The Status of Virginia's Public Oyster Resource 2014

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Part I. OYSTER RECRUITMENT IN VIRGINIA DURING 2014

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 throughout Virginia's 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 spatfall 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.

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 (shell that is available for larvae to settle on) 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 2014 settlement season in three tributaries in the Virginia portion of the Chesapeake Bay.

METHODS

Settlement during 2014 was monitored from the last week of May through the first week of October in the James, Piankatank and Great Wicomico Rivers. 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. Between 1993 and the mid-2000s, VMRC built numerous artificial oyster shell reefs in several tributaries of the western Chesapeake Bay and in both Pocomoke and Tangier Sounds on the eastern side of the Chesapeake Bay (http://www.vims.edu/research/units/labgroups/molluscan_ecology/restoration/va_restoration_a tlas/index.php). The change in the number and location of shellstring sites during 1998 was implemented to provide a means of quantitatively 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 2014 ranged from 6 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. Spat shell^{-1} values were categorized for comparison purposes as follows: 0.10-1.00, light; 1.01-10.00, moderate; and 10.01 or more, heavy. Unqualified references to diseases in this text imply diseases caused by *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 2014 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 (1989-2014) at the historical sites in all three-river systems and over the past sixteen years (1998-2014) 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 noticeable 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 2014 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 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 2014. Comparisons were made over the past sixteen 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 17 June at seven out of the eight sites monitored (Table S1). Settlement was then light and consistent throughout most of the rest of the recruitment period, with at least some settlement occurring at 50% of the sites in any given week. Although there were no obvious large peaks in settlement observed in the James River in 2014, two notable periods of heavier settlement occurred during the last week of June into the first week of July and in mid-September (Figure S3).

Settlement in the James River during 2014 was moderate (three sites) to heavy (five sites), with cumulative spat shell^{-1} ranging from a low of 2.3 at Deep Water Shoal to a high of 21.7 at Dry Shoal (Table S1; Figure S4). Settlement during 2014 was higher than the previous year (2013) at five out of the eight sites, with essentially no change when compared with the previous year at the remaining three sites. However, settlement in 2014 was lower than the 5, 10, 20 and 25-yr means at all eight sites monitored. Overall, settlement in the James River during 2014 was in the middle of the range of that observed during the past twenty-five years of monitoring, with the long term means being primarily driven by a few exceptionally high years (1991, 1993, 2002, 2008, 2010 and 2012).

Average river water temperatures during the monitoring period ranged from 22.7 to 27.6°C (Figure S5A). Water temperature reached the maximum for the year at the end of June into early July. This maximum occurred several weeks to a month earlier and was approximately 2°C less than what is the typical maximum for the James River. Water temperature during this maximum period in 2014 was approximately 1.5°C higher than the long-term means (5, 10, 20 and 25-yr; Figure S5A). However, during the time period when the temperature maximum is typically observed (late July into early August), water temperatures in the James River were 1 to 2°C lower than the long-term means (5, 10, 20 and 25-yr; Figure S5A). Water temperatures were similar to the long-term means (5, 10, 20 and 25-year; Figure S5A) throughout most of the rest of the recruitment period.

Average salinities in the James River ranged from 5.7 to 14.7, generally increasing throughout the sampling period. Salinity was 3 to 4 lower than the long-term means (5, 10, 20 and 25-yr means; Figure S5B) when monitoring began at the end of May and remained 1 to 2 lower through the end of July. Salinity was similar to the long-term means throughout the rest of the sampling period. The difference in salinity in any given week between the most upriver site (Deep Water Shoal) and the most downriver sites (Day's Point and/or Wreck Shoal; Figure 1) ranged from 6 to 11.

Piankatank River

Settlement in the Piankatank River was first observed during the week of 10 June at Ginney Point (Table S1; Figure S6). Settlement was relatively consistent throughout the system from the week of 17 June through 12 August. The majority of settlement for the year occurred during a four-week period from 24 June through 15 July (Figure S6). Settlement during this time period accounted for 82 (Wilton Creek) to 98% (Cape Toon) of the total settlement for the season, with approximately 50% of the total settlement for the season occurring during the week of 15 July (Figure S6).

Cumulative spat $shell^{-1}$ for the year was heavy at all eight sites, ranging from a low of 24.8 at Palace Bar to a high of 271.0 at Cape Toon (Table S1). Settlement during 2014 was higher than that observed during 2013 at every site except Stove Point. Settlement at the three historical sites was higher than the 10, 20 and 25-yr means and higher than the 5-yr mean at Burton Point (Table S2; Figure S7A). Settlement during 2014 was the second highest recorded over the past twenty-five years of monitoring at Ginney Point and the third highest recorded at Burton Point. At the modern sites, settlement during 2014 was higher than both the 5 and 10-yr means at Heron Rock and Cape Toon and higher than the 10-yr mean at Stove Point (Table S2; Figure S7B). At the modern sites, settlement during 2014 ranked the highest (Cape Toon), second highest (Wilton Creek and Heron Rock) and third highest (Stove Point) observed since monitoring began at those sites in 1998.

The average water temperature during the 2014 sampling period in the Piankatank River ranged from 21.6 to 28.0°C, reaching the maxima during the first week of July (Figure S8A), several weeks earlier than is typical. Water temperature in the Piankatank River was similar to the long-term means (5, 10, 20 and 25-yr) throughout most of the sampling period (Figure S8A). The one exception occurred during the last week of July (the time when temperature in the system is typically at its maximum) when temperature was around 2°C less than the long-term means.

Salinity in the Piankatank River during 2014 ranged from 12.0 to 16.2 generally increasing over the sampling period. Salinity was consistently lower (1 to 3) than the long-term (5, 10, 20 and 25-yr) means throughout the entire sampling period (Figure S8B). The difference recorded in any given week 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 10 June at eight out of the nine sites and was consistent (at least one spat set during each week at each site) from then through 22 July (Table S1; Figure S9). Settlement throughout the rest of the sampling period was light and intermittent. The majority of settlement for the season in the system occurred during a three-week period from 17 June through 1 July. Settlement during this time period accounted for 78 (Fleet Point) to 97% (Rogue Point and Hilly Wash) of the total settlement for the year.

Cumulative spat $shell^{-1}$ for the year was heavy at all nine sites ranging from a low of 77.5 at Fleet Point to a high of 442.5 at Rogue Point (Table S1; Figure S10). Settlement in the Great Wicomico River in 2014 was higher than that observed in 2013 at all nine sites monitored (Table S2; Figure S10). Settlement in 2014 was higher than the 5, 10, 20 and 25-yr means at four out of the five historical sites. The one exception was Glebe Point where settlement was lower than all of the long-term means. The means at Glebe Point are primarily being driven by one exceptional year (2009), when settlement was five times higher than the next highest observed over the twenty-five year time period. Settlement in 2014, when compared with the past twenty-five years, was the highest recorded at Haynie Point, the second highest at Hudnall, Whaley's East and Fleet Point and the fourth highest at Glebe Point. At the modern sites, settlement was higher than both the 5 and 10-yr means at Rogue Point and Shell Bar and higher than the 10-yr mean at Hilly Wash. During 2014, settlement at the modern sites ranked the second highest (Rogue Point, Hilly Wash and Shell Bar) and third highest (Harcum Flats) observed since monitoring began at those sites in 1998.

Average river water temperatures in the Great Wicomico River ranged from 21.7 to 28.1°C throughout the sampling period, reaching the maxima on 1 July and again on 22 July (Figure S11A). Temperature increased fairly quickly over the first four weeks of sampling from around 23°C on 29 May to 27.9°C by 17 June, at which time the water temperature was approximately 2°C higher than the 5, 10 and 16-yr means (Figure S11A). Water temperature was relatively stable from then through mid-July, at which time it decreased, remaining 1 to 2°C lower than the long-term (5, 10 and 16-yr) means through mid-August. This mid-July drop in temperature occurred at the time when water temperature is typically at a maximum for the season.

Salinity in the Great Wicomico River during the 2014 sampling period ranged from 10.8 to 15.7 generally increasing throughout the time period (Figure S11B). Similar to what was observed in the Piankatank River, salinity in the Great Wicomico River was consistently lower (1 to 3) than the long-term (5, 10 and 16-yr) means throughout the entire sampling period (Figure S11B). 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 sampling period.

DISCUSSION

During the fourteen-year period between 1994 and 2007, settlement on the shellstrings was low to moderate; with 84% 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 eight years (2007-2014) has been on the rise such that 75% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat shell^{-1}) and 25% of all of the year/site combinations had very 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, 86% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat shell^{-1}) and 35% of the total year/site combinations had very heavy spatfall (seasonal cumulative total of > 100 spat shell^{-1}; Table S2). Settlement in 2014 was heavy to very heavy at all but three (Deep Water Shoal, Horsehead and Point of Shoal) of the twenty-five sites monitored.

Overall, settlement on shellstrings in the James River during 2014 was moderate (Deep Water Shoal, Horsehead, Point of Shoal) to heavy (Swash, Dry Shoal, Rock Wharf, Wreck Shoal and Day's Point). As has been the case for the past several years, settlement tended to be higher along the southern shore of the river. Since 2008, the James River has had several very strong year classes. The average cumulative spat shell^{-1} for all eight sites combined from 1989 to 2007 was 12.3, whereas the average for all eight sites combined over the past seven years (2008 to 2014) was 88.1. This translates to a seven-fold increase in settlement over the past seven years compared with the previous twenty years. In recent years, the timing of settlement in the James River has been getting progressively earlier (Southworth & Mann 2004). While some settlement occurred throughout most of the sampling period, the majority of the settlement occurred during two periods. The first was a three-week period in late June into early July, which accounted for 41% of the total settlement for the season and the second was a two-week period in mid-September accounting for an additional 31% of the total settlement for the season. This pattern of two major recruitment periods (one early and one late) is similar to historical patterns observed in the James River system (Haven & Fritz 1985).

Overall, settlement on the shellstrings in the Piankatank River was heavy, with cumulative number of spat shell^{-1} for the season at two out of the three historical sites and four out of the five modern sites being among the highest observed over the past twenty-six and seventeen years of monitoring respectively. Similar to the James River, the Piankatank River has had several very strong year classes in recent years, including the 2014-year class. 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 combined the average from 1993 to 2006 was 7.4 cumulative spat shell^{-1}, whereas from 2007 to 2014 the average at those three sites was 128.2 cumulative spat shell^{-1}, a seventeen-fold increase over the previous fourteen-year average. Since the addition of the modern sites in 1998, the average combined cumulative spat shell^{-1} across the river increased from 32.5 cumulative spat shell^{-1} (1998 to 2006) to 380.7 cumulative spat shell^{-1} (2007 to 2013), an eleven-fold increase. For the past several years potential broodstock (small plus market) in the system has been on the rise. The number of potential brookstock in the system during 2014 was among the highest observed during the past twenty-five years of monitoring (Part II, this report). Density of the broodstock is an important factor in determining fertilization success (Mann & Evans 1998).

For the ninth year in a row, overall settlement on the shellstrings in the Great Wicomico River was heavy, especially when compared with most of the 1990s and the early 2000s. For the five historical sites the average spat shell^{-1} between 1991 and 2005 ranged from 1.2 (Whaley's East) to 21.7 (Glebe Point), whereas the average between 2006 and 2014 ranged from 22.8 (Fleet Point) to 380.7 (Glebe Point). This was a 10 to 26-fold increase in settlement during the past nine years compared with the previous fifteen years. For the modern sites, the average spat shell^{-1} between 1998 and 2005 ranged from 3.2 (Shell Bar) to 5.4 (Harcum Flats), whereas the average between 2006 and 2014 ranged from 118.0 (Shell Bar) to 243.7 (Rogue Point). This was a 37 to 59 fold increase during the past nine years when compared with the previous eight years.

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	5/27 147	6/3 154	6/10 161	6/17 168	6/24 175	7/1 182	7/8 189	7/15 196	7/22 203	7/29 210	8/5 217	8/12 224	8/19 231	8/26 238	9/2 245	9/9 252	9/16 259	9/23 266	9/30 273	YEAR TOTAL
JAMES RIVER																				
Deep Water Shoal	D	-	0	0	0.3	0.5	0.1	0	-	0	0.1	0	0.2	-	0.1	0.7	0.1	-	0.2	2.3
Horsehead	D	-	0	0.3	0.4	1.2	0.9	0	-	0.2	0	0.2	0.1	-	0.5	1.2	0.8	-	0.3	6.1
Point of Shoal	D	-	0	0.2	0.7	1.5	-	0.3	-	0.1	0.1	0.2	0.1	-	0.1	1.0	0.8	-	0.4	5.5
Swash	D	-	0	0.1	1.5	5.5	1.7	0.4	-	0.3	0	0.1	0.1	-	0.4	1.3	1.1	-	0.3	12.8
Dry Shoal	D	-	0	0.5	3.2	-	0.4	0.9	-	0.6	0.5	0.1	1.1	-	1.9	5.2	4.9	-	2.4	21.7
Rock Wharf	D	-	0	0.1	2.5	1.2	-	0.7	-	0.1	0	-	1.5	-	0.2	1.3	2.8	-	1.1	11.5
Wreck Shoal	D	-	0	0.8	2.6	2.9	0.7	0	-	0.3	0	0	0.2	0.7	0.6	2.2	-	-	1.3	12.3
Day's Point	D	-	0	0.4	2.2	1.7	3.7	0.5	-	-	0.1	0.1	0.2	-	0.1	1.0	2.5	0.4	0.4	13.3
PIANKATANK RIVER																				
Wilton Creek	D	0	0	0	1.9	5.0	1.1	16.3	2.0	0.1	1.2	0.5	1.0	0.1	0.4	0.1	0	0	0	29.7
Ginney Point	D	0	0.1	0.3	3.5	5.3	4.5	49.0	1.6	0.2	3.8	1.0	1.1	0	0	0.1	0	0	0	70.5
Palace Bar	D	0	0	0.1	4.9	5.7	2.7	9.7	0.1	0	0.8	0.4	0	0.2	0.1	0	0.1	0	0	24.8
Bland Point	D	0	0	0.5	7.9	11.7	1.0	5.7	0.4	0	2.1	0.1	0	0	0	0	0.2	0	0	29.6
Heron Rock	D	0	0	0.3	6.3	14.6	-	27.0	0.1	0.1	1.6	0.3	0	0	0.5	0	-	0	0	50.8
Cape Toon	D	0	0	0.7	28.1	46.7	47.9	142.1	1.3	0.4	1.3	1.1	0.3	0.4	0.5	0.2	0	0	0	271.0
Stove Point	D	0	0	0.3	6.8	11.4	6.0	4.9	0.3	0	1.1	0	0	0.1	0.3	0	0.1	0	0.1	31.4
Burton Point	D	0	0	0.1	5.4	7.4	11.1	30.4	1.6	0.1	1.1	0.4	0.2	0.1	0.3	0	0.2	0	0	58.4
GREAT WICOMICO																				
Glebe Point	D	0	0.2	128.8	52.3	56.5	9.6	1.5	0.9	0	0.1	0	0.3	0.7	0	0	0.5	0	0	251.4
Rogue Point	D	0	0.1	216.0	72.9	139.9	2.7	3.7	3.7	0	0.2	0.1	0.8	1.4	0.3	0.2	0.5	0	0	442.5
Hilly Wash	D	0	0.3	119.5	88.1	68.0	1.5	1.1	1.8	0.4	0.1	0.2	0.6	0.7	0.5	0.1	0.1	0	0	283.0
Harcum Flats	D	0	0.1	35.6	62.8	44.2	5.3	3.5	3.9	0	0	0	0.2	0.3	0.2	0	0.3	0.1	0.1	156.6
Hudnall	D	0	0	47.1	44.1	51.7	2.6	1.5	2.3	0.3	0	0	0.1	0.1	0.4	0	0.2	0	0.1	150.5
Shell Bar	D	0	0.1	87.9	81.7	94.4	18.4	4.3	5.6	0.2	0.1	0.4	0.1	0.4	0.3	0.3	0.7	0	0.1	295.0
Haynie Point	D	0	0.6	72.5	40.0	78.8	6.7	6.1	11.6	1.3	0.3	0	0.4	0.1	0.6	0.4	0.7	0.1	0.2	220.4
Whaley's East	D	0	0.1	23.5	7.6	44.8	2.6	0.9	2.2	0.2	0.1	0	0	0.1	0.3	0.3	0.1	0.2	0	83.0
Fleet Point	D	0	0.1	11.7	23.1	26.0	5.3	7.6	0.7	1.1	0.1	0	0.2	0.2	0	0.8	0.4	0.1	0.1	77.5

Table S2: Spatfall totals for historical sites (1989-2013) and modern sites (1998-2013) 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 2014 in reference to 2013 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	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Mean 09-13	Mean 04-13	Mean 94-13	Mean 89-13	Ref. 2013	Ref. 5-yr	Ref. 10-yr	Ref. 20-yr	Ref. 25-yr
JAMES																																			
Deep Water Shoal	2.0	2.6	10.6	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	9.0	30.7	17.7	15.4	NC	-	-	-	-
Horsehead	1.5	0.9	24.7	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	45.0	46.4	25.5	23.3	+	-	-	-	-
Point of Shoal	3.7	14.3	21.4	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	28.8	45.3	25.9	25.5	+	-	-	-	-
Swash	3.8	3.3	68.7		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	26.5	63.5	34.3	33.7	+	-	-	-	-
Dry Shoal	10.0	30.9	217.1	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	90.9	74.9	41.0	48.4	NC	-	-	-	-
Rock Wharf	2.1	1.8		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	85.7	81.2	43.7	38.5	NC	-	-	-	-
Wreck Shoal	10.2	4.0	35.3	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	31.7	77.6	40.4	35.1	+	-	-	-	-
Day's Point	26.1	22.4	145.6	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	111.5	84.5	46.2	50.6	+	-	-	-	-
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	60.4	32.2			+	-	-		
Ginney Point	29.9	62.6	25.4	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	72.3	39.1	20.8	21.9	+	-	+	+	+
Palace Bar	42.4	119.2	38.9	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	44.5	23.7	13.2	19.8	+	-	+	+	+
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	65.6	35.5			+	-	-		
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	26.7	15.3			+	+	+		
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	98.1	55.0			+	+	+		
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	43.7	26.2			-	-	+		
Burton Point	31.6	87.4	16.4	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	46.5	25.6	14.2	17.5	+	+	+	+	+
GREAT WICOMICO																																			
Glebe Point	8.2	19.5	1.9	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	550.2	317.8	174.9	141.1	+	-	-	-	-
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	285.0	175.4			+	+	+		
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	284.9	173.5			+	-	+		
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	272.3	188.3			+	-	-		
Hudnall	26.4	94.8	4.5	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	89.2	62.0	33.9	32.2	+	+	+	+	+
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	125.8	76.8			+	+	+		
Haynie Point	17.0	68.2	12.4	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	55.7	36.5	19.7	19.8	+	+	+	+	+
Whaley's East	8.4	39.1	7.9	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	34.6	20.3	10.6	10.7	+	+	+	+	+
Fleet Point	7.9	17.4	5.8	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	21.1	12.8	7.1	7.1	+	+	+	+	+

Figure S1: Map showing the location of the 2014 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, 19) Hilly Wash (M), 20) Harcum Flats (M), 21) Hudnall, 22) Shell Bar (M), 23) Haynie Point, 24) Whaley's East, 25) Fleet Point.

