2010

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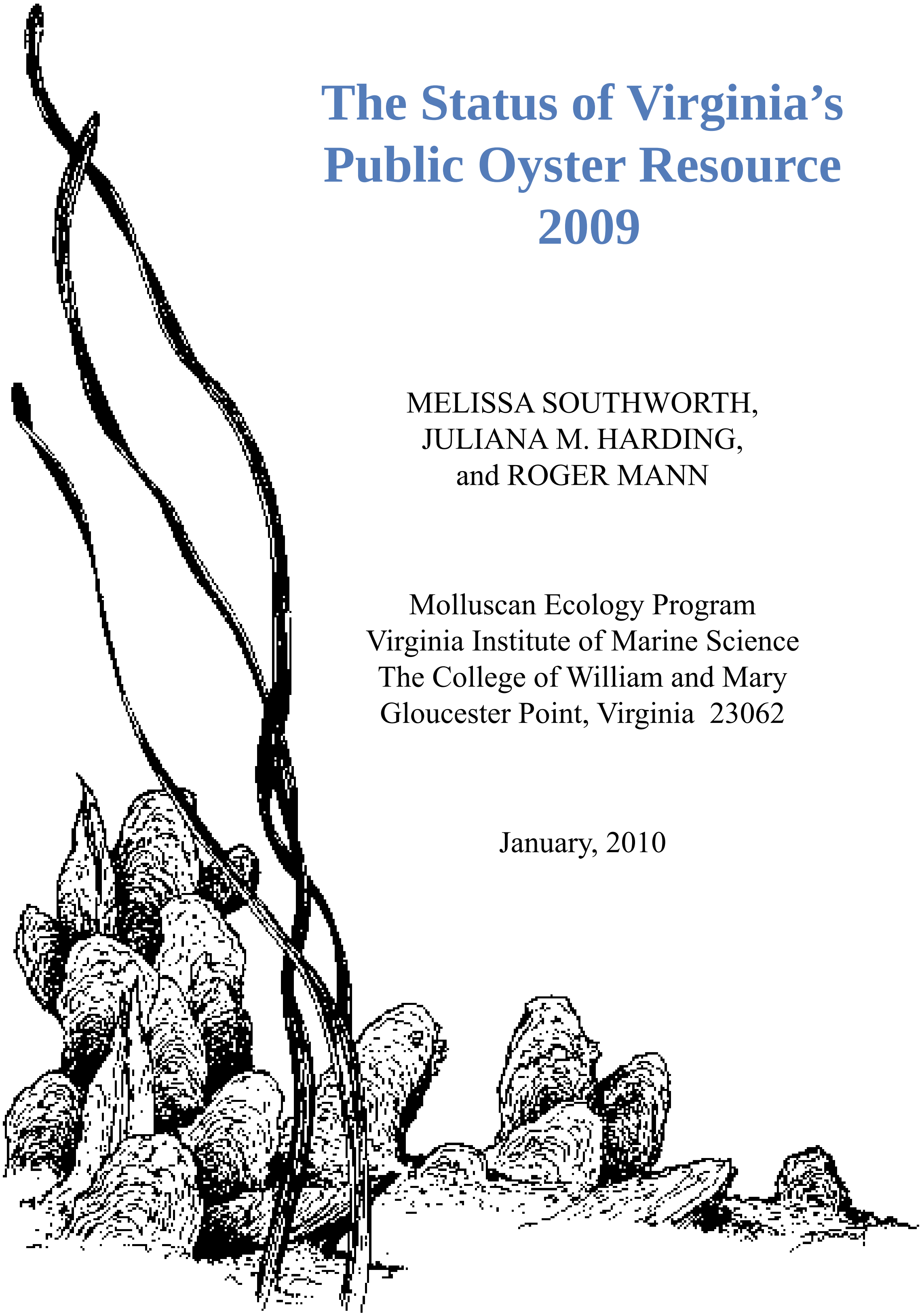

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Proper citation for this report:

Southworth, M., J.M. Harding, and R. Mann. 2010. The status of Virginia's public oyster resource 2009. Molluscan Ecology Program, Virginia Institute of Marine Science, Gloucester Point, Virginia, College of William and Mary. https://doi.org/10.21220/V5459R

Part I.

Oyster Spatfall In Virginia During 2009

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 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 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 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 2009 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2009 was monitored from the last week of May through the last week of September in the James, Piankatank and Great Wicomico Rivers. Spatfall sites included eight historical sites in the James River, three historical and five modern sites in the Piankatank River and five historical and four modern sites in the Great Wicomico River (Figure S1). In this report, "historical" sites refer to those that have been monitored annually for at least the past twenty years whereas "modern" sites are sites that were added during 1998 to 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. Since 1993, the Virginia Marine Resources Commission (VMRC) has built numerous artificial oyster shell reefs in several tributaries of the western Chesapeake Bay, in both Pocomoke and Tangier Sounds on the eastern side of the Chesapeake Bay as well as in several embayments on the Eastern Shore of Virginia (http://www.vims.edu/mollusc/monrestoration/restsitemaps/Varfrestsite.htm). 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 provide 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 both broodstock oysters on the reef and shell plants on the bottom surrounding the reefs.

Oyster shellstrings were used to monitor oyster spatfall. A shellstring consists of twelve oyster shells of similar size (about 76 mm, (3-in) in length) drilled through the center and strung (inside of shell facing 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 station. 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 stations were deployed for seven-day periods, there were some weather related deviations such that shellstring deployment periods ranged from 7 to 21 days. These periods did not always coincide among the different rivers and areas monitored. Therefore, spat counts for different deployment dates and periods were standardized to correspond to the 7-day standard periods specified in Table 1. Standardized spat shell^{-1} (S) was computed using the formula:

$$S = \Sigma \text{ (spat shell}^{-1}\text{)/ weeks (W)}$$

where W = number of days deployed / 7. Standardized weekly periods allow comparison of spatfall trends over the course of the season between the various stations in a river as well as between data for different years.

The cumulative spatfall for each station was computed by adding the standardized weekly values of spat shell^{-1} for the entire season. This value represents the average number of spat that would fall on any given shell if allowed to remain at that station for the entire sampling season. 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 and salinity measurements were taken weekly approximately 0.5 m off the bottom at all sites using a handheld electronic probe (YSI 85). Water temperature was recorded in degrees Celsius (C) and salinity was recorded in parts per thousand (ppt).

RESULTS

Settlement on shellstring collectors during 2009 is summarized in Table S1 and is discussed below for each river system monitored. Table S2 includes a summary of settlement for the past twenty years at the historical sites in all three-river systems and the past ten years for the modern sites 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 2009 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 new (modern) sites during 1998 in the Piankatank and Great Wicomico Rivers, any comparison made to historical data could not include data from all of the sites sampled during 2009. Comparisons were made over the past ten years for the modern sites whereas the historical sites include twenty 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 (Cranes Creek in data reports prior to 1997).

James River

Oyster settlement in the James River was first observed during the week of July 8 at Dry Shoal (Table S1). Settlement was intermittent throughout the river system from then until the week of August 26. Settlement continued until early October with consistent settlement throughout the system during the last two weeks of monitoring. One major peak occurred system-wide during the week of August 28 (Figure S3). Settlement during this one week accounted for 51% of the total spatfall in the system for the year. Settlement at the individual sites during this one week accounted for 19 (Rock Wharf) to 82% (Swash) of the total for the year.

Settlement in the James River during 2009 was moderate ranging from a low of 1.7 (Deep Water Shoal) to a high of 8.9 (Dry Shoal) cumulative spat shell^{-1}. Settlement during 2009 in the James River was lower than that observed during 2008 as well as the 5, 10 and 20-year means at all of the sites monitored (Table S2; Figure S4).

Average river water temperatures ranged from 23 to 28 degrees C, reaching a maximum in late August (Figure S5A). Water temperature was similar to the long term means in the beginning of the monitoring period, but was slow to rise averaging 2 degrees C lower than the long term means (5, 10 and 20-year) throughout most of the month of July, reaching the maximum about a month later than is typical for that system. After reaching the maximum in late August, water temperature experienced a relatively quick drop (4 degrees C in one week) between the last week of August and the first week of September (Figure S5A).

At the beginning of the sampling period and lasting until the end of June, salinity was approximately 2 ppt lower than the previous 5, 10 and 20-year means (Figure S5B). Salinity then increased and was similar to the long-term means through the end of August. Salinity was 1 to 2 ppt higher than the long term means for most of the month of September (Figure S5B). 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 5 to 12 ppt.

Piankatank River

Settlement in the Piankatank River was first observed during the week of July 1 at three out of eight sites monitored. Settlement was intermittent throughout the system from that time until the week of August 5. Settlement continued until the end of the monitoring period with consistent settlement (i.e. settlement at all eight sites) occurring during the weeks of August 5, August 12, August 19 and September 23. The largest peak in settlement occurred during a two-week period in mid August, which accounted for 57% of the total spatfall in the system for the year (Table S1; Figure S6).

Cumulative spat shell^{-1} for the year was moderate ranging from a low of 3.0 at Burton Point to a high of 9.9 at Cape Toon. For the sixth year in a row, Cape Toon had the highest cumulative spat shell^{-1} (Table S2) in the system. Spatfall during 2009 was lower than that observed during 2008 at all eight sites monitored (Table S2; Figure S7). Settlement during 2009 was higher than the 5-year mean at Wilton Creek, Palace Bar and Heron Rock and higher than the 10-year mean at Palace Bar, Heron Rock and Cape Toon. There was no change observed at Ginney Point and Bland Point when compared with the 5-year mean and there was no change observed at Wilton Creek and Ginney Point when compared with the 10-year mean. Spatfall during 2009 was lower than the 20-year mean at all three historical sites.

The average water temperature ranged from 24 to 29 degrees C throughout the sampling period, reaching a maximum in mid to late August. Water temperature was approximately 2 degrees C higher than the long-term means the week sampling began, but was within normal ranges by the second week of sampling. Similar to what was observed in the James River, water temperature was several degrees lower than the 5, 10 and 20-year means in late July, reaching the seasonal maximum approximately one month later than is typical for the system (Figure S8A). After reaching the maximum in late August, water temperature experienced a relatively quick drop (4 degrees C in one week) between the last week of August and the first week of September (Figure S8A).

Salinity was approximately 2 ppt higher than the 5, 10 and 20-year means when sampling began in the end of May, but quickly returned to more normal conditions by the middle of June (Figure S8B). Salinity was similar to that previously recorded in the system throughout most of the rest of the sampling period, with the exception of the end of July and the end of August when salinity was approximately 1 ppt higher than the previous 5, 10 and 20-year means. The difference recorded in any given week between Wilton Creek (the most upriver site) and Burton Point (the most downriver site: Figure S1) ranged between 1 and 2 ppt throughout most of the sampling period.

Great Wicomico River

Settlement began the week of June 17 at seven out of the nine sites in the Great Wicomico River (Table S1) and was relatively consistent from then through the week of July 22. There was little settlement observed during the last two weeks of July and settlement was light and intermittent for the rest of the sampling period. There was one major pulse in setting in the Great Wicomico River during 2009 that occurred during the weeks of July 8 and July 15 (Figure S9). This two-week period accounted for approximately 93% of the total spatfall recorded in the system for the entire season ranging from 73 (Fleet Point) to 96% (Glebe Point) of the total at the individual sites. This peak was especially strong at the seven most upriver sites, those sites located upriver of the sand spit at Sandy Point (Figure S1).

Cumulative spat shell^{-1} for the year was moderate at the three most downriver sites, Fleet Point, Whaley's East and Haynie Point ranging from 1.3 to 8.6. Settlement at the six remaining sites was heavy to very heavy, ranging from a low of 18.5 at Shell Bar to a high of 405.6 at Glebe Point. Similar to years past, settlement was lowest at the two sites downriver of Sandy Point, Whaley's East and Fleet Point, with settlement generally increasing in an upriver fashion. Settlement during 2009 was lower than the previous year (2008) at all of the sites monitored except Glebe Point (Table S2: Figure S10). Settlement during 2009 was higher than the 5-year mean at the five most upriver sites and higher than the 10-year mean at the six most upriver sites (Table S2: Figure S10). At the five historical sites, settlement was higher than the 20-year mean at Glebe Point, Hudnall and Haynie Point. Settlement during 2009 was the highest observed in the past twenty years of monitoring at Glebe Point and the fourth highest observed at Hudnall. For the modern sites, 2009 marked the third highest settlement observed at Rogue Point, Hilly Wash and Harcum Flats and the fourth highest at Shell Bar since monitoring began at those sites in 1998.

Average river water temperatures ranged from 23 to 29 degrees C throughout the sampling period reaching a maximum the last week of August (Figure S11A). Water temperature at the beginning of the sampling period was slightly higher than the 5 and 11-year means, but was then lower than the long-term means for most of June and July (Figure S11A), reaching the maximum approximately a month later than is typical for this system. Similar to what was observed in the other two systems, after reaching the seasonal maximum in late August, water temperature experienced a relatively quick drop (4 degrees C in one week) between the last week of August and the first week of September (Figure S11A).

Salinity ranged from 14 to 18 ppt, reaching a maximum at the very end of the sampling period (Figure S11B). Similar to what was observed in the Piankatank River, salinity was 2 ppt greater than the long-term means when sampling began the end of May but returned to normal by mid June and remained similar to the long-terms means throughout most of the rest of the sampling period (Figure S11B). There was a 1 to 3 ppt difference in salinity between the most upriver site (Glebe Point) and the most downriver site (Fleet Point: Figure S1) throughout most of the sampling period.

DISCUSSION

With some exceptions in each of the rivers during various years, low or moderate spatfall (seasonal cumulative total of less than 10 spat $shell^{-1}$) has been common in Virginia since 1993 (78% of all year/site combinations). Settlement during 2009 was moderate in all areas except the six most upriver sites in the Great Wicomico River. Settlement at the upriver Great Wicomico River sites was exceptionally high for the fourth year in a row and ranks among the highest settlement observed in the system since the mid 1980s.

Settlement in the James River was moderate and similar to what has been observed over the past decade and a half of monitoring. The timing of the set followed the historical peak in settlement timing, occurring in early September (Andrews 1951, 1982). In more recent years, settlement in the James River has been getting progressively earlier (Southworth & Mann 2004). Settlement during 2009 may have been later and more similar to historical patterns due to slightly lower than normal salinities throughout most of June. While temperature is the single most important factor affecting both timing and magnitude of oyster spawning (Shumway 1996), depressed salinities have been shown to delay gametogensis and thus spawning in oysters (Butler 1949). Approximately 20% of the spatfall for the season occurred during the last two weeks of monitoring. Hayes and Menzel (1981) proposed that a sharp decline in water temperature might be the stimulus for oysters spawning in the fall. The James River experienced a relatively sharp decline in water temperature (4 degrees C) between the last week of August and the first week of September, approximately three weeks before the second smaller peak in settlement. Oyster larvae spend two to three weeks in the plankton before metamorphosing and settling to a hard substrate (Kennedy 1996).

Settlement throughout the Piankatank River was moderate, with cumulative number of spat $shell^{-1}$ for the season in the mid range of what has been observed over the past twelve (modern sites) to twenty (historical sites) years of monitoring. The number of broodstock in the Piankatank River was exceptionally low for several years in the mid 2000s following a large die-off that occurred in late 2003/early 2004 (Southworth et al., 2005). The lack of observed settlement in the Piankatank since 2004, when compared with historical numbers was most likely due to this decline in broodstock. Density of the broodstock is an important factor in determining fertilization success (Mann & Evans 1998) and size is important in that fecundity, the number of eggs produced per oyster, increases non-linearly with an increase in biomass (Cox & Mann 1992, Mann & Evans 1998). For the past two years however, the total number of potential broodstock oysters (small plus market) at Ginney Point, Palace Bar and Burton Point were among the highest observed during the past twenty years (Part II, this report) of monitoring, which may help explain why settlement has returned to more moderate numbers for the system.

Settlement at the six most upriver sites in the Great Wicomico River was exceptionally high for the fourth year in a row. Settlement at the two historical sites ranked among the highest observed since the mid 1980s and settlement at the four modern sites was among the fourth highest since monitoring began at those sites in 1998. The majority of the settlement occurred over a two-week period in early July. Timing of the spatset during 2009 in the Great Wicomico River was similar to historical patterns for the system (Andrews 1951, Southworth & Mann 2004).

