of small oysters at Haynie Point and Whaley's East (Figure D11 and D12). The number of small oysters ranked the highest observed at Whaley's East, the second highest at Haynie Point and the third highest at Fleet Point since prior to the early 1990s. There was a fairly large decrease in the number of spat observed at all three sites, with settlement overall (average over all three sites) being in the 70th percentile of spatfall over the past twenty-five years. The total number of boxes bushel$^{-1}$ was low to moderate accounting for 5 (Whaley's East) to 12% (Fleet Point) of the total (live oysters plus boxes). The majority (>72%) of the boxes at all three sites were old. Water temperature on the day of sampling ranged between 20.7 (Whaley's East) and 22.0°C (Haynie Point) and salinity was around 14 at all three sites.

## *DISCUSSION*

The abundance of market oysters throughout the Chesapeake Bay region has been in serious decline since the beginning of the 20$^{th}$ century (Hargis & Haven 1995, Rothschild et al. 1994). For the past several decades, the greatest concentration of market oysters on Virginia public 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 46.7 market oysters bushel$^{-1}$). From 2007 to 2015, the number of market oysters on the thirty bars that are sampled annually slowly increased, going from an average of 16.5 bushel$^{-1}$ in 2007 to an average of 60.9 bushel$^{-1}$ in 2015, a little over a 3-fold increase over the nine-year period. However, over the past two years, the overall number of market oysters on the thirty bars has been slowly declining.

For the past several decades, the bulk of Virginia's oyster population has been composed primarily of small oysters and spat. During 2017, the largest majority of oysters were small accounting for approximately 66% of the population with approximately 28% spat and 6% market oysters. At nineteen of the thirty sites monitored, small oysters accounted for greater than 50% of the live oysters present, with spat dominating at six out of the thirty sites. The four most upriver sites in the Rappahannock River (Ross Rock, Bowler's Rock, Long Rock and Morattico) were the only sites with greater than 50% market oysters. 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 has remained at higher levels for the past several years. Since 2013, the average number of small and market oysters combined over the three sites monitored has consistently remained above 300 bushel$^{-1}$.

Settlement during 2017 varied widely throughout the Virginia portion of the bay, with less than 20 spat bushel$^{-1}$ at three out of the thirty sites and greater than 100 spat bushel$^{-1}$ at eighteen out of the thirty sites. In the Rappahannock River, settlement tends to be highest at the more downriver sites (see Figure D1), with often no settlement at the upriver sites. In 2017, the highest settlement was again observed at the more downriver sites, but four of the more upriver sites

(Bowler's Rock, Long Rock, Morattico Bar and Smokey Point) had the highest settlement observed at those sites over the past twenty-five years of monitoring.

The average total number of boxes observed during 2017, was low to moderate at most sites, accounting for less than 13% of the total (live oysters plus boxes) oysters at every site except Bell Rock, Hog House, Middle Ground and Parrot Rock and less than 10% of the total (live oysters plus boxes) at twenty-two of the sites. 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 2017 Bell Rock (for the second year in a row) and Hog House both has a relatively large number of small and market size boxes (approximately 32 and 23% of the total, live small and market oysters plus new and old boxes, respectively). At the majority of the other sites (seventeen of twenty-eight), less than 10% of the total (live small and market oysters plus new and old boxes) small and market oysters were boxes.

In general, drill holes have become more prevalent in spat boxes since the early 2000s. During 2017, there were drill holes present in spat boxes at Tow Stake 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) up until the occurrence of Hurricane Agnes (1972) which wiped them out in 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 during recent years in the lower James River, in the lower York River, in the mouths of the Piankatank and Rappahannock Rivers, and in Mobjack Bay. While the observed number of spat boxes that contained a drill hole in the 2017 dredge samples was relatively low compared to more recent years, it should be noted that drill holes as well as live animals of both drill species were observed at multiple sites in the James, York, Piankatank and Rappahannock Rivers and in Mobjack Bay during the patent tong survey in October and November of 2017 (Southworth, personal observation), so the predation of spat by oyster drills in these systems remains a concern.

Table D1: Station locations for the 2017 VIMS 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 06.400 | 76 38.033 |
| 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 03.683 | 76 36.233 |
| Wreck Shoal | 37 03.617 | 76 34.333 |
| Thomas Rock | 37 01.766 | 76 29.597 |
| Nansemond Ridge | 36 55.333 | 76 27.167 |
| 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 49.600 | 76 44.117 |
| Long Rock | 37 48.810 | 76 42.504 |
| Morattico Bar | 37 46.917 | 76 39.550 |
| 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 2017. 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 subestuary 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 | 10/23 | 21.1 | 10.7 | 70.0 | 1073.3 | 363.3 | 1506.6 | 20.0 | 57.3 | 11.3 | 88.6 |
| Mulberry Point | 10/23 | 20.9 | 12.0 | 4.7 | 1920.7 | 600.7 | 2526.1 | 20.7 | 86.7 | 10.7 | 118.1 |
| Horsehead | 10/23 | 20.9 | 11.8 | 41.3 | 1546.7 | 499.3 | 2087.3 | 32.7 | 82.0 | 18.7 | 133.4 |
| Point of Shoal | 10/23 | 20.9 | 11.9 | 50.7 | 1401.3 | 380.7 | 1832.7 | 21.3 | 39.3 | 3.3 | 63.9 |
| Swash | 10/23 | 21.0 | 13.8 | 8.7 | 1273.3 | 510.0 | 1792.0 | 24.0 | 77.3 | 4.7 | 106.0 |
| Long Shoal | 10/23 | 20.5 | 12.6 | 10.0 | 1792.7 | 659.3 | 2462.0 | 26.7 | 88.7 | 2.0 | 117.4 |
| Dry Shoal | 10/23 | 20.6 | 13.4 | 44.0 | 600.7 | 387.3 | 1032.0 | 24.7 | 97.3 | 2.0 | 124.0 |
| Wreck Shoal | 10/23 | 20.7 | 15.1 | 42.7 | 680.0 | 478.0 | 1200.7 | 14.0 | 66.0 | 4.7 | 84.7 |
| Thomas Rock | 10/18 | 20.5 | 18.2 | 52.5 | 283.5 | 223.5 | 559.5 | 11.0 | 38.5 | 2.5 | 52.0 |
| Nansemond Ridge | 10/18 | 19.7 | 18.2 | 2.0 | 65.5 | 137.5 | 205.0 | 1.0 | 3.0 | 9.0 | 13.0 |
| York River | | | | | | | | | | | |
| Bell Rock * | 10/10 | 23.9 | 13.5 | 50.5 | 47.5 | 18.5 | 116.5 | 1.0 | 44.0 | 0.0 | 45.0 |
| Aberdeen Rock | 10/10 | 24.8 | 17.3 | 29.0 | 72.5 | 109.5 | 211.0 | 3.0 | 19.0 | 1.0 | 23.0 |
| Mobjack Bay | | | | | | | | | | | |
| Tow Stake | 10/10 | 23.7 | 18.1 | 21.5 | 149.5 | 76.0 | 247.0 | 2.0 | 16.0 | 3.0 | 21.0 |
| Pultz Bar | 10/10 | 23.7 | 17.8 | 91.0 | 293.0 | 23.0 | 407.0 | 3.5 | 18.0 | 1.0 | 22.5 |
| Piankatank River | | | | | | | | | | | |
| Ginney Point | 10/12 | 23.8 | 15.2 | 86.5 | 297.5 | 153.0 | 537.0 | 3.5 | 36.0 | 3.5 | 43.0 |
| Palace Bar | 10/12 | 23.8 | 15.9 | 12.5 | 187.5 | 411.5 | 611.5 | 2.5 | 19.0 | 1.0 | 22.5 |
| Burton Point | 10/12 | 23.7 | 16.9 | 52.0 | 372.0 | 122.5 | 546.5 | 4.5 | 39.0 | 1.0 | 44.5 |
| Rappahannock River | | | | | | | | | | | |
| Ross Rock | 10/4 | 22.1 | 10.2 | 121.5 | 61.0 | 4.5 | 187.0 | 1.0 | 4.5 | 0.0 | 5.5 |
| Bowler's Rock | 10/4 | 22.0 | 12.0 | 79.0 | 29.0 | 9.0 | 117.0 | 3.5 | 7.0 | 0.0 | 10.5 |
| Long Rock | 10/4 | 22.0 | 12.7 | 43.5 | 9.5 | 20.0 | 73.0 | 0.5 | 6.0 | 0.5 | 7.0 |
| Morattico Bar | 10/4 | 22.4 | 13.6 | 67.0 | 19.0 | 30.5 | 116.5 | 0.5 | 4.5 | 0.5 | 5.5 |
| Smokey Point | 10/4 | 22.6 | 14.4 | 94.0 | 71.0 | 72.0 | 237.0 | 3.0 | 25.5 | 0.0 | 28.5 |
| Hog House | 10/4 | 22.9 | 14.7 | 60.0 | 44.0 | 45.5 | 149.5 | 3.5 | 28.0 | 2.5 | 34.0 |
| Middle Ground # | 10/4 | 22.8 | 14.2 | 49.0 | 150.0 | 78.5 | 277.5 | 5.5 | 35.5 | 3.0 | 44.0 |
| Drumming Ground | 10/4 | 22.7 | 15.0 | 26.0 | 231.0 | 118.5 | 375.5 | 5.5 | 27.5 | 1.0 | 34.0 |
| Parrot Rock | 10/4 | 22.3 | 15.1 | 46.5 | 97.0 | 79.5 | 223.0 | 1.5 | 29.5 | 6.0 | 37.0 |
| Broad Creek | 9/26 | 24.6 | 15.3 | 55.5 | 363.0 | 121.0 | 539.5 | 13.5 | 50.0 | 3.0 | 66.5 |
| Great Wicomico River | | | | | | | | | | | |
| Haynie Point | 10/3 | 22.0 | 14.2 | 26.5 | 462.5 | 133.0 | 622.0 | 7.0 | 46.0 | 7.5 | 60.5 |
| Whaley's East | 10/3 | 20.7 | 13.9 | 27.0 | 627.5 | 196.0 | 850.5 | 3.0 | 32.0 | 5.0 | 40.0 |
| Fleet Point | 10/3 | 21.3 | 14.1 | 35.5 | 203.5 | 98.0 | 337.0 | 7.0 | 32.0 | 5.5 | 44.5 |

Figure D1: Map showing the location of the oyster bars sampled during the 2017 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.