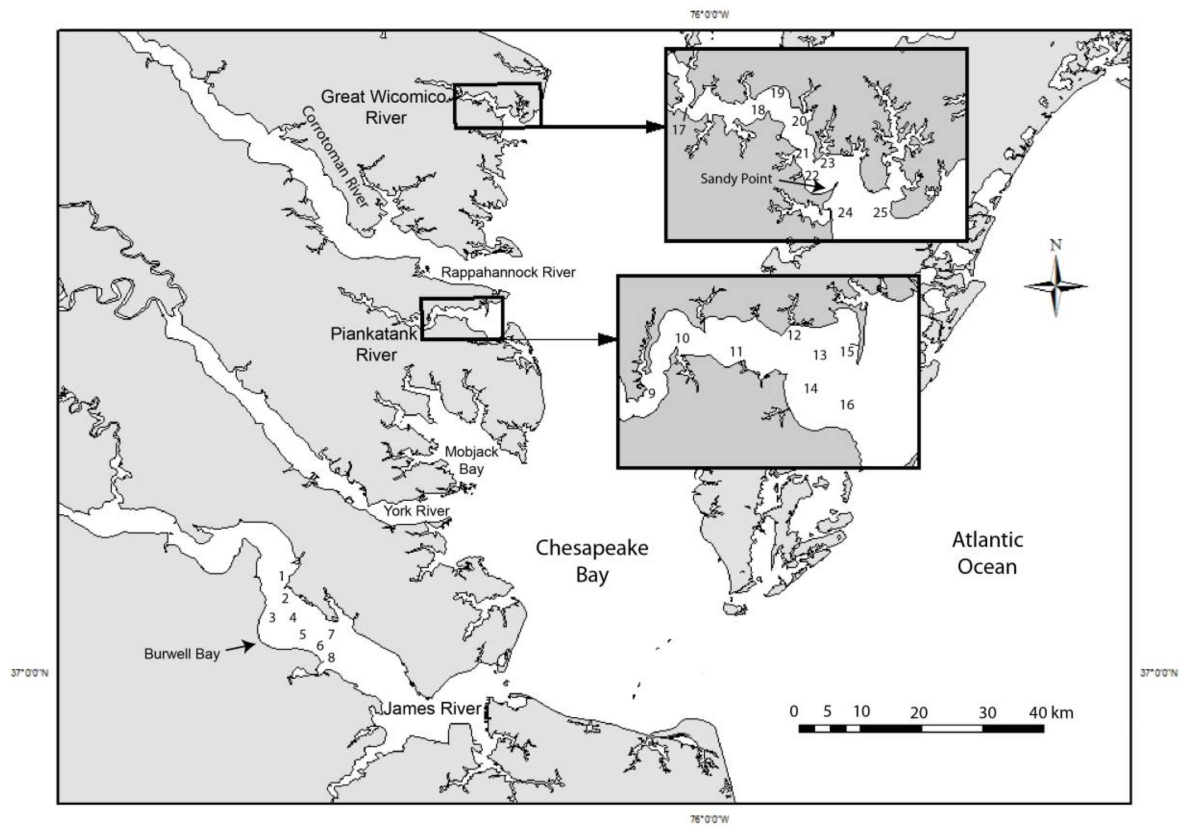


Figure S2: Diagram of shellstring setup on buoys with picture of a shellstring embedded.

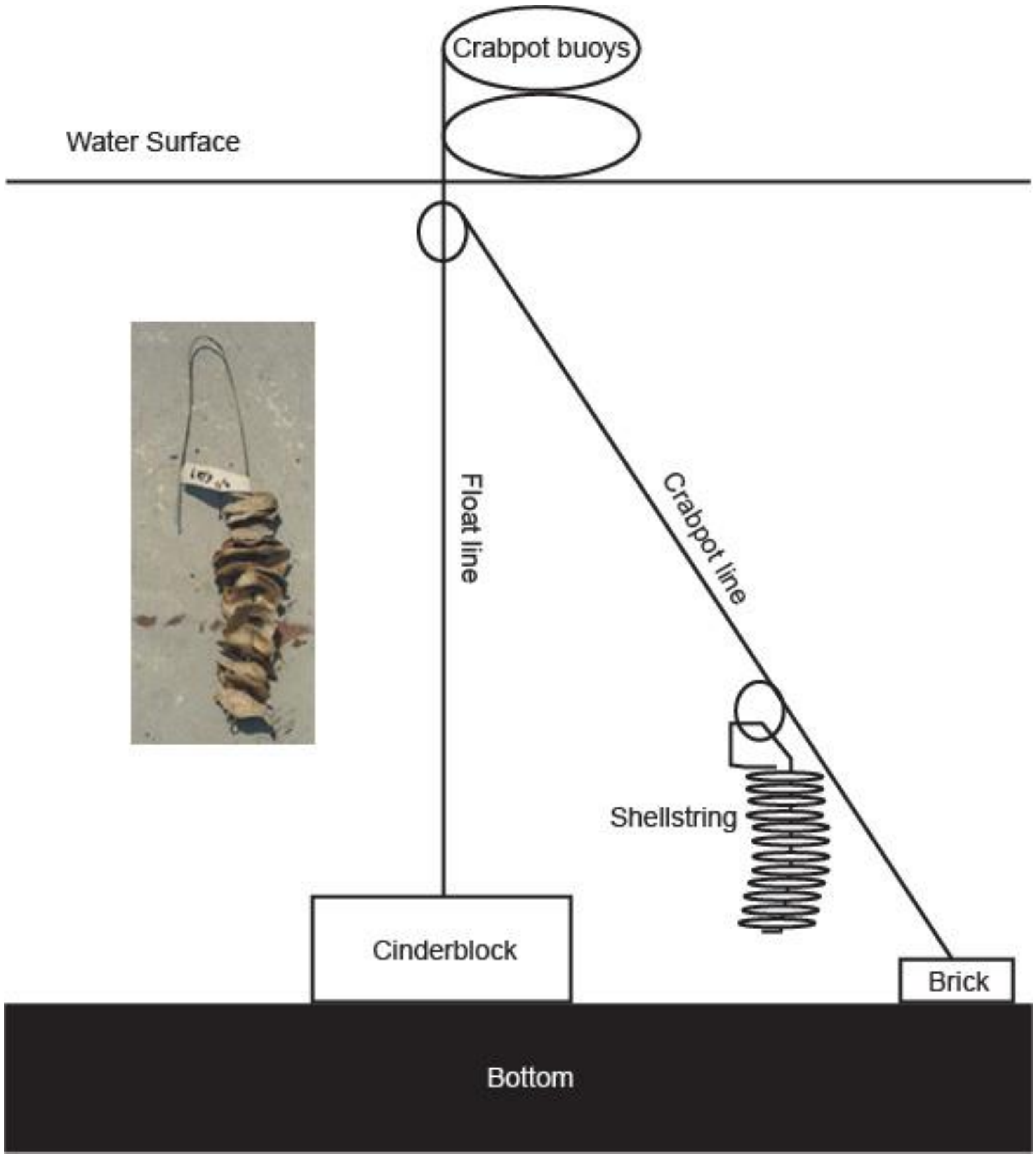


FIGURE S3: JAMES RIVER (2014) WEEKLY RECRUITMENT INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}

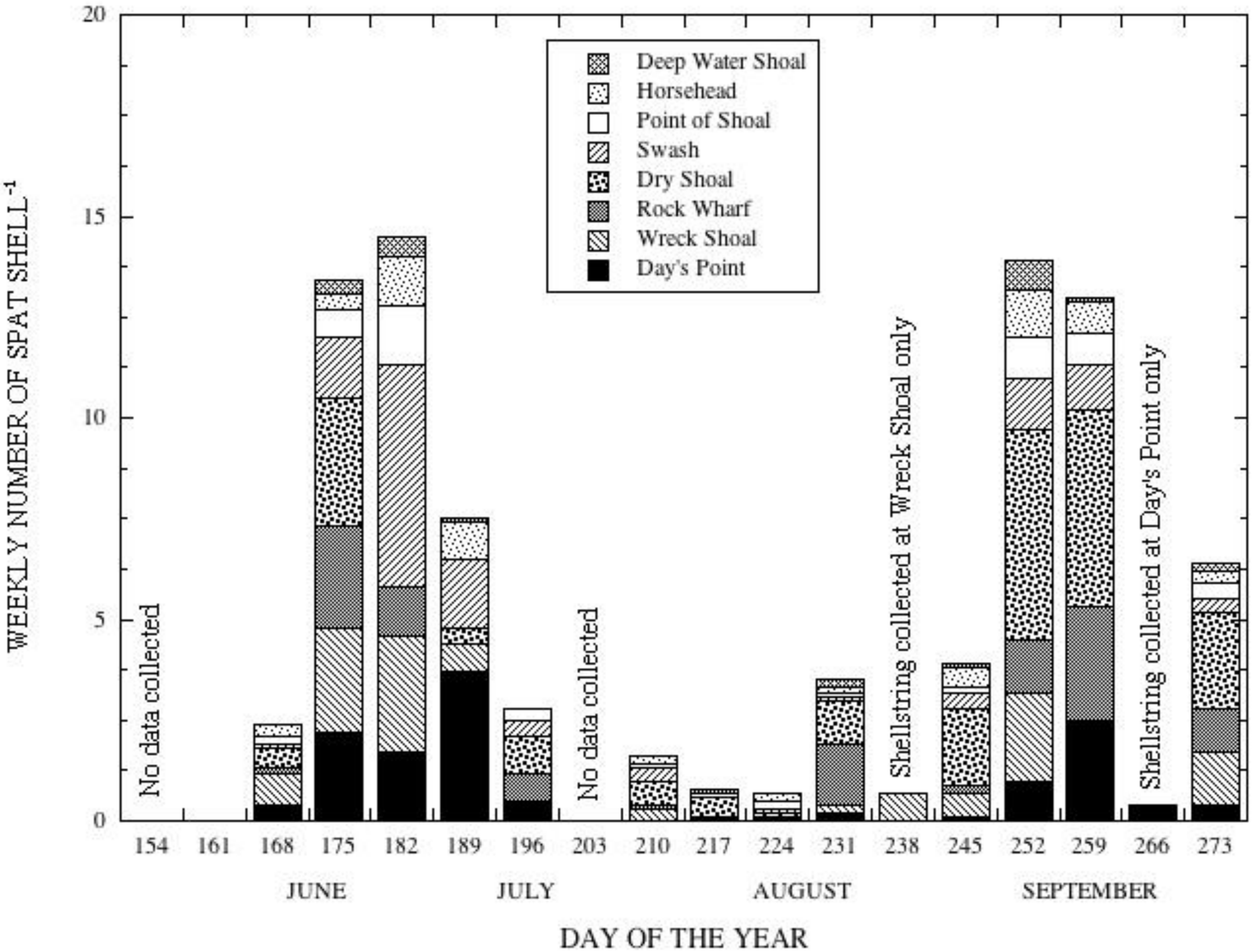


FIGURE S4: RECRUITMENT TRENDS OVER THE PAST 25 YEARS AT ALL EIGHT SITES IN THE JAMES RIVER (upriver sites in panel A; downriver sites in panel B) (expressed as cumulative weekly spatfall)

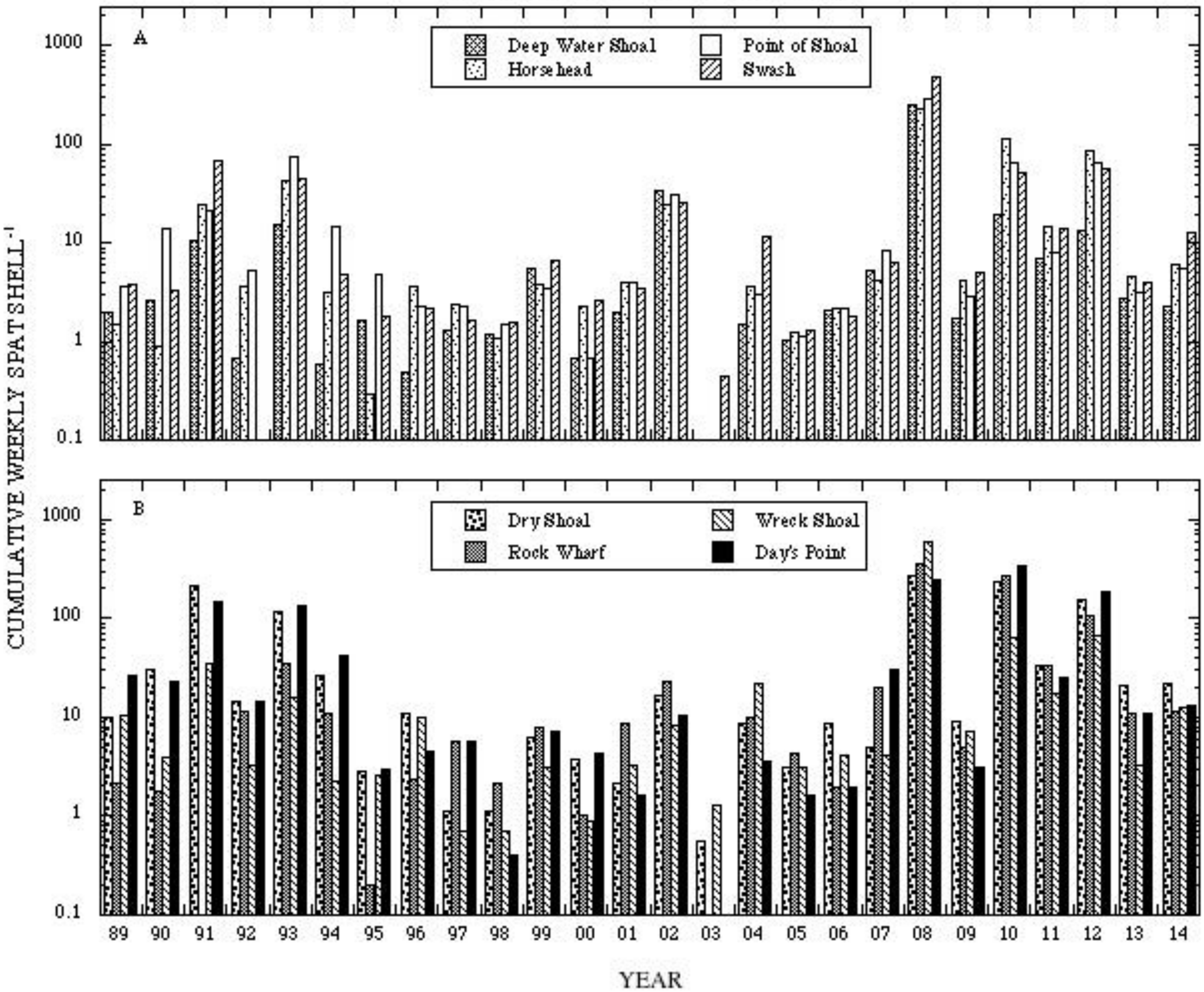


FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE RECRUITMENT PERIOD: 5, 10, 20 AND 25-YEAR MEANS COMPARED WITH 2014
(Error bars represent standard error of the mean; shaded area represents the bulk of recruitment during 2014; n is the number of data points used to calculate the mean)