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

STATION	5/27	6/3	6/10	6/17	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/2	9/9	9/16	9/23	9/30	YEAR
	147	154	161	168	175	182	189	196	203	210	217	224	231	238	245	252	259	266	273	TOTAL
James River																				
Deep Water Shoal	D	0	0	0	0	0	0	0	0	0	0	0.05	0	0.95	-	-	0.03	0.65	0.05	1.73
Horsehead	D	0	0	0	0	0	0	0	0	0.1	0.05	0.05	0	3.3	-	-	0	0.35	0.3	4.15
Point of Shoal	D	0	0	0	0	0	0	0	0	0	0.1	0	0.05	1.4	0.3	-	0	0.9	0.1	2.85
Swash	D	0	0	0	0	0	0	0.05	0	0	0.15	0	0.05	4.2	-	-	0	0.4	0.3	5.15
Dry Shoal	D	0	0	0	0	0	0.15	0.25	0	0	0.7	0.8	0.5	3.6	0.95	-	0.05	1.1	0.75	8.85
Rock Wharf	D	0	0	0	0	0	0	0	0	1.7	0.35	0.4	0.6	0.95	0.05	-	0	0.45	0.5	5.0
Wreck Shoal	D	0	0	0	0	0	0	0.1	0.05	0.35	0.35	0.35	1.1	3.6	0.35	-	0	0.4	0.45	7.1
Day's Point	D	0	0	0	0	0	0	0.05	0	0.05	0.05	0.45	0.53	1.4	0	-	0	0.2	0.3	3.03
Piankatank River																				
Wilton Creek	D	0	0	0	0	0	0	0	0	0.2	0.25	2.5	0.55	0.4	0	-	0	0.15	0	4.05
Ginney Point	D	0	0	0	0	0.1	0.05	0	0	0.2	0.15	2.5	0.4	0.15	0.10	-	0.45	0.3	0.05	4.45
Palace Bar	D	0	0	0	0	0	0	0	0.05	0.15	0.2	3.4	1.5	0.05	0.35	-	0.08	0.1	0	5.88
Bland Point	D	0	0	0	0	0	0.15	0.1	0	0.05	0.15	2.2	1.2	0.1	0.6	-	0.1	0.05	0	4.7
Heron Rock	D	0	0	0	0	0.1	0.05	0	0	0.1	0.15	2.2	0.5	0.05	1.1	-	0.38	0.45	0.32	5.4
Cape Toon	D	0	0	0	0	0.1	0.05	0.35	0.05	1.1	1.3	1.9	2.2	0	1.7	-	0.28	0.2	0.7	9.93
Stove Point	D	0	0	0	0	0	0	0.2	0	0.6	0.3	1.3	0.89	0	1.8	-	0.53	0.4	0	6.02
Burton Point	D	0	0	0	0	0	0.05	0	0	0	0.05	0.75	0.7	0.05	0.95	-	0.28	0.15	0	2.98
Great Wicomico River																				
Glebe Point	D	0	0	0.4	1.2	8.1	166	224	0.6	0	0.1	3.3	0.25	1.2	0.2	-	0.18	0.05	0	405.6
Rogue Point	D	0	0	0.34	2.2	2.6	62.9	21.7	0.1	0.05	0.28	1.4	0.1	0.8	0.2	-	0.13	0	0.05	92.6
Hilly Wash	D	0	0	0.5	1.6	3.3	41.8	31.6	0.15	0	0.05	0.55	0.1	0.6	1.3	-	0.1	0.05	0	81.7
Harcum Flats	D	0	0	0.4	0.95	2.4	60.3	45.4	0.35	0	0.5	1.0	0.2	0.35	0.4	-	0.08	0	0	112.3
Hudnall	D	0	0	0.1	1.4	3.7	22.5	15.4	0.15	0	0.05	0.27	0	0.35	0.25	-	0.1	0	0.05	44.3
Shell Bar	D	0	0	0	1.1	1.5	5.9	9.3	0.1	0	0	0.1	0.05	0.15	0.2	-	0.1	0	0	18.5
Haynie Point	D	0	0	0.05	0.3	0.8	1.8	4.8	0.15	0	0	0.2	0.1	0.05	0.2	-	0.05	0	0.05	8.55
Whaley's East	D	0	0	0.05	0	0.2	1	0.75	0	0	0	0	0.1	0.1	0	-	0	0.05	0	2.25
Fleet Point	D	0	0	0	0.15	0	0.2	0.75	0.05	0	0	0.05	0.05	0.05	0	-	0	0	0	1.3

Table S2: Spatfall totals for historical sites (1988-2009) and for 1998-2009 at sites where historical data are not available. Values are presented as the cumulative sum of spat shell^{-1} values for each year. "+" and "-" indicate direction of change in 2009 in reference to 2008 and to the five, ten, and twenty-year means. Blank cells for a site indicate years where data are not available. "NC" indicates a change of less than 1 spat per shell 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	Mean 04-08	Mean 99-08	Mean 89-08	Ref. 2008	Ref. 5-yr	Ref. 10-yr	Ref. 20-yr
James River																												
Deep Water Shoal	2	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	52.4	30.4	17.1	-	-	-	-
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	47.8	27.3	17.9	-	-	-	-
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	61.7	34.8	24.6	-	-	-	-
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	100.6	54.2	35.6	-	-	-	-
Dry Shoal	10	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	269.9	8.9	59.0	32.4	37.8	-	-	-	-
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	76.7	42.4	26.0	-	-	-	-
Wreck Shoal	10.2	4	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	123.4	63.4	35.9	-	-	-	-
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	57.4	31.1	35.3	-	-	-	-
Piankatank River																												
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	3.9	3.6		-	+	NC	
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	5.9	5.0	9.3	-	NC	NC	-
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	3.0	3.2	13.6	-	+	+	-
Bland Point										2.3	44.1	2.7	1.3	6.7	0.2	0.4	1.0	3.7	11	11.1	4.7	5.4	8.2		-	NC	-	
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	3.9	3.8		-	+	+	
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	11.9	8.4		-	-	+	
Stove Point										1.0	7.1	1.8	1.6	31.0	0.1	0.7	1.7	7.0	19.9	14.4	6.0	8.7	8.5		-	-	-	
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	4.7	4.7	10.2	-	-	-	-
Great Wicomico River																												
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	85.5	72.3	38.9	+	+	+	+
Rogue Point										0.9	2.0	2.6	0.7	16.6	7.0	0.5	2.6	88.1	112	126.2	92.9	65.9	35.8		-	+	+	
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	62.2	34.3		-	+	+	
Harcum Flats										0.1	1.3	0.8	1.1	33.7	3.7	0.7	1.5	110.7	135.3	273.3	112.3	104.3	56.2		-	+	+	
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	44.3	34.7	19.3	18.0	-	+	+	+
Shell Bar										0	2.9	0.8	0.8	17.8	1.9	0.3	0.9	29.6	30.3	78.1	18.5	27.8	16.3		-	-	+	
Haynie Point	17	68.2	12.5	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	17.2	10.6	10.8	-	-	-	+
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	6.0	3.6	4.8	NC	-	-	-
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	4.5	2.9	3.6	-	-	-	-

Figure S1: Map showing the location of the 2009 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.

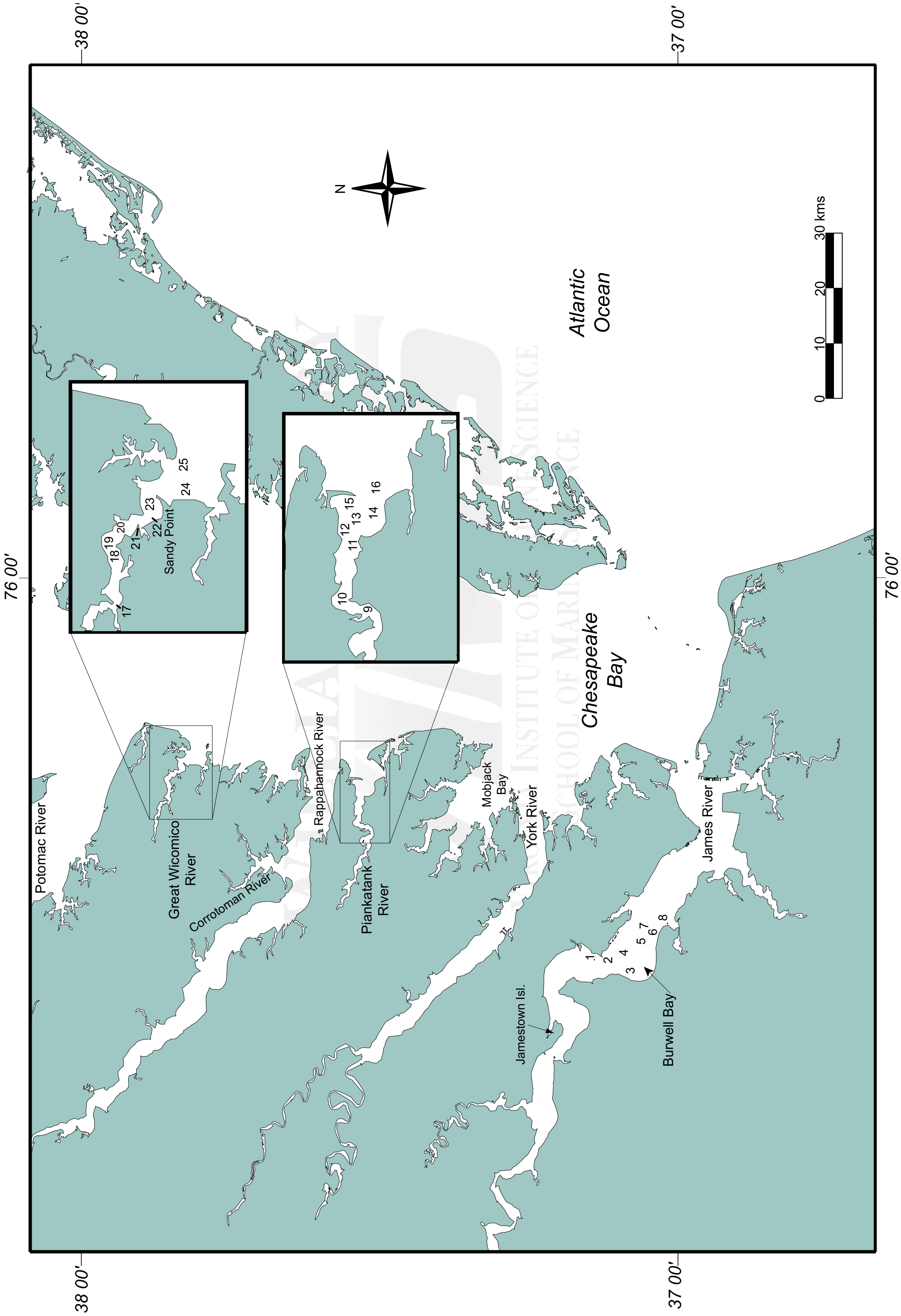

38 00'
37 00'
76 00'
N
Atlantic Ocean
Chesapeake Bay
0 10 20 30 kms
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Jamestown Isl.
Burwell Bay
Sandy Point
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25

Figure S2: Diagram of shellstring setup on buoys.

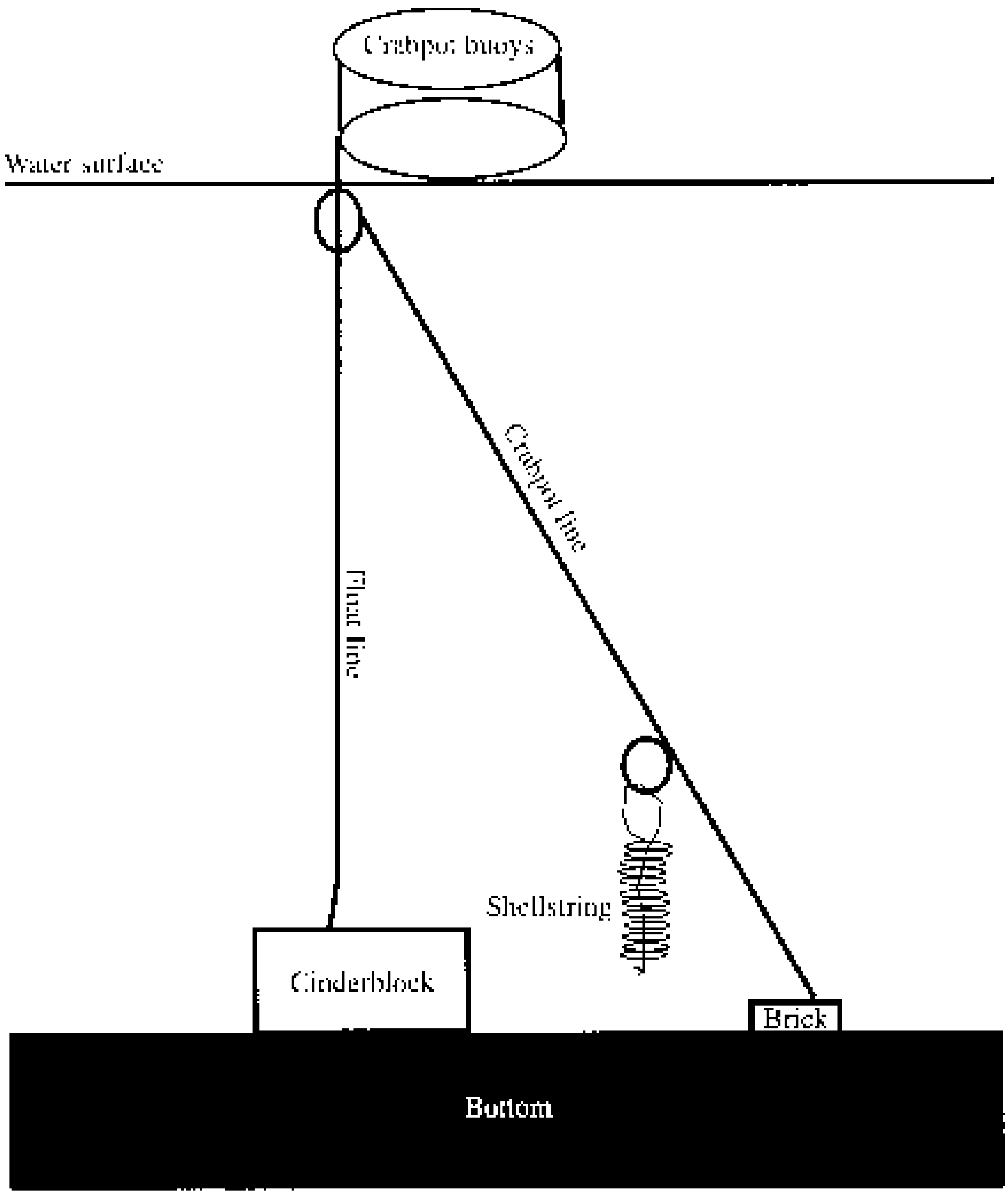


FIGURE S3: JAMES RIVER (2009) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$

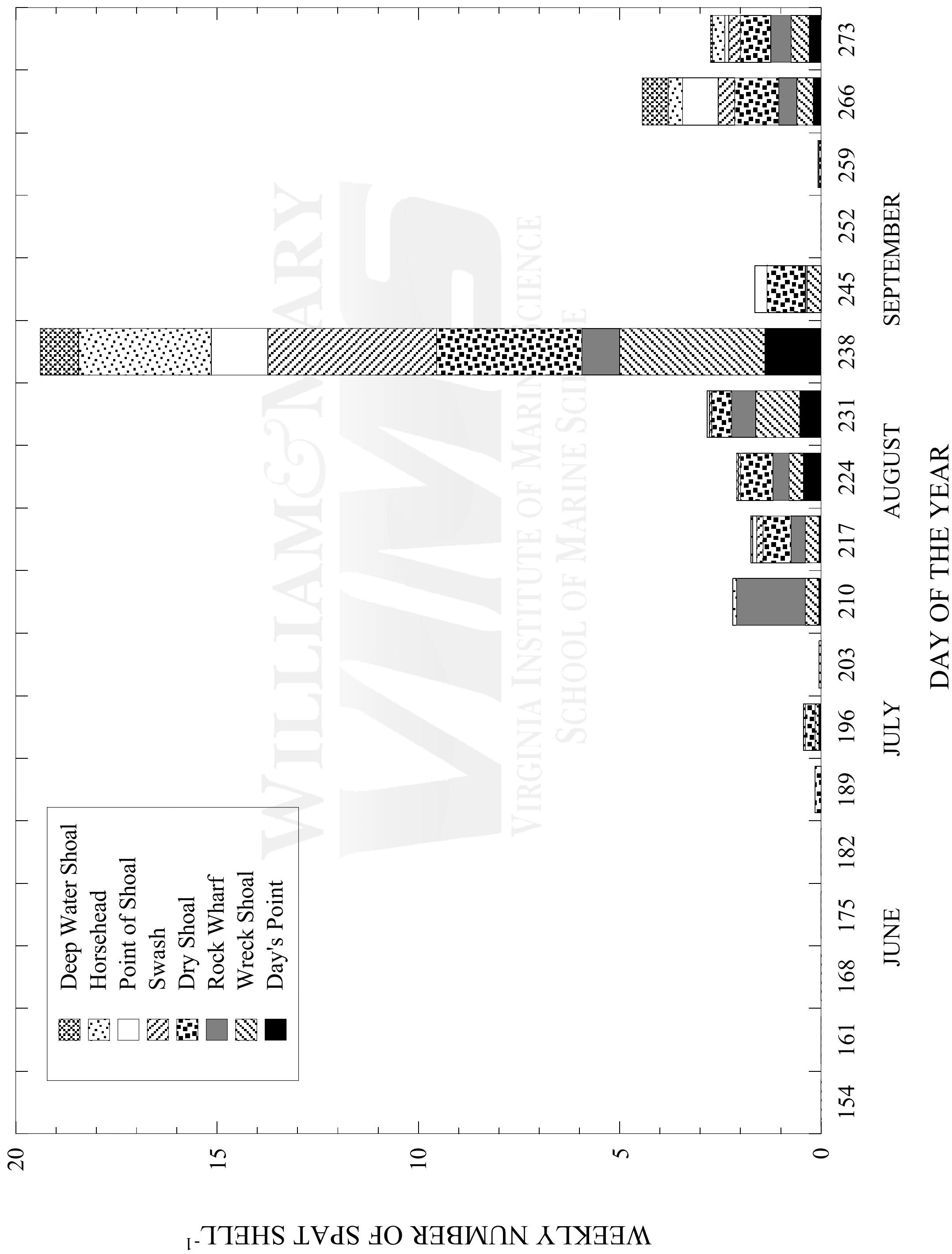


FIGURE S4: SPATFALL TRENDS OVER THE PAST 20 YEARS AT ALL 8 SITES IN THE JAMES RIVER (upriver sites in panel A; downriver sites in panel B) (expressed as cumulative weekly spatfall)

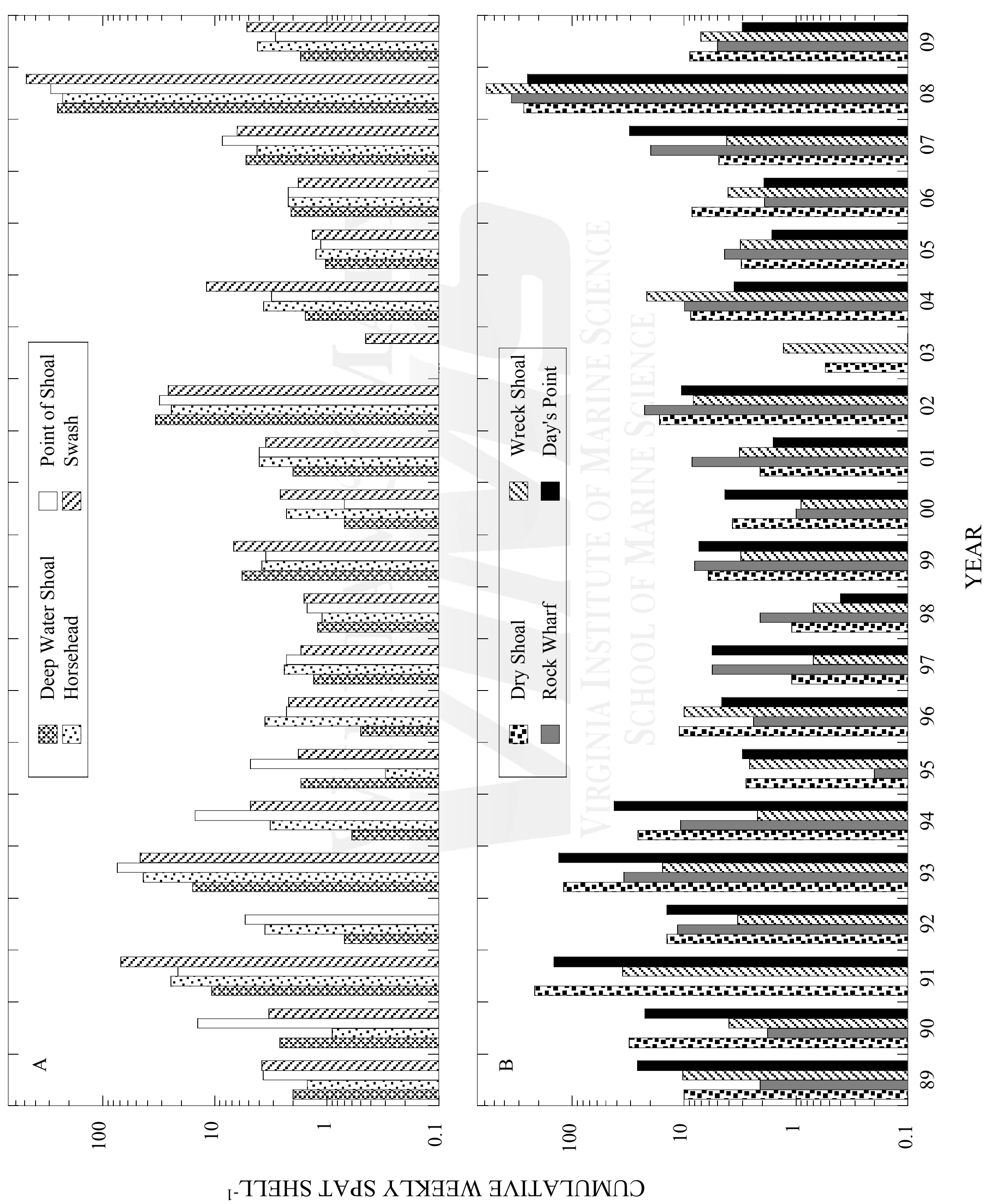


FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 20-YEAR MEANS COMPARED WITH 2009 (Error bars represent standard error of the mean; shaded area represents the bulk of the settlement during 2009; n is the number of data points used to calculate the mean)