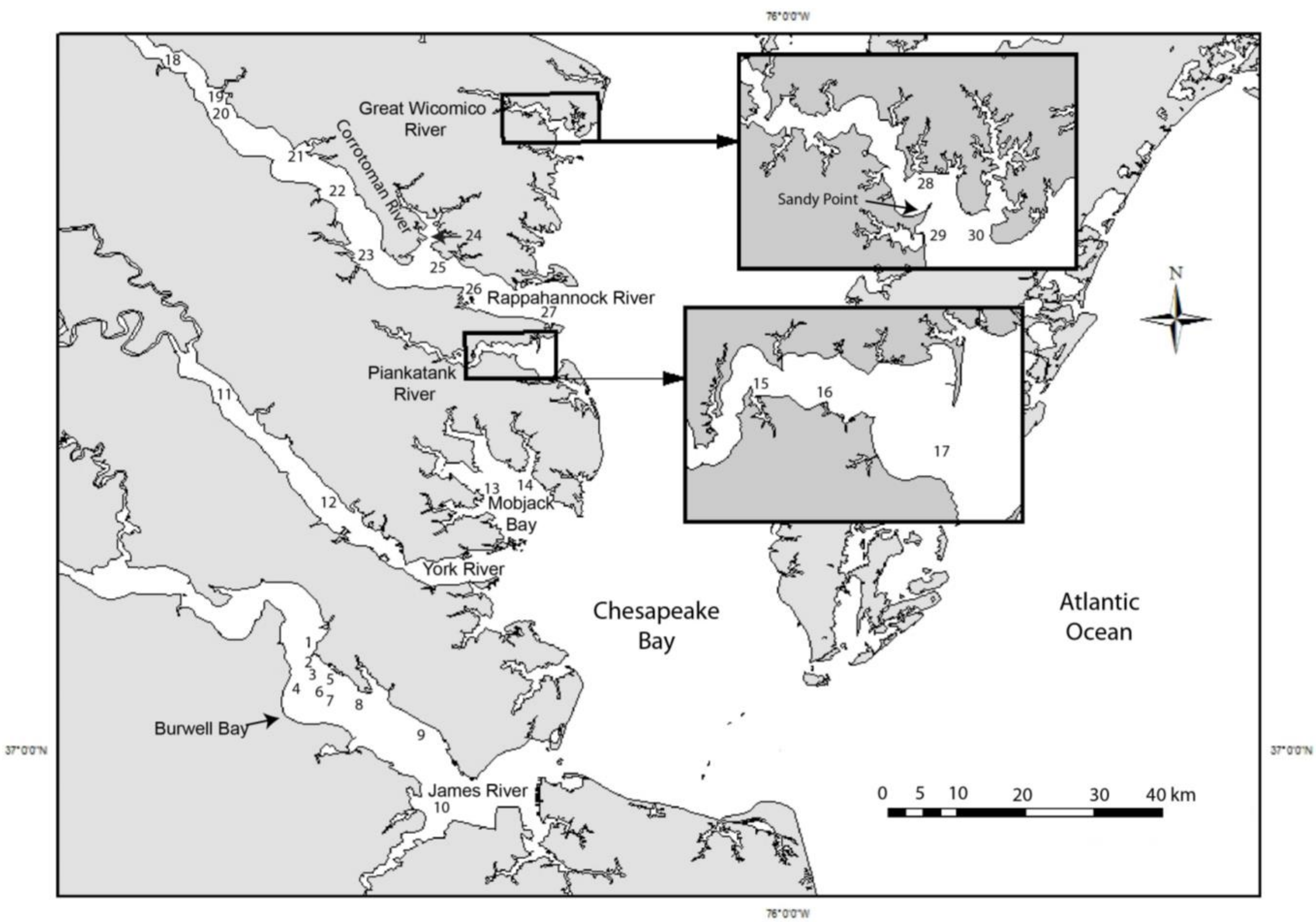


FIGURE D2: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE JAMES RIVER (2016-2017)
(Error bars represent standard error of the mean)

