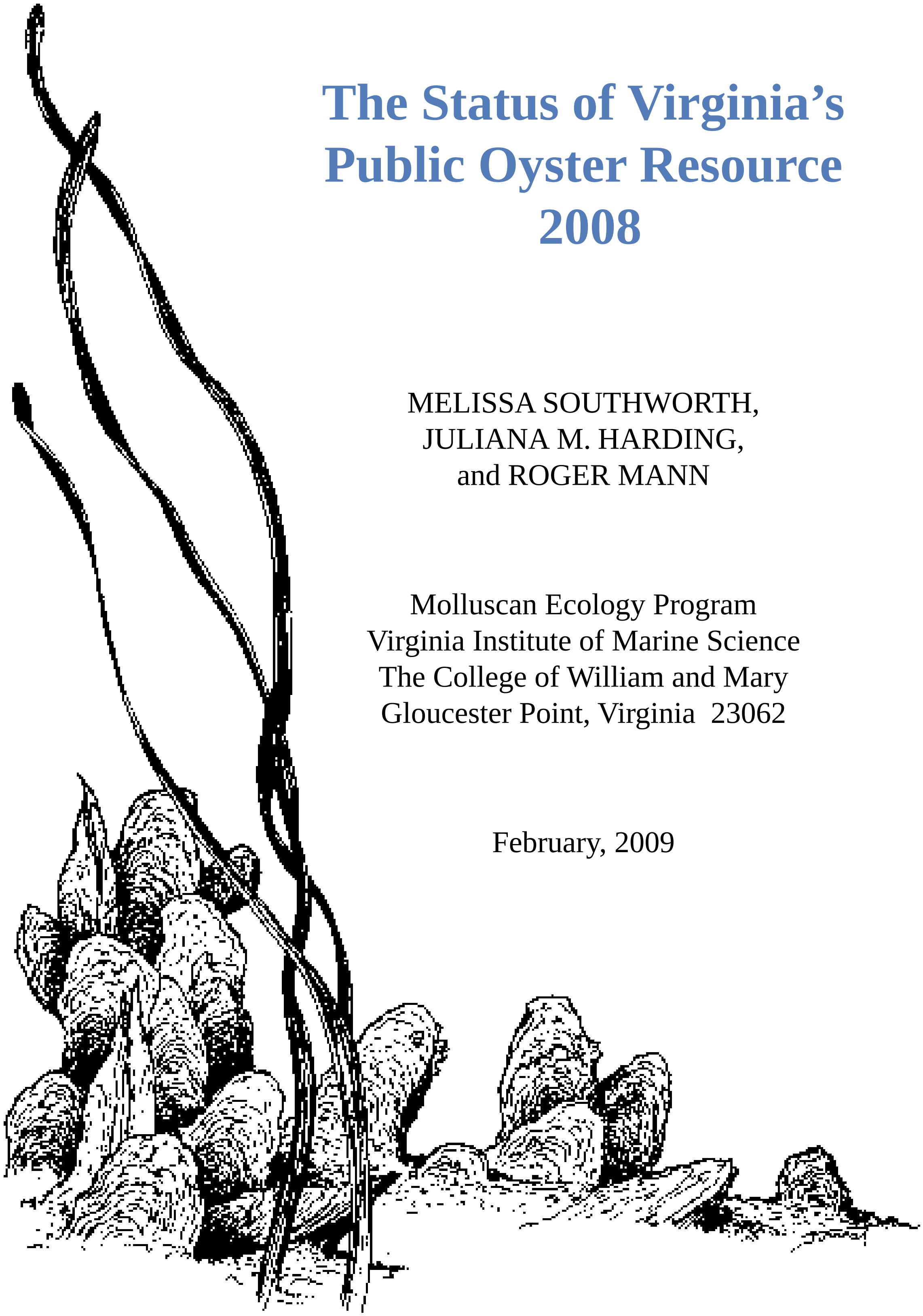

The Status of Virginia's Public Oyster Resource 2008

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Table of Contents

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Part I.

Oyster Spatfall In Virginia During 2008

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) monitors the recruitment activity 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 stations 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 2008 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2008 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 6 to 14 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).

Weekly water temperature and salinity measurements were taken approximately 0.5 m off the bottom at all stations 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 2008 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 2007 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 2008. 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 six out of the eight sites monitored (Table S1). Beginning the week of July 15, settlement was consistently observed throughout the system and continued until the end of the survey. One major peak occurred system-wide during the last two weeks of July (Figure S3). Settlement during this two-week period accounted for 86 (Rock Wharf) to 98% (Wreck Shoal) of the total settlement observed, with greater than 72% of the total settlement in the system for the entire season occurring during the week of July 22.