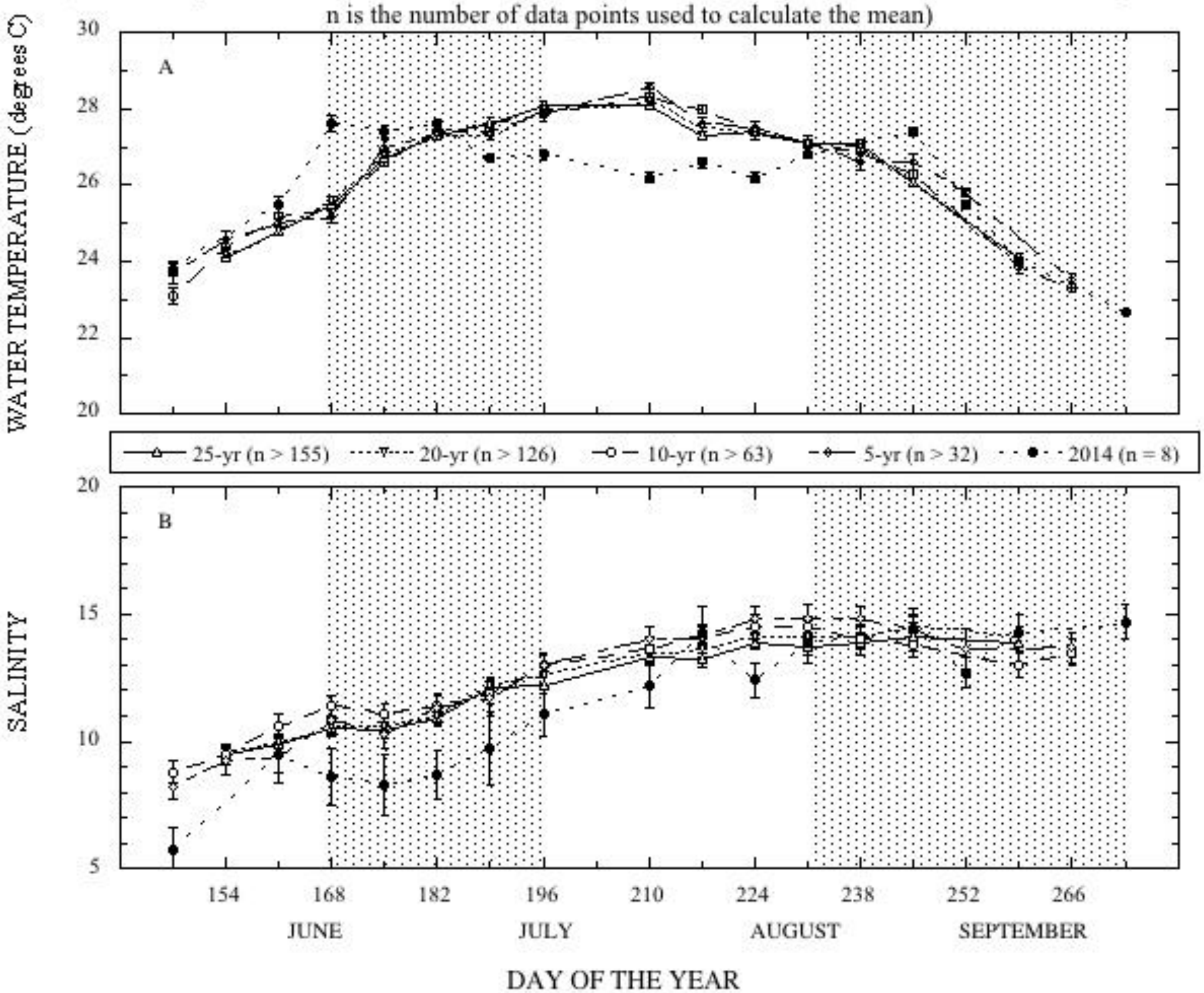


FIGURE S6: PIANKATANK RIVER (2014) WEEKLY RECRUITMENT INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}
(H = historical station: M = modern station as described in text)

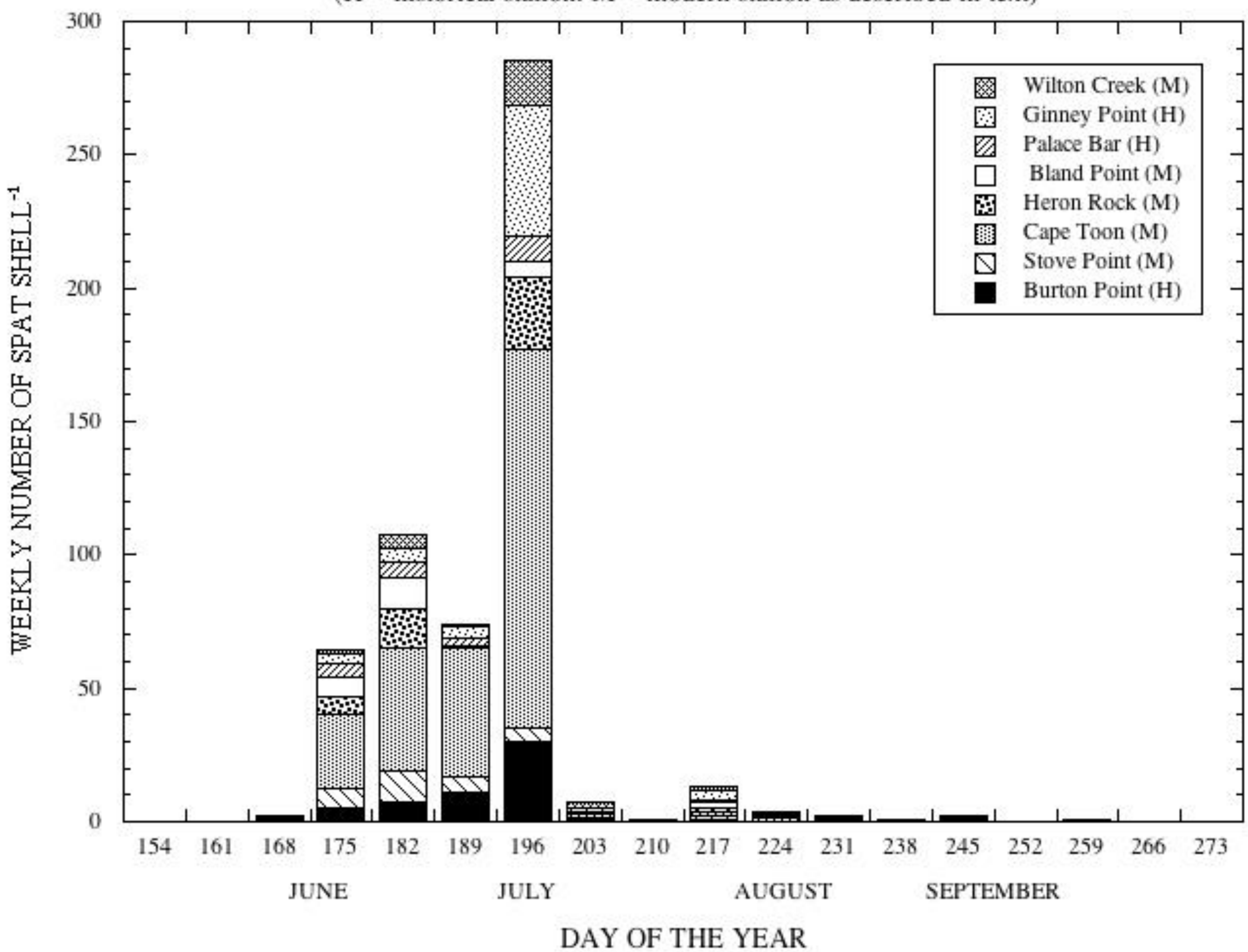


FIGURE S7: RECRUITMENT TRENDS IN THE PIANKATANK RIVER AT THE THREE HISTORICAL SITES (panel A: 25 years) AND THE FIVE MODERN SITES (panel B: 16 years)
(Expressed as cumulative weekly spatfall)

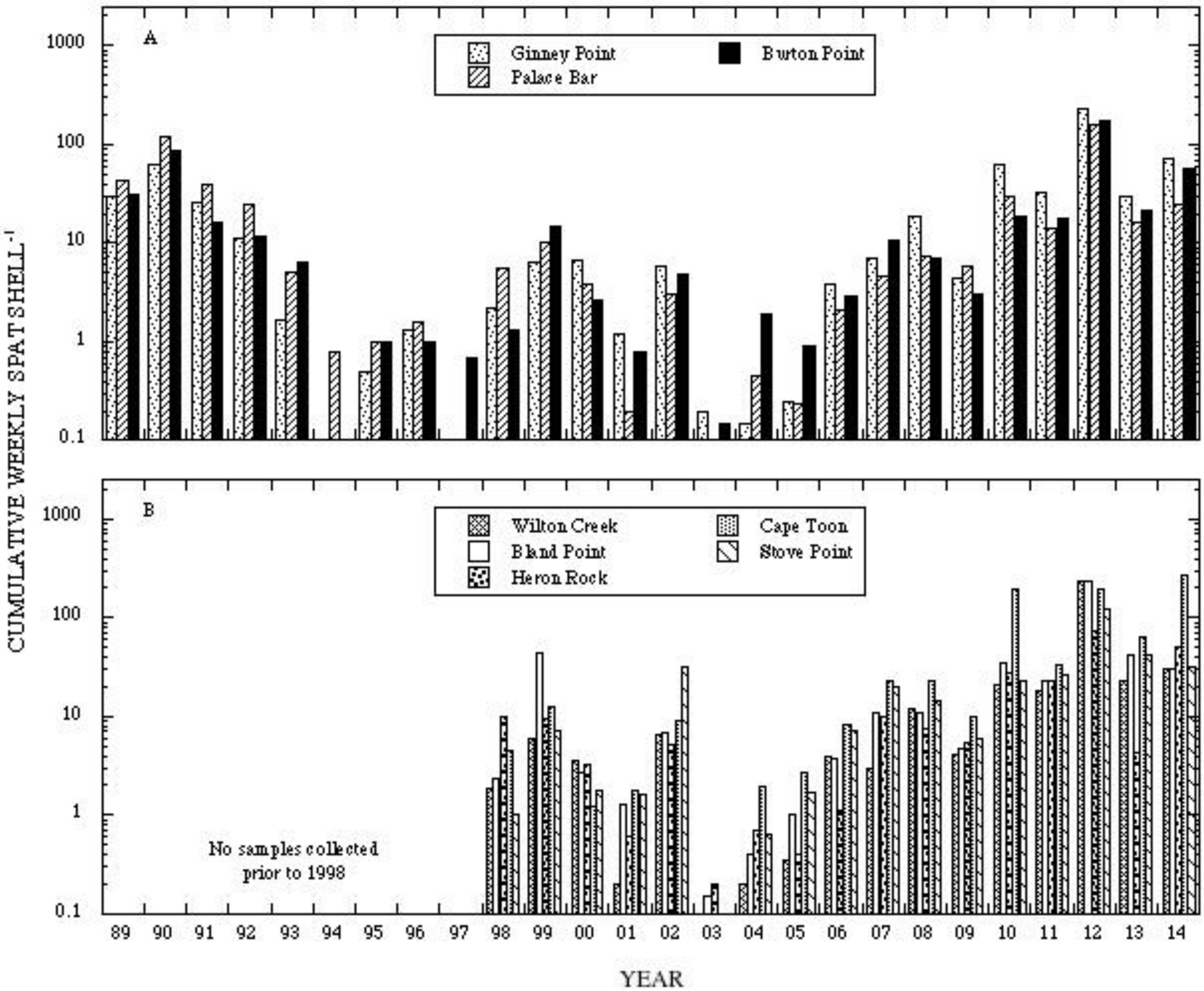


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE RECRUITMENT PERIOD: 5, 10, 20 AND 25-YEAR MEANS COMPARED WITH 2014

(Error bars represent standard error of the mean; shaded area represents the bulk of recruitment during 2014; n is the number of data points used to calculate the mean)

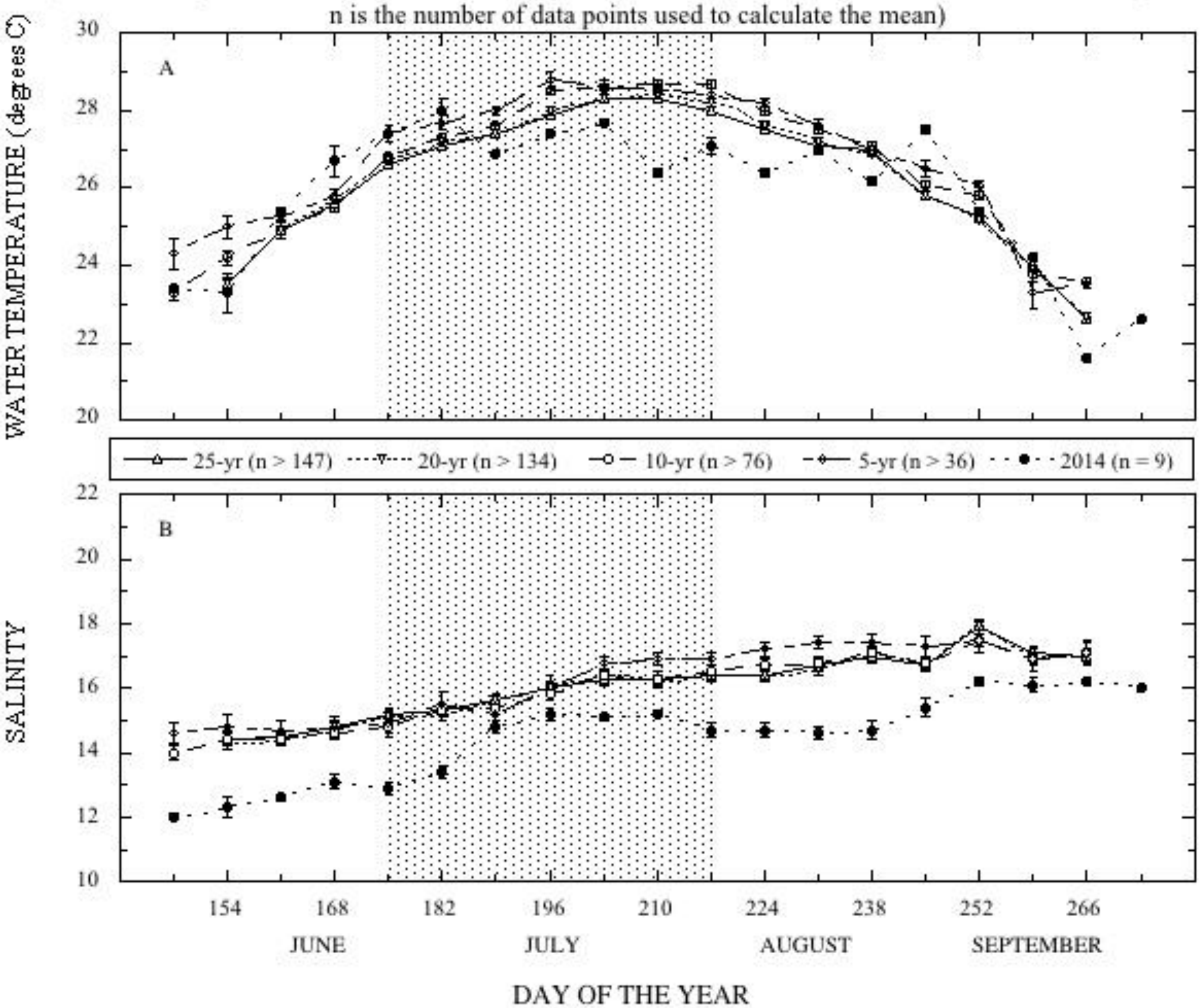


FIGURE S9: GREAT WICOMICO RIVER (2014) WEEKLY RECRUITMENT INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}
(H = historical station: M = modern station as described in text)

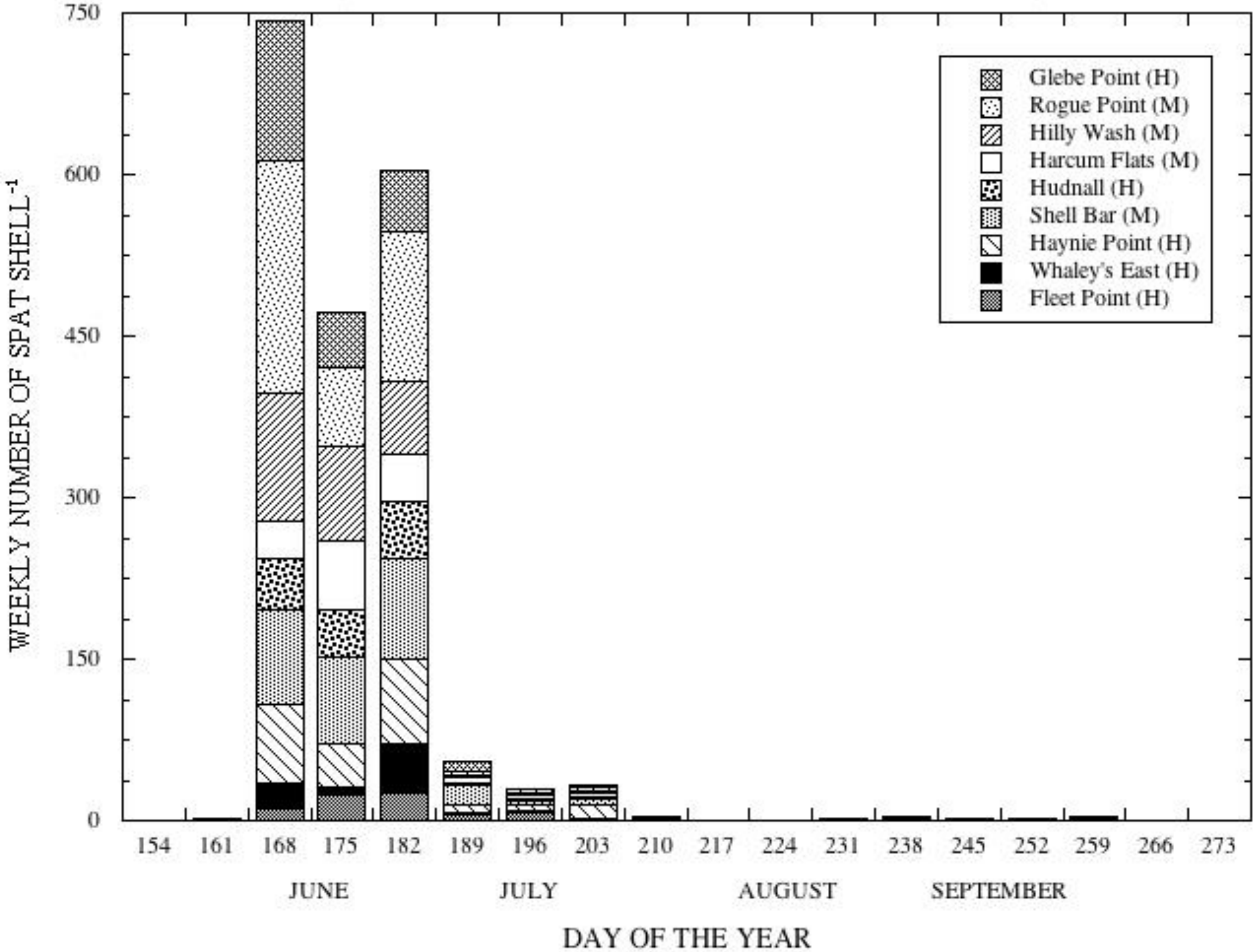


FIGURE S10: RECRUITMENT TRENDS IN THE GREAT WICOMICO RIVER AT THE FIVE HISTORICAL SITES (panel A: 25 years) AND THE FOUR MODERN SITES (panel B: 16 years) (Expressed as cumulative weekly spatfall)