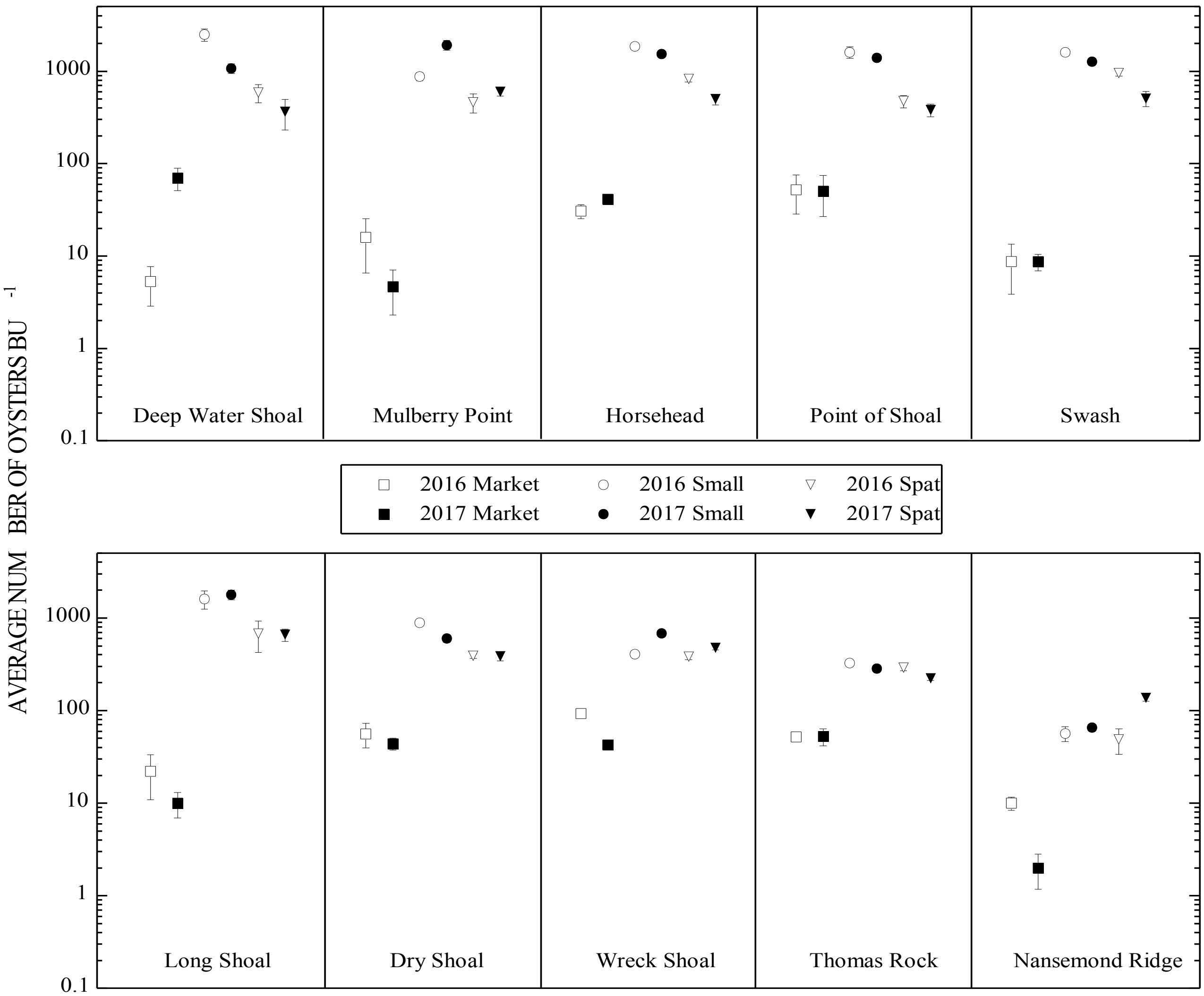
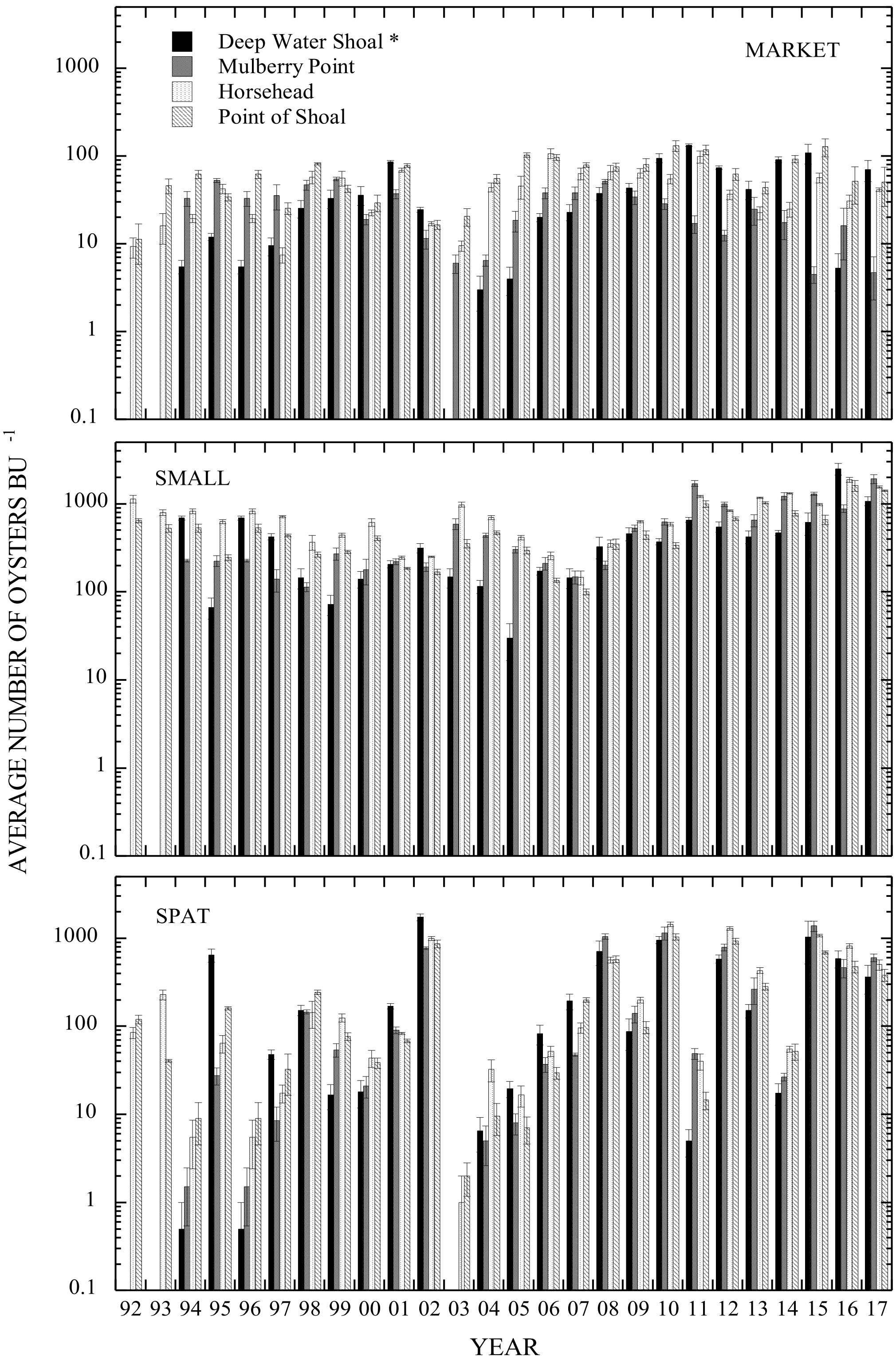
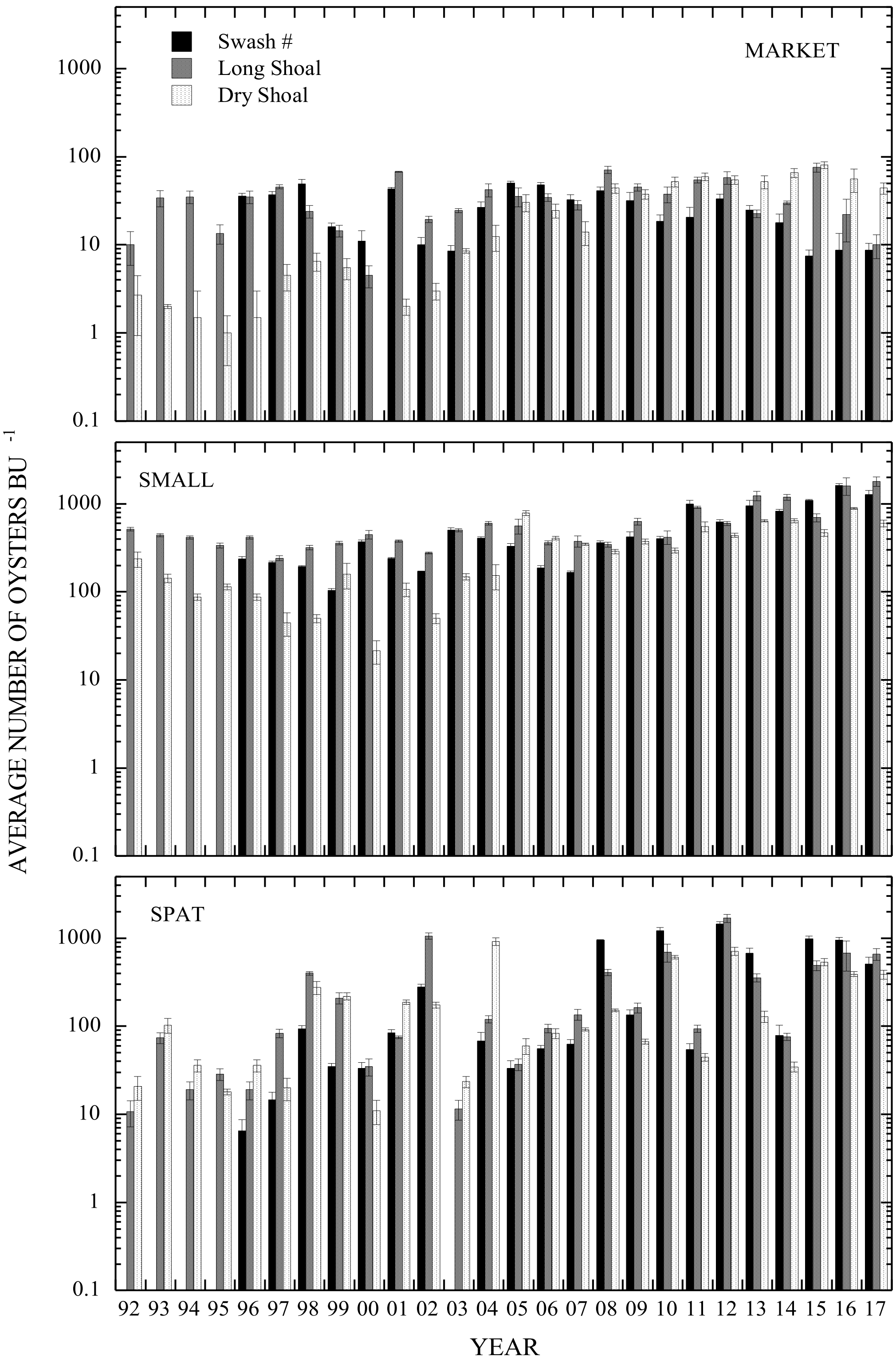


FIGURE D3A: JAMES RIVER OYSTER TRENDS
OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)




* No data prior to 1994

FIGURE D3B: JAMES RIVER OYSTER TRENDS
OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)




# No samples collected prior to 1996

FIGURE D3C: JAMES RIVER OYSTER TRENDS
OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)

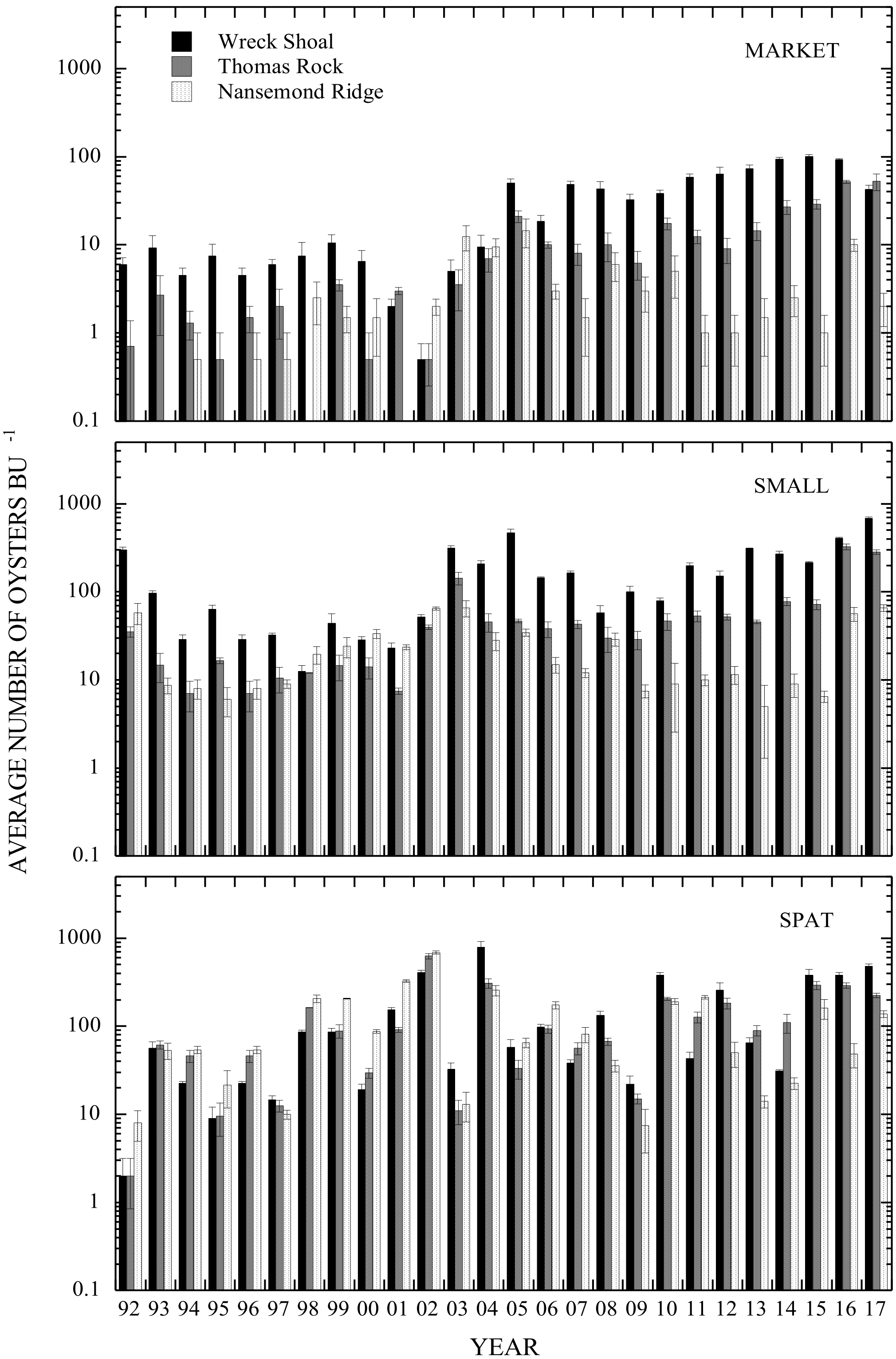


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE YORK RIVER AND MOBJACK BAY (2016-2017)
(Error bars represent standard error of the mean)