Settlement in the James River during 2008 was very heavy ranging from a low of 227.6 (Horsehead) to a high of 584.3 (Wreck Shoal) cumulative spat shell^{-1}. Settlement during 2008 in the James River was higher than that observed during 2007 as well as the 5, 10 and 20-year means at all of the sites monitored (Table S2; Figure S4). Settlement at all eight sites in the system was the highest observed over the past twenty years of monitoring.

Average river water temperatures ranged from 22 to 29 degrees C, reaching a maximum in late July (Figure S5A). Water temperature was about 2 degrees C lower than the long term (5, 10 and 20-year) means at the beginning of the observation period and increased 5 degrees C in the first two weeks of monitoring, such that water temperature by the week of June 10 was almost 3 degrees C higher than the long term means for June (Figure S5A). In general, for the remainder of the sampling period there was less than a 2 degrees C difference between average water temperature during 2008 and the long term means for the system. At the beginning of the sampling period, salinity was approximately 3 ppt lower than the previous 5, 10 and 20-year means (Figure S5B). Salinity then increased and for most of June was 1 to 2 ppt higher than the long-term means. From mid July through early September salinity continued to increase and was 2 to 6 ppt higher than the previous 5, 10 and 20-year means. The maximum difference between 2008 salinities and the long-term means occurred during the week of August 28 when salinity was approximately 6 ppt higher than the 10 and 20-year means and 8 ppt higher than the 5-year mean. The difference in salinity in any given week between the most upriver site (Deep Water Shoal) and the most downriver site (Day's Point; Figure 1) ranged from 4 to 10 ppt.

Piankatank River

Settlement in the Piankatank River was first observed during the week of July 29 at all eight sites monitored. Settlement was consistent throughout the system from that time until the week of September 16. On a system wide basis the largest peak in settlement occurred during the week of August 12, which accounted for 41% of the total spatfall in the system for the year (Table S1; Figure S6). There was a small peak observed at Wilton Creek and Palace Bar during the week of August 2 accounting for 56 and 58% of the cumulative spatfall for the season respectively. Cumulative spat shell^{-1} for the year was moderate to heavy ranging from a low of 7.1 at Burton Point to a high of 23.4 at Cape Toon.

Spatfall during 2008 showed an increase when compared with 2007 at three out of the eight sites monitored (Wilton Creek, Ginney Point and Palace Bar: Table S2; Figure S7). Settlement during 2008 was higher than both the 5 and 10-year means at all eight stations monitored and higher than the 20-year mean at Ginney Point. Settlement at Ginney Point, Palace Bar and Burton Point (the three historical sites) were the fourth, sixth and seventh highest observed during the past twenty years of monitoring respectively. Settlement at the five modern sites was among the highest observed (ranging from the highest at Wilton Creek to the fourth highest at Heron Rock) since monitoring at those sites began in 1998.

The average water temperature ranged from 21 to 29 degrees C throughout the sampling period, reaching a maximum in late July. Similar to what was observed in the James River, temperature was slightly lower than the long term means at the end of May, but increased almost 6 degrees C in the first two weeks of June such that by the week of June 10, temperature was about 3 degrees C higher than the 5, 10 and 19-year means (Figure S8A). Water temperature was similar to the long-term means (< 2 degrees C difference) throughout the rest of the sampling period. While the water temperature during 2008 was similar to the long-term means throughout this time-period, it should be noted that the increase in temperature observed between July 8 and July 22, was sharper than that observed over the long term. Similar to what occurred during the first two weeks of the survey, temperature increased by almost 4 degrees C during this two week period in July. Salinity was approximately 2 ppt lower than the 5, 10 and 19-year means when sampling began in the end of May and remained 2 to 3 ppt lower throughout the month of June (Figure S8B). Salinity was similar to that previously recorded in the system throughout the rest of the sampling period. 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 the sampling period.

Great Wicomico River

Settlement began the week of June 17 at all nine sites in the Great Wicomico River (Table S1) and was consistent from then until the week of July 15. There was little settlement observed during the last two weeks of July and settlement was intermittent from the first week of August through mid September. There was one major pulse in setting in the Great Wicomico River during 2008 that occurred during the last two weeks of June and the first week of July (Figure S9). This three-week period accounted for approximately 96% of the total spatfall recorded in the system for the entire season. 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 two most downriver sites, Whaley's East and Cranes Creek, 1.9 and 8.4 respectively. Settlement at the seven remaining sites was heavy, ranging from a low of 43.1 at Haynie Point to a high of 273.3 at Harcum Flats. 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 2008 was higher than the previous year (2007) at all of the sites except Whaley's East and Fleet Point (Table S2: Figure S10). When compared with the 5 and 10-year means settlement was higher during 2008 at all of the sites except Whaley's East. At the five historical sites, settlement was also higher than the 20-year mean at all sites except Whaley's East. This translated to the second highest (Hudnall and Haynie Point), third highest (Glebe Point) and fourth highest (Fleet Point) settlement at these sites in the past twenty years of monitoring. Settlement at the four modern sites has steadily increased since 2006 and settlement during 2008 at these sites was the highest observed since monitoring began in 1998.