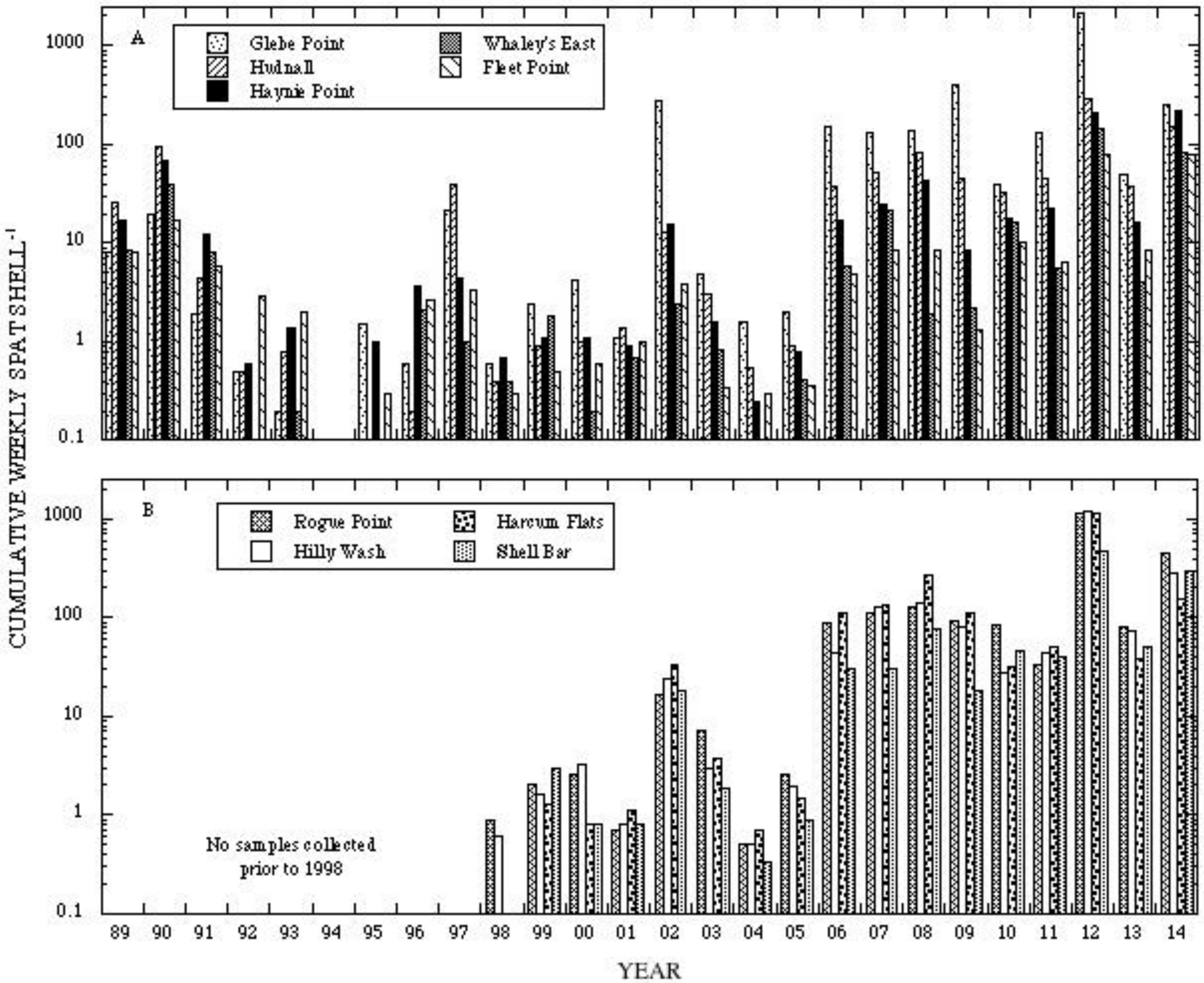
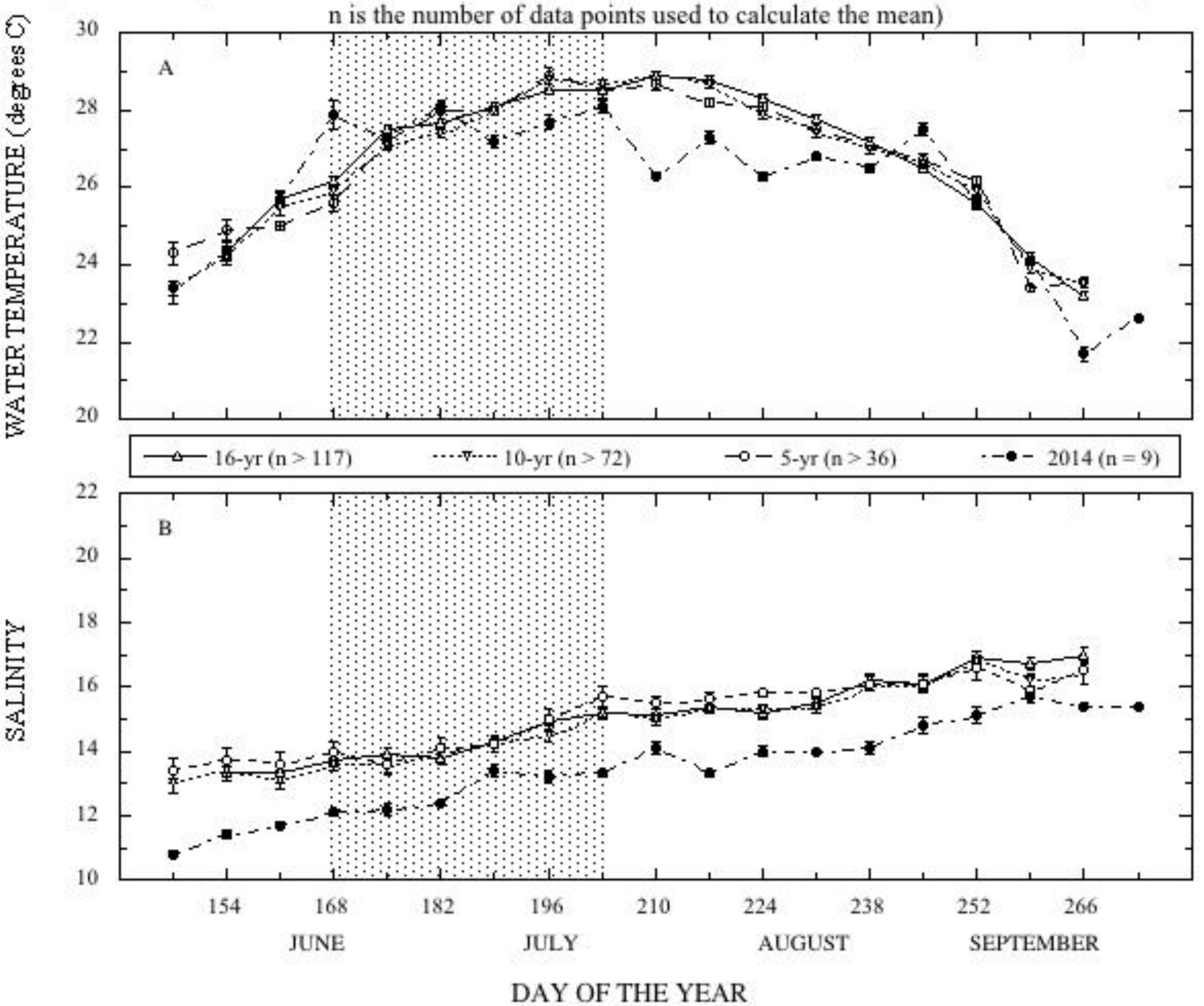


FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE RECRUITMENT PERIOD: 5, 10 AND 16-YEAR MEANS COMPARED WITH 2014
(Error bars represent standard error of the mean; shaded area represents the bulk of recruitment during 2014; n is the number of data points used to calculate the mean)



Part II. DREDGE SURVEY OF SELECTED OYSTER BARS IN VIRGINIA DURING 2014

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 (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); they 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 bar surveys conducted during October 2014.

Spatial variability in 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 Southworth et al. (1999) by the width of the confidence interval around the average count of spat at Horsehead (James River, VA) during 1998. Dredges provide semi-quantitative data, have been used with consistency over extended periods (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 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.

METHODS

Locations of the oyster bars sampled during Fall 2014 are shown in Figure D1. Geographic coordinates of the bars are given in Table D1.

Four 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 2014) and in surveys in the James, Piankatank, Rappahannock and Great Wicomico Rivers in 1994, 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 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 four samples collected at each bar for live oysters and box counts after conversion to a full bushel.

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, 2014 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 8 October and 21 October, 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 figure for that particular site/system. All other blanks on the figures 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 34.0 bushel^{-1} at Nansemond Ridge to a high of 1388.5 bushel^{-1} at Horsehead. The total number of live oysters at Horsehead and Long Shoal was the fourth highest observed over the past twenty years of monitoring. When spat are excluded, the total number of small and market oysters combined was the highest (Horsehead), second highest (Mulberry Point, Long Shoal, Dry Shoal and Thomas Rock) and third highest (Point of Shoal, Swash and Wreck Shoal) observed over the past twenty years. The number of oysters at Nansemond Ridge has been at fairly low levels for the past several years and the total number of oysters on Nansemond Ridge during 2014 was the fifth lowest observed during the past twenty years of monitoring.

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 several sites in the system. All of the sites monitored had low to moderate numbers of market oysters ranging from 2.5 (Nansemond Ridge) to 93.5 bushel^{-1} (Wreck Shoal). There was a notable increase in the number of market oysters at Deep Water Shoal, Point of Shoal and Thomas Rock when compared with 2013 with no notable change in the number of market oysters observed at the other seven sites (Figures D2 and D3). The number of market oysters at Wreck Shoal has been steadily increasing since about 2009 (approximately a three-fold increase over the six-year time period) and 2014 had the highest number of market oysters observed since prior to 1994. The number of market oysters at Dry Shoal and Thomas Rock was the highest observed during the past twenty years of monitoring (Figure D3).

The average number of small oysters bushel^{-1} ranged from a low of 9.0 at Nansemond Ridge to a high of 1308.5 at Horsehead. When compared with 2013, there was a relatively small, but notable increase in the number of small oysters at Mulberry Point and Thomas Rock (Figures D2 and D3). Comparing 2014 with the past twenty years, the number of small oysters was the third highest (Point of Shoal), second highest (Mulberry Point, Long Shoal, Dry Shoal and Thomas Rock) and highest (Horsehead) observed during that time period. For the sixth year in a row, the number of small oysters at Nansemond Ridge was at very low levels (Figure D3C).

Overall, recruitment in the James River in 2014 was relatively low especially when compared with that observed in the system over the past few years. The average number of spat bushel^{-1} ranged from a low of 22.5 at Nansemond Ridge to a high of 109.5 at Thomas Rock. When compared with 2013, there was a large decrease in spat observed at the eight most upriver sites (see Figure D1), with essentially no change at Thomas Rock and Nansemond Ridge (Figure D2 and D3). Recruitment 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 2014, the majority of the oysters at the eight most upriver sites were primarily small whereas the majority of the oysters at the two most down river sites (Thomas Rock and Nansemond Ridge) were primarily spat, somewhat similar to the historical patterns observed in the system (Figure D1 and D3). With the exception of Thomas Rock, which had a moderate number of spat, overall recruitment in the James River during 2014 was low (falling on the low end of the range) when compared with observed numbers over the past twenty years.

The average number of boxes bushel^{-1} was low, ranging from 4.0 at Nansemond Ridge to 55.0 at Deep Water Shoal. Boxes accounted for less than 6% of the total (live oysters plus boxes) at every site except Nansemond Ridge, where they accounted for about 11% of the total. Approximately 20% of the boxes at Horsehead and Swash were new boxes, indicating some recent mortality at those two sites. Overall however, the majority (greater than 79% at all ten sites) of boxes were old boxes.

Water temperature during the two days of sampling ranged between 18.3 and 19.1°C (Table D2). Salinity was variable depending on location in the river, increasing in a downriver direction, from 11.0 at Deep Water Shoal to 18.6 and 18.4 at Thomas Rock and Nansemond Ridge respectively.

York River

In the York River, the average total number of live oysters bushel^{-1} was 231.5 at Bell Rock and 96.5 at Aberdeen Rock. The total number of oysters at Bell Rock was at the second highest level observed since prior to 1994 (Figure D5) and were primarily a 50/50 split between small and market oysters with very few spat present. At Aberdeen Rock the oysters were primarily small and spat. When compared with 2013, there was a fairly large decrease in both market and small oysters and an increase in spat observed at Aberdeen Rock (Figure D4). At Bell Rock, there was a fairly large increase in the number of market oysters, a notable, but small increase in the number of spat and no change in the number of small oysters observed when compared with 2013 (Figure D4). Despite the small increase in spat at both sites, overall recruitment was relatively low. The average number of boxes bushel^{-1} was low at both sites (26.6 bushel^{-1} at Bell Rock; 8.0 bushel^{-1} at Aberdeen Rock) accounting for approximately 10 and 8% of the total oysters (live oysters plus boxes) at Bell Rock and Aberdeen Rock respectively. At Bell Rock 90% of the total boxes were old boxes, but at Aberdeen, 25% of the total boxes were new boxes, indicating some recent mortality at that site. Water temperature on the day of sampling was around 21°C at both sites. The difference in salinity between the two sites was 3.6: 15.2 at Bell Rock and 18.8 at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters at Tow Stake and Pultz Bar were 196.0 and 291.5 oysters bushel^{-1} respectively. There was a fairly large increase in both small oysters and spat at Pultz Bar when compared with 2013 such that the number of small oysters was the third highest and the number of spat was the second highest observed over the past twenty years of monitoring at that site (Figures D4 and D6). The number of market oysters at Pultz Bar however, remains low (Figure D6). The number of market oysters observed at Tow Stake has remained relatively stable over the past six years (Figure D6), with 2014 ranking the highest observed since prior to 1994 and accounting for approximately 35% of the oysters at that site. The number of spat observed at Tow Stake in 2014 was low, ranking among the lowest observed over the past twenty years of monitoring (Figure D6). The total number of boxes observed in the system was low, accounting for 4 (Pultz Bar) and 8% (Tow Stake) of the total (live oysters plus boxes). The majority of boxes at Tow Stake were old boxes, whereas those at Pultz Bar were primarily a 50/50 split of old and spat boxes. This is not unexpected given that 43% of the live oysters were spat. At Pultz Bar, 56% of the observed spat boxes 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 cinera*, both of which are found in the Chesapeake Bay. On the day of sampling, water temperature was 20.5°C and salinity was between 20 and 21 (Table D2) at both sites.

Piankatank River

The average total number of live oysters in the Piankatank River ranged from a low of 344.5 bushel^{-1} at Burton Point to a high of 789.5 bushel^{-1} at Palace Bar. For the second year in a row, there was an increase in the number of market oysters observed at Burton Point (Figure D7), such that 34% of the live oysters in 2014 were market oysters. The number of market oysters at all three sites has been relatively high (comparing values over the past twenty years) and stable since about 2008, ranking the highest (Burton Point), second highest (Ginney Point) and fourth highest (Palace Bar) recorded over the past twenty years of monitoring (Figure D8). There was a notable decrease in the number of small oysters at Ginney Point when compared with 2013 (Figures D7 and D8). However, the number of small oysters at all three sites was relatively high, ranking the fifth highest (Ginney Point), fourth highest (Palace Bar) and second highest (Burton Point) over the past twenty years of monitoring (Figure D8). When compared with 2013, there was a notable increase in the number of spat at all three sites (Figure D7). The number of boxes observed was low, accounting for 3 (Palace Bar) to 6% (Burton Point) of the total (live oysters plus boxes). At Ginney Point, 29% of the boxes were new boxes, indicating some recent mortality at that site. On the day of sampling, water temperature ranged between 20.1 (Ginney Point) and 21.0ºC (Palace Bar) and salinity was around 17.5.

Rappahannock River

In the Rappahannock River, the average total number of live oysters bushel^{-1} ranged from a low of 45.0 at Morattico Bar to a high of 196.0 at Middle 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. With the exception of Ross Rock, this pattern again held true during 2014. 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, remaining relatively stable over the past two years.

The average number of market oysters bushel^{-1} ranged from 9.5 (Middle Ground) to 94.5 (Ross Rock). When compared with 2013, there was a small increase in the number of market oysters observed at Hog House and a small decrease at Morattico Bar and Smokey Point (Figure D9 and D10). Overall the number of market oysters in the Rappahannock River in recent years has been on the rise and 2014 ranked among the highest to fourth highest over the past twenty years at seven out of the ten sites monitored. At six out of the ten sites (Ross Rock, Bowler's Rock, Long Rock, Morattico Bar, Hog House and Parrot Rock) market oysters accounted for greater than 55% of the total live oysters and greater than 25% at every site except Middle Ground. The number of market oysters at Ross Rock has been slowly but steadily increasing since 2008 such that there were approximately twice as many market oysters observed in 2014 compared with 2008 (Figure D10A).

When compared with 2013, there was a fairly large decrease in the number of small oysters observed at Drumming Ground and 2014 marked the first time in thirteen years that Drumming Ground did not have the highest number of small oysters bushel^{-1} (Figure D9 and D10) in the system. There was a notable increase in the number of small oysters observed at Bowler's Rock, Long Rock and Middle Ground and a decrease at Smokey Point and Broad Creek when compared with 2013 (Figure D9). At Hog House and Ross Rock the number of small oysters ranked the highest and third highest numbers observed at those sites respectively since prior to 1994 (Figure D10)

Overall, recruitment in the Rappahannock River in 2014 was relatively low, ranging from a complete lack of recruitment at Long Rock to a high of 38.0 spat bushel^{-1} at Broad Creek. There was at least one spat found at all of the sites except Long Rock. For the second year in a row, recruitment at Drumming Ground was among the lowest observed at that site during the past twenty years of monitoring (Figure D10C). When compared to 2013, there was a notable increase in the number of spat observed at Broad Creek (Figure D9), however recruitment at Broad Creek in 2013 was extremely low and 2014 was only slightly higher.