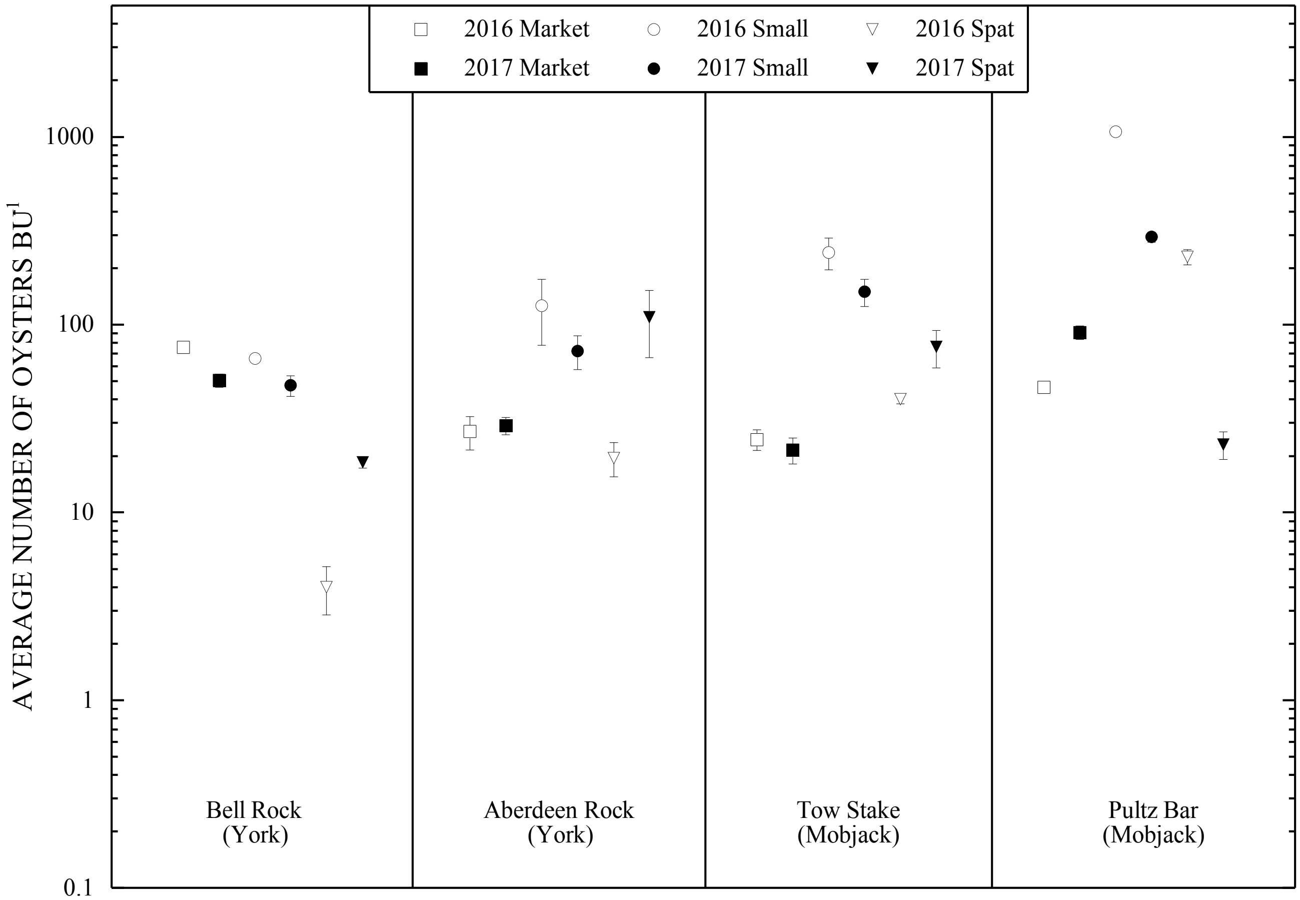


FIGURE D5: YORK RIVER OYSTER TRENDS OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)

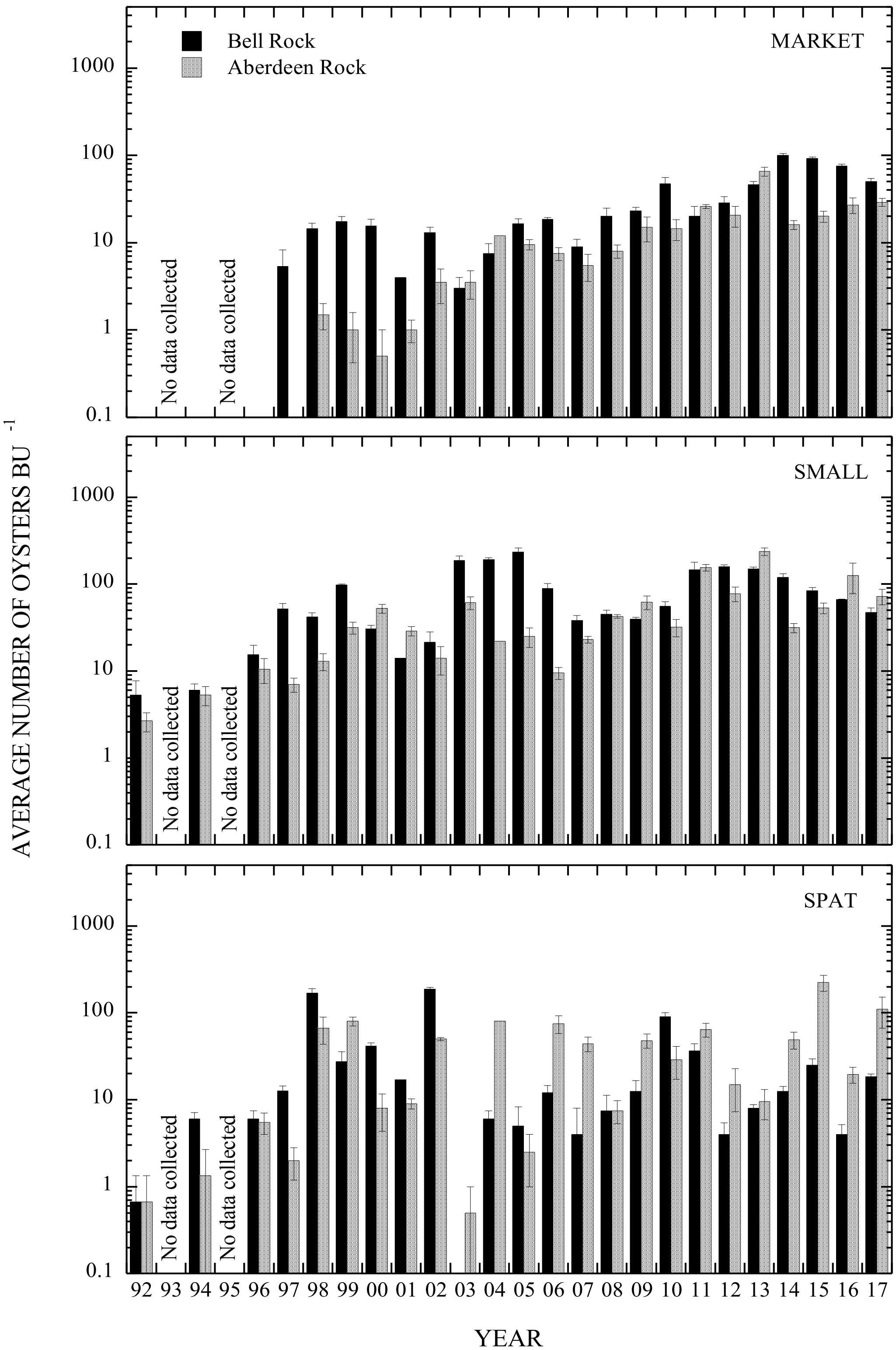


FIGURE D6: MOBJACK BAY OYSTER TRENDS OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)