Average river water temperatures ranged from 21 to 29 degrees C throughout the sampling period reaching a maximum the week of July 22 (Figure S11A). Similar to that observed in both the James and Piankatank Rivers, water temperature at the beginning of the sampling period was slightly lower than the 5 and 10-year means, but then increased almost 7 degrees C during the first two weeks of June (Figure S11A). Unlike the James and the Piankatank, this increase is more typical for the Great Wicomico, but the increase during 2008 was slightly sharper than what has been observed in the past (a 7 degrees C increase during 2008 versus a 4 degrees C increase in the 5 and 10-year means; Figure S11A). Temperature was similar (<2 degrees C difference) to that previously recorded in the system throughout most of the rest of the sampling period with the exception of a three-week period in August when water temperature was 2 to 3 degrees C lower than the 5 and 10-year means. Salinity ranged from 11 to 18 ppt during the sampling period. Similar to what was observed in the Piankatank River, salinity was 2 ppt less than the long-term means when sampling began the end of May and remained low throughout June (Figure S11B). There was a 1 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 (79% of all year/site combinations). Settlement during 2008 however, was relatively high in all three systems examined. Settlement in the Great Wicomico River was exceptionally high for the third year in a row and among the highest settlement events observed in the system since the mid 1980s.

Settlement in the James River was among the highest settlement ever observed in that system, at least an order of magnitude higher than what has become typical for the system since the early 1990s. What is remarkable is that the bulk of this settlement occurred within a single two-week period in mid July. Historically, the peak in setting in the James River occurred in early September (Andrews 1982), but in more recent years, settlement in the James River has been occurring earlier in the season (Southworth & Mann 2004) and the timing of the spat set during 2008 follows this trend. Salinity in the James River during 2008, while lower than the long term means when monitoring began in late May, became elevated shortly thereafter and remained elevated for the majority of the rest of the season. This sustained high salinity along with the rather sharp increase (5 degrees C) in temperature in the first two weeks of June may have contributed to the exceptionally high settlement observed. Temperature is the single most important factor affecting both timing and magnitude for oyster spawning (Shumway 1996) and sustained high salinities have been shown to contribute to greater spat production in the Maryland portion of the Chesapeake Bay (Ulanowitz et al. 1980).

Settlement in the Piankatank River was among the highest observed since the early 1990s. 2008 was the second year in a row with good settlement in this system. For the past few years, the number of broodstock has been exceptionally low 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). In 2008, the total number of potential broodstock oysters (small plus market) at Ginney Point and Palace Bar were among the highest observed during the past twenty years (Part II, this report) of monitoring. The majority of settlement in the Piankatank River occurred during the latter half of the season (August and September), shortly after the second sharp increase in water temperature. Sudden increases in water temperature have long been thought to induce spawning in oysters (Medcof 1939, Butler 1956).