The average total number of boxes bushel^{-1} was low to moderate, accounting for 3 (Ross Rock and Bowler's Rock) to 14% (Drumming Ground) of the total (live oysters plus boxes). Greater than 24% of the total boxes at Long Rock, Middle Ground and Broad Creek were new boxes, indicating some recent mortality at those sites.

Water temperature on the day of sampling ranged from 20.3 to 21.1°C. Salinity increased as one moved from the most upriver site (Ross Rock: 9.2) toward the mouth (Broad Creek: 18.5).

Great Wicomico River

In the Great Wicomico River, the average total number of live oysters bushel^{-1} ranged from a low of 330.0 at Fleet Point to a high of 516.5 at Haynie Point. Overall the total number of oysters at Fleet Point and Whaley's East was relatively high, ranking the fourth highest and third highest respectively over the past twenty years of monitoring (Figure D12). If you only include small and market size oysters, 2014 had the highest (Whaley's East), second highest (Fleet Point) and third highest (Haynie Point) counts over the past twenty years (Figure D12) of monitoring. When compared with 2013 numbers, there was a notable increase in market oysters and a decrease in small oysters at both Haynie Point and Fleet Point (Figure D11). There was also a small but notable increase in the number of small oysters observed at Whaley's East (Figure D11). Overall, recruitment in 2014 was relatively moderate, especially compared to the high numbers that have become more prevalent in the system over the past several years (since about 2006). The total number of boxes bushel^{-1} was low accounting for less than 8% of the total (live oysters plus boxes) at all three sites. Around 22% of the boxes at Fleet Point were new boxes, indicating some recent mortality at that site. Water temperature on the day of sampling was between 19.7 and 20.2°C and salinity was around 17.5 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 20th century (Hargis & Haven 1995, Rothschild et al. 1994). For the past few 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 52.9 market oysters bushel^{-1}). However, over the past eight years, the number of market oysters on the thirty bars that are sampled annually has been on the rise, going from an average of 16.5 bushel^{-1} in 2007 to an average of 52.9 bushel^{-1} in 2014, a little over a three-fold increase.

For the past several decades, the bulk of Virginia's oyster population has been composed primarily of small oysters and spat. During 2014, the majority of the oysters were primarily small, making up approximately 73% of the total oysters observed across all of the bars and river systems sampled. At seventeen of the thirty sites monitored small oysters accounted for greater than 50% of the live oysters. Ross Rock, Bowler's Rock, Long Rock, Morattico Bar, Hog House and Parrot Rock all in the Rappahannock River were the only sites with greater than 50% market oysters. However, three of these sites, Bowler's Rock, Morattico Bar and Hog House, all have relatively low (less than 100 oysters bushel^{-1}) oyster populations. The oyster population in the Piankatank River has been steadily increasing since 2004. This increase has followed a large die-off of broodstock oysters that occurred in late 2003 early 2004 (Southworth et al. 2005). The numbers of both small and market oysters at all three sites in the Piankatank in 2014 were among the highest observed over the past twenty years of monitoring.

Recruitment during 2014 varied widely throughout the Virginia portion of the bay, but with the exception of the three Piankatank River sites and Pultz Bar in Mobjack Bay, it was relatively low to moderate when compared with recruitment numbers over the past twenty years. Recruitment in the Piankatank River was relatively moderate to high when compared to that observed over the past twenty years, ranking the fifth highest at all three sites, but this was still two (Ginney Point) to ten (Burton Point) times lower than the highest observed during the time period. Long Rock in the Rappahannock River was the only site out of the thirty monitored that had a complete lack of recruitment. In the Rappahannock River, recruitment tends to be highest at the more downriver sites (see Figure D1), but for the second year in a row, recruitment at both Drumming Ground and Broad Creek (two of the most downriver sites) was relatively low.

The average total number of boxes observed during 2014, was low to moderate at most sites, accounting for less than 14% of the total (live oysters plus boxes) oysters at all thirty sites and less than 10% of the total (live oysters plus boxes) at twenty-five 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 2014 Nansemond Ridge was the only site that had a relatively large number of small and market size boxes (approximately 26% of the total, live and dead) and the oyster population at that site has remained very low for several years. At the majority of the other sites (twenty-four of twenty-nine), 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 2014, there was a live *Urosalpinx cinerea* caught in the dredge at Nansemond Ridge in the James River and there were drill holes present in spat boxes at Pultz Bar in the Mobjack Bay. The presence of drill holes 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 mouths of the Piankatank and Rappahannock Rivers, and in Mobjack Bay. While Pultz Bar was the only site where drill holes were observed during the 2014 survey, predation by oyster drills in the lower reaches of the western Chesapeake Bay tributaries continues to be a problem as noted by the presence of drill holes as well as the collection of live animals of both drill species at multiple sites in the James, Piankatank and Rappahannock Rivers and Mobjack Bay during the patent tong survey in November and December of 2014 (Southworth, personal observation).

Table D1: Station locations for the 2014 VIMS fall dredge survey.

Station	Latitude	Longitude
James River		
Deep Water Shoal	37 08 06	76 38 08
Mulberry Point	37 07 09	76 37 55
Horsehead	37 06 24	76 38 02
Point of Shoal	37 04 33	76 38 32
Swash	37 05 32	76 36 44
Long Shoal	37 04 31	76 36 07
Dry Shoal	37 03 41	76 36 14
Wreck Shoal	37 03 37	76 34 20
Thomas Rock	37 01 32	76 29 33
Nansemond Ridge	36 55 20	76 27 10
York River		
Bell Rock	37 29 03	76 44 59
Aberdeen Rock	37 20 07	76 36 02
Mobjack Bay		
Tow Stake	37 20 20	76 23 10
Pultz Bar	37 21 11	76 21 10
Piankatank River		
Ginney Point	37 32 00	76 24 12
Palace Bar	37 31 36	76 22 12
Burton Point	37 30 54	76 19 42
Rappahannock River		
Ross Rock	37 54 04	76 47 21
Bowler's Rock	37 49 36	76 44 07
Long Rock	37 48 59	76 42 50
Morattico Bar	37 46 55	76 39 33
Smokey Point	37 43 09	76 34 56
Hog House	37 38 19	76 32 30
Middle Ground	37 41 00	76 28 24
Drumming Ground	37 38 38	76 27 59
Parrot Rock	37 36 21	76 25 20
Broad Creek	37 34 37	76 18 03
Great Wicomico River		
Haynie Point	37 49 47	76 18 33
Whaley's East	37 48 31	76 18 00
Fleet Point	37 48 35	76 17 19

Table D2: Results of the Virginia public oyster grounds survey, Fall 2014. 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	10/21	19.1	11.0	91.0	468.0	17.5	576.5	1.5	32.5	0.0	34.0
Mulberry Point	10/21	18.7	12.2	17.5	1217.0	26.5	1261.0	4.0	51.0	0.0	55.0
Horsehead	10/21	18.8	14.3	25	1308.5	55	1388.5	9.5	38.5	0	48.0
Point of Shoal	10/21	18.4	14.0	93.0	780.0	52.0	925.0	6.0	40.5	0.0	46.5
Swash	10/21	18.9	16.6	18.0	823.0	78.5	919.5	9.5	38.0	0.5	48.0
Long Shoal	10/21	18.9	16.4	30.0	1188.5	76.0	1294.5	4.0	35.0	0.0	39.0
Dry Shoal	10/21	19.1	17.8	66.0	643.5	34.5	744.0	4.5	22.0	0.0	26.5
Wreck Shoal	10/21	18.7	17.4	93.5	268.5	31.0	393.0	3.0	21.5	1.0	25.5
Thomas Rock	10/20	18.8	18.6	27.0	78.0	109.5	214.5	1.5	9.5	1.0	12.0
Nansemond Ridge	10/20	18.3	18.4	2.5	9.0	22.5	34.0	0.0	4.0	0.0	4.0
York River											
Bell Rock *	10/8	20.7	15.2	99.5	119.5	12.5	231.5	2.0	24.0	0.6	26.6
Aberdeen Rock	10/8	20.8	18.8	16.0	31.5	49.0	96.5	2.0	6.0	0.0	8.0
Mobjack Bay											
Tow Stake	10/8	20.5	20.3	69.0	119.0	8.0	196.0	3.0	13.0	0.0	16.0
Pultz Bar	10/8	20.4	20.8	1.5	166.0	124.0	291.5	1.5	4.5	4.5	10.5
Piankatank River											
Ginney Point	10/9	20.1	17.5	93.0	209.0	244.0	546.0	6.0	13.0	1.5	20.5
Palace Bar	10/9	21.0	17.7	38.0	334.5	417.0	789.5	1.0	14.0	8.0	23.0
Burton Point	10/9	20.9	17.6	118.5	145.5	80.5	344.5	2.0	18.0	0.5	20.5
Rappahannock River											
Ross Rock	10/16	20.3	9.2	94.5	74.5	2.5	171.5	0.0	5.5	0.0	5.5
Bowler's Rock	10/16	20.4	12.2	45.0	22.5	1.5	69.0	0.0	2.0	0.0	2.0
Long Rock	10/16	20.4	13.5	85.5	17.5	0.0	103.0	1.0	3.0	0.0	4.0
Morattico Bar	10/16	20.6	14.9	32.5	11.5	1.0	45.0	0.0	3.5	0.0	3.5
Smokey Point	10/16	20.6	16.0	18.5	26.5	3.5	48.5	0.0	2.5	0.0	2.5
Hog House	10/16	20.6	17.0	50.0	32.0	10.5	92.5	0.0	4.5	0.0	4.5
Middle Ground #	10/16	21.1	16.7	9.5	162.5	24.0	196.0	2.5	8.0	0.0	10.5
Drumming Ground	10/16	20.7	17.2	37.5	92.0	15.5	145.0	4.0	19.0	0.0	23.0
Parrot Rock	10/16	20.6	17.5	67.0	40.0	11.0	118.0	1.5	16.0	0.0	17.5
Broad Creek	10/16	20.9	18.5	52.5	67.0	38.0	157.5	5.5	15.0	0.5	21.0
Great Wicomico River											
Haynie Point	10/14	20.2	17.5	97.0	297.0	122.5	516.5	5.0	36.5	2.5	44.0
Whaley's East	10/14	19.7	17.6	26.0	357.5	109.0	492.5	2.5	12.0	1.0	15.5
Fleet Point	10/14	19.8	17.5	71.0	204.5	54.5	330.0	5.5	17.5	1.5	24.5

Figure D1: Map showing the location of the oyster bars sampled during the 2014 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.

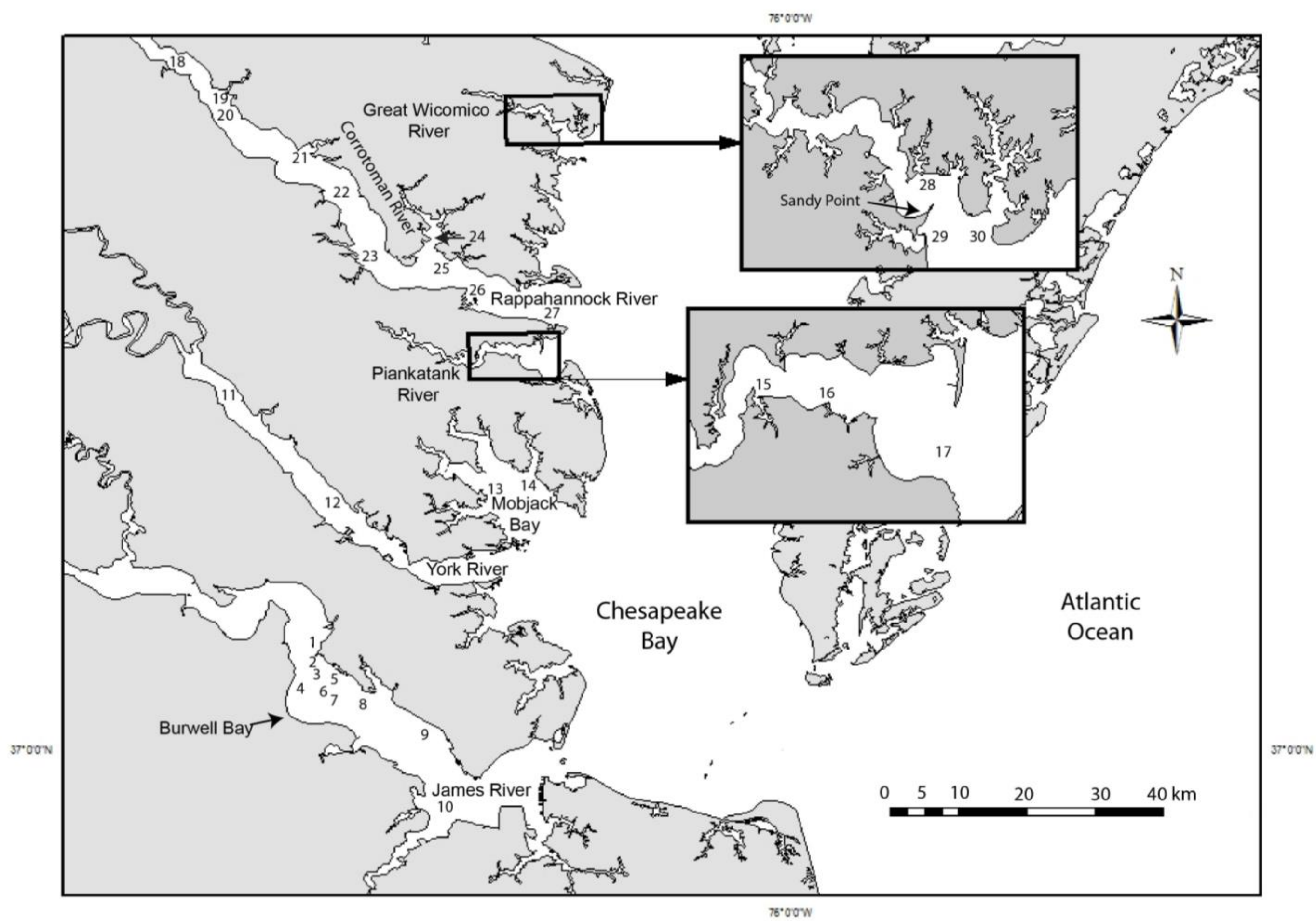


FIGURE D2: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE JAMES RIVER (2013-2014)
(Error bars represent standard error of the mean)