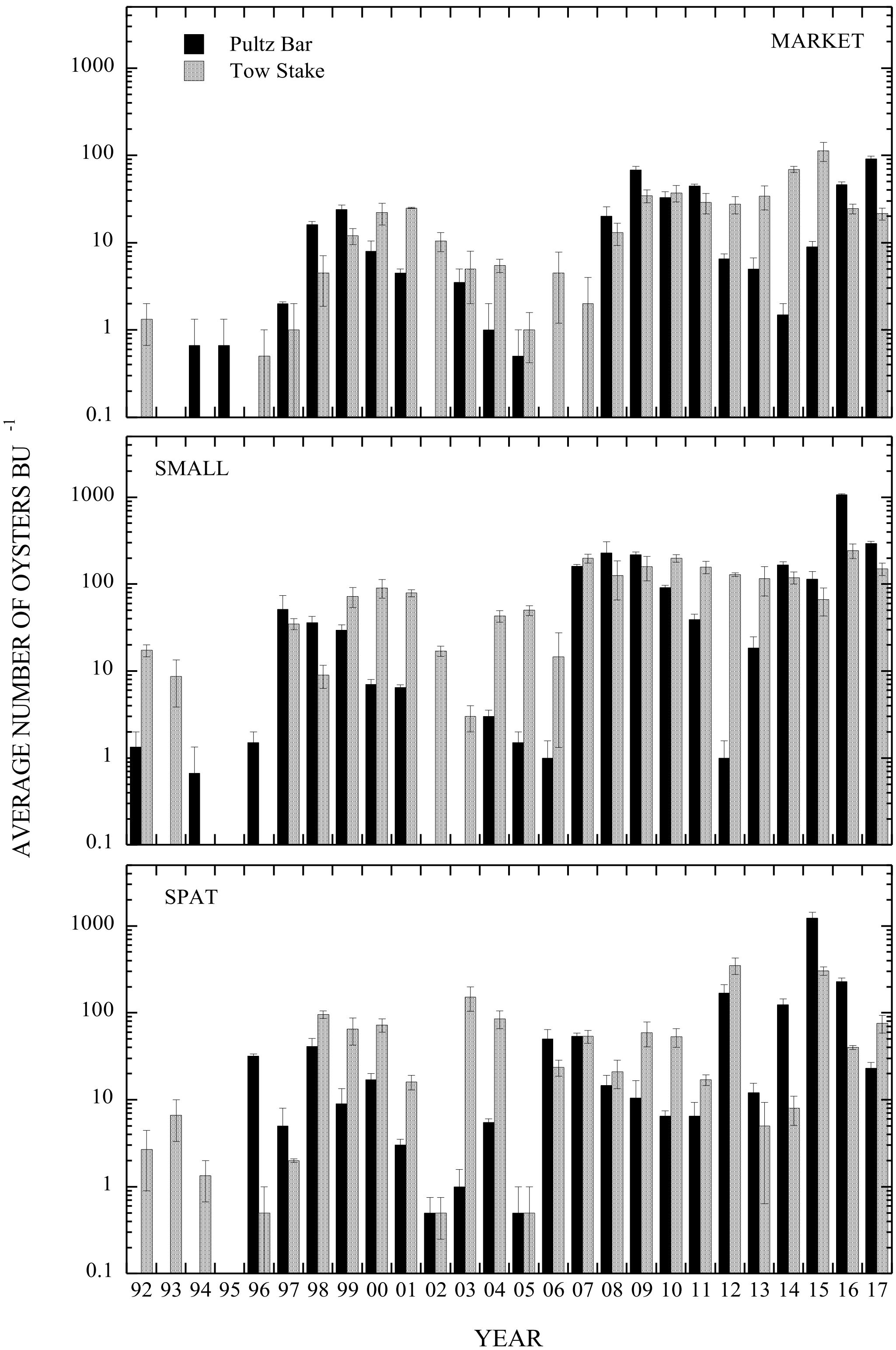


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE PIANKATANK RIVER (2016-2017)
(Error bars represent standard error of the mean)

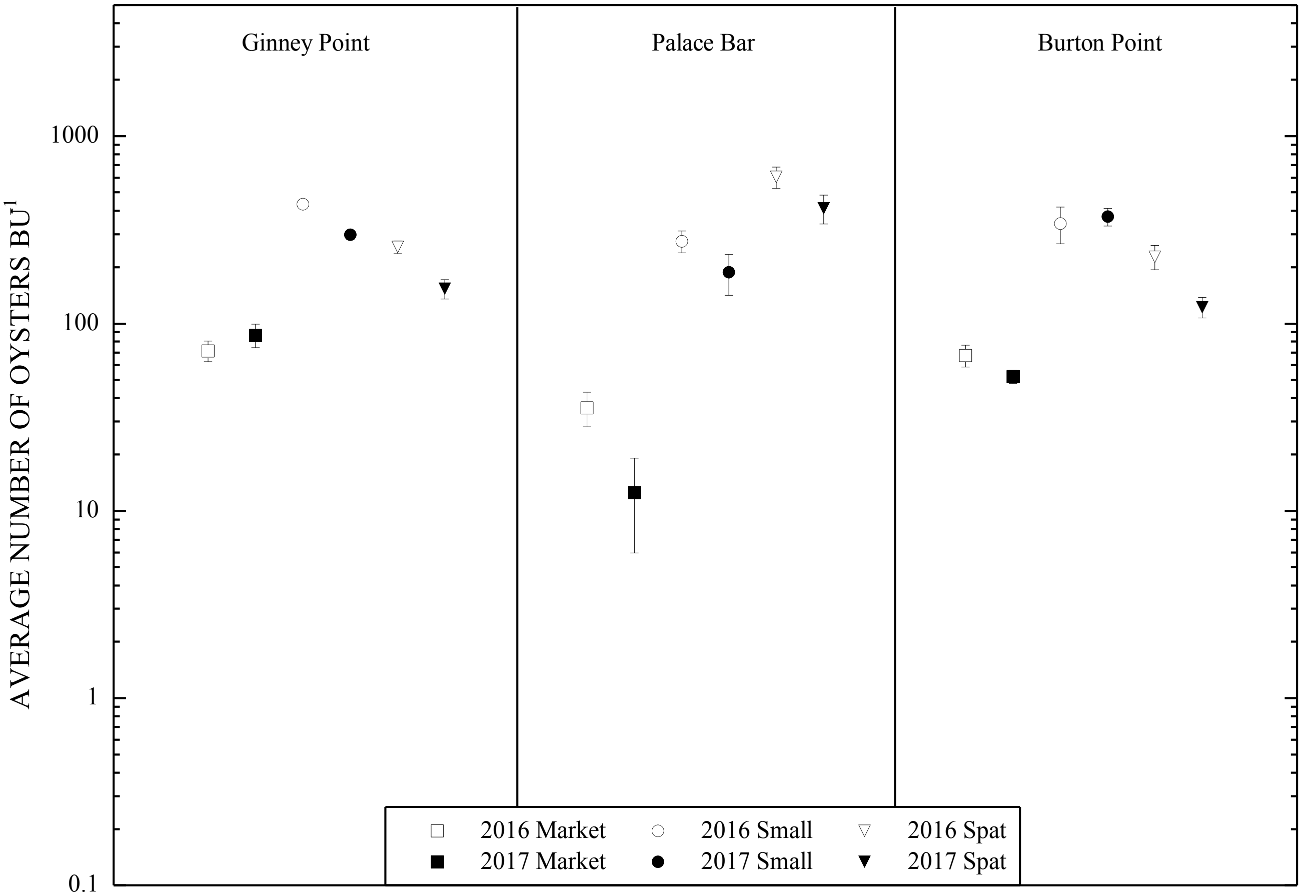
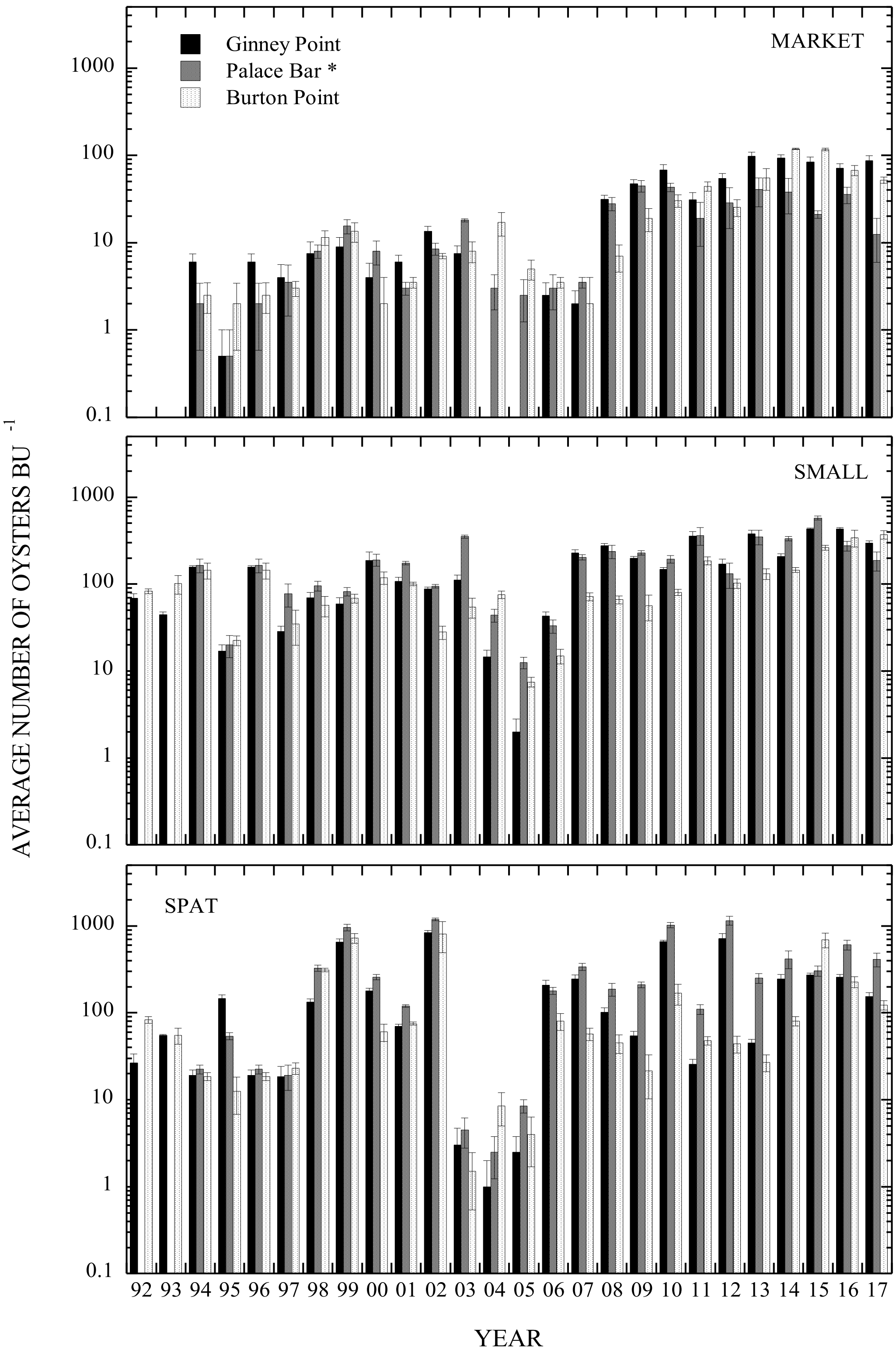