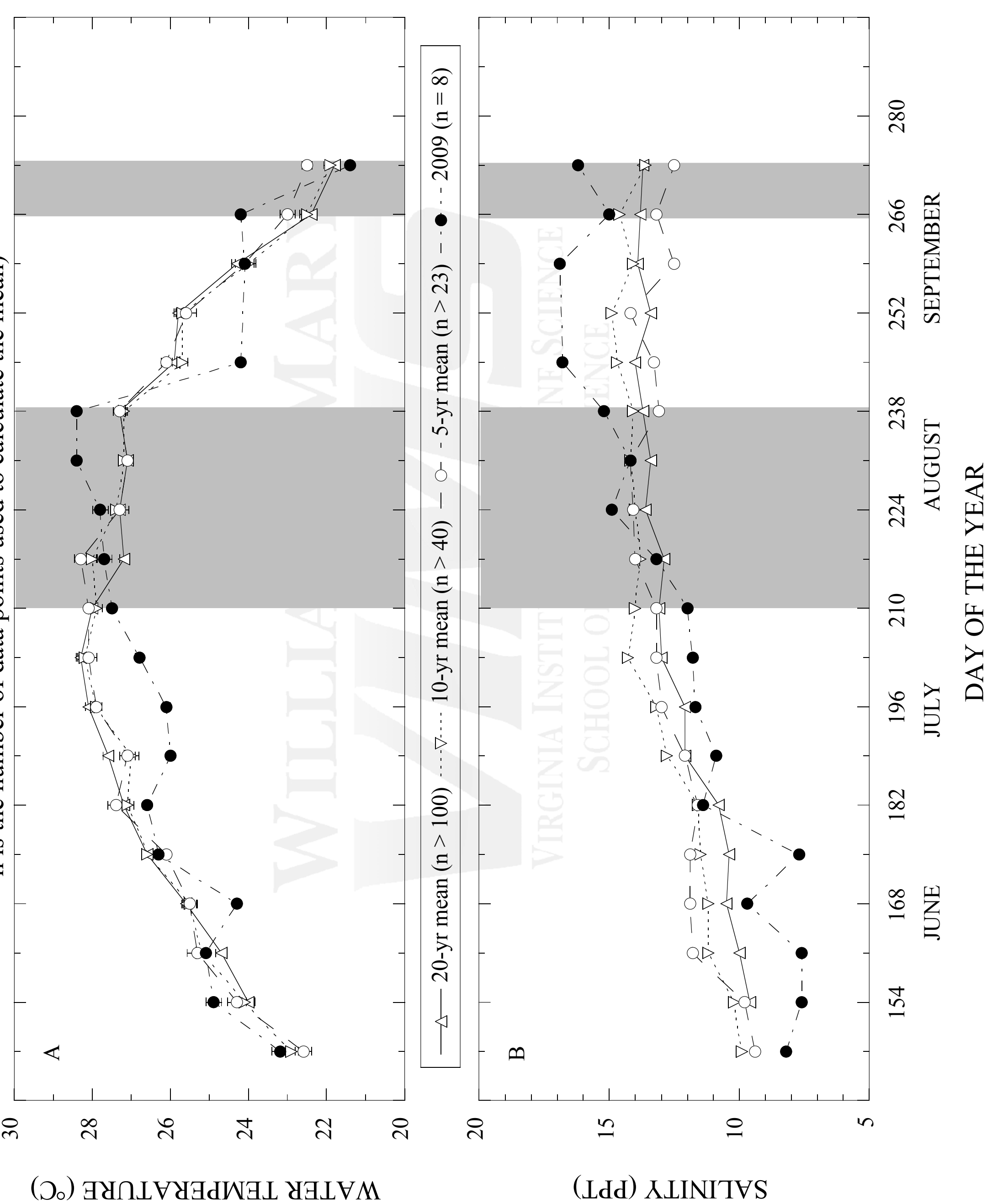


FIGURE S6: PIANKATANK RIVER (2009) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: M = modern station as described in text)

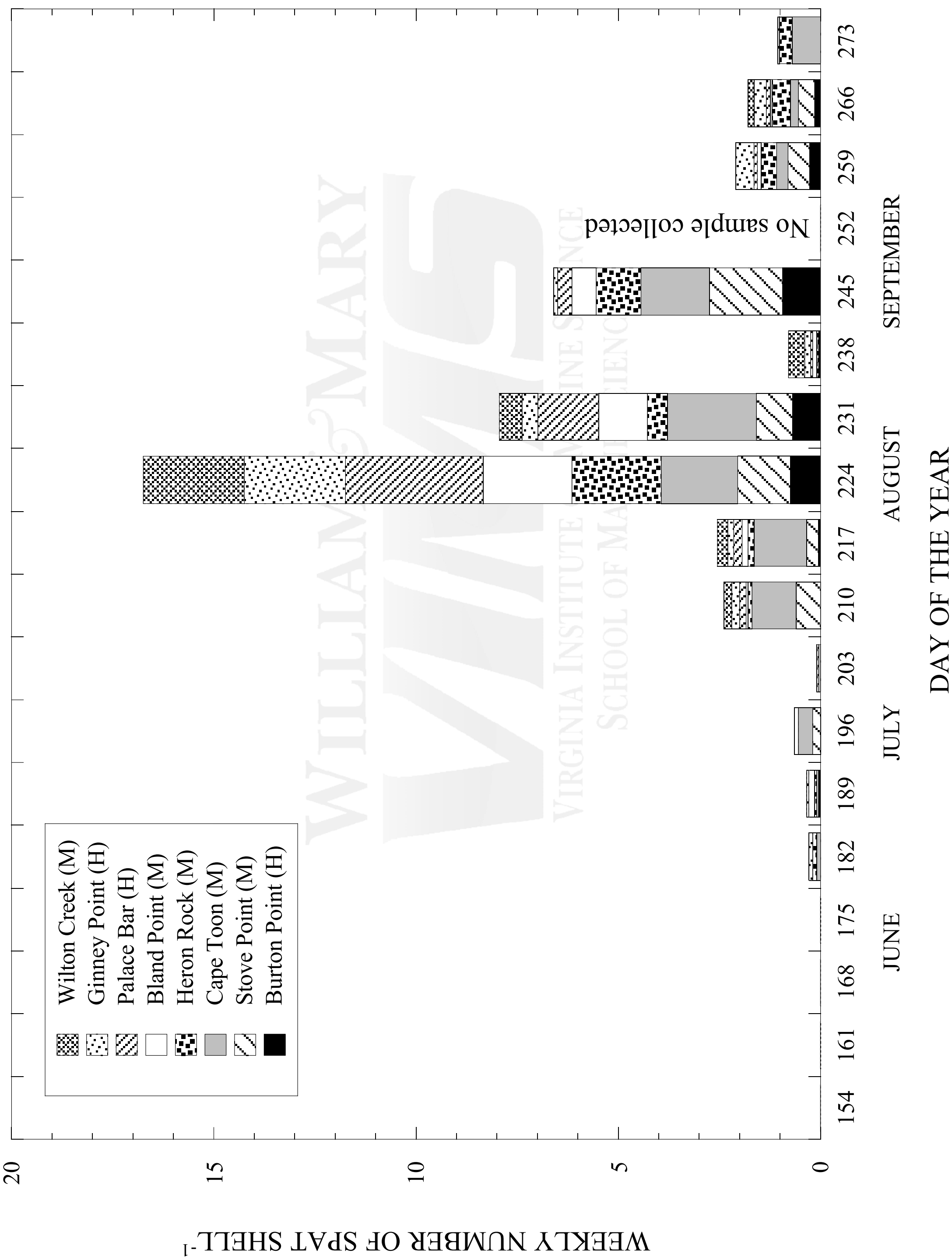


FIGURE S7: SPATFALL TRENDS IN THE PIANKATANK RIVER AT THE 3 HISTORICAL SITES (panel A: 20 years) AND THE 5 MODERN SITES (panel B: 11 years)
(Expressed as cumulative weekly spatfall)

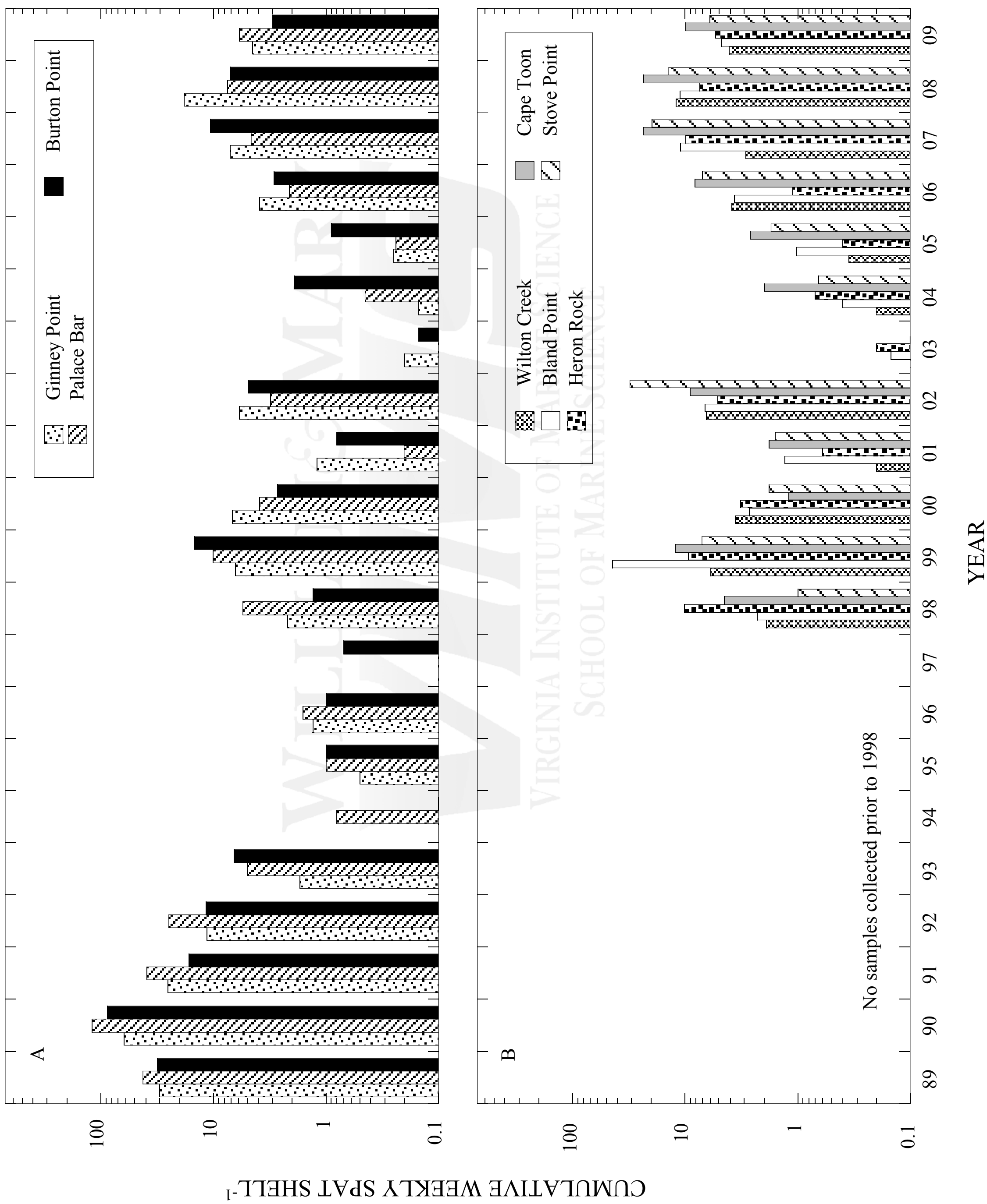


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 20-YEAR MEANS COMPARED WITH 2009
(Error bars represent standard error of the mean; shaded area represents the bulk of settlement during 2009; n is the number of data points used to calculate the mean)

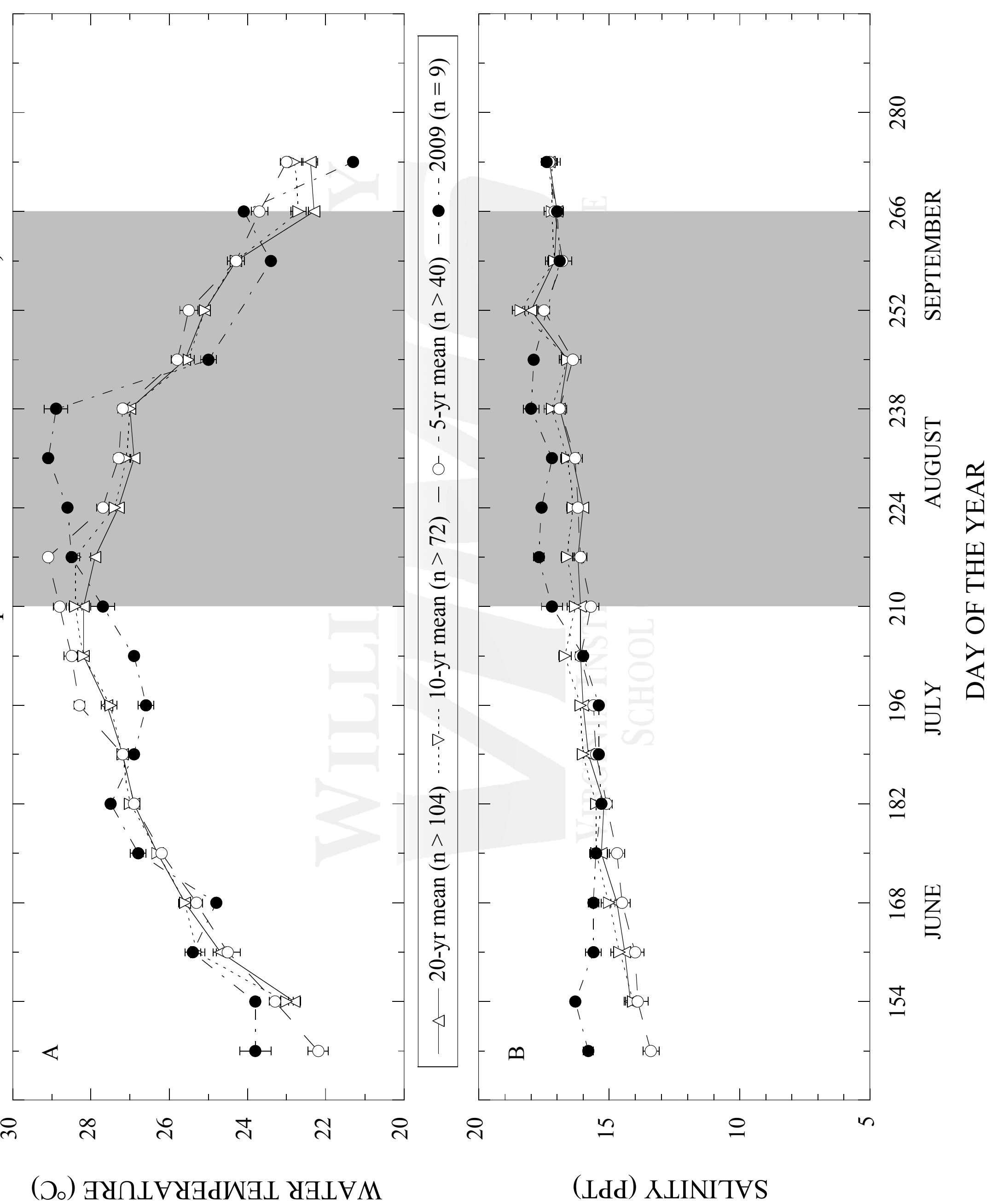


FIGURE S9: GREAT WICOMICO RIVER (2009) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: M = modern station as described in text)