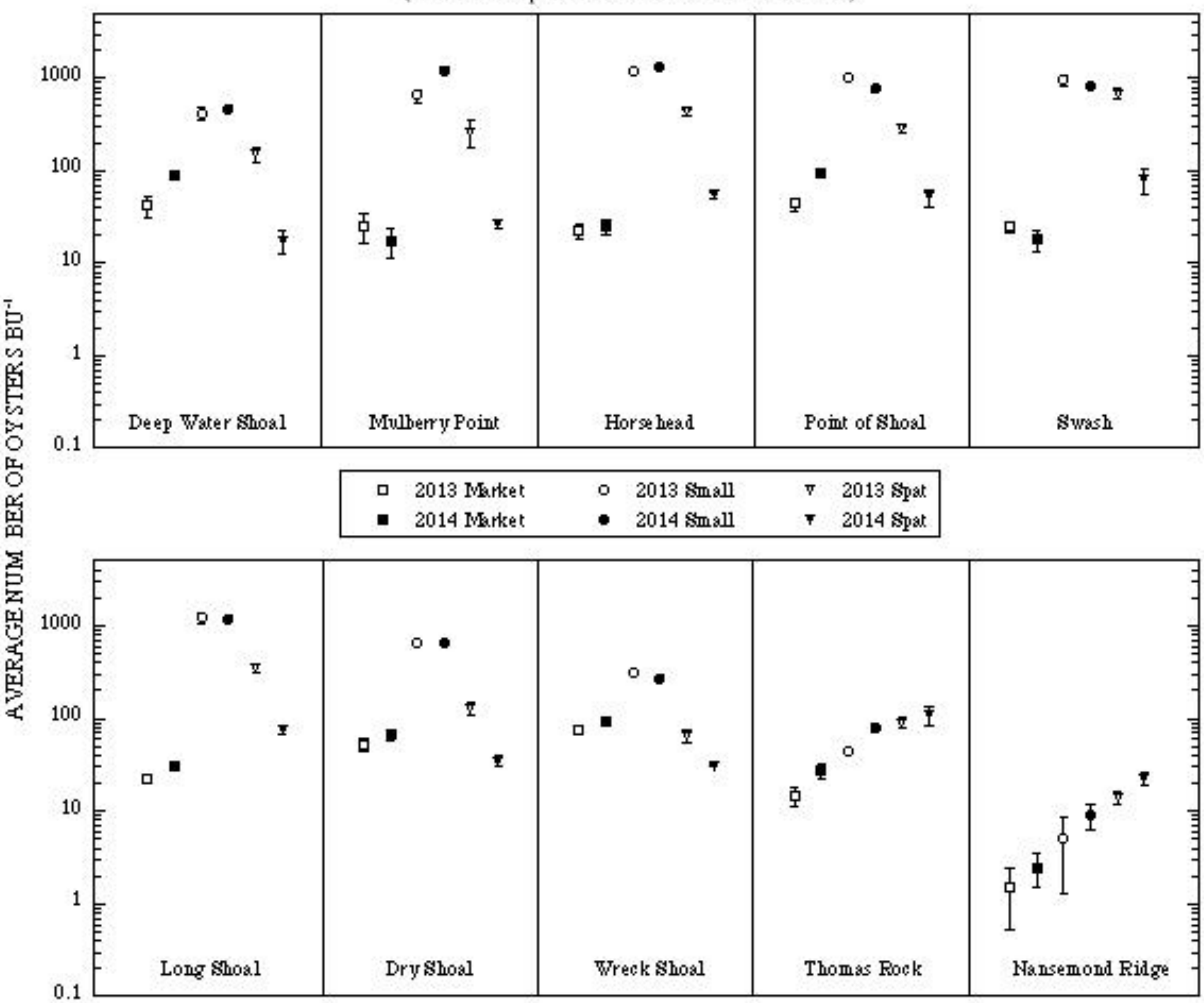


FIGURE D3A: JAMES RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

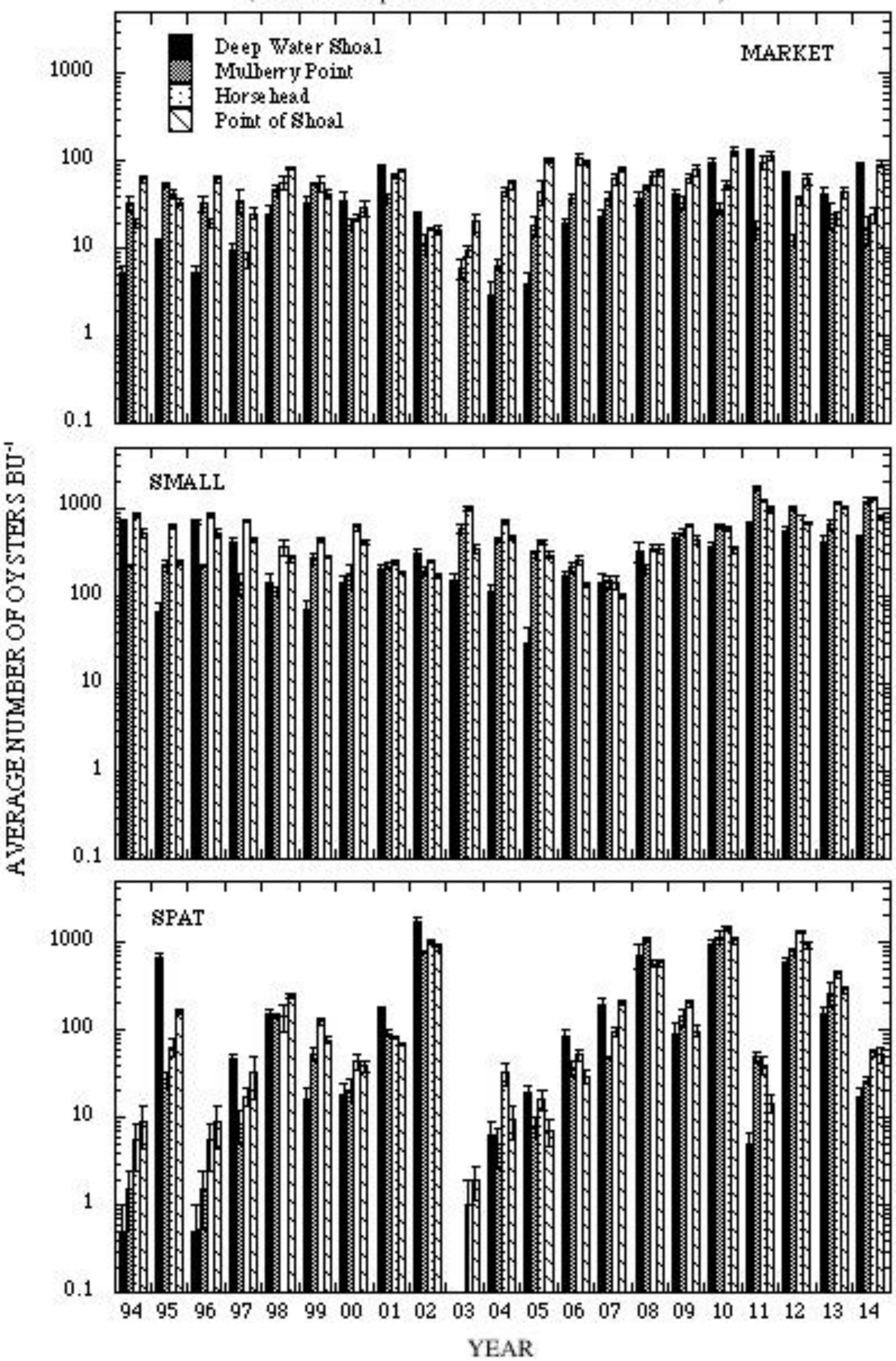
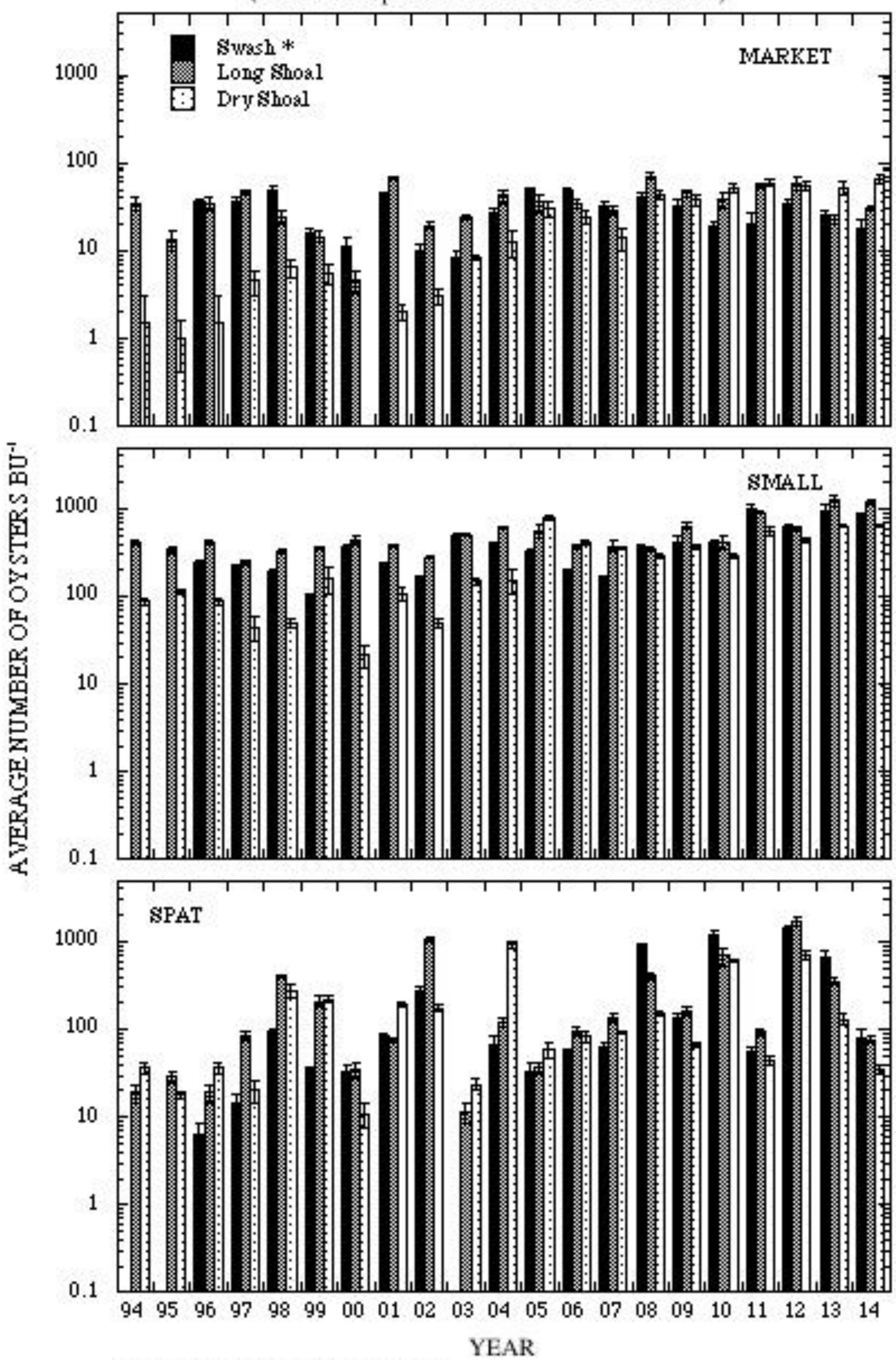


FIGURE D3B: JAMES RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No samples collected prior to 1996

FIGURE D3C: JAMES RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

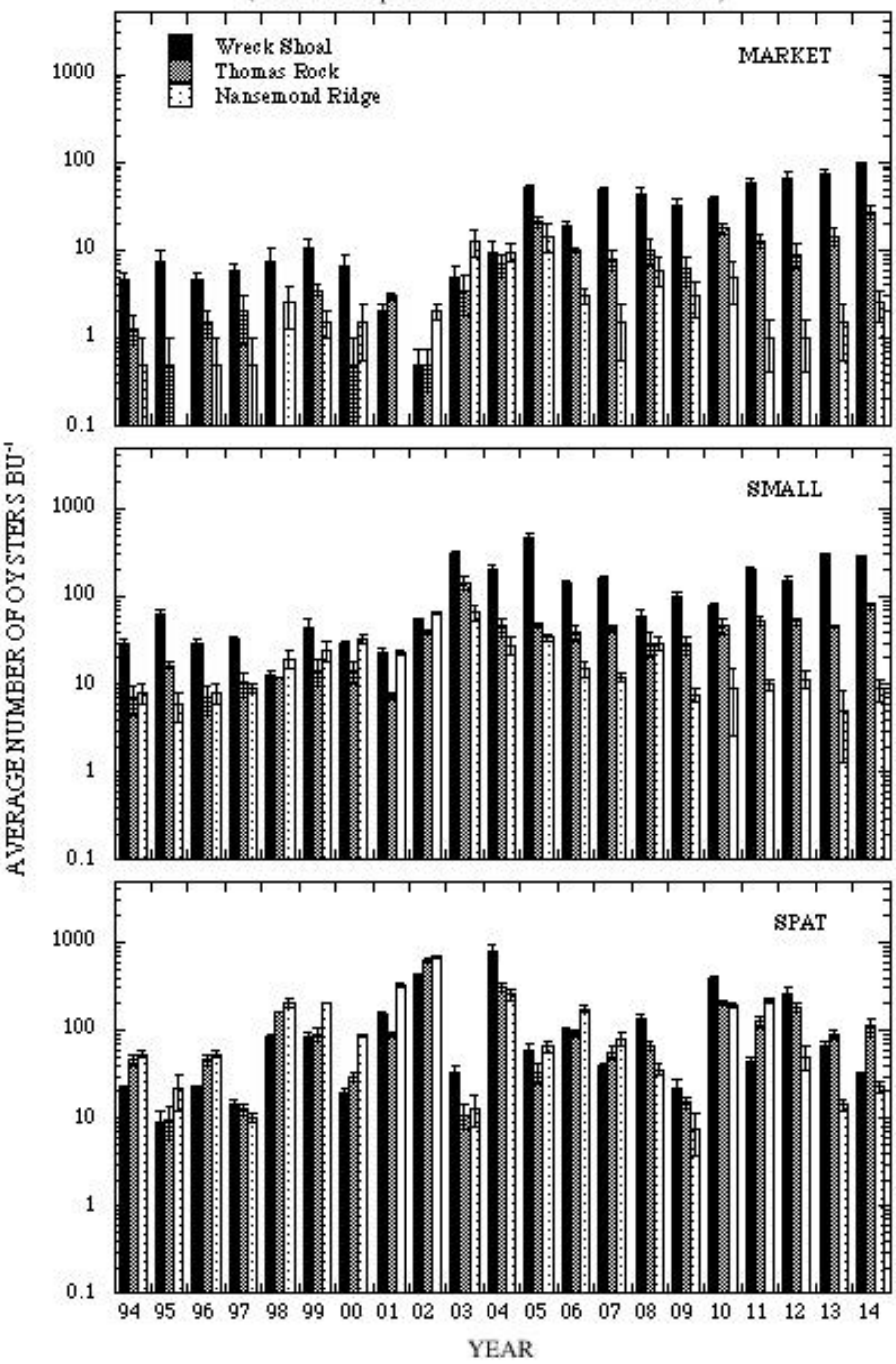


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE YORK RIVER AND MOBJACK BAY (2013-2014)
(Error bars represent standard error of the mean)

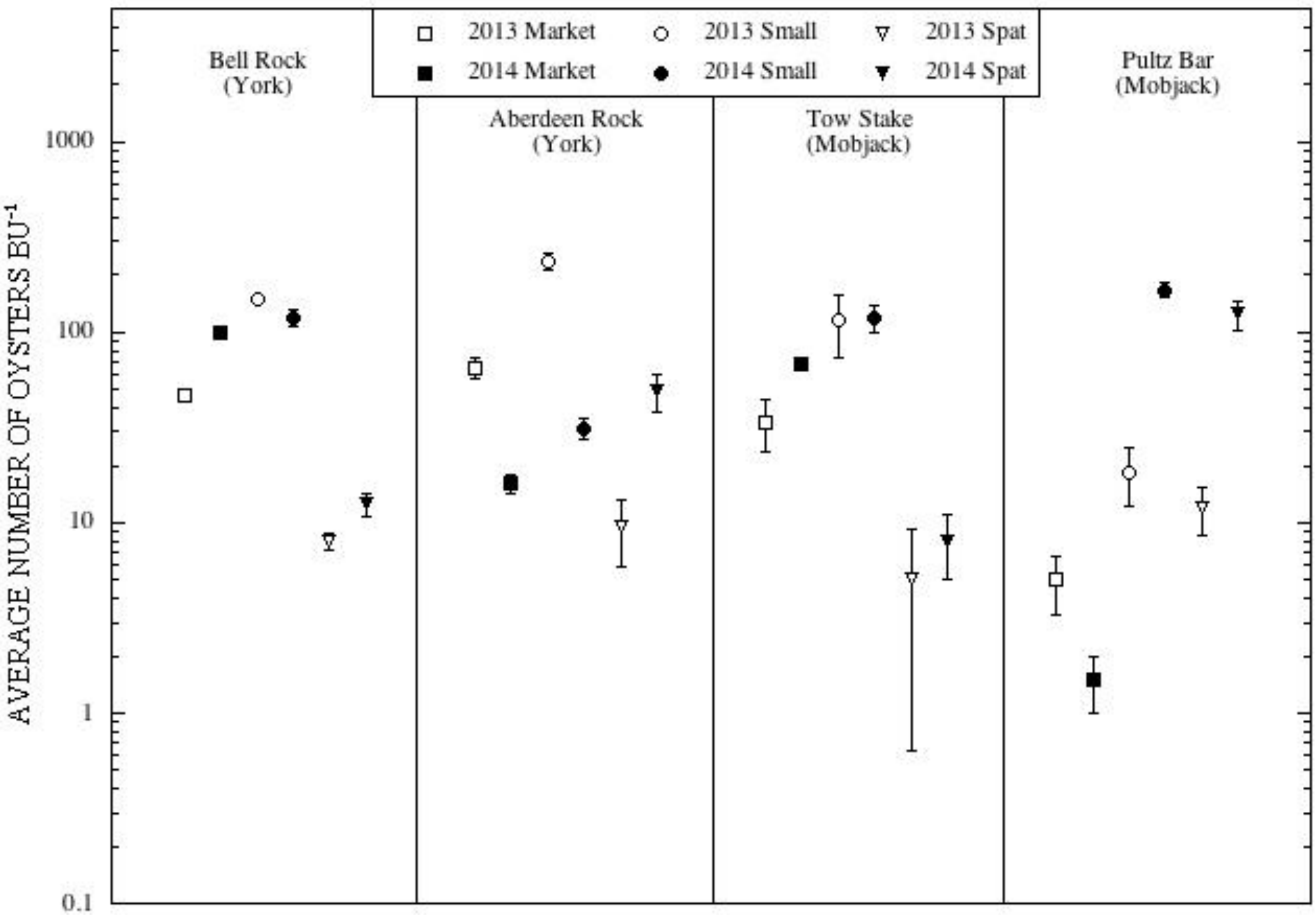


FIGURE D5: YORK RIVER OYSTER TRENDS OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

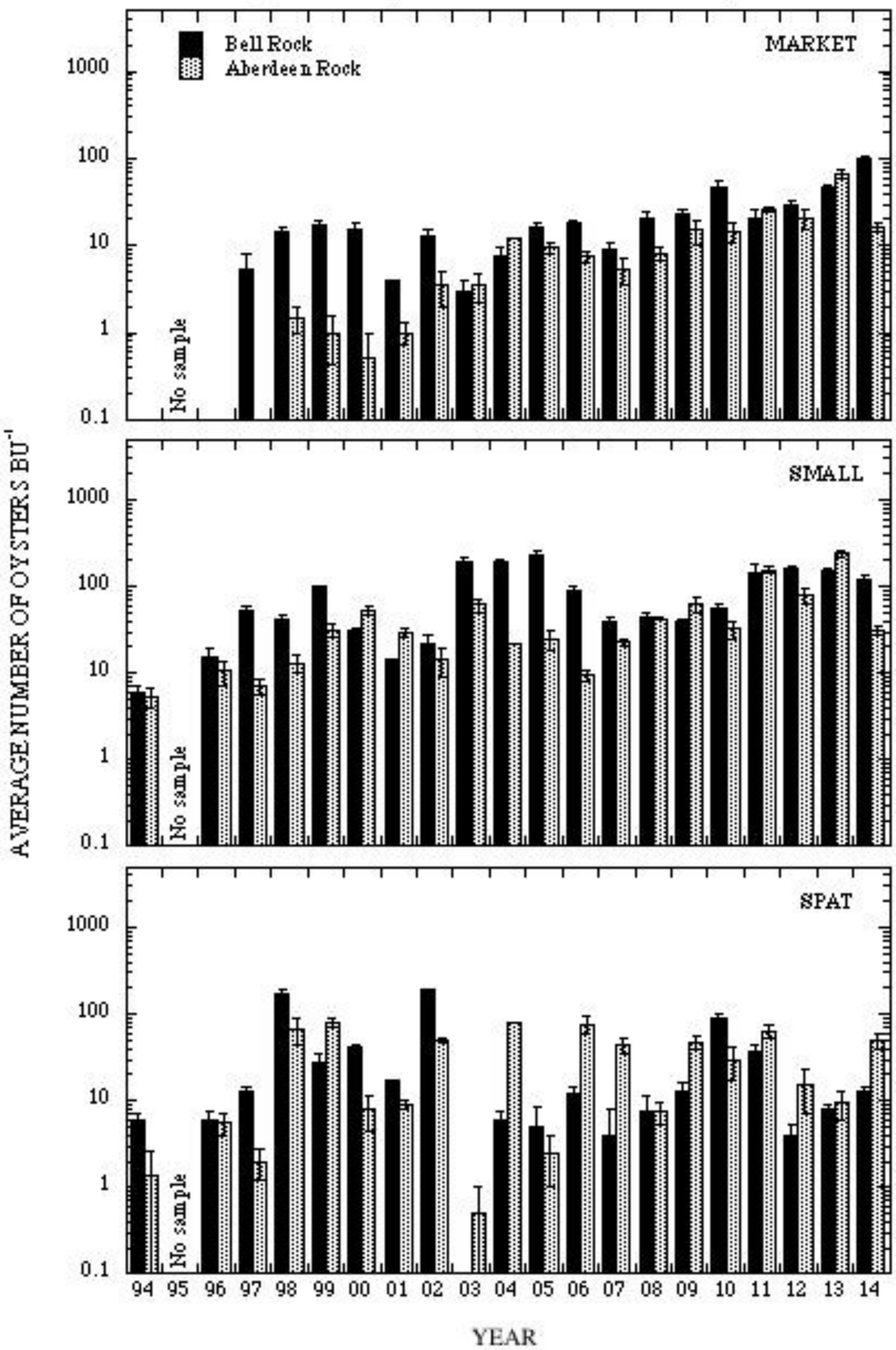


FIGURE D6: MOBJACK BAY OYSTER TRENDS OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