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)




* No data in1992 and 1993

FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2016-2017)
(Error bars represent standard error of the mean)

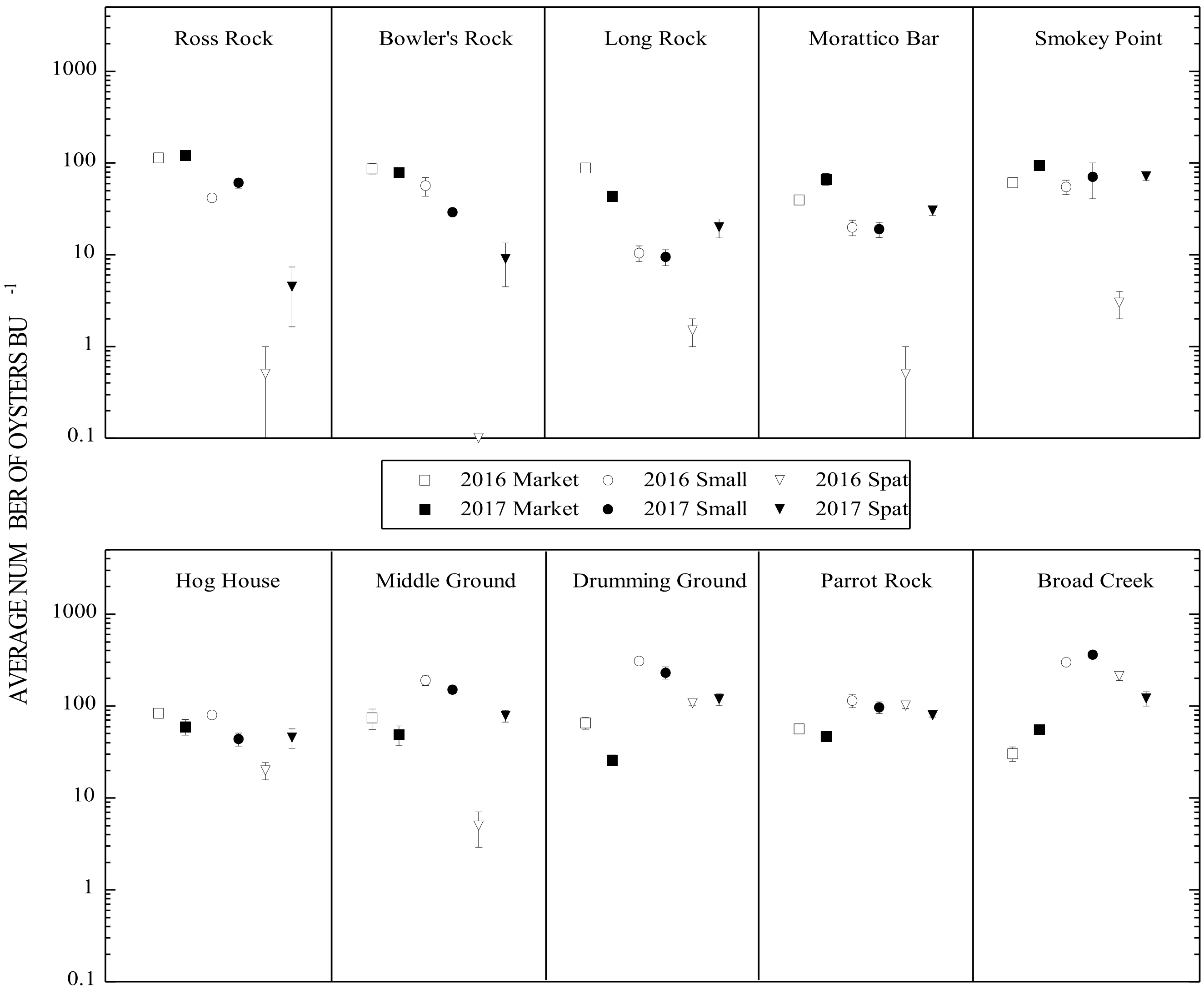
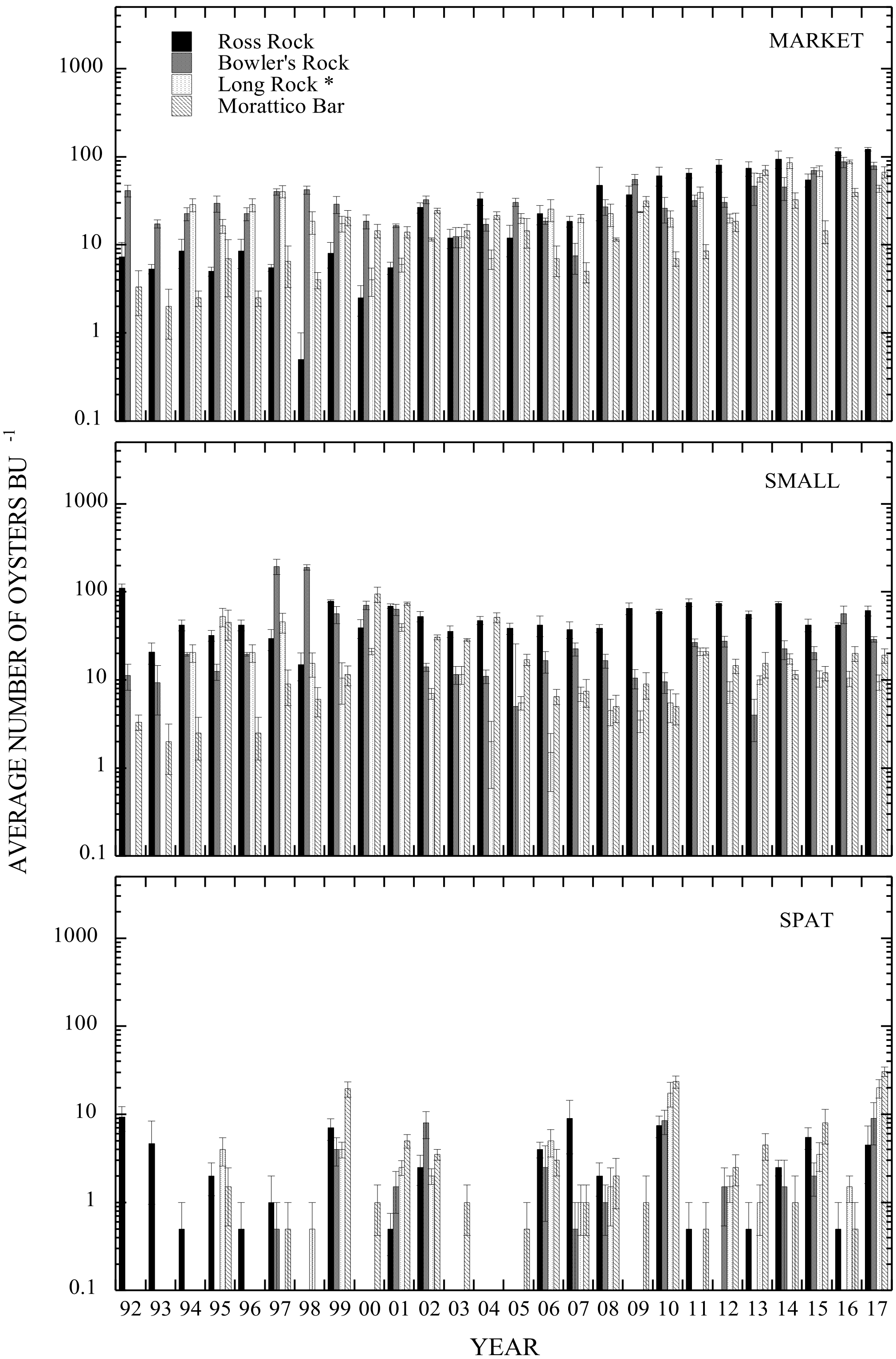


FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)




* No data prior to 1993

FIGURE D10B: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)