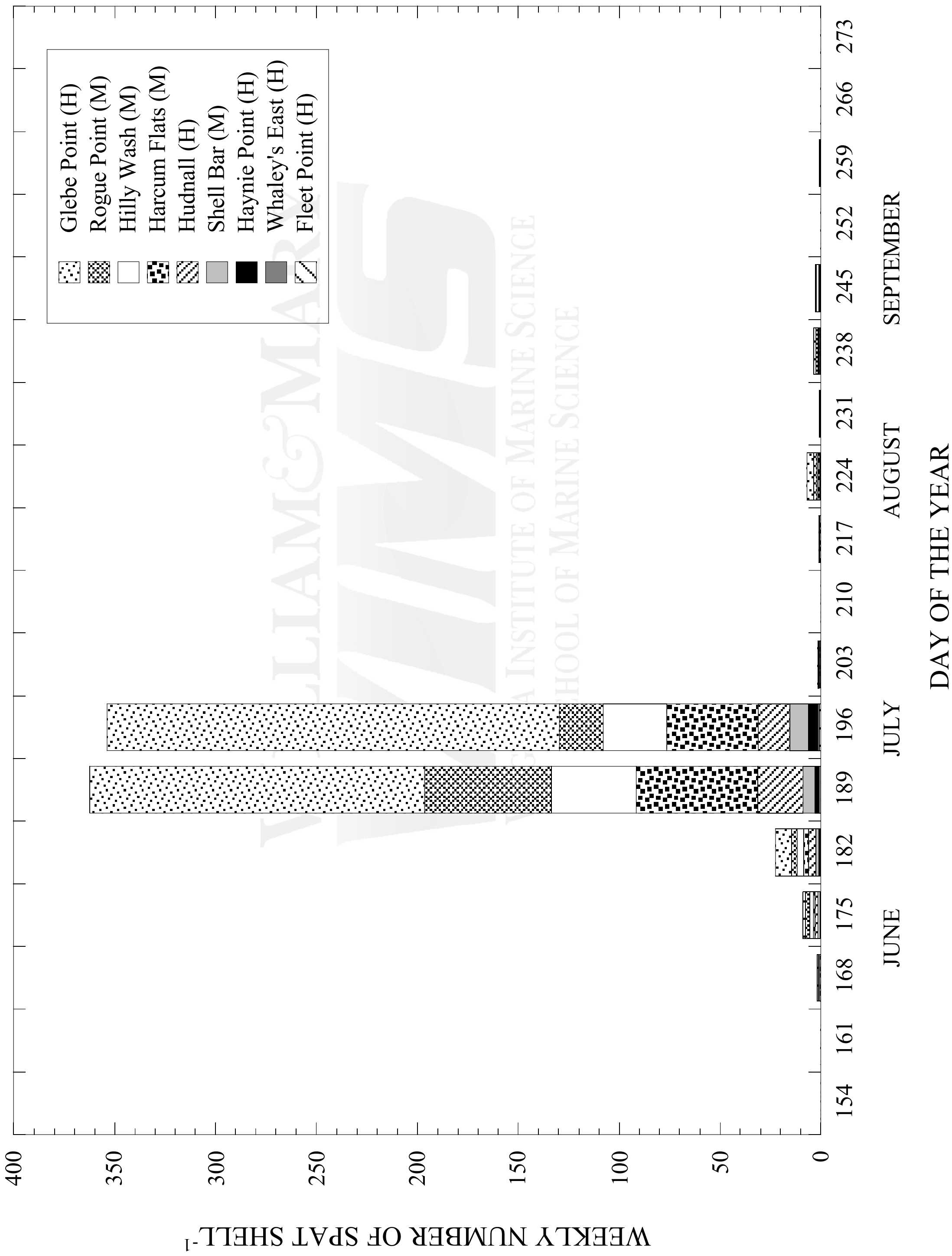


FIGURE S10: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER AT THE 5 HISTORICAL SITES (panel A: 20 years) AND THE 4 MODERN SITES (panel B: 11 years)
(Expressed as cumulative weekly spatfall)

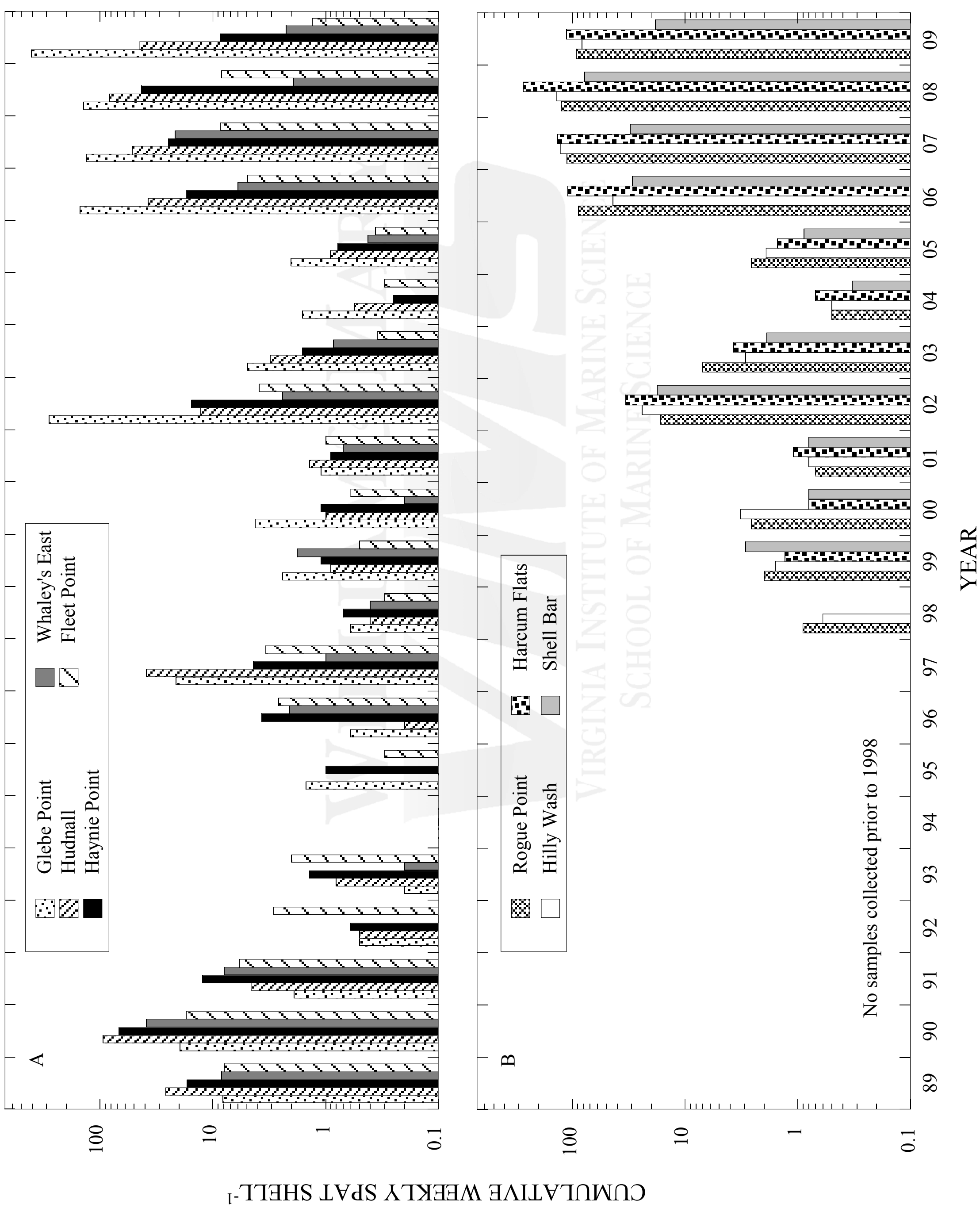
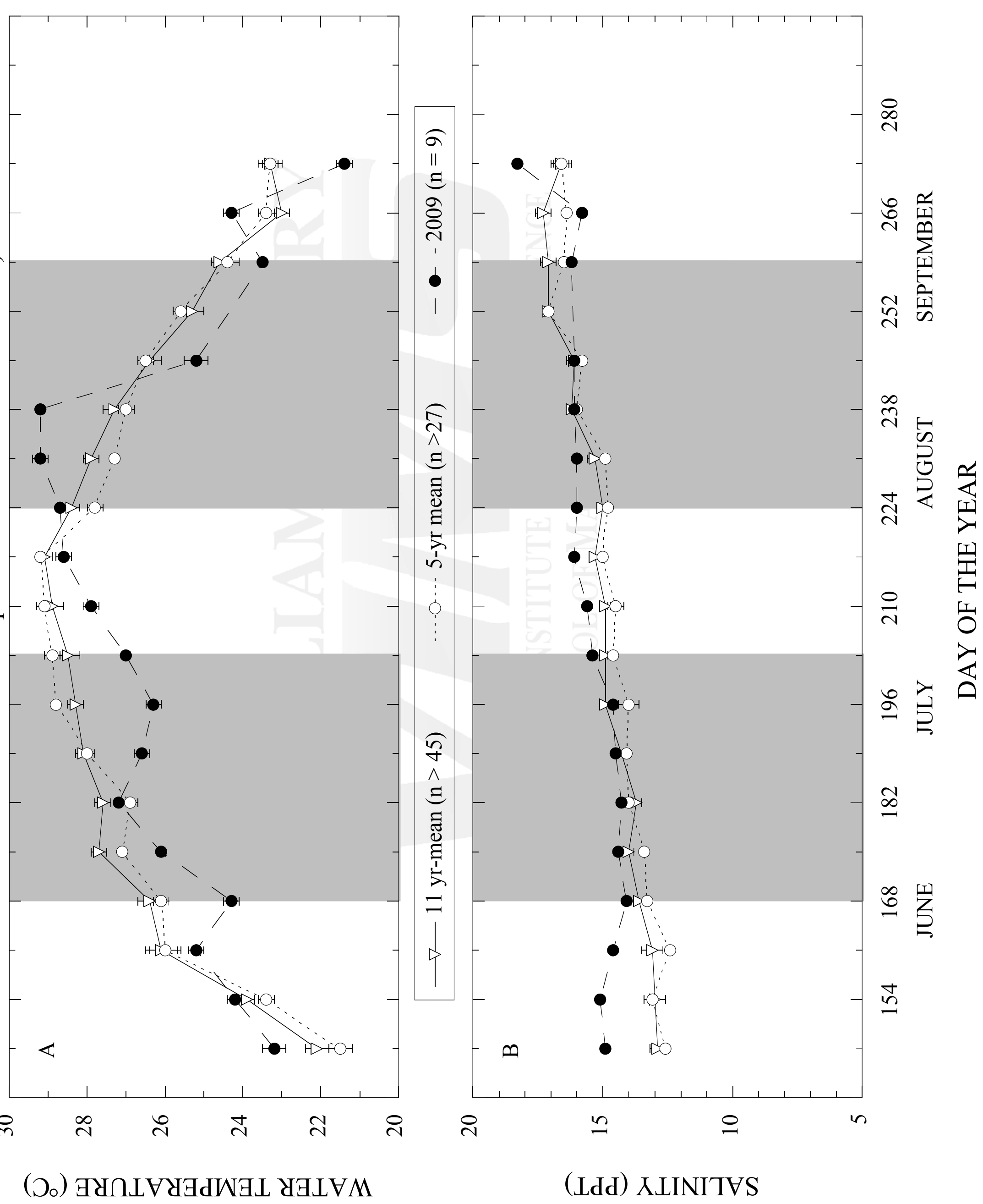


FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE SETTLEMENT PERIOD: 5 AND 11-YEAR MEANS COMPARED WITH 2009
(Error bars represent standard error of the mean; shaded area represents the bulk of settlement during 2009; n is the number of data points used to calculate the mean)



Part II. Dredge Survey of Selected Oyster Bars in Virginia During 2009

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 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/mollusc/oyrestatlas/); they are presently under management by the Virginia Marine Resources Commission (VMRC).

Every year the Virginia Institute of Marine Science (VIMS) 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 spatfall 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 2009.

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.

Each year, the VMRC Conservation and Replenishment Group plants clean shell or cultch on selected oyster bars in the Virginia portion of the Chesapeake Bay. Seed (a mix of spat, small and market oysters) from private leases in the Great Wicomico River was planted on Smokey Point and Morattico Bar in the Rappahannock River in the spring of 2008.

METHODS

Locations of the oyster bars sampled by VIMS during Fall 2009 are shown in Figure D1. Geographic coordinates of the bars are given in Table D1.

Four samples of bottom material were collected at a single station on each bar using an oyster scrape/dredge. In all surveys in the York River and Mobjack Bay (through 2009) and in all surveys in the James, Piankatank, Rappahannock and Great Wicomico Rivers preceding 1995, 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, samples from the James, Piankatank, Rappahannock, and Great Wicomico Rivers were collected using a 4-ft dredge with 4-in teeth towed from the 43-ft long VMRC vessel *J. B. Baylor*; volume collected in the bag of that dredge is 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 station 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, 2009 recruits), new boxes (inside of shells perfectly clean; presumed dead for approximately < 1 week), old boxes and spat boxes 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 (in degrees C) and salinity (in ppt, parts per thousand) were recorded approximately 0.5 meters off the bottom at each of the dredge stations using a handheld electronic probe (YSI 85).

Each year, the VMRC Conservation and Replenishment Group plants clean shell or cultch on selected oyster bars in the Virginia portion of the Chesapeake Bay. Seed (a mix of spat, small and market oysters) from private leases in the Great Wicomico River was planted on Smokey Point and Morattico Bar in the Rappahannock River in the spring of 2008.

RESULTS

Thirty oyster bars were sampled between October 5 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 a private bar 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 18 bushel^{-1} at Nansemond Ridge to a high of 891.5 bushel^{-1} at Horsehead. The total number of oysters observed during 2009 at Nansemond Ridge was the lowest it has been over the past twenty years of monitoring.

The average number of market oysters in the James River remains low when compared with historical numbers. All of the sites monitored had low to moderate numbers of market oysters ranging from 3.0 (Nansemond Ridge) to 80.5 bushel^{-1} (Point of Shoal). There was a small decrease in the number of market oysters at Long Shoal and Mulberry Point when compared with 2008 (Figure D2 and D3). The number of market oysters at Wreck Shoal was at an all time low in 2002, but steadily increased to the highest numbers observed in the past twenty years by 2005 and has remained at similar levels since (Figure D3C).

The average number of small oysters bushel^{-1} ranged from a low of 7.5 at Nansemond Ridge to a high of 629 at Horsehead. When compared with 2008, there was an increase in the number of small oysters observed during 2009 at Mulberry Point, Horsehead, Long Shoal, Dry Shoal and Wreck Shoal (Figure D2). This increase is not unexpected given the large spatfall that was observed in the system during 2008. There was a decrease in the number of small oysters observed at Nansemond Ridge in 2009 relative to 2008 yielding the lowest small oyster abundance described during the past twenty years of monitoring (Figure D3C).

The average number of spat bushel^{-1} ranged from a low of 7.5 at Nansemond Ridge to a high of 198.5 at Horsehead. There was a decrease in the number of spat observed at all ten sites when compared with 2008. Historically, the typical pattern observed in the James River was an increasing percentage of small oysters and a decreasing percentage of spat as one moved from the most downriver site (Nansemond Ridge) to the most upriver site (Deep Water Shoal). This pattern has not been observed as often as spatfall over the past decade has been increasing at the more upriver sites while decreasing at the more downriver sites. During 2009, while the two most downriver sites (Nansemond Ridge and Thomas Rock) had the highest percentage of spat, the total number of oysters at these two sites was among the lowest observed in the past twenty years of monitoring (the lowest at Nansemond Ridge and the fifth lowest at Thomas Rock). The highest percentage of oysters occurred in the small oyster category at all ten sites monitored during 2009.

The average number of boxes bushel^{-1} ranged from a low of 4.0 (Nansemond Ridge) to a high of 102.5 (Dry Shoal). Boxes accounted for 4 (Deep Water Shoal and Horsehead) to 29% (Wreck Shoal) of the total (live and dead) oysters observed. More than 57% of the observed boxes were old and less than 5% of the total boxes were spat boxes at all ten sites. More than 21% of the boxes were new at the seven most upriver sites indicating some recent mortality. An average of 25% of the total larger oysters (includes all categories except spat and spat boxes) were boxes at the four most downriver sites (Dry Shoal, Wreck Shoal, Thomas Rock and Nansemond Ridge), indicating some disease mortality.

Water temperature during the two days of sampling ranged from 15.1 to 16.5 degrees C (Table D2). Salinity was variable depending on location in the river, increasing in a downriver direction, from 11.0 ppt at Deep Water Shoal to 20.2 ppt at Nansemond Ridge.

York River

In the York River, the average total number of live oysters bushel^{-1} was 75.0 at Bell Rock and 125.0 at Aberdeen Rock. The live oysters at Bell Rock were primarily a combination of small oysters (50% of the total) and spat (38% of the total) with no change observed in any size category when compared with 2008. At Aberdeen Rock there was a small increase in all size categories when compared with 2008 (Figure D4 and D5). The number of market oysters at both sites was the highest observed during the past twenty years of monitoring. The average number of boxes (new and old) bushel^{-1} was low (Bell Rock; 15.0 bushel^{-1} and Aberdeen Rock; 16.5 bushel^{-1}), accounting for approximately 17 and 12% of the total oysters respectively (live and dead) at the two sites. At both sites, the majority of the boxes (greater than 76% of the total) were old boxes. Water temperature on the day of sampling was approximately 21 degrees C at both sites. There was a 4.2 ppt difference in salinity: 15.7 ppt at Bell Rock and 19.9 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters at Tow Stake and Pultz Bar were 253.0 and 298.0 oysters bushel^{-1} respectively. For a second year in a row there was an increase in the number of market oysters at both sites (Figure D4 and D6) and the number of market oysters during 2009 was the highest observed over the past twenty years of monitoring (Figure D6). The number of small oysters was also among the highest observed at both sites during the past twenty years of monitoring (second highest at Pultz Bar, third highest at Tow Stake). There was a small increase in the number of spat at Tow Stake when compared with 2008 and the number of spat ranked the third highest observed during the past twenty years of monitoring. The live oysters were primarily small oysters at both sites accounting for 63% of the total at Tow Stake and 74% of the total at Pultz Bar.

There were very few boxes observed at either site (less than 10% of the total live and dead) and of the boxes observed at Tow Stake 18% were spat boxes. At Tow Stake, three out of the nine spat boxes observed had 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. Water temperature was between 21.1 degrees C and salinity was approximately 20.6 ppt at both sites (Table D2) on the day of sampling.

Piankatank River

The total number of live oysters bushel^{-1} in the Piankatank River ranged from 97.0 at Burton Point to 485.0 at Palace Bar. There was an increase in the number of market oysters observed at all three sites when compared with 2008 and the increase at Ginney Point and Palace Bar marked the fourth year in a row that showed an increase in market oyster abundance at these two sites (Figure D7 and D8). The abundance of market oysters at all three sites during 2009 was the highest observed over the past twenty years of monitoring (Figure D8). The number of small oysters at Palace Bar and Ginney Point was similar to that observed during 2007 and 2008 and was among the highest observed over the past twenty years (Figure D8), however there was a small decrease in the number of both small and spat oysters observed at Ginney Point when compared with 2008. Despite the decrease in spat at Ginney Point, settlement during 2009 was relatively good for the fourth year in a row at all three sites following three years (2003-2005) of record low settlement (Figure D8).