Settlement in the Great Wicomico River was exceptionally high for the third year in a row. Settlement was among the highest observed in the system since the mid 1980s at the five historical sites and the highest observed at the four modern sites since monitoring began at those sites in 1998. The majority of the settlement occurred over a three-week period in late June early July. This peak was immediately following the large increase in water temperature that occurred during the first two weeks of monitoring. This increase while also occurring in the other two systems, was sharpest in the Great Wicomico, but is also more typical for this system. As previously mentioned, sudden increases in water temperature have long been thought to induce spawning in oysters (Medcof 1939, Butler 1956) and may help explain why settlement tends to occur earlier in the Great Wicomico River than in the other two systems (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	1.77	206	34.6	1.35	0.7	4.5	2.15	0.55	0.26	0.06	-	0.38	252.3
Horsehead	D	0	0	0	0	0	0.09	3.27	176	38.6	1.35	0.8	4.9	1.25	0.6	0.44	0.23	-	0	227.6
Point of Shoal	D	0	0	0	0	0	0.13	4.65	228	48.4	3.2	1.55	4.1	2.65	0.85	0.13	0.41	-	-	293.6
Swash	D	0	0	0	0	0	1.88	2.45	359	109	3.05	0.55	3.45	0.55	0.75	0.31	0.23	-	0.21	481.5
Dry Shoal	D	0	0	0	0	0	0	6.18	152	102	3.9	0.85	3	0.6	0.4	0.83	0	-	0.04	269.9
Rock Wharf	D	0	0	0	0	0	1.01	11.2	226	74.5	11.3	2.45	5.65	14	0.7	0.74	0.18	-	0.3	347.5
Wreck Shoal	D	0	0	0	0	0	0.13	6.88	421	153	1.2	0.45	0.6	0.2	0.2	0.04	0.23	-	0.25	584.3
Day's Point	D	0	0	0	0	0	0.04	3.56	172	59.5	4.80	2.35	4.5	2.4	0.4	0	0.06	-	0.23	249.2
Piankatank River																				
Wilton Creek	D	0	0	0	0	0	0	0	0	0.9	0.85	6.75	2.08	0.2	0.85	0.35	0.05	0.05	0	12.1
Ginney Point	D	0	0	0	0	0	0	0	0	1.3	1.98	8.95	3.7	0.45	1.2	0.3	0.4	0	0	18.3
Palace Bar	D	0	0	0	0	0	0	0	0	0.35	1.45	4.35	0.9	0.1	0	0	0.05	0	0	7.45
Bland Point	D	0	0	0	0	0	0	0	0	1.05	2.05	4.18	1.45	0.6	1.45	0.05	0.1	0.2	0	11.1
Heron Rock	D	0	0	0	0	0	0	0	0	0.6	1.1	3.1	0.7	0.9	0.7	0.2	0.05	0.05	0	7.4
Cape Toon	D	0	0	0	0	0	0	0	0	3.3	4.25	6.55	1.5	2.9	3.2	1.1	0.48	0.05	0.1	23.4
Stove Point	D	0	0	0	0	0	0	0	0	1.05	2.2	5.15	1.95	1.7	1.62	0.25	0.11	0	0.05	14.1
Burton Point	D	0	0	0	0	0	0	0	0	1	0.9	2.65	1.05	0.5	0.55	0.15	0.25	-	0.03	7.08
Great Wicomico River																				
Glebe Point	D	0	0	21.4	83.7	28.5	4.05	0.5	0	0.25	1.2	0.05	0.25	0.2	0	0.12	0	0	0	140.6
Rogue Point	D	0	0	29.1	60.1	29.5	1.95	0.7	0	0.1	1.45	0.35	0.4	0.75	1.1	0.06	0.35	0.05	0.25	126.2
Hilly Wash	D	0	0	40.6	65.7	25.2	3.4	0.4	0	0	0.6	0.05	0	0.25	0.6	0.23	0	0.05	0.15	137.7
Harcum Flats	D	0	0	59.9	99.4	106	4.05	0.95	0	0	0.4	0.15	0.3	0.3	0.4	0.35	0.3	0.05	0.05	273.3
Hudnall	D	0	0	32.2	29.7	17.9	1.6	0.3	0.1	0	0.15	0.1	0	0.1	0.05	0.12	0.2	0.05	0	83
Shell Bar	D	0	0	21.1	39.2	15.4	0.9	0	0	0	0.2	0.05	0.15	0.1	0.05	0.06	0.6	0.05	0	78.1
Haynie Point	D	0	0	14.3	20.9	6	0.91	0.15	0	0	0.2	0.06	0	0.05	0	0.29	0	0	0	43.1
Whaley's East	D	0	0	0.5	0.45	0.15	0.15	0	0	0.05	0	0	0	0.1	0.15	0.13	0.1	0.05	0.05	1.93
Fleet Point	D	0	0	2.5	2.9	1.6	0.6	0	0	0	0	0	0	0.05	0.2	0.23	0.35	0	0	8.43