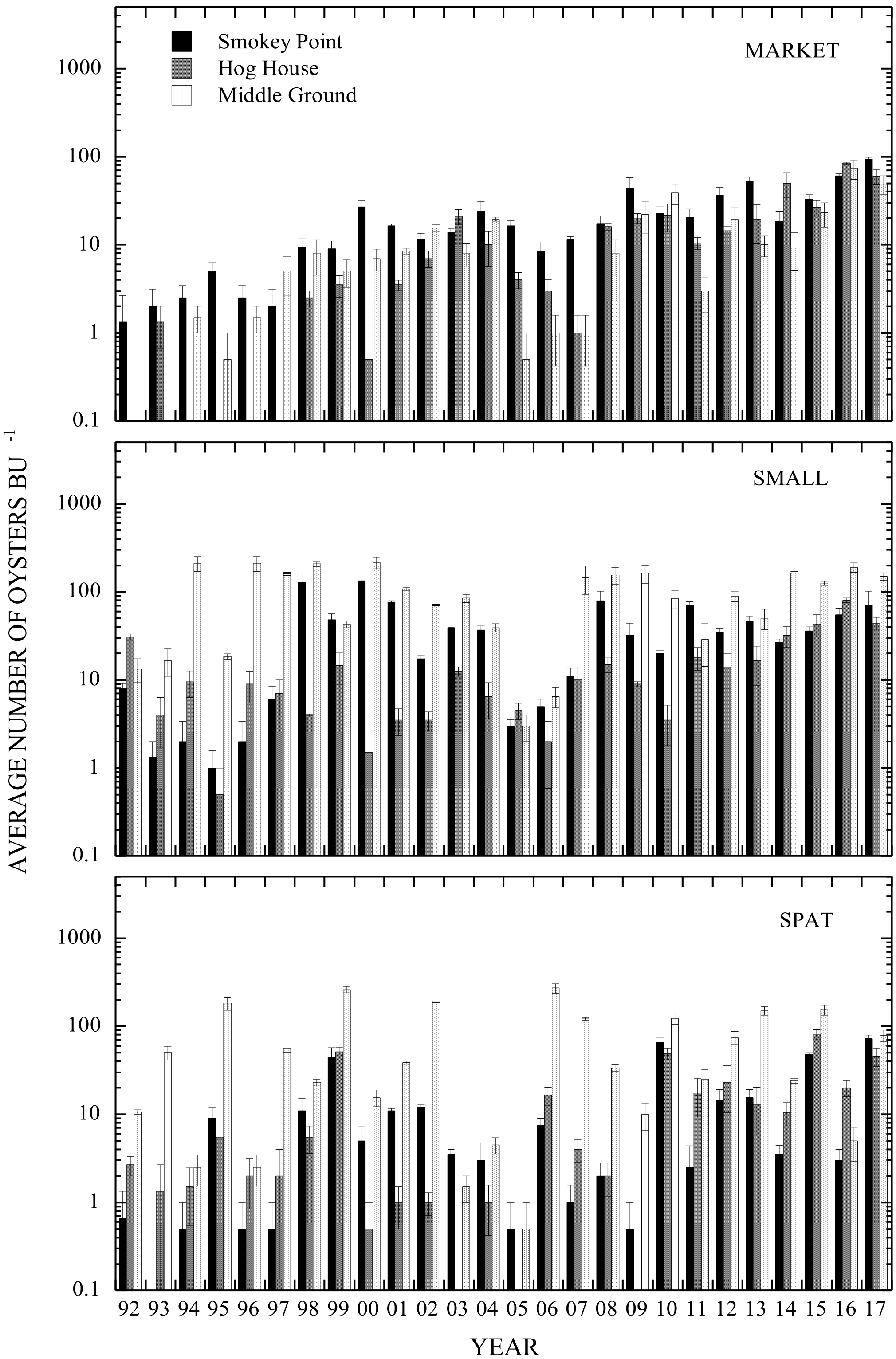
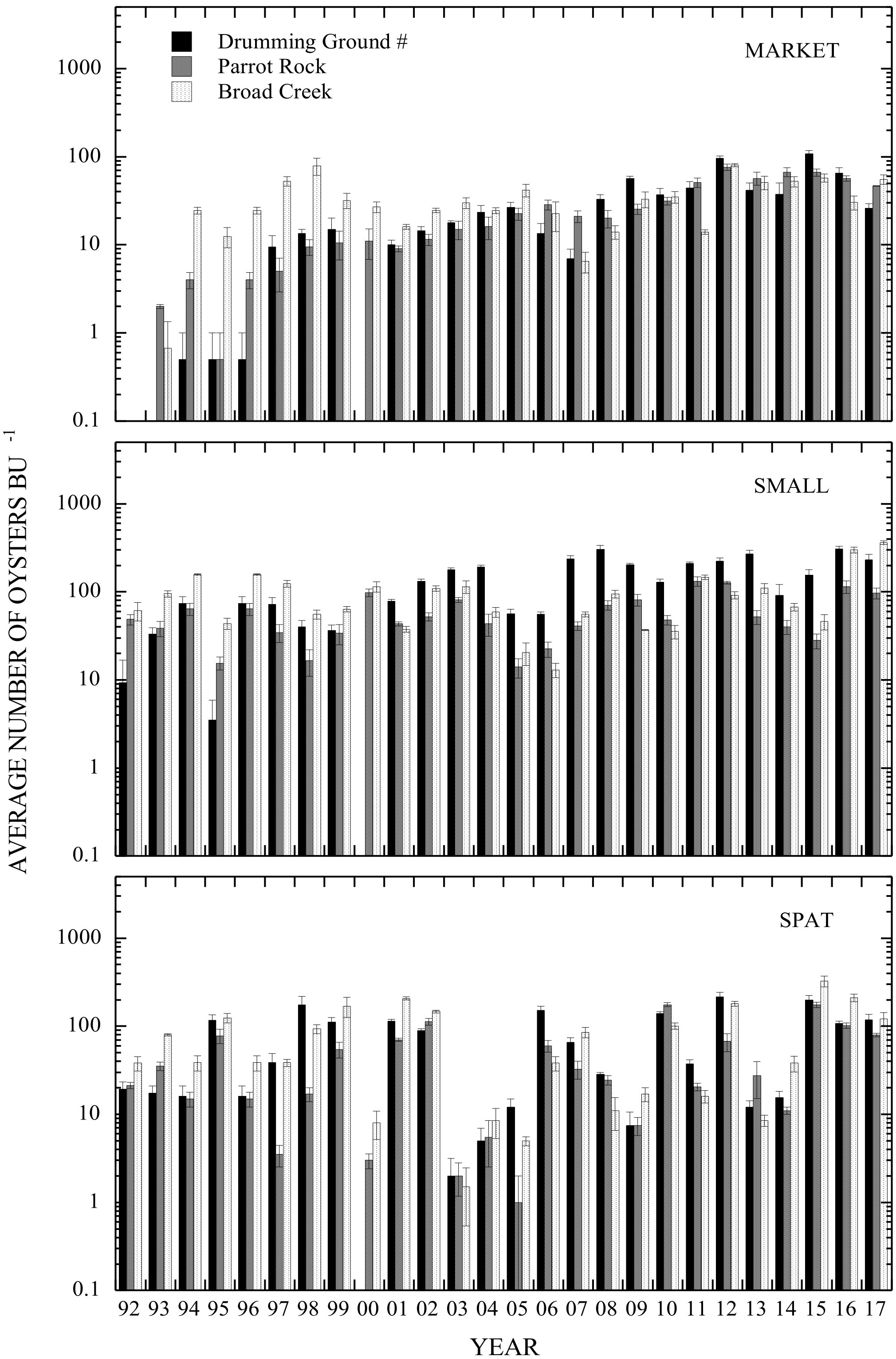


FIGURE D10C: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)




# No sample collected in 2000

FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE GREAT WICOMICO RIVER (2016-2017)
(Error bars represent standard error of the mean)