The number of boxes observed was low at all three sites accounting for 11 (Palace Bar) to 15% (Burton Point) of the total (live and boxes). The majority of the boxes at Ginney Point and Burton Point were old boxes, whereas the boxes at Palace Bar were a combination of old (73%) and new (22%) indicating some recent mortality at this site. For the first time since 2005, there were no spat boxes attributed to oyster drills found at Burton Point. Water temperature on the day of sampling was between 17 and 18 degrees C at all three sites. Salinity ranged between 18.0 (Ginney Point) and 18.4 ppt (Burton Point).

Rappahannock River

In the Rappahannock River, the average total number of live oysters bushel^{-1} ranged from a low of 27.0 at Long Rock to a high of 267.5 at Drumming Ground. 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). As has been observed during the previous two years, the sites with the highest number of oysters were located in the Corrotoman River (Middle Ground) and just outside the mouth of the Corrotoman River (Drumming Ground). For the second year in a row, Middle Ground had the second highest total number of oysters (194.5 bushel^{-1}). This suggests that the population at Middle Ground is rebounding after the almost 100% die-off that occurred at the site in 2005 (Southworth et al. 2006).

The average number of market oysters bushel^{-1} ranged from 20.0 (Hog House) to 57.0 (Drumming Ground). There was an increase in the number of market oysters observed at Bowler's Rock, Morattico Bar, Smokey Point, Drumming Ground and Broad Creek (Figure D9 and D10) when compared with 2008. The number of market oysters at eight out of the ten sites was among the highest observed over the past twenty years of monitoring (highest at Bowler's Rock, Morattico Bar, Smokey Point, and Middle Ground; second highest at Ross Rock, Hog House, Drumming Ground and Parrot Rock). It should be noted however that the increase observed at both Smokey Point and Morattico Bar may have been a result of the planting of seed oysters from the Great Wicomico River in spring 2008 (VMRC, unpublished data).

Drumming Ground near the mouth of the Corrotoman River had the highest average number of small oysters bushel^{-1} (203.0) for the eighth year in a row, although this was a small decrease when compared with 2008. There was also a decrease in the number of small oysters observed at Smokey Point, Hog House and Broad Creek and an increase at Ross Rock (Figure D9).

For the first time in three years there were no spat observed at Ross Rock, Bowler's Rock, Long Rock or Hog House. In addition to a lack of spat at those four sites there was also a decrease in the number of spat observed at Middle Ground, Drumming Ground and Parrot Rock when compared with 2008 (Figure D9). Settlement throughout the system has been low (typically less than 100 spat bushel^{-1}) since the early 1990s (Figure D10) and 2009 was no exception.

The average total number of boxes bushel^{-1} was low, accounting for less than 15% of the total (live and dead) at eight out of the ten sites. The total number of boxes at Broad Creek and Middle Ground were moderate accounting for 25 and 31% of the total (live and dead) respectively. At nine out of the ten sites, the observed boxes were primarily old accounting for greater than 89% of the total (live and dead). The exception was Drumming Ground, with 73% old boxes and 25% new boxes indicating some recent mortality at that site. Middle Ground and Drumming Ground (the sites with the highest settlement) were the only sites with spat boxes.

Water temperature on the day of sampling ranged from 12.7 to 15.4 degrees C, increasing as one moved up the river system. Salinity increased in the opposite direction moving from the most upriver site (Ross Rock: 10.8 ppt) toward the mouth (Broad Creek: 18.2 ppt).

Great Wicomico River

In the Great Wicomico River, the average total number of live oysters bushel^{-1}was low to moderate ranging from 146.5 at Fleet Point to 288.5 at Whaley's East. The live oysters found at all three sites were primarily a mixture of spat and small oysters. There was a small increase in the number of market oysters observed at Haynie Point and Whaley's East when compared with 2008 (Figure D11 and Figure D12) and the number of market oysters at these two sites were among the highest observed during the past twenty years of monitoring (highest at Haynie Point; fourth highest at Whaley's East). There was a decrease in the number of small oysters at Haynie Point and a decrease in the number of spat at all three sites when compared with 2008 (Figure D11). Settlement had been relatively high over the past several years comparable to what was observed in the late 1980s and early 1990s, but 2009 marked the first year with more average settlement (Figure D12). The total number of boxes bushel^{-1} was moderate ranging from 29.5 (Fleet Point) to 84.5 (Haynie Point). This accounted for 14 (Whaley's East) to 23% (Haynie Point) of the total (live and dead) number of oysters observed. At all three sites 88% of these were old boxes, and the majority of the rest were new boxes with very few spat boxes. Water temperature on the day of sampling was approximately 14 degrees C and salinity was approximately 18.0 ppt at all three sites monitored.

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 34.9 market oysters bushel^{-1}), but slightly higher than that observed during 2008 marking the second year in a row with a small overall increase.

For the past several decades, the bulk of Virginia's oyster population has been composed primarily of small oysters and spat. During 2009, small oysters dominated (were greater than 50% of the total) populations at twenty-four out of the thirty sites and market oysters dominated at five out of the remaining six. It should be noted however, that the five sites with predominately market oysters (Bowler's Rock, Long Rock, Morattico Bar and Hog House) all have extremely low (< 80 oysters bushel^{-1}) oyster populations. The oyster populations in the mesohaline reaches of the Piankatank River (on Ginney Point and Palace Bar) have 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). At both of these sites the number of small and market oysters combined are the second highest observed during the past twenty years and while this seems to suggest that the oyster population at these sites is increasing, several more years of consistent numbers of small and market oysters along with good settlement is needed to know if these increases in the number of oysters will persist.

Overall, settlement during 2009 was low to moderate. In the Great Wicomico River, settlement on the shellstrings (Part I of this report) was relatively high for the fourth year in a row, but this was not reflected in the spat collected on the bottom in the dredge survey. The disconnect between what is observed on the shellstrings and on the bottom may be attributed to a lack of hard substrate or poor substrate quality, either of which reduce the available settlement habitat (substrate limitation). For the first time in four years, there was no settlement observed at several of the sites in the Rappahannock River and overall settlement in that system was low. Settlement in the York River and Mobjack Bay was relatively low with less than 60 spat bushel^{-1} observed at all of the sites. Settlement in the James River was similar to the patterns that have been observed in more recent years, with higher settlement at the eight most upriver sites when compared with the two most downriver sites. This is in contrast to the historical settlement pattern where settlement increased as one moved from the downriver sites to the upriver sites (Haven & Fritz 1985). Settlement at the two most downriver sites during 2009 (Thomas Rock and Nansemond Ridge) was among the lowest observed over the past twenty years.

The average total number of boxes observed during 2009 was low to moderate accounting for 3 to 31% of the total (live and dead) oysters. On a system basis, the James River had the highest number of boxes for the fourth year in a row, which is not surprising given that the James River also has the highest population of oysters. When spat were excluded from the live count, the four most downriver sites in the James River (Dry Shoal, Wreck Shoal, Thomas Rock and Nansemond Ridge) all had a fairly high percentage of boxes (between 17 and 32%). This may be indicative of increased mortality during 2009 caused by disease. Middle Ground and Broad Creek in the Rappahannock River as well as Haynie Point and Fleet Point in the Great Wicomico River also experienced an elevated number of boxes relative to 2008 when spat were excluded from the live count. As in the James River, this may be indicative of increased disease mortality at these sites.

In general, drill holes have become more prevalent in spat boxes since the early 2000s. However during 2009, drill holes were only present in the spat boxes observed at Tow Stake in the Mobjack Bay. For the first time since 2005, there were no spat boxes with drill holes present in the Piankatank River. 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 mouths of the Piankatank and Rappahannock Rivers, and in Mobjack Bay. While there were very few spat boxes with drill holes observed during the 2009 dredge survey, it should be noted that drill holes were observed at multiple sites in both the Piankatank River and Mobjack Bay during the patent tong survey in November of 2009 (Southworth, personal observation), so the predation of spat by oyster drills in these systems remains a concern.

Table D1: Station locations for the 2009 VIMS Fall dredge survey.

Station	Latitude	Longitude
James River		
Deep Water Shoal	37 08 56	76 38 08
Mulberry Point	37 07 09	76 37 55
Horsehead	37 06 24	76 38 02
Point of Shoal	37 04 37	76 38 36
Swash	37 05 32	76 36 44
Long Shoal	37 04 35	76 37 01
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 30	76 33 04
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 2009. Note that the bushel measure used is a Virginia bushel which is equivalent to 3003.9 cubic inches. A Virginia bushel differs in volume from both a U.S. bushel (2150.4 cubic inches) and a Maryland bushel (2800.7 cubic inches). "**" indicates a private bar. Middle Ground (#) is located in the Corrotoman River, a subestuary of the Rappahannock River system.

Station	Date	Water temp. (deg C)	Salinity (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	16.5	11.0	43.5	455.5	87	586	8.5	12.5	1	22
Mulberry Point	10/23	16.2	13.5	34	528	139	701	6	23	0.5	29.5
Horsehead	10/23	16.3	12.2	64	629	198.5	891.5	20.5	41.5	1.5	63.5
Point of Shoal	10/23	15.8	13.8	80.5	440.5	97	618	9	32.5	1	42.5
Swash	10/23	16.0	14.6	32	422.5	135	589.5	11	37	2	50
Long Shoal	10/23	15.5	14.4	45	627.5	162	834.5	22.5	79.5	0.5	102.5
Dry Shoal	10/22	15.5	17.4	37.5	374	67	478.5	18.5	67.5	3	89
Wreck Shoal	10/22	15.8	18.1	32.5	100.5	22	155	11	51	0.5	62.5
Thomas Rock	10/22	15.5	19.8	6.5	29	15	50.5	1.5	9.5	0.5	11.5
Nansemond Ridge	10/22	15.1	20.2	3	7.5	7.5	18	0	4.0	0	4
York River											
Bell Rock **	10/6	21.2	15.7	23	39.5	12.5	75	2	12.5	0.5	15
Aberdeen Rock	10/6	21.4	19.9	15	62	48	125	1	12.5	3	16.5
Mobjack Bay											
Tow Stake	10/5	21.1	20.5	34.5	159	59.5	253	4.5	16.5	4.5	25.5
Pultz Bar	10/5	21.1	20.7	68	219.5	10.5	298	7	26.5	0	33.5
Piankatank River											
Ginney Point	10/16	17.7	18	47	198.5	54.5	300	3.5	47	0	50.5
Palace Bar	10/16	17.2	18.2	44.5	230	210.5	485	13.5	45.5	3	62
Burton Point	10/16	17	18.4	19	56.5	21.5	97	1.5	15	0.5	17
Rappahannock River											
Ross Rock	10/20	12.7	10.8	37	65	0	102	0	2.5	0	2.5
Bowler's Rock	10/20	13.5	13.6	55.5	10.5	0	66	0	4	0	4
Long Rock	10/20	13.4	14.1	23.5	3.5	0	27	0	3.5	0	3.5
Morattico Bar	10/20	13.6	15.5	31.5	9	1	41.5	0	3.5	0	3.5
Smokey Point	10/20	14.8	16.8	44.5	32	0.5	77	2	12	0	14
Hog House	10/20	14.7	17.2	20	9	0	29	0	1.5	0	1.5
Middle Ground #	10/20	14.8	17	22	162.5	10	194.5	7.5	78	0.5	86
Drumming Ground	10/20	15.1	17.6	57	203	7.5	267.5	11.5	33.5	1	46
Parrot Rock	10/20	15.4	18.3	25.5	81.5	7.5	114.5	1.5	15.5	0.2	17.5
Broad Creek	10/20	15.4	18.2	33	37	17	87	2	26.5	0.5	29
Great Wicomico River											
Haynie Point	10/19	14.2	18.1	34.5	203.5	42	280	10	74	0.5	84.5
Whaley's East	10/19	14.1	18	19	226	43.5	288.5	4.5	40	1	45.5
Fleet Point	10/19	14	18	12.5	102	32	146.5	3.5	26	0.5	29.5

Figure D1: Map showing the location of the oyster bars sampled during the 2009 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.

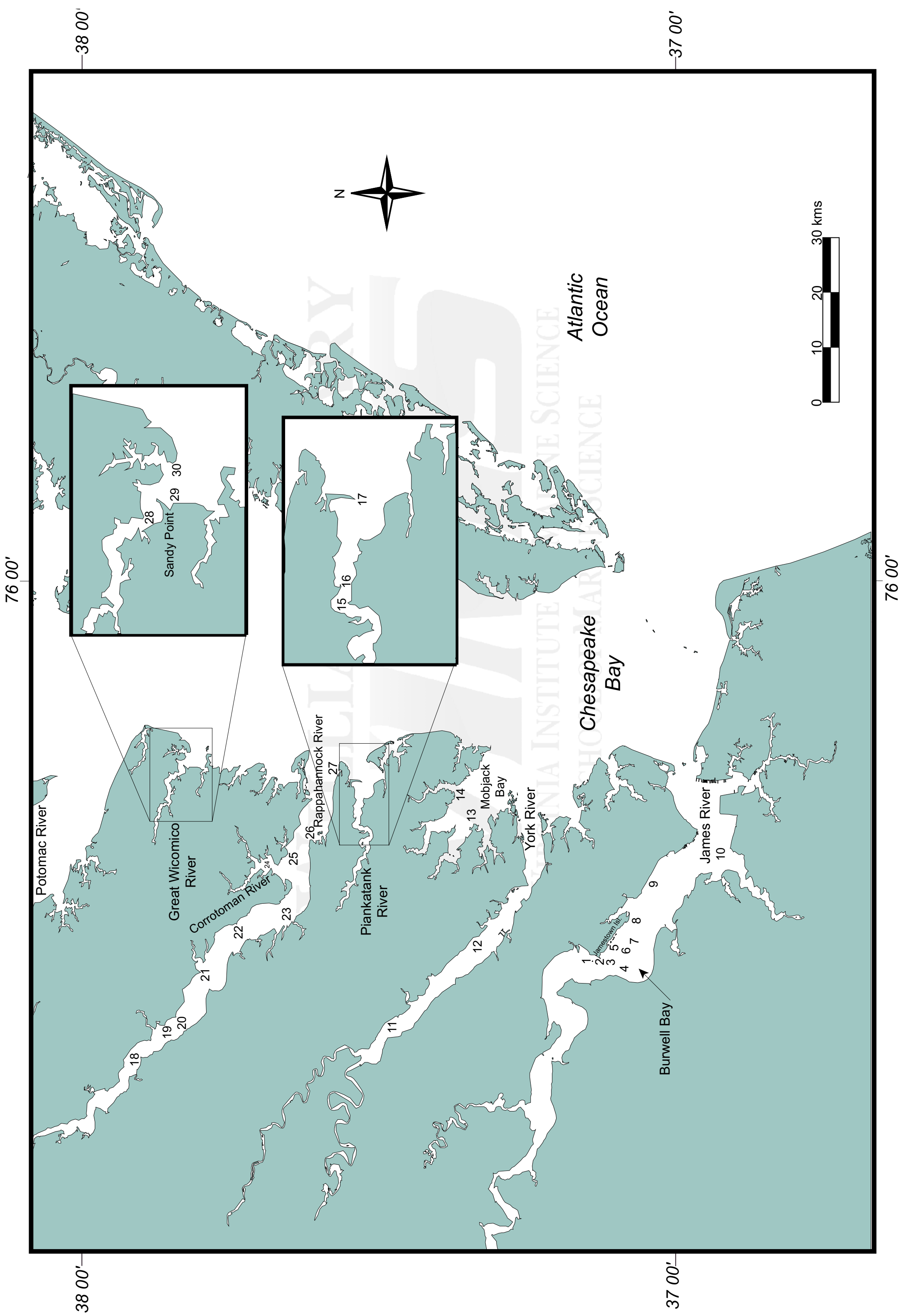
York River: 11) Bell Rock, 12) Aberdeen Rock.

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.



38 00'
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76 00'
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Great Wicomico
River
Corrotoman River
Rappahannock River
Piankatank
River
Mobjack
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York River
James River
Burwell Bay
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FIGURE D2: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE JAMES RIVER (2008-2009)
(Error bars represent standard error of the mean)