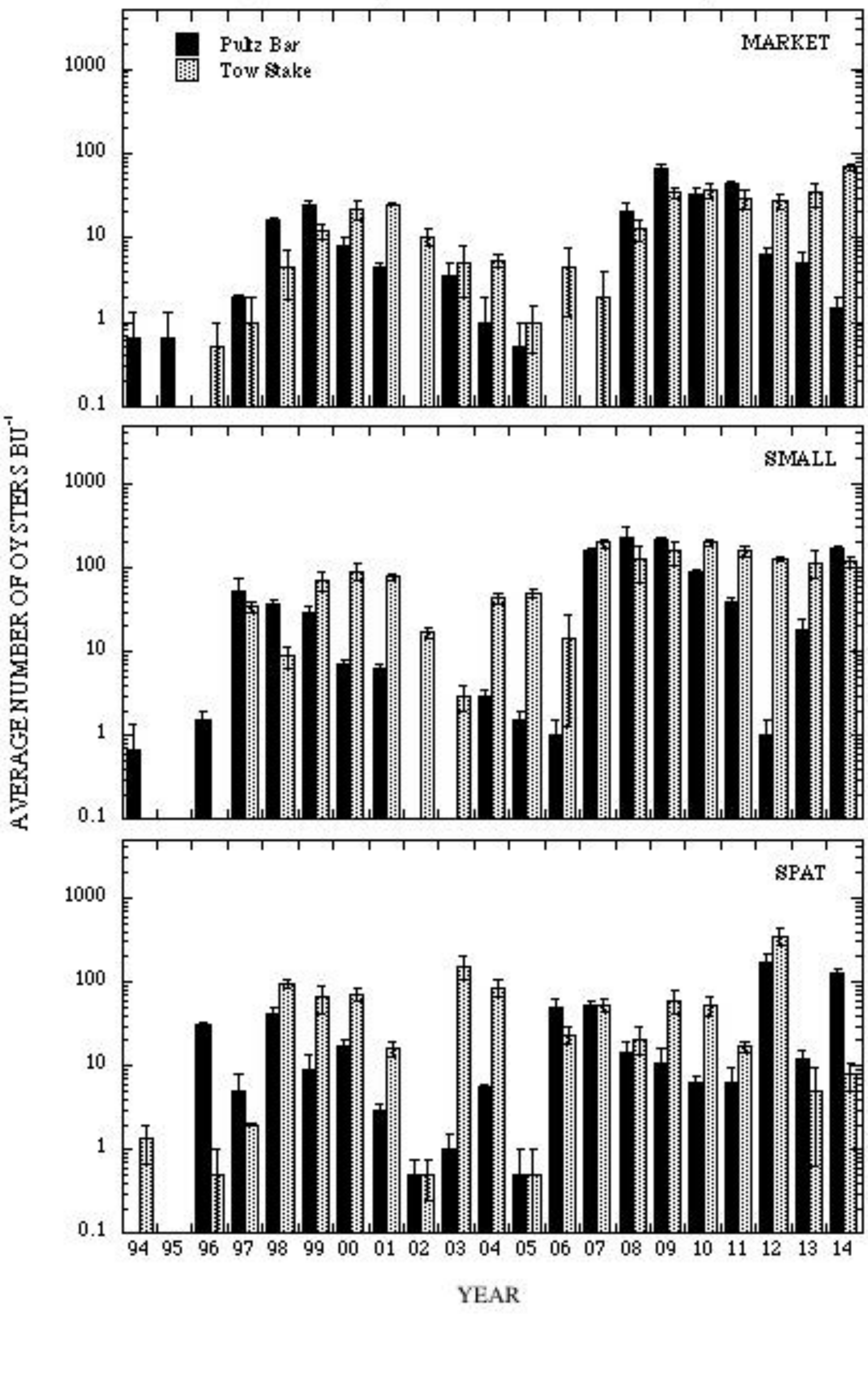


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE PIANKATANK RIVER (2013-2014)
(Error bars represent standard error of the mean)

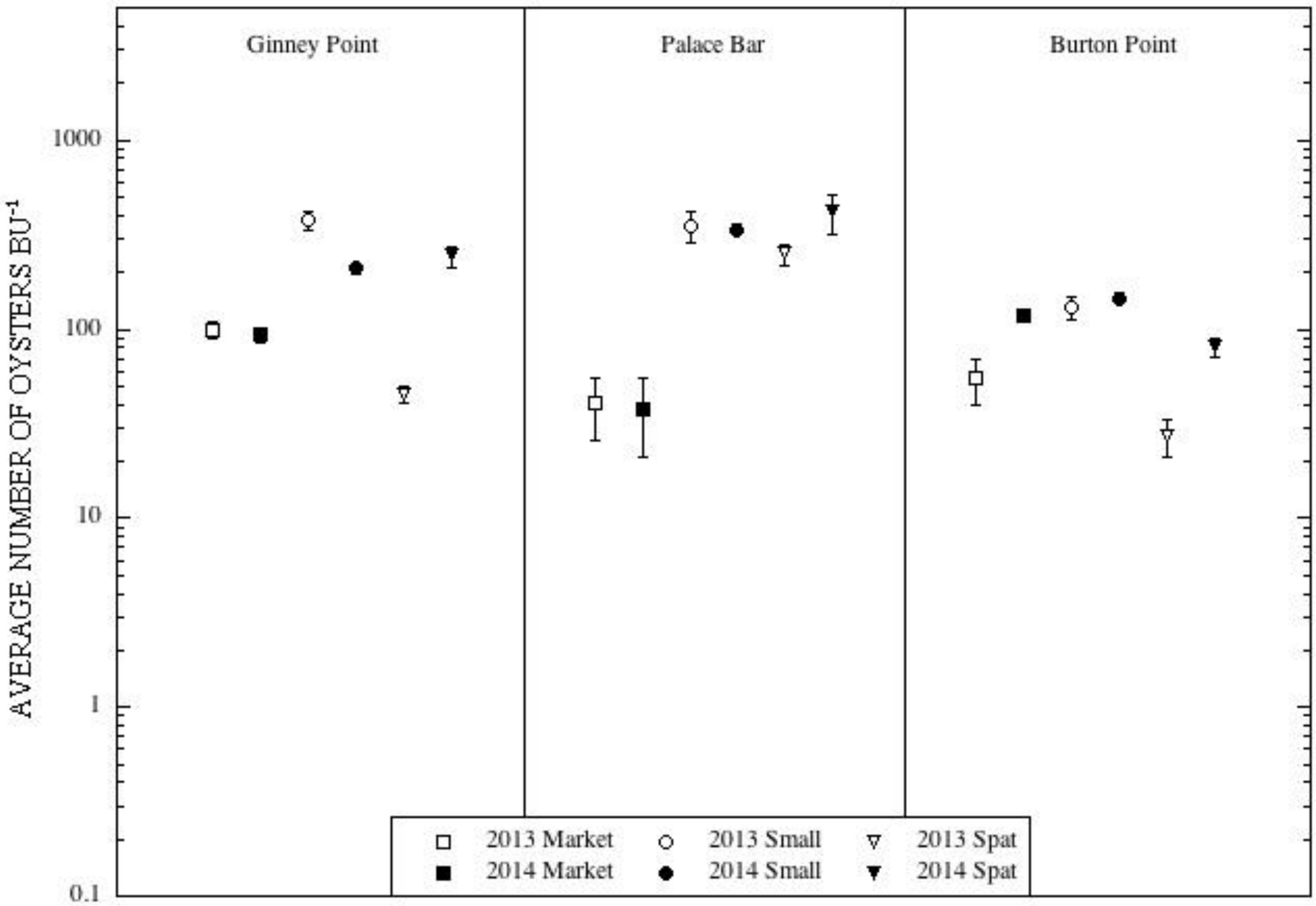


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

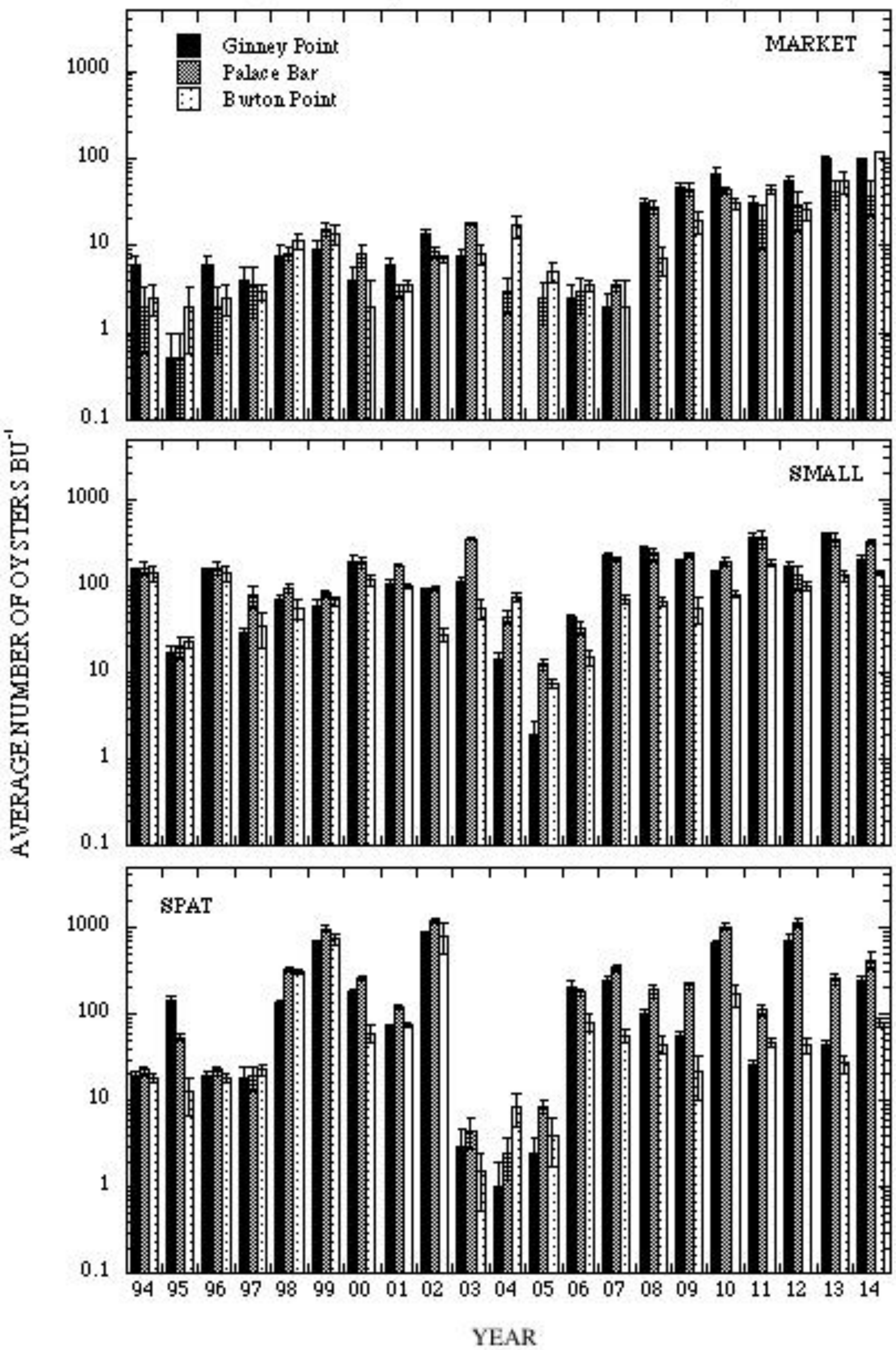


FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2013-2014)
(Error bars represent standard error of the mean)