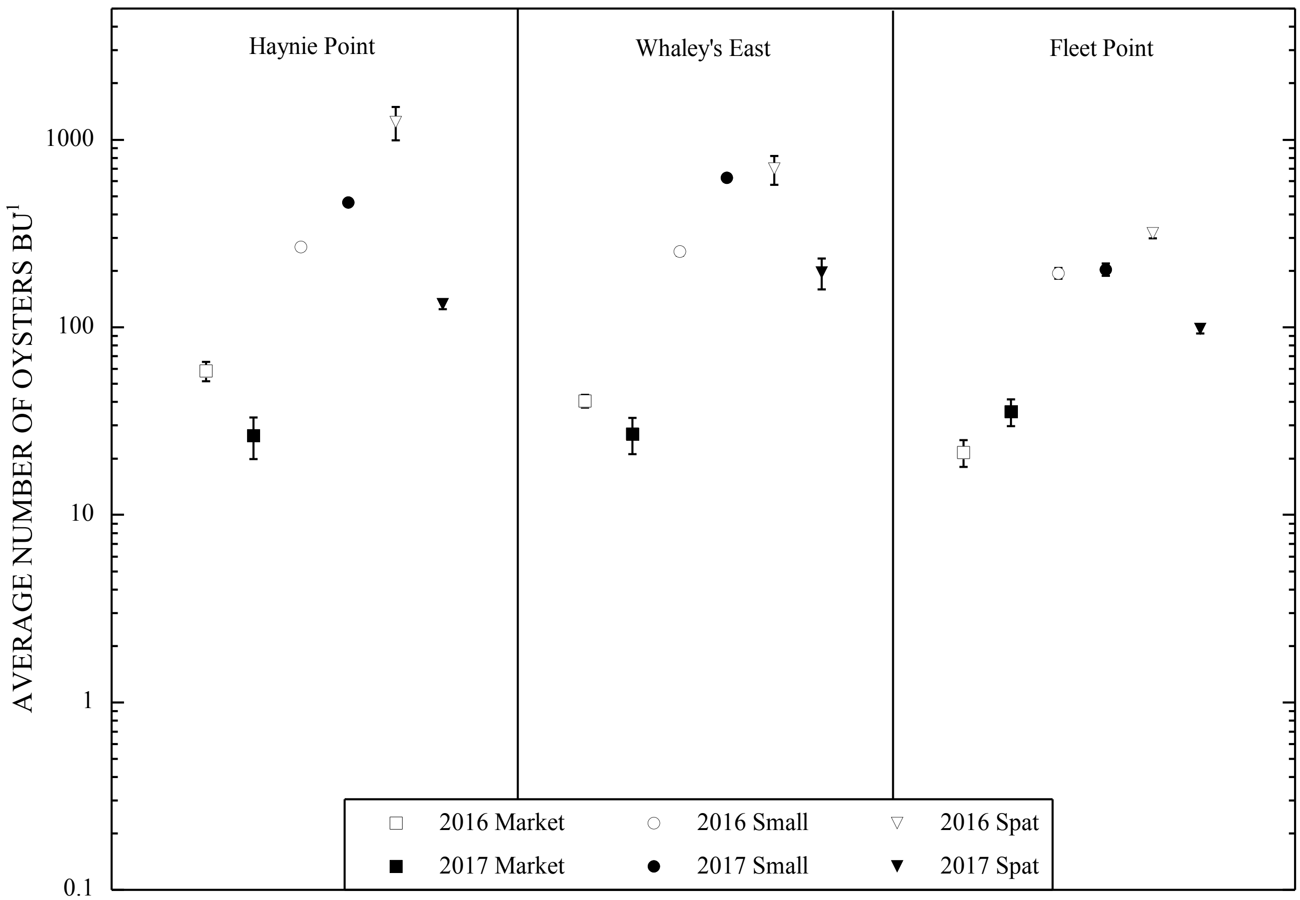
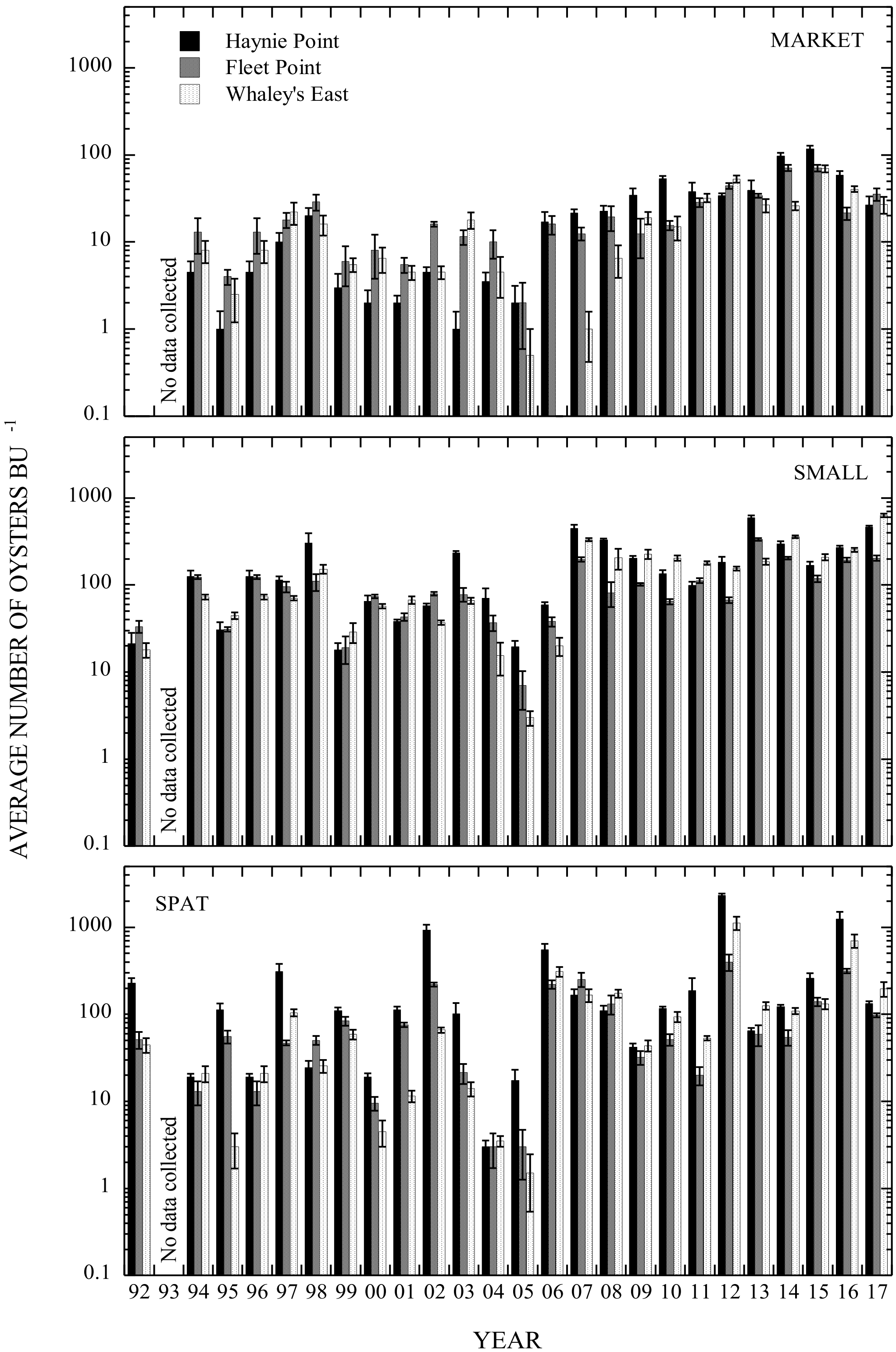


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS OVER THE PAST 25 YEARS
(Error bars represent standard error of the mean)



## ACKNOWLEDGMENTS

These monitoring programs required the assistance of many people, without whose contributions they could not have been successfully completed. We are deeply grateful to the following: Tim Gass (VIMS Field Operations) for help with vessel operations. Patricia McGrath (VIMS Fisheries Science) assisted in making the shellstrings and in field collection. Matthew Long, Steven Cantara, James Wesson and Vernon Rowe assisted in field collection. Cindy Forrester (Department of Fisheries Science, Budget Manager) and Grace Tisdale (Department of Fisheries Science, Purchasing Agents) helped with purchasing field equipment and materials. VIMS Field Operations Department provided assistance with boat scheduling and operation throughout the year, namely Raymond Forrest, Jim Goins and Terri Major. Robin Rennie from VIMS Vehicle Operations Department provided assistance with truck scheduling and operation. Andrew Button, Division Head, Conservation and Replenishment Division of the Virginia Marine Resources Commission provided the *J. B. Baylor* vessel for use during the dredge survey and assisted with data collection during the dredge survey. Vernon Rowe, John Ericson, and Vas Dutton of the VMRC and James Wesson provided assistance during the fall 2017 dredge survey.

## REFERENCES

Baylor, J.B. 1896. Method of defining and locating natural oyster beds, rocks and shoals. Oyster Records (pamphlets, one for each Tidewater, Virginia county, that listed the precise boundaries of the Baylor Survey). Board of Fisheries of Virginia.

Carriker, M.R. 1955. Critical review of biology and control of oyster drills *Urosalpinx* and *Eupleura*. Special Scientific Report: Fisheries No. 148. 150 pp.

Hargis, W.J., Jr. & D.S. Haven. 1995. The precarious state of the Chesapeake public oyster resource. In: P. Hill and S. Nelson, editors. Proceedings of the 1994 Chesapeake Research Conference. Toward a sustainable coastal watershed: The Chesapeake experiment. June 1-3, 1994, Norfolk, VA. Chesapeake Research Consortium Publication No. 149. pp. 559-584.

Haven, D.S. 1974. Effect of Tropical Storm Agnes on oysters, hard clams, and oyster drills. In: The effects of Tropical Storm Agnes on the Chesapeake Bay estuarine system. Chesapeake Research Consortium Publication No. 27. 28 pp.

Haven, D.S. & L.W. Fritz. 1985. Setting of the American oyster *Crassostrea virginica* in the James River, Virginia, USA: temporal and spatial distribution. Mar. Biol. 86:271-282.

Haven, D.S., W.J. Hargis Jr. & P. Kendall. 1981. The present and potential productivity of the Baylor Grounds in Virginia. Va. Inst. Mar. Sci., Spec. Rep. Appl. Mar Sci. & Ocean Eng. No 243. 154 pp.

Mann, R. and D.A. Evans. 1998. Estimation of oyster, *Crassostrea virginica*, standing stock, larval production, and advective loss in relation to observed recruitment in the James River, Virginia. J. Shellfish Res. 17(1):239-254.

Mann, R., M. Southworth, J.M. Harding & J. Wesson. 2004. A comparison of dredge and patent tongs for estimation of oyster populations. J. Shellfish Res. 23(2):387-390.

Rothschild, B.J., J.S. Ault, P. Goulletquer & M. Heral. 1994. Decline of the Chesapeake Bay oyster population: A century of habitat destruction and overfishing. Mar. Ecol. Prog. Ser. 111(1-2):22-39.

Southworth, M., J.M. Harding & R. Mann. 2005. The status of Virginia's public oyster resource 2004. Molluscan Ecology Program, Virginia Institute of Marine Science, Gloucester Point, Virginia. 51 pp.

Southworth, M. and R. Mann. 2004. Decadal scale changes in seasonal patterns of oyster recruitment in the Virginia sub estuaries of the Chesapeake Bay. J. Shellfish Res. 23(2):391-402.