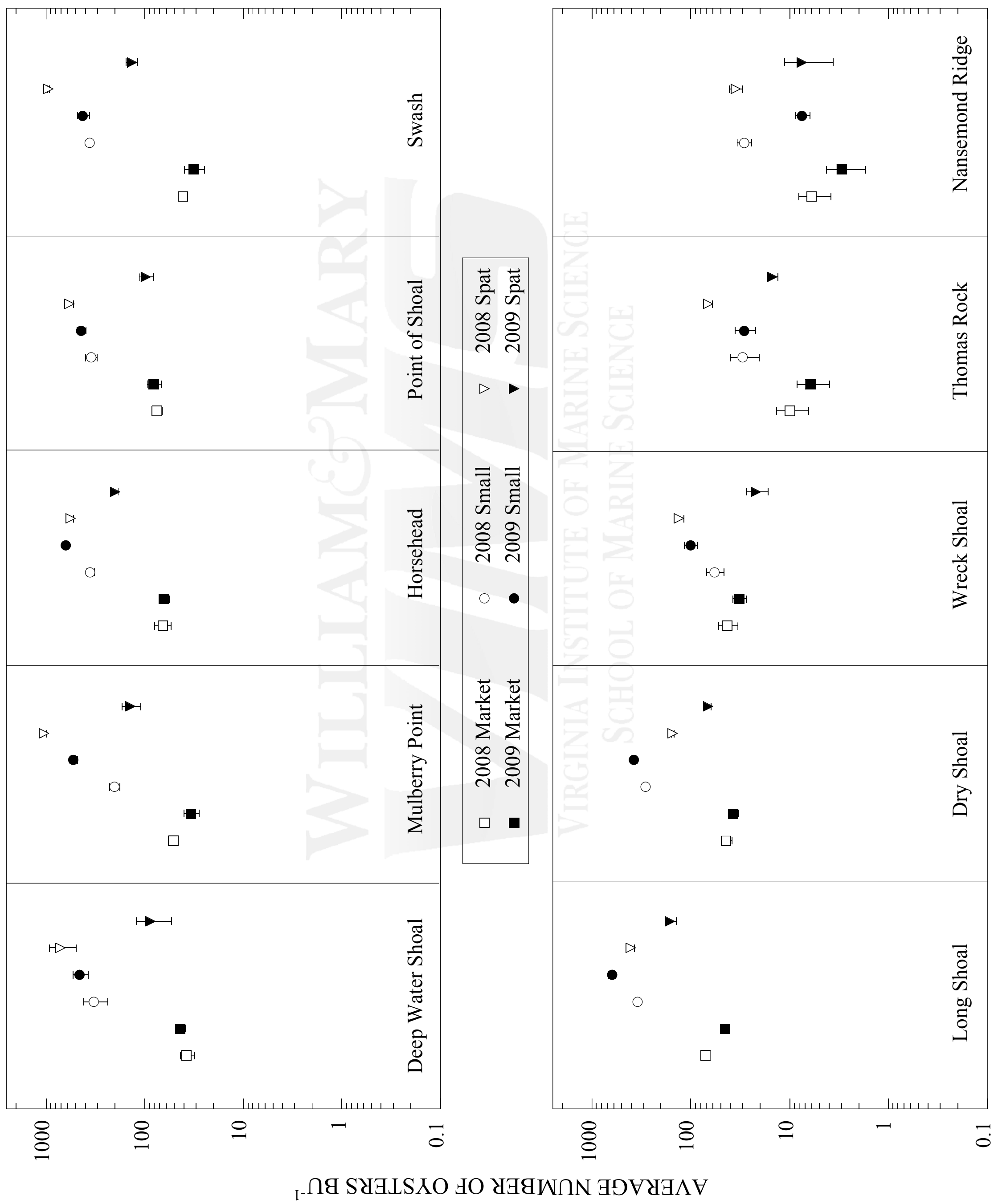
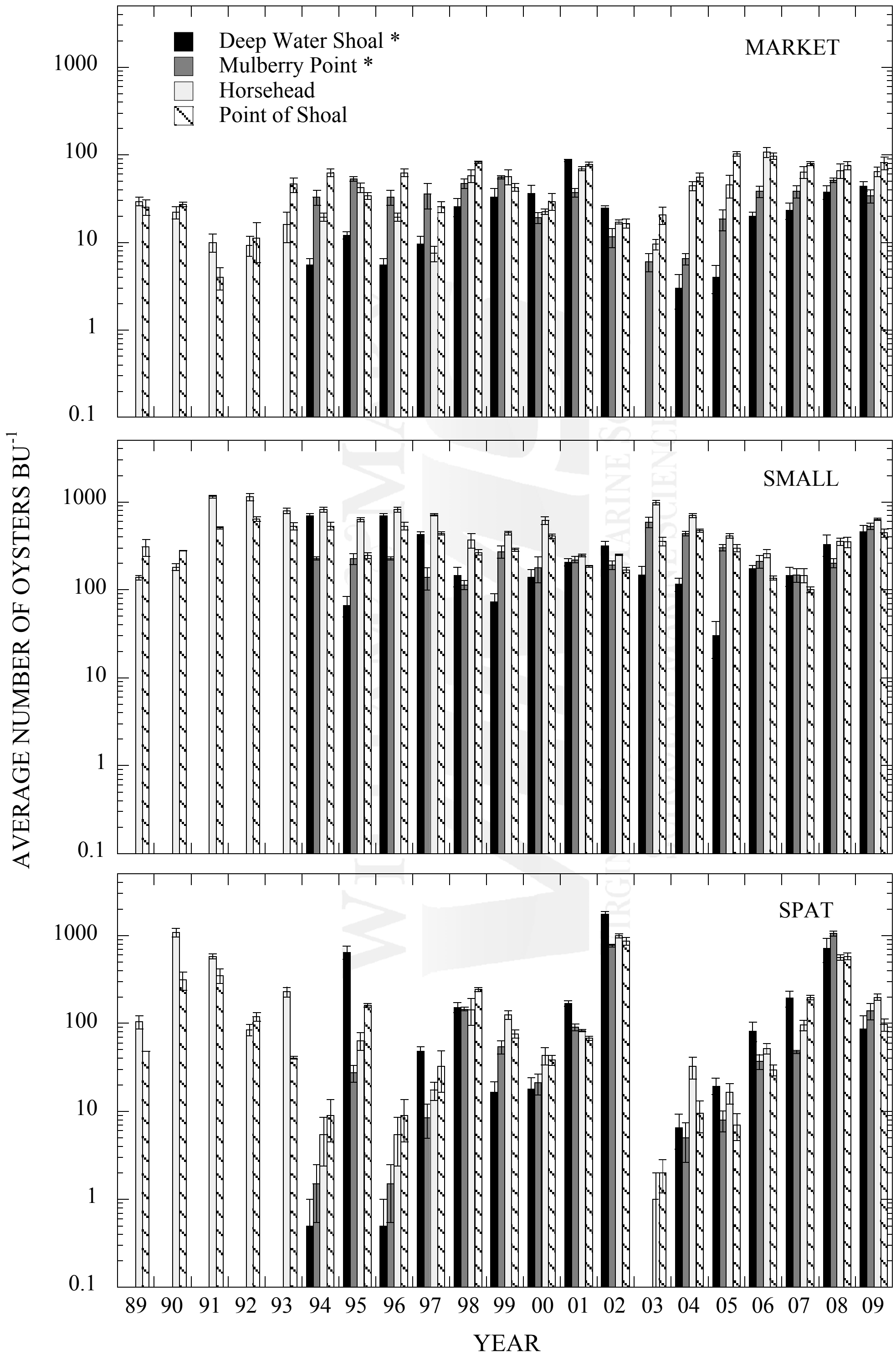
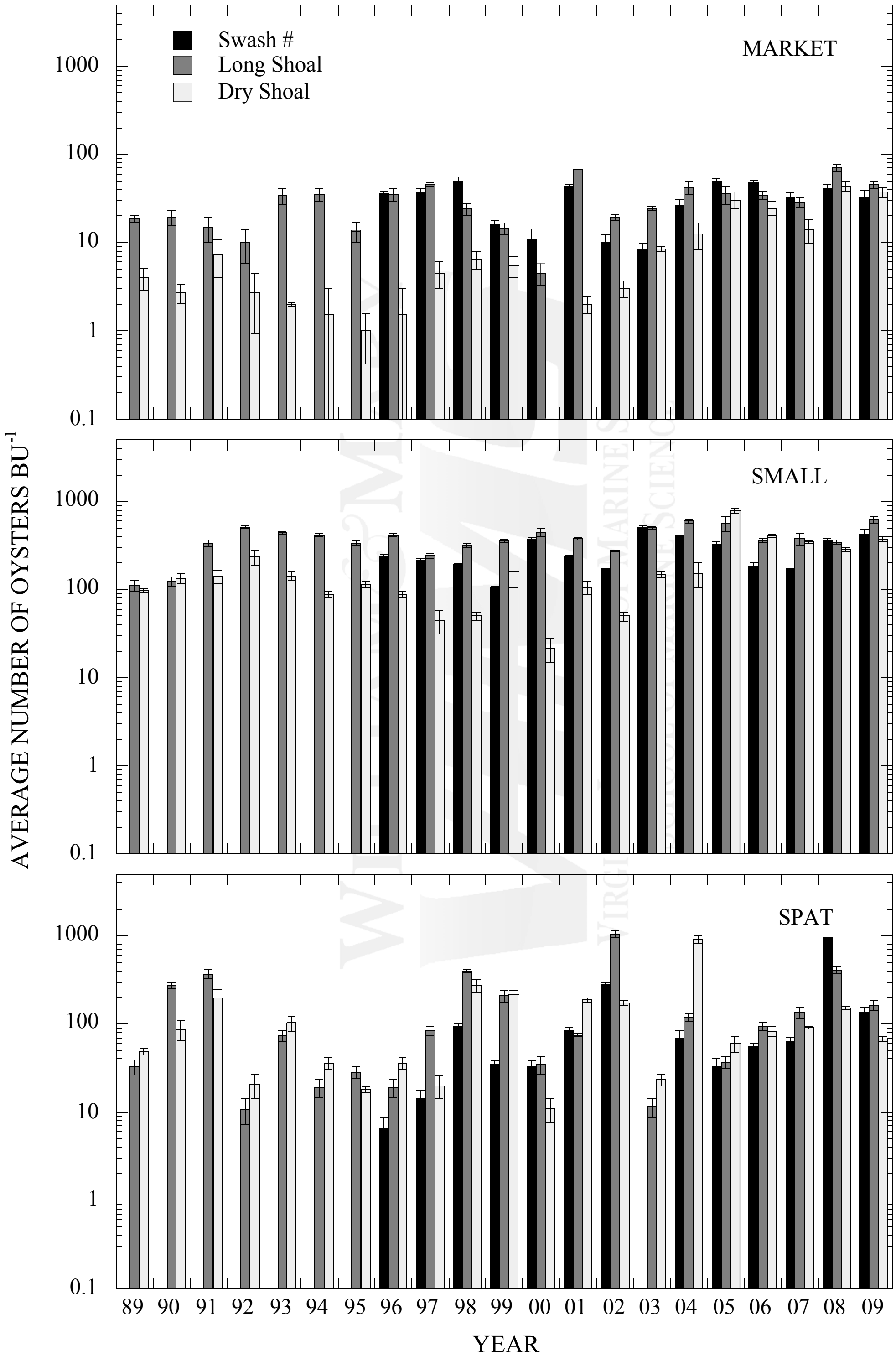


FIGURE D3A: JAMES RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No samples collected prior to 1994

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)

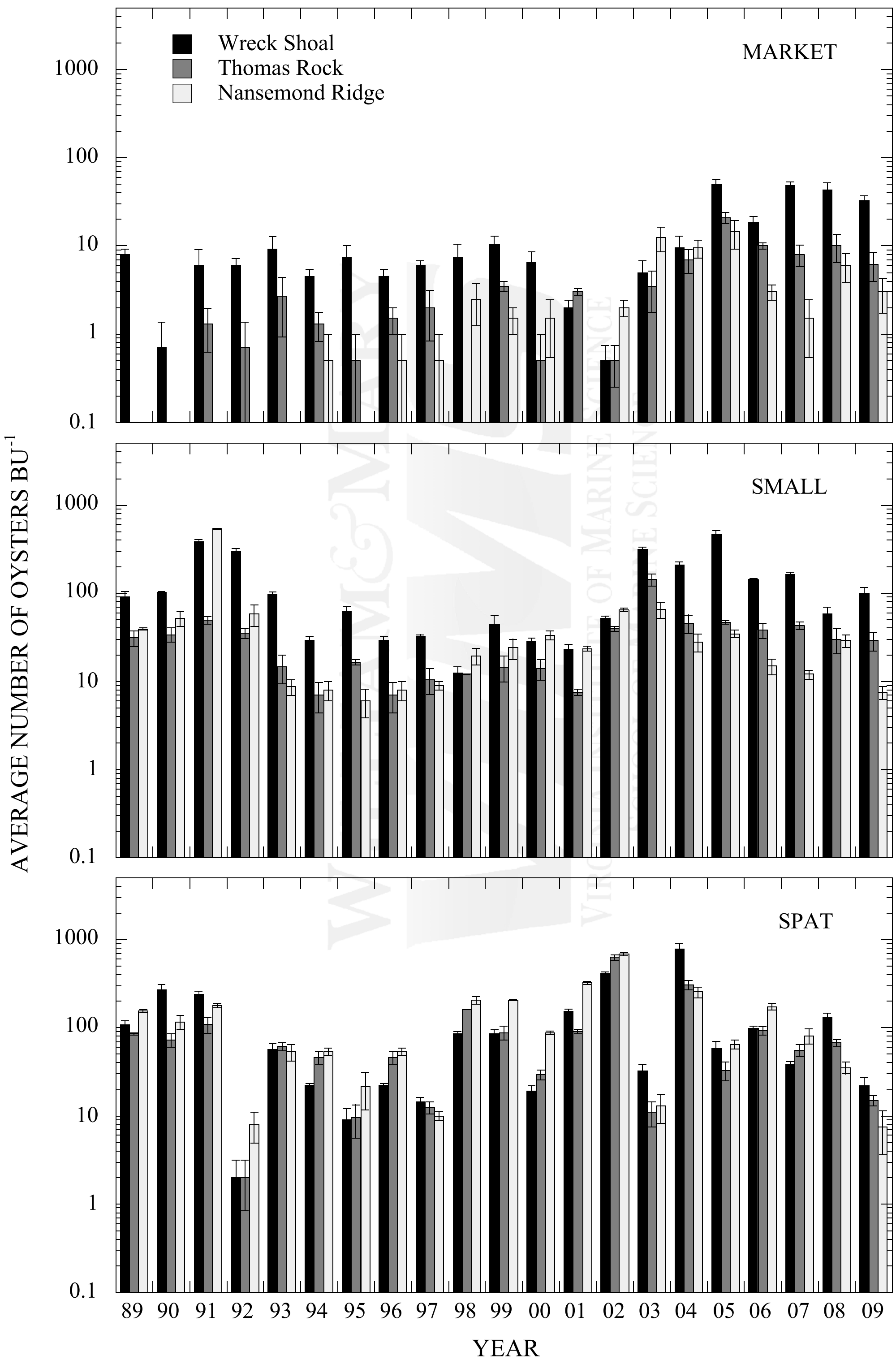


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE YORK RIVER AND MOBJACK BAY (2008-2009)
(Error bars represent standard error of the mean)

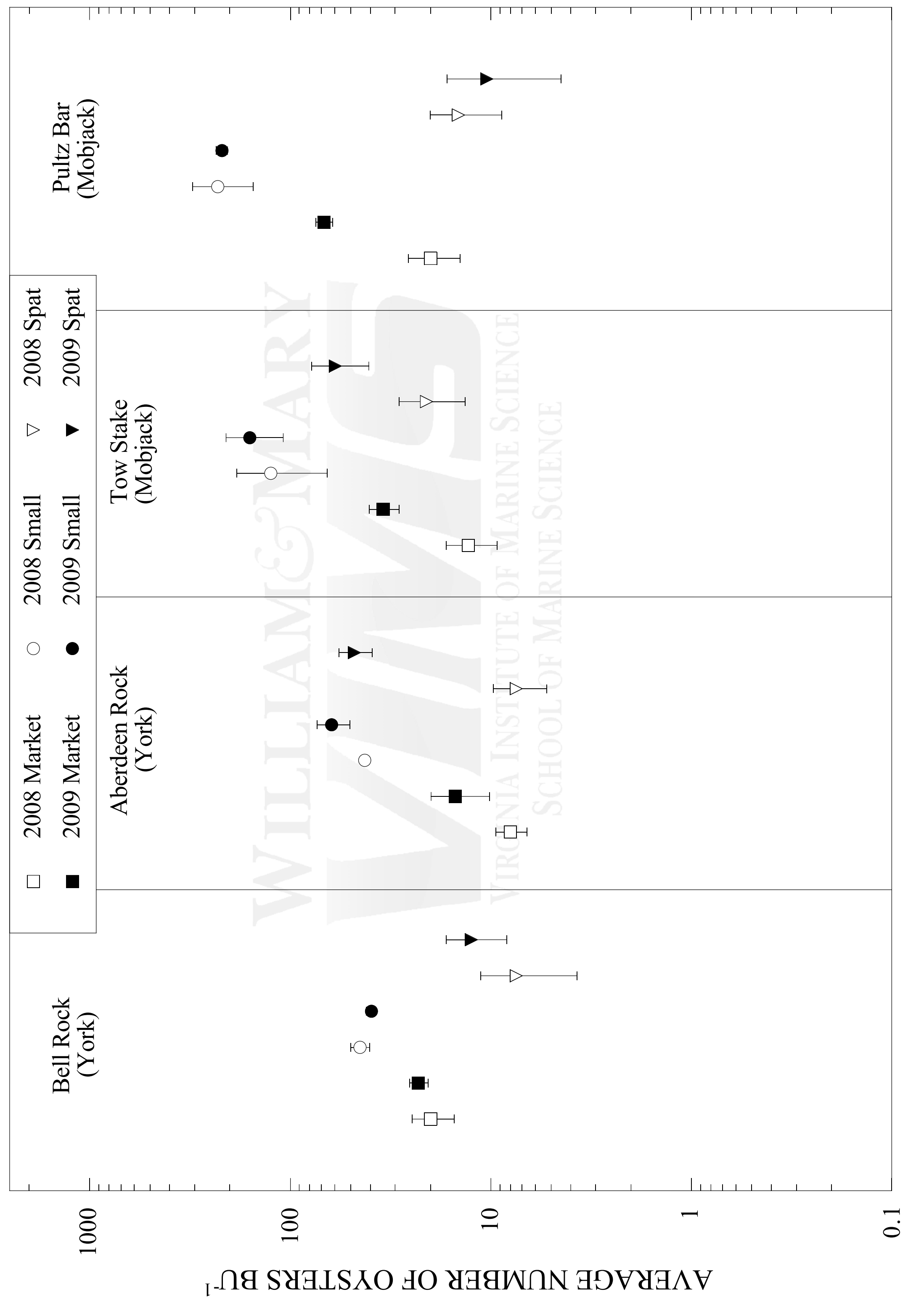


FIGURE D5: YORK RIVER OYSTER TRENDS OVER
THE PAST 20 YEARS
(Error bars represent standard error of the mean)

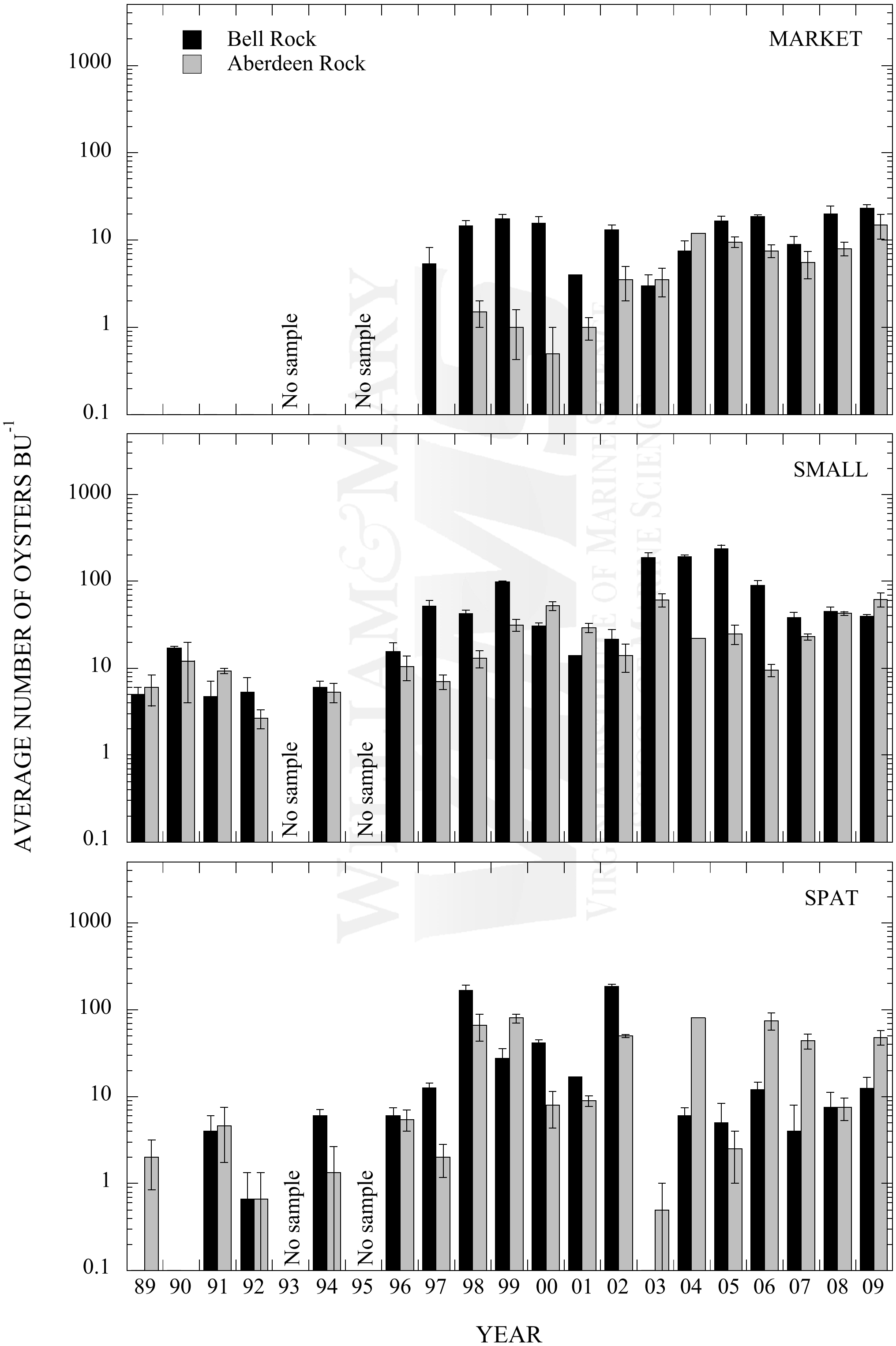


FIGURE D6: MOBJACK BAY OYSTER TRENDS OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