Table S2: Spatfall totals for historical sites (1988-2008) and for 1998-2008 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 2008 in reference to 2007 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	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean 03-07	Mean 98-07	Mean 88-07	Ref. 2007	Ref. 5-yr	Ref. 10-yr	Ref. 20-yr
James River																												
Deep Water Shoal	4.3	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	2	5.3	4.7	+	+	+	+
Horsehead	3.5	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	2.3	4.7	6.7	+	+	+	+
Point of Shoal	41.7	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	3	5.6	12	+	+	+	+
Swash	7.6	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	4.4	6.2	10.7	+	+	+	+
Dry Shoal	13.2	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	5.1	5.5	25	+	+	+	+
Rock Wharf	9.9	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	7.2	7.8	8.3	+	+	+	+
Wreck Shoal	6.4	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	6.8	5	7	+	+	+	+
Day's Point	17.3	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	7.6	6.2	23.7	+	+	+	+
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	1.5	2.6		+	+	+	
Ginney Point	3.3	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	2.3	3.4	8.5	+	+	+	+
Palace Bar	3.6	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	1.5	3	13.4	+	+	+	-
Bland Point											2.3	44.1	2.7	1.3	6.7	0.2	0.4	1.0	3.7	11	11.1	3.2	7.3		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	2.5	4.1		-	+	+	
Cape Toon											4.5	12.3	1.2	1.8	9.1	0.1	2.0	2.6	8.2	23.5	23.4	7.3	6.5		NC	+	+	
Stove Point											1.0	7.1	1.8	1.6	31.0	0.1	0.7	1.7	7.0	19.9	14.4	5.9	7.2		-	+	+	
Burton Point	2	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	3.3	4.1	10	-	+	+	-
Great Wicomico River																												
Glebe Point	23.9	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	58.3	58.3	33	+	+	+	+
Rogue Point											0.9	2.0	2.6	0.7	16.6	7.0	0.5	2.6	88.1	112	126.2	42	23.3		+	+	+	
Hilly Wash											0.6	1.6	3.2	0.8	24.1	2.9	0.5	1.9	43.9	126.9	137.7	35.2	20.6		+	+	+	
Harcum Flats											0.1	1.3	0.8	1.1	33.7	3.7	0.7	1.5	110.7	135.3	273.3	50.4	28.9		+	+	+	
Hudnall	51.3	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	18.7	11	16.4	+	+	+	+
Shell Bar											0	2.9	0.8	0.8	17.8	1.9	0.3	0.9	29.6	30.3	78.1	12.6	8.5		+	+	+	
Haynie Point	38.5	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	8.9	6.4	10.6	+	+	+	+
Whaley's East	14.6	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	5.8	3.4	5.4	-	-	-	-
Fleet Point	8.7	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	2.9	2.1	3.6	NC	+	+	+

Figure S1: Map showing the location of the 2008 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.

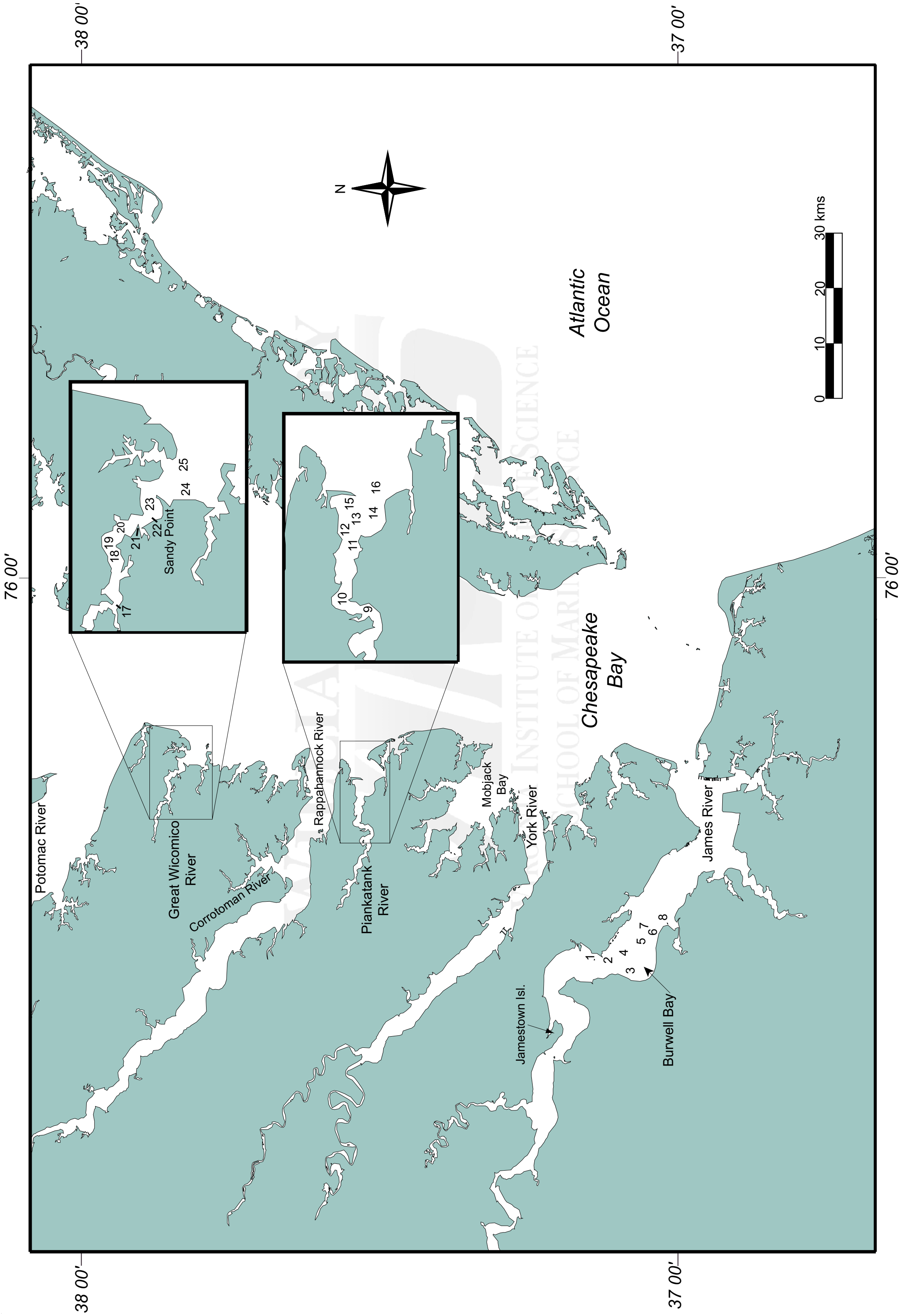
38 00'
37 00'
76 00'
N
Atlantic Ocean
Chesapeake Bay
0
10
20
30 kms
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Jamestown Isl.
Burwell Bay
Sandy Point
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Figure S2: Diagram of shellstring setup on buoys.

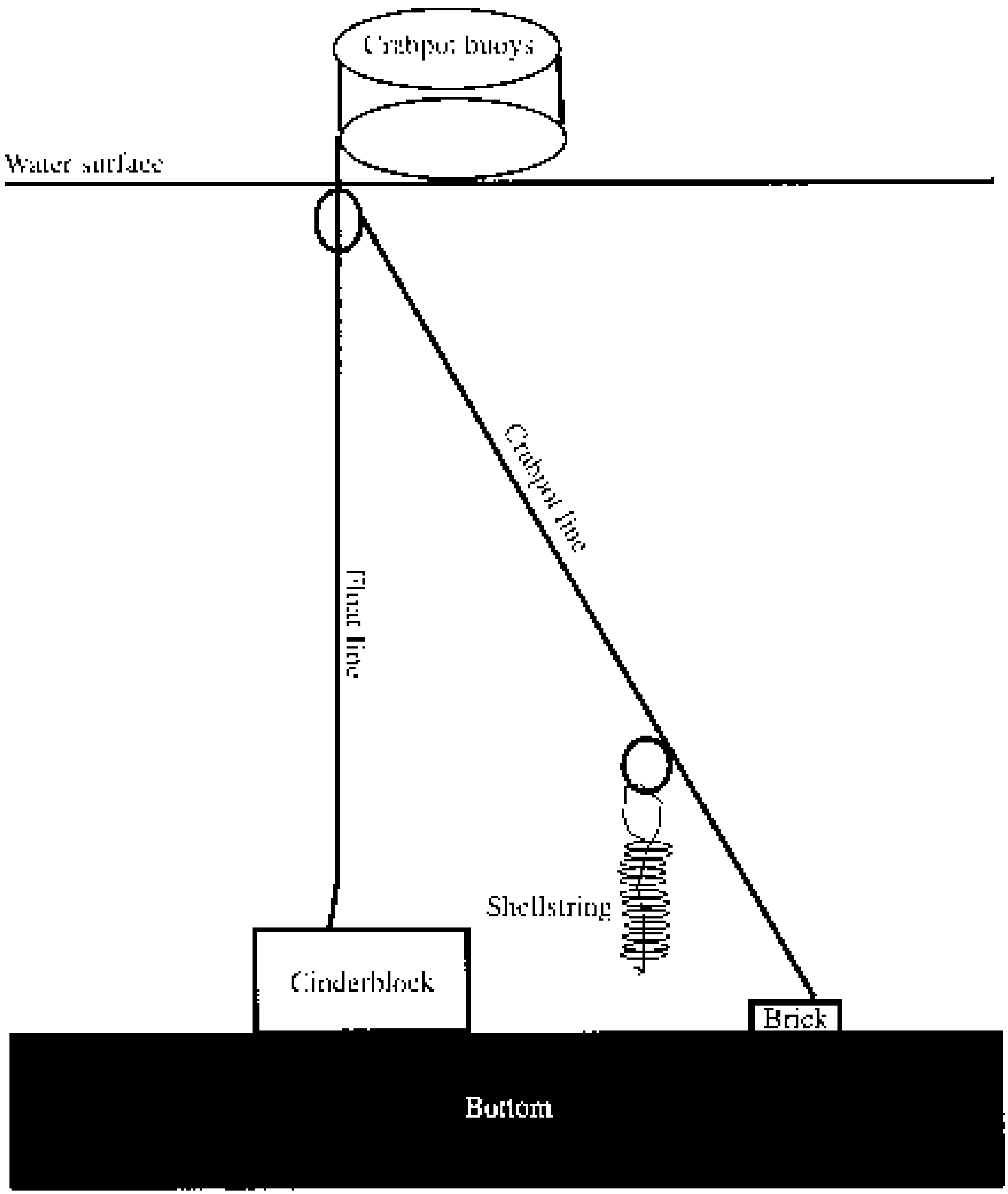
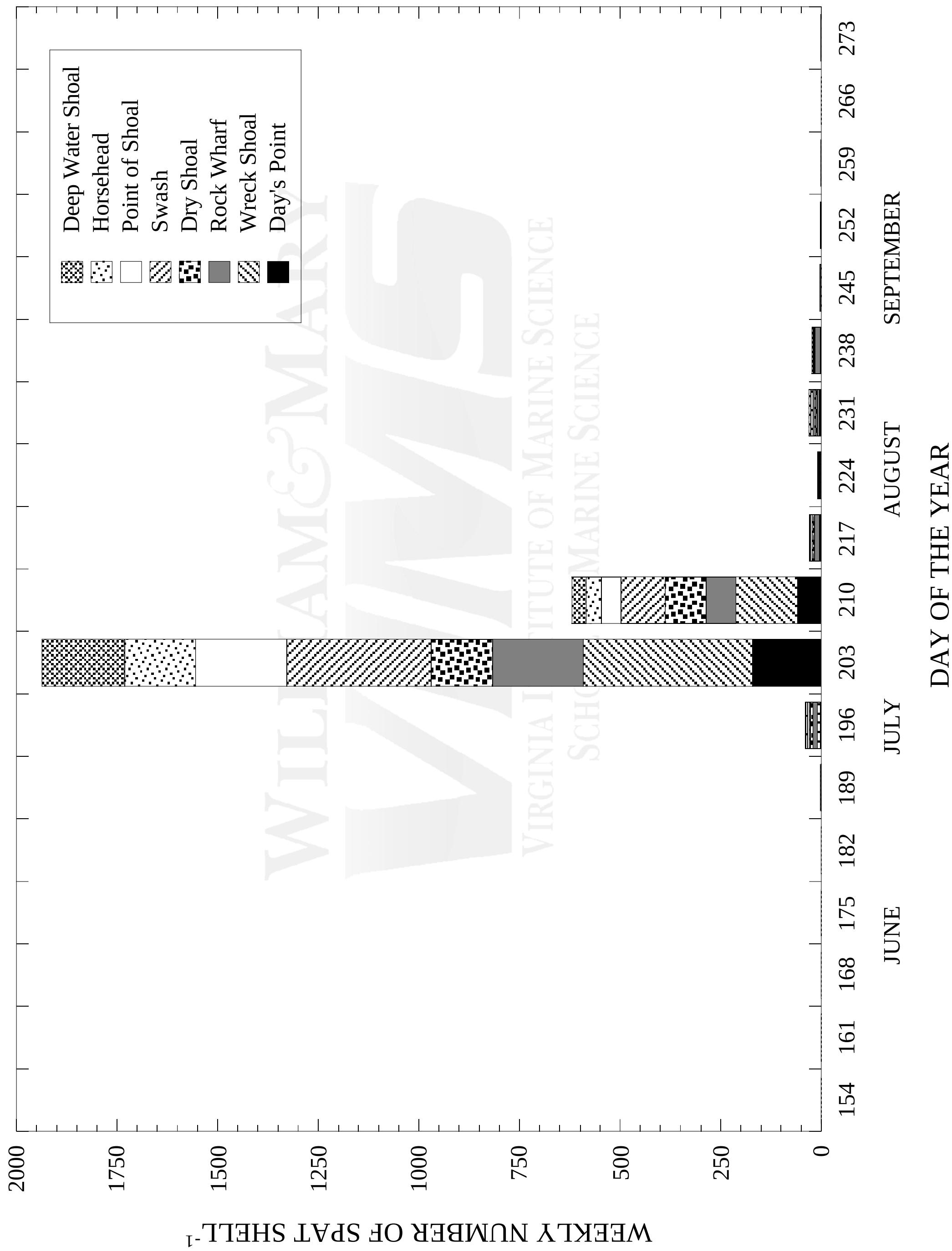


FIGURE S3: JAMES RIVER (2008) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$



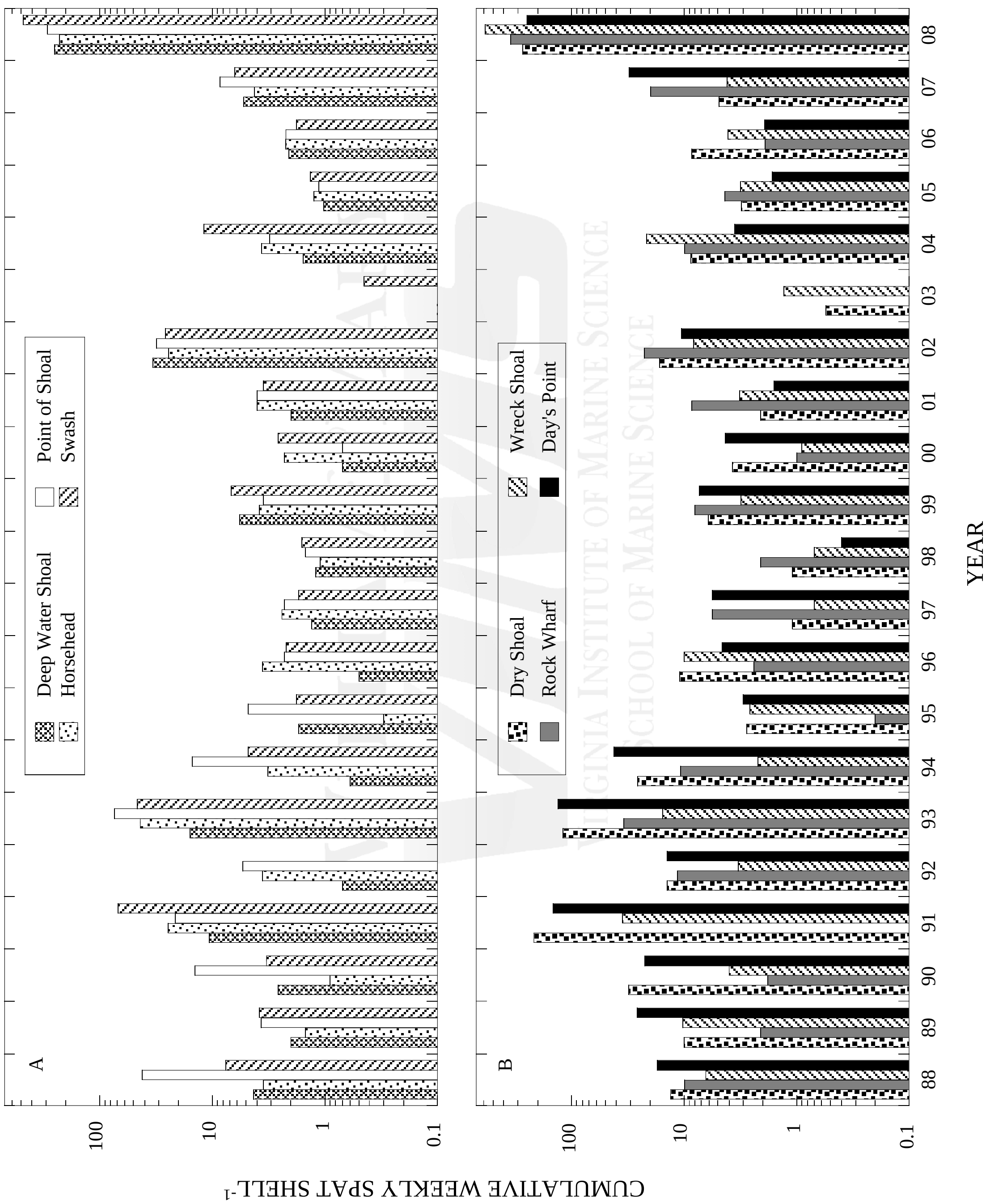


FIGURE S4: SPATFALL TRENDS OVER THE PAST 20 YEARS AT ALL 8 SITES IN THE JAMES RIVER (upriver sites in panel A; downriver sites in panel B) (expressed as cumulative weekly spatfall)

FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 20-YEAR MEANS COMPARED WITH 2008 (Error bars represent standard error of the mean; shaded area represents the bulk of the settlement during 2008; n is the number of data points used to calculate the mean)