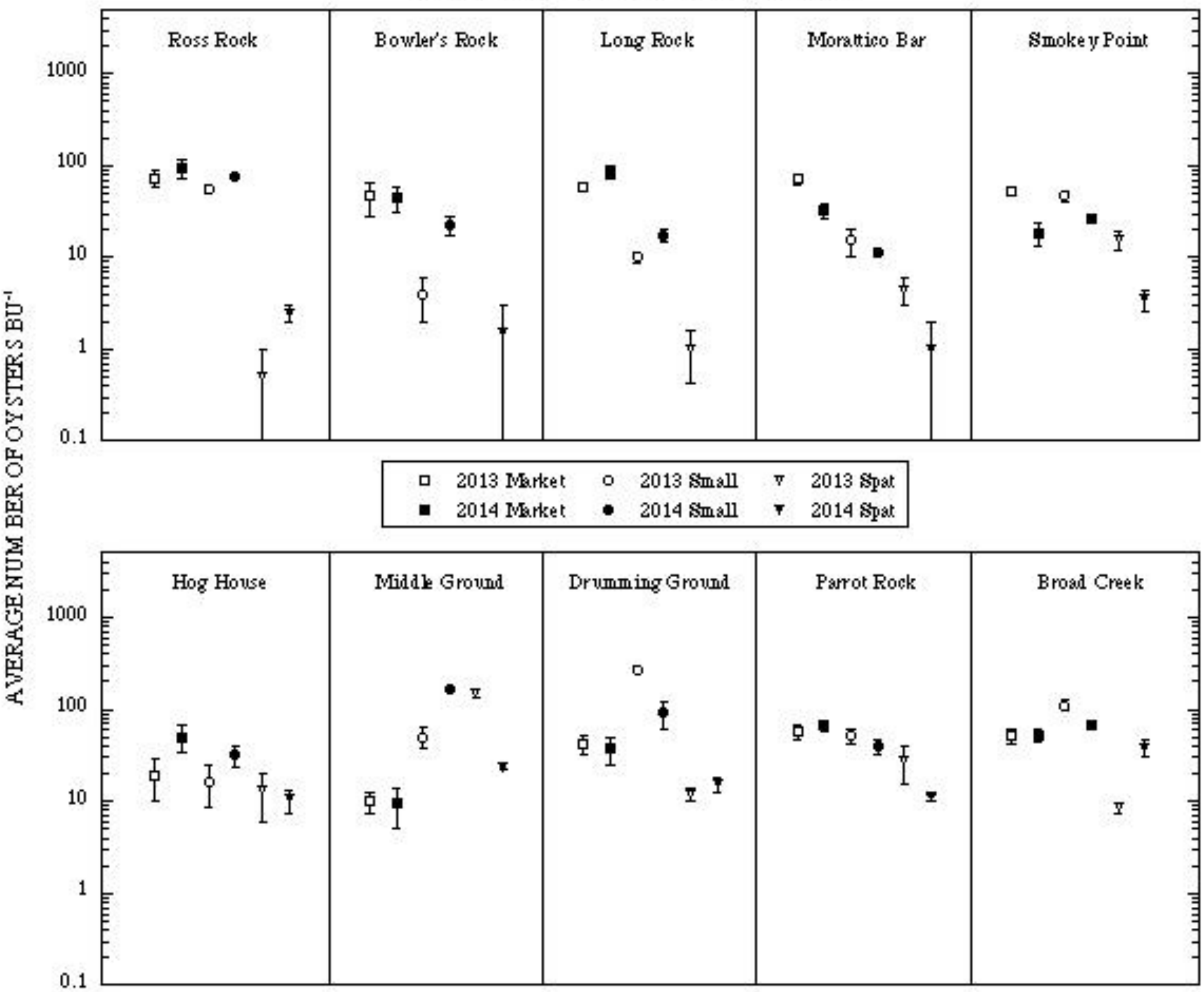


FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

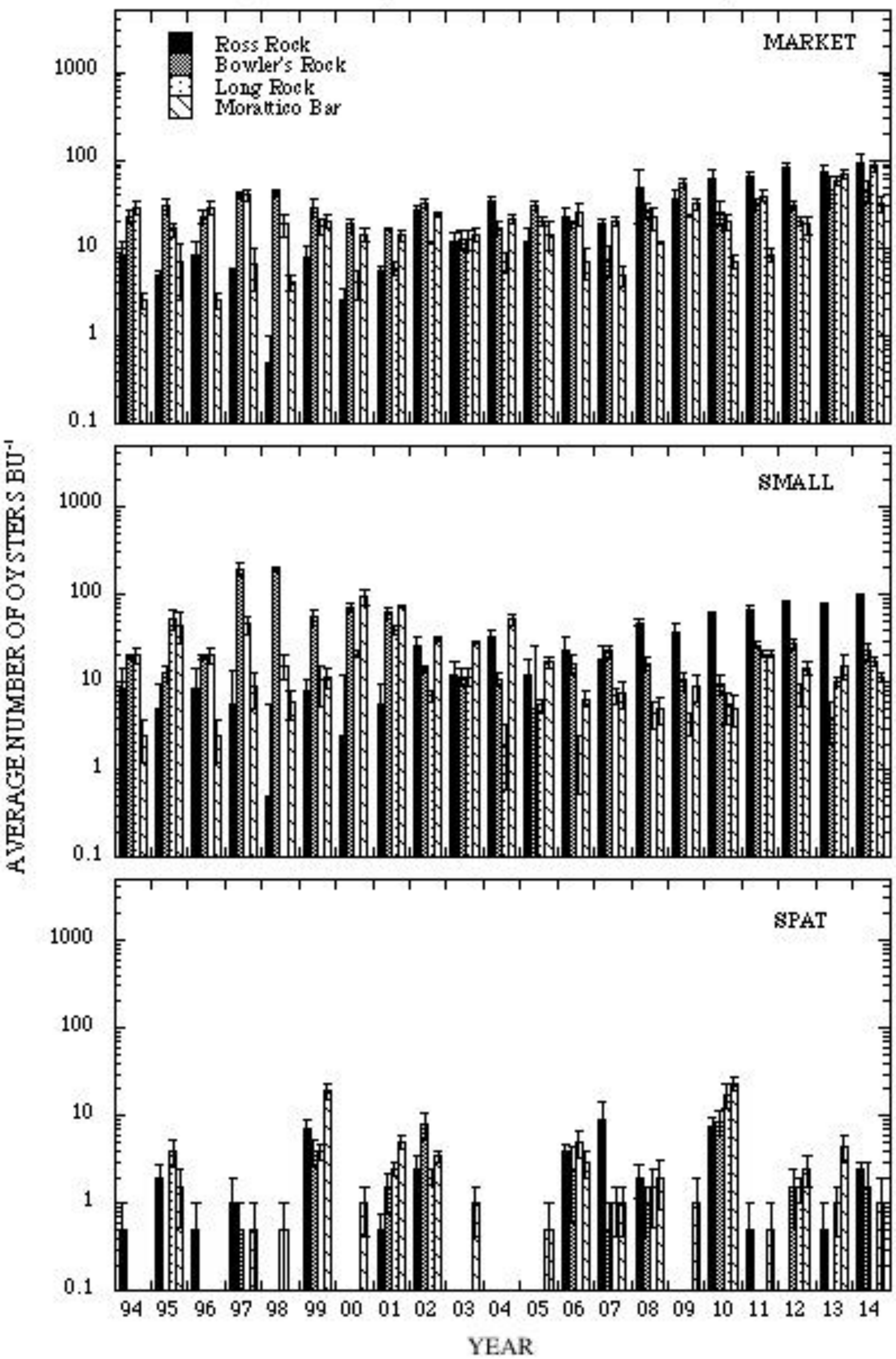


FIGURE D10B: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

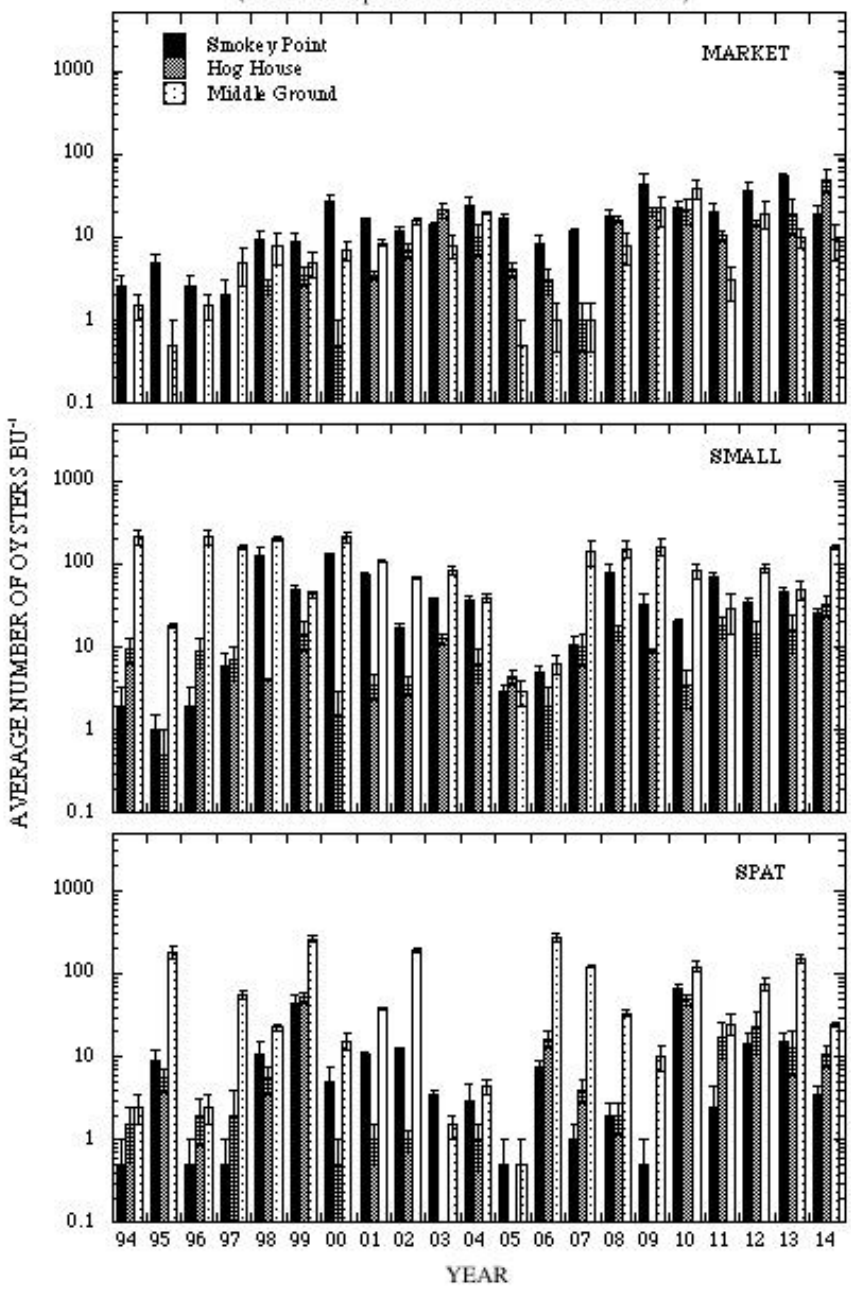
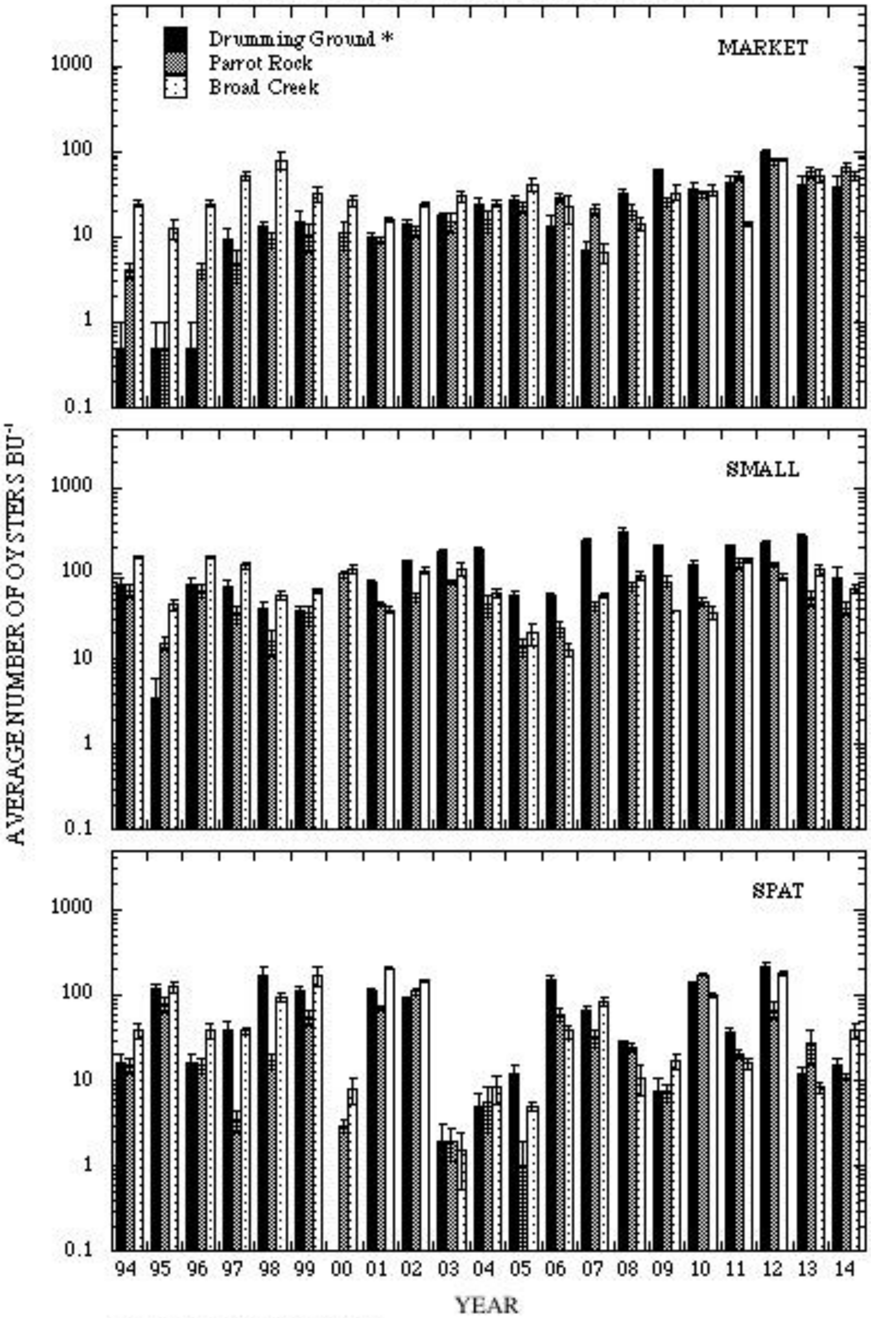


FIGURE D10C: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No sample collected in 2000

FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE GREAT WICOMICO RIVER (2013-2014)
(Error bars represent standard error of the mean)

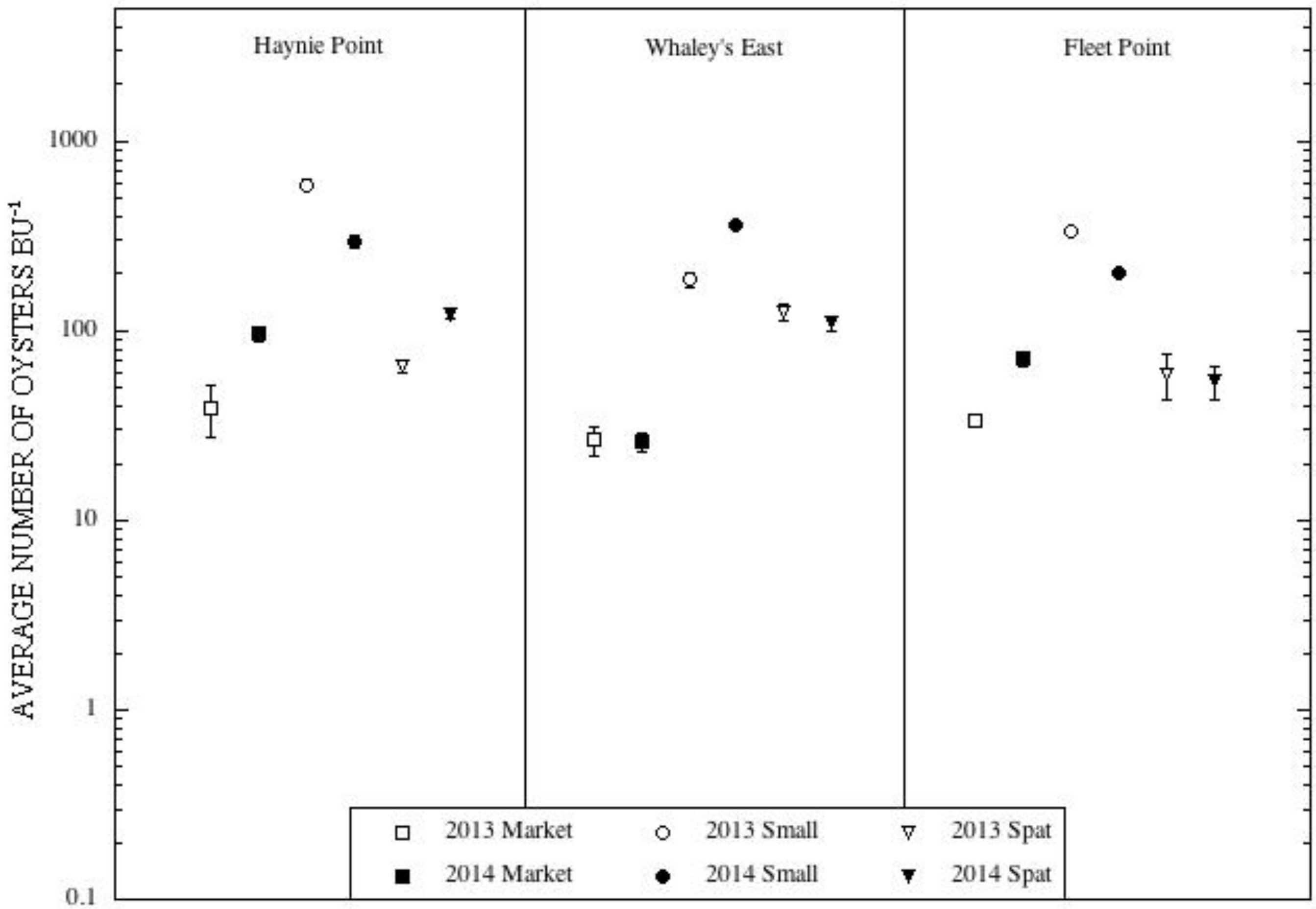
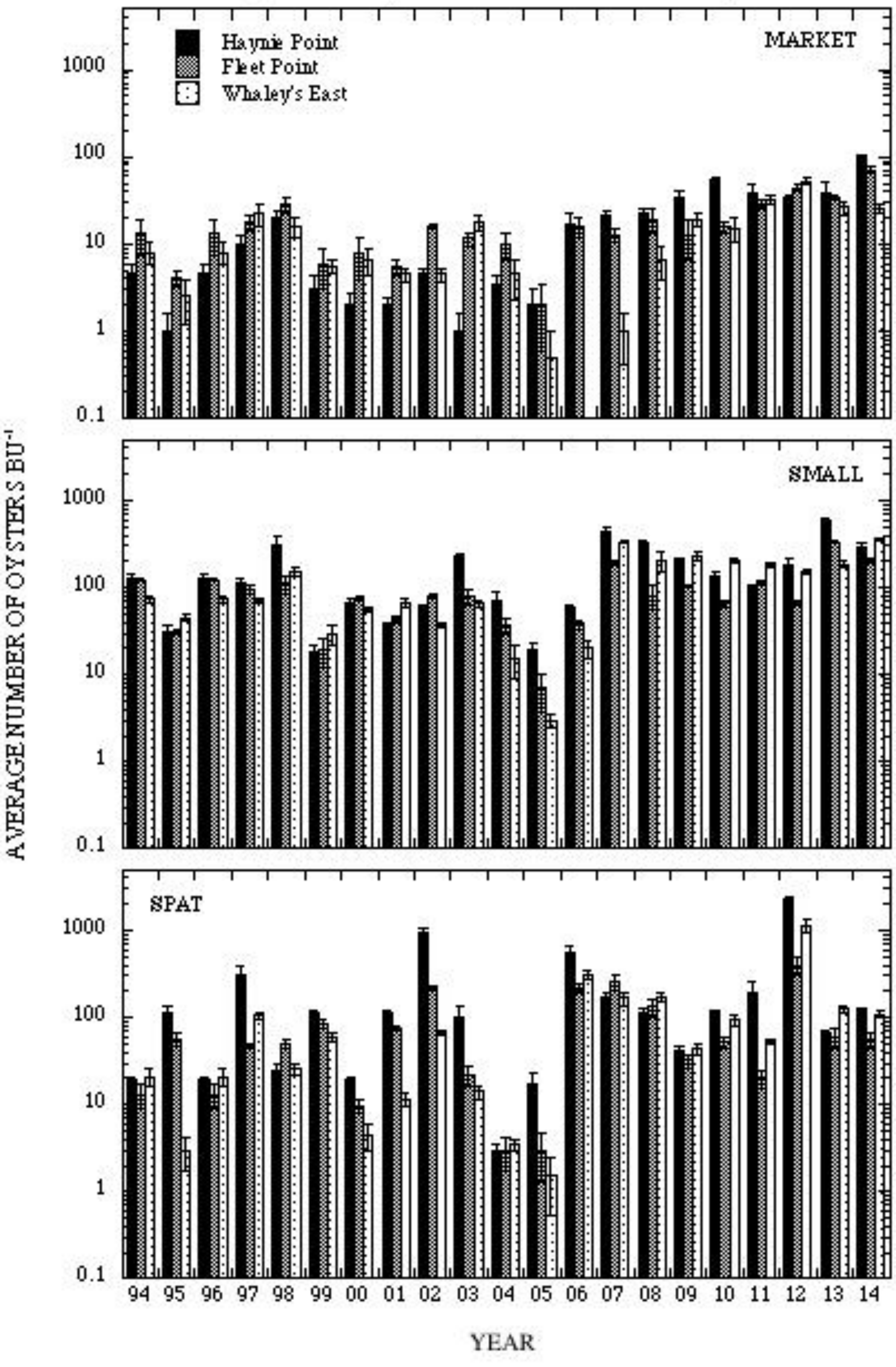


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



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