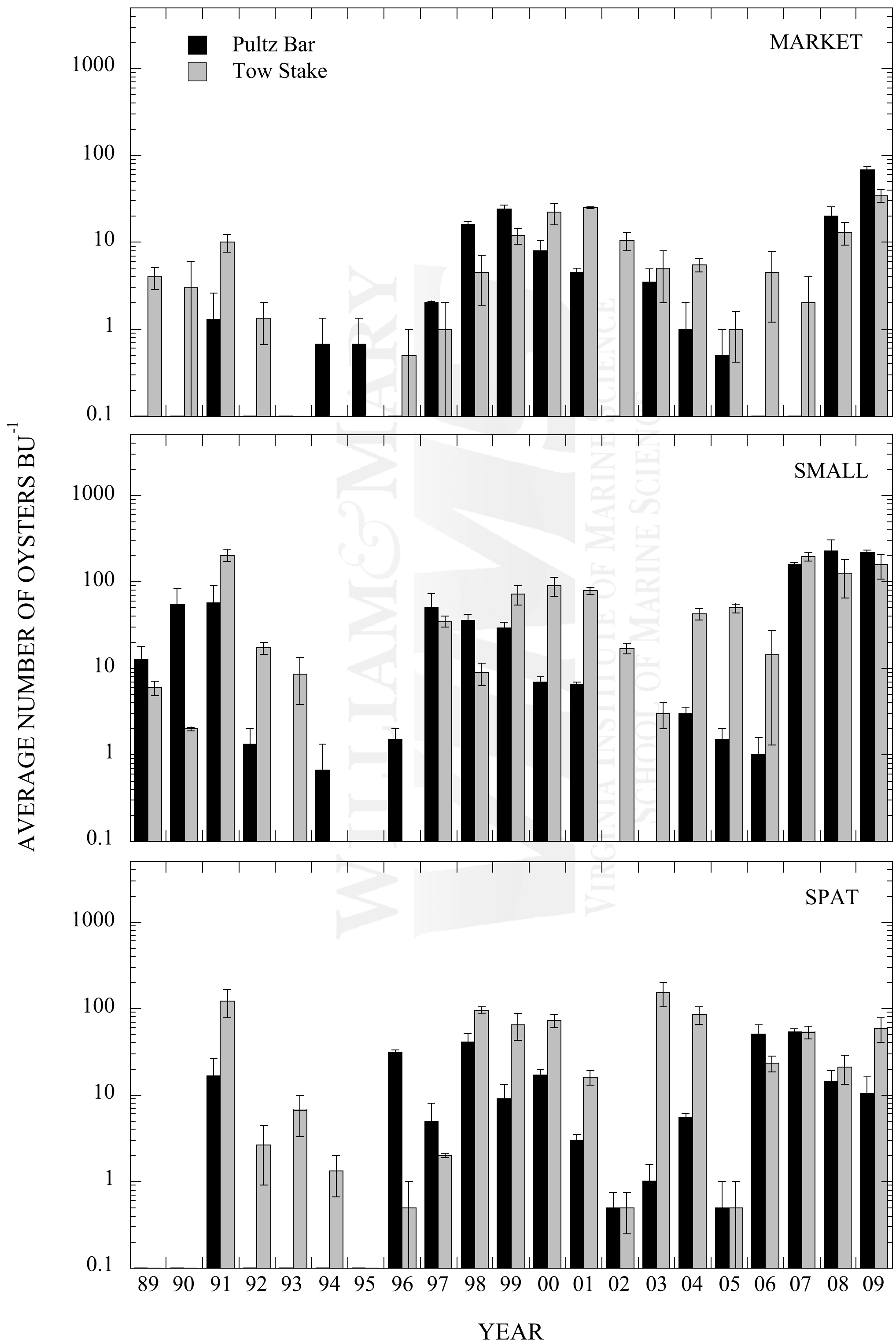


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE PIANKATANK RIVER (2008-2009)
(Error bars represent standard error of the mean)

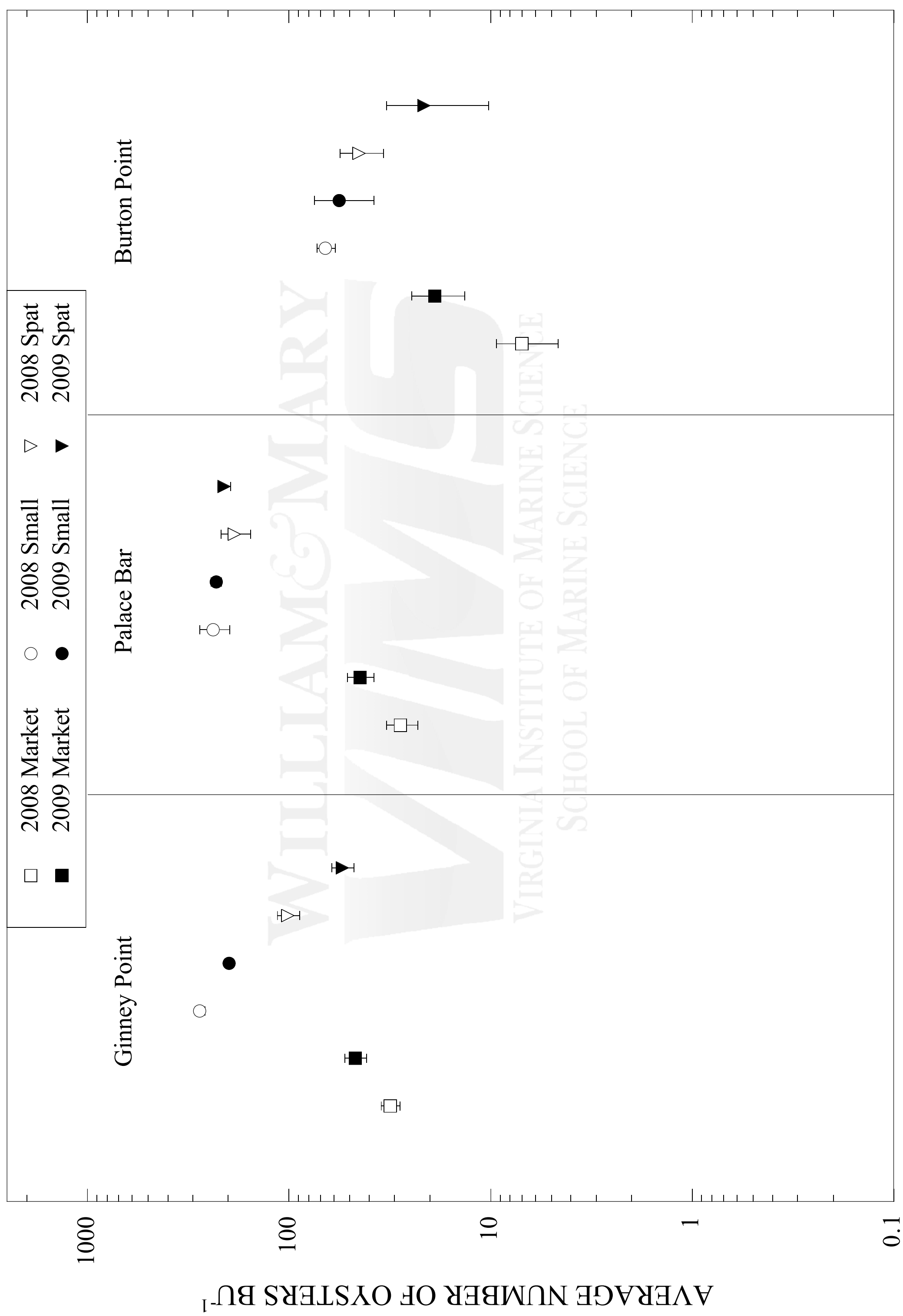
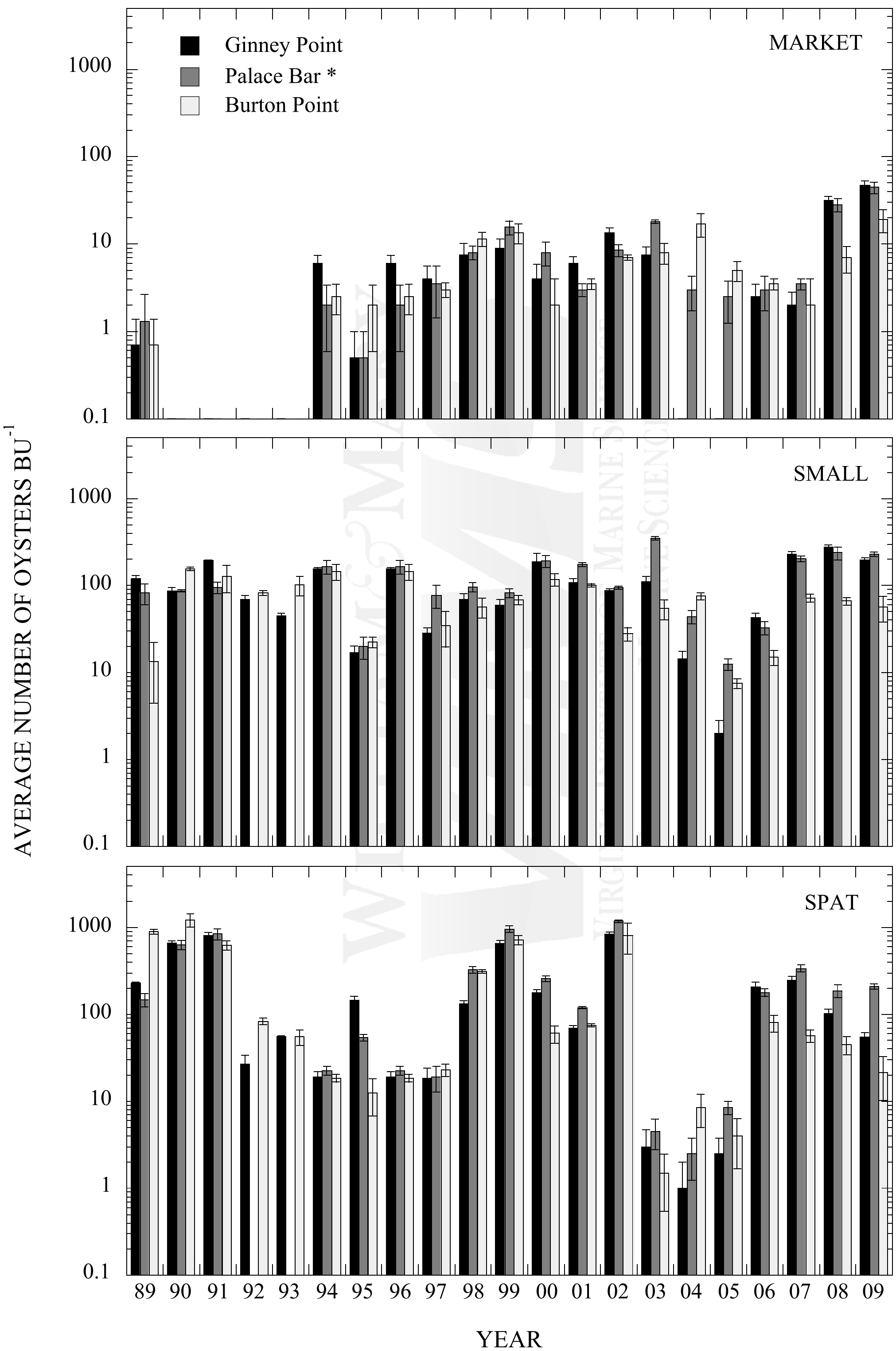


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No sample collected in 1992 and 1993

FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2008-2009)
(Error bars represent standard error of the mean)

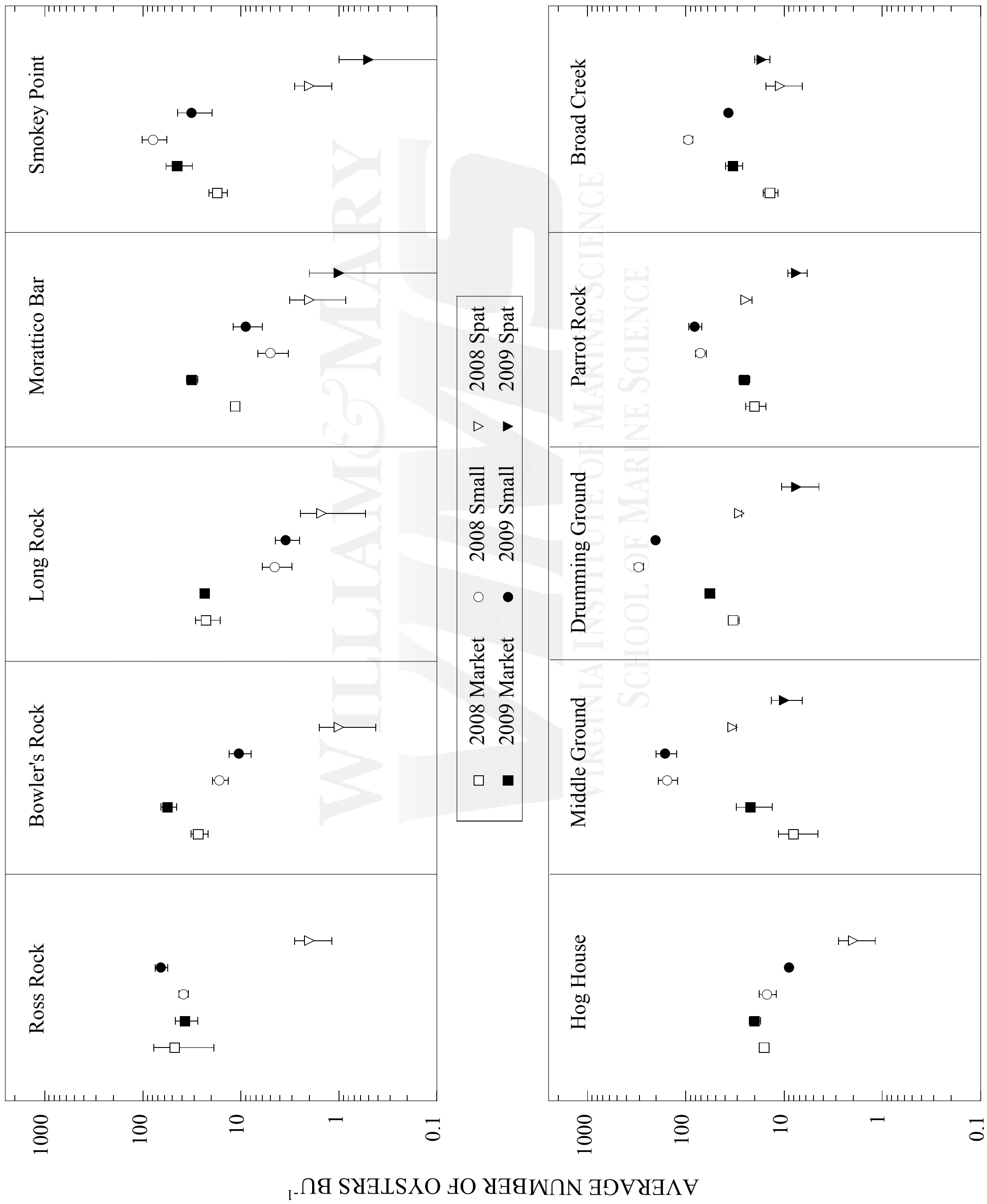
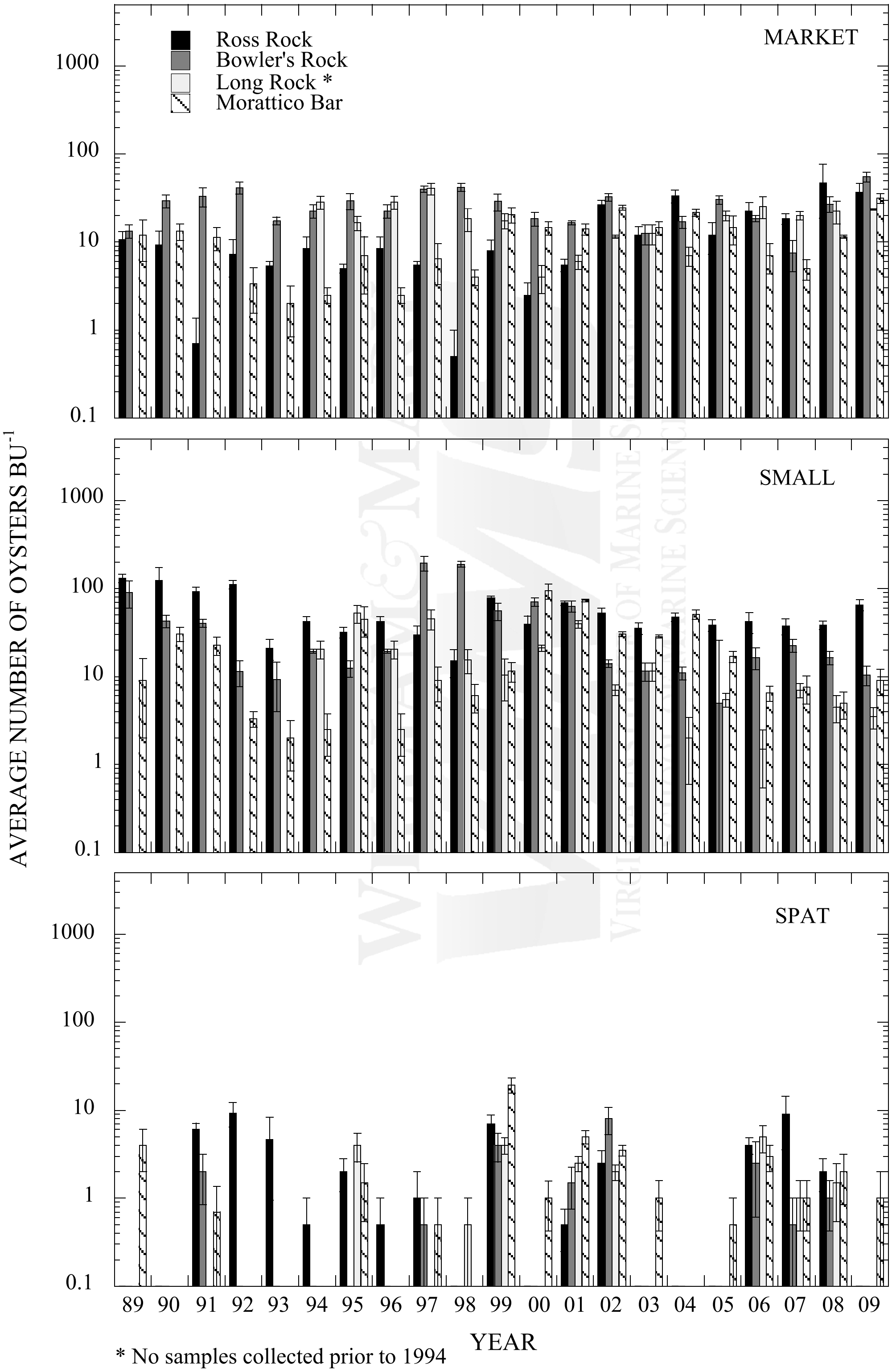


FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No samples collected prior to 1994

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

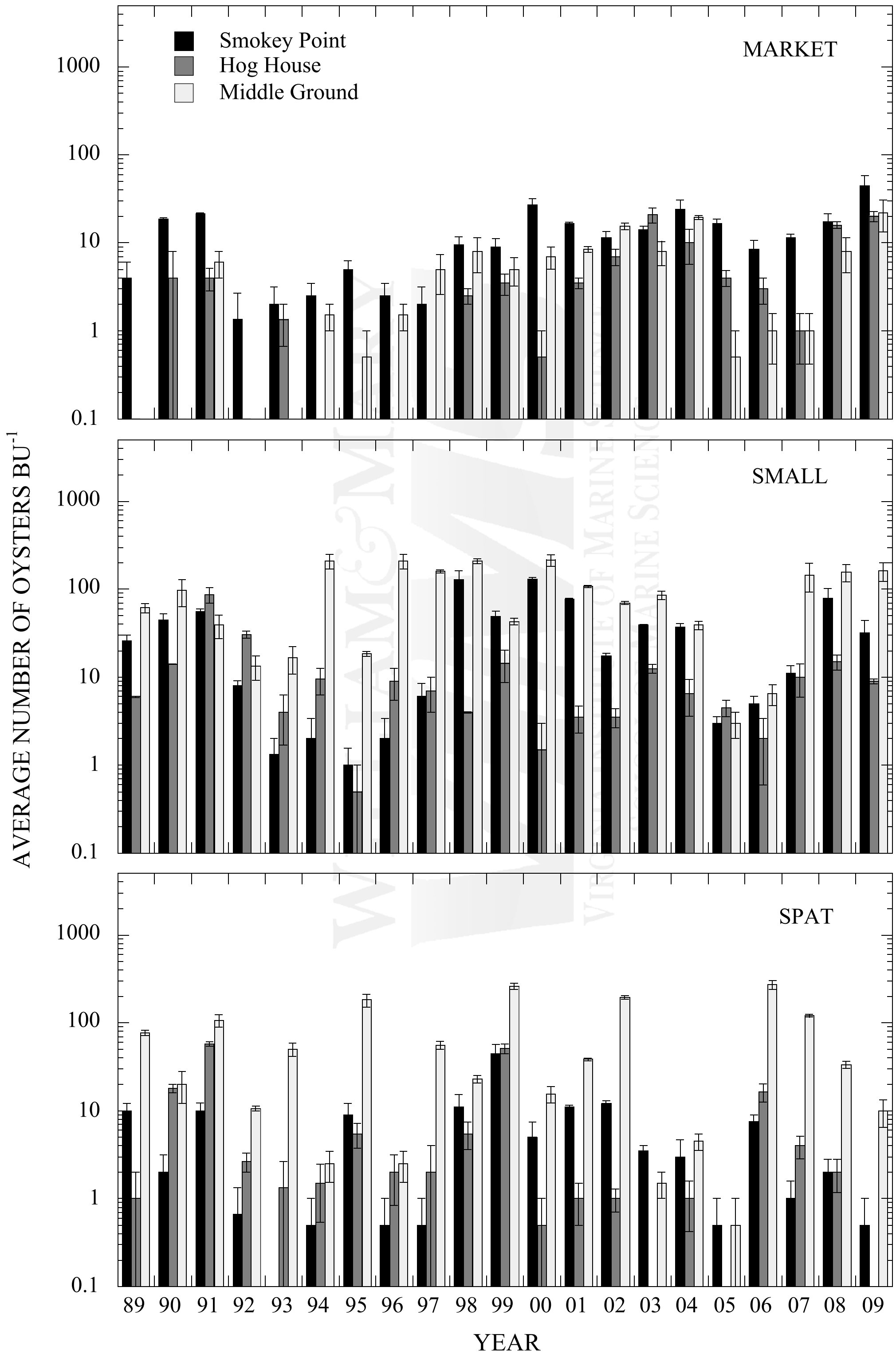
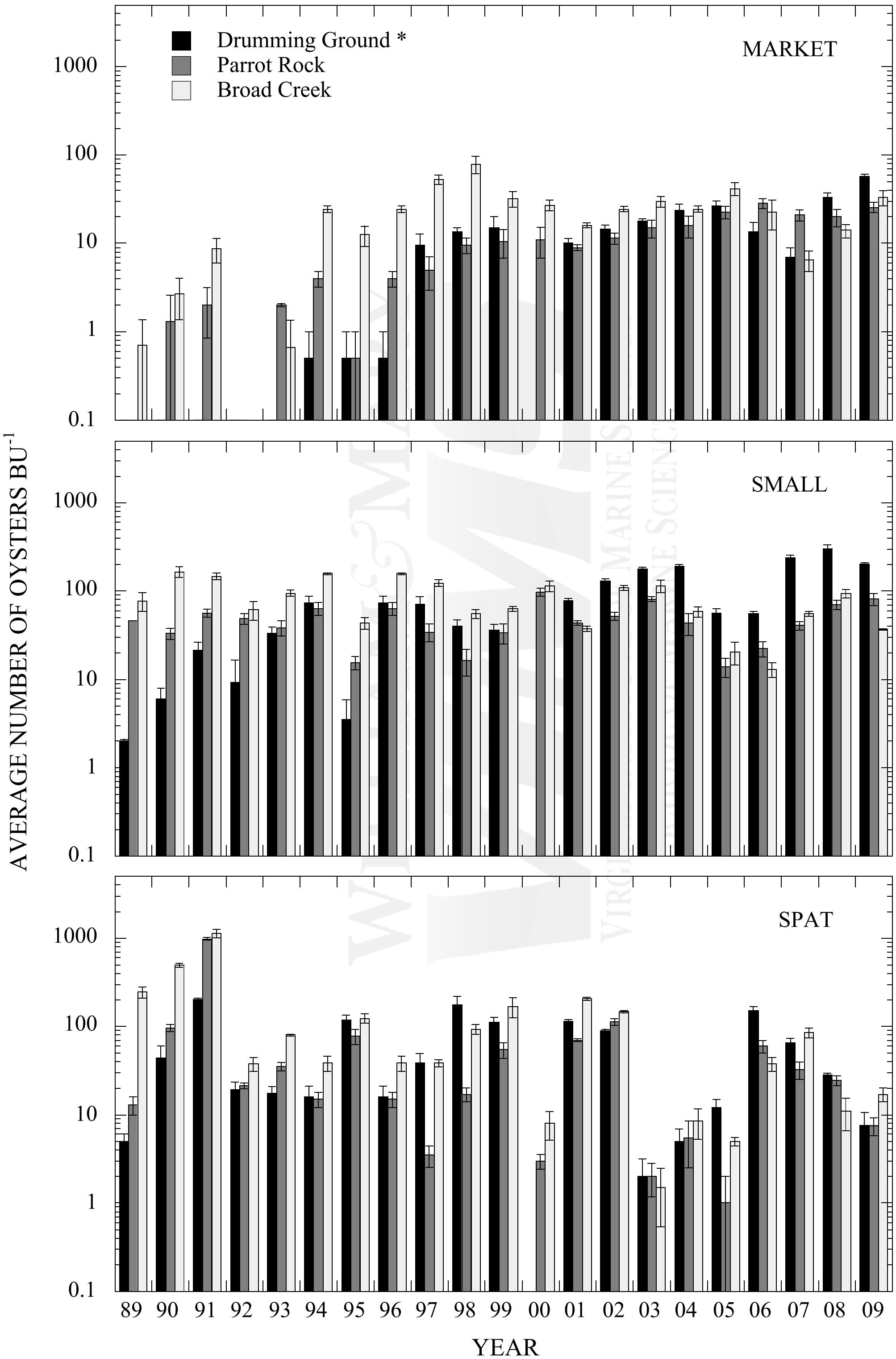


FIGURE D10C: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No sample collected in 2000

FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE GREAT WICOMICO RIVER (2008-2009)
(Error bars represent standard error of the mean)

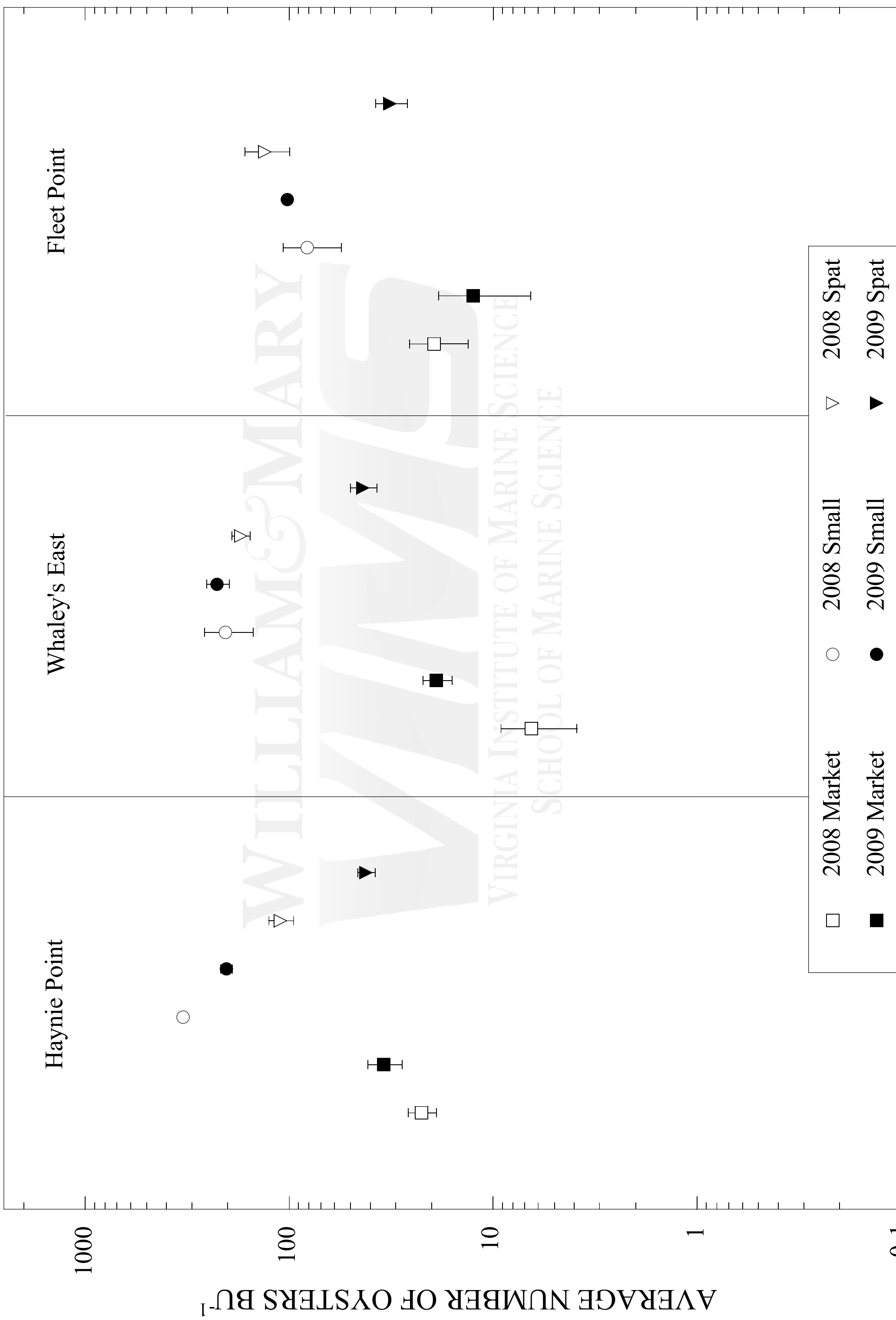
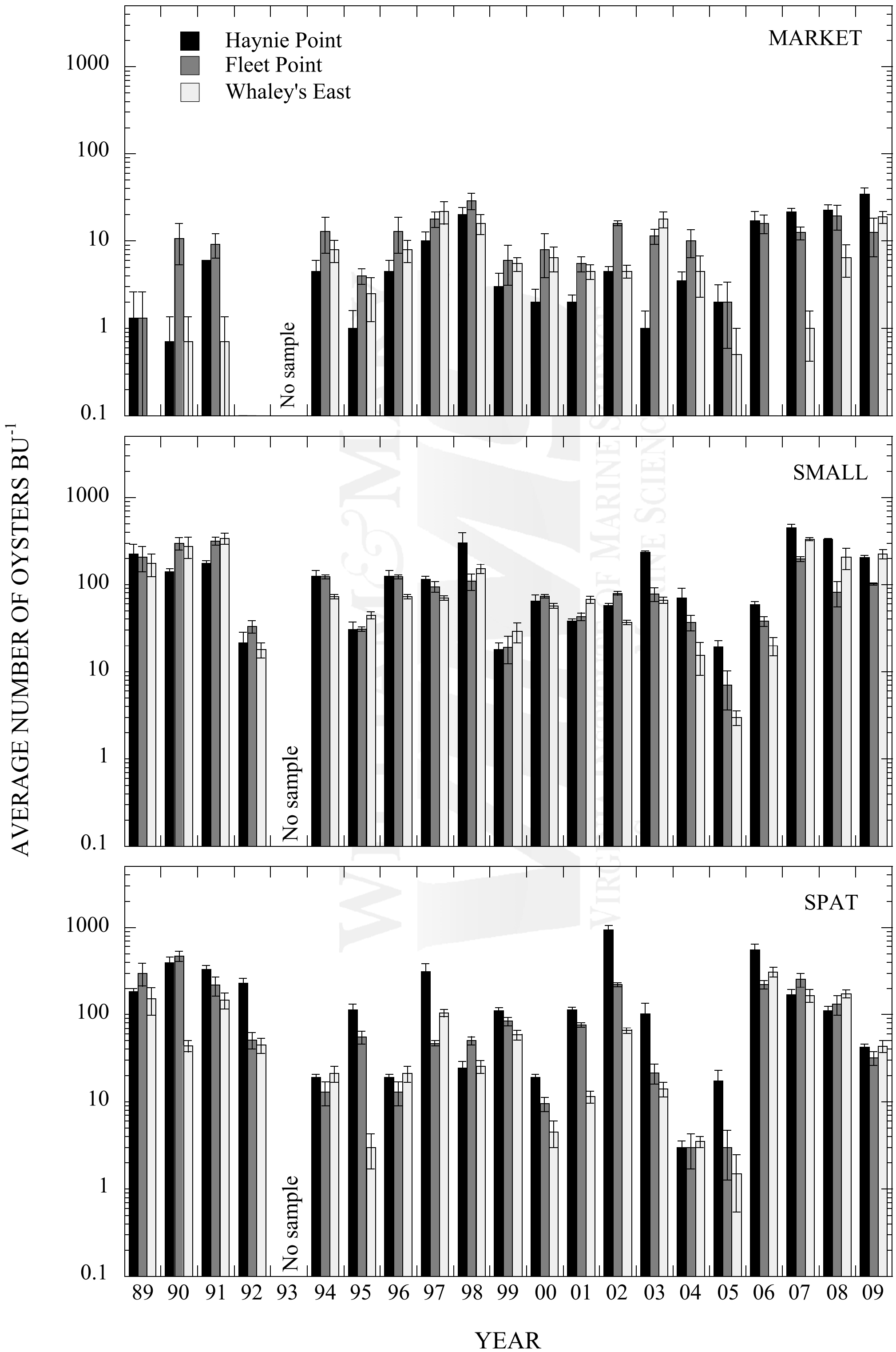


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



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, Wayne Reisner and Bob Gammisch (VIMS Physical Science) for help with vessel operations. Erin Reilly (VIMS Fisheries Science) assisted in making and examining the shellstrings as well as helping out with fieldwork. Cindy Forrester (Department of Fisheries Science, Budget Manager) and Grace Walser (Department of Fisheries Science, Purchasing Agents) helped with purchasing field equipment and materials. VIMS Vessel Operations Department provided assistance with boat scheduling and operation throughout the year, namely George Pongonis (superintendent), Raymond Forrest and Susan Rollins. Roland Billups and Christine Bata from VIMS Vehicle Operations Department provided assistance with truck scheduling and operation. Dr. James A. Wesson, Division Head, Conservation and Replenishment Division of the Virginia Marine Resources Commission provided the vessel *J. B. Baylor* for use during the dredge survey. He also assisted during the dredge survey and provided data on shell replenishment and oyster movement. Adam Crocket, John Ericson and Vernon Rowe of the VMRC provided assistance during the fall 2009 dredge survey.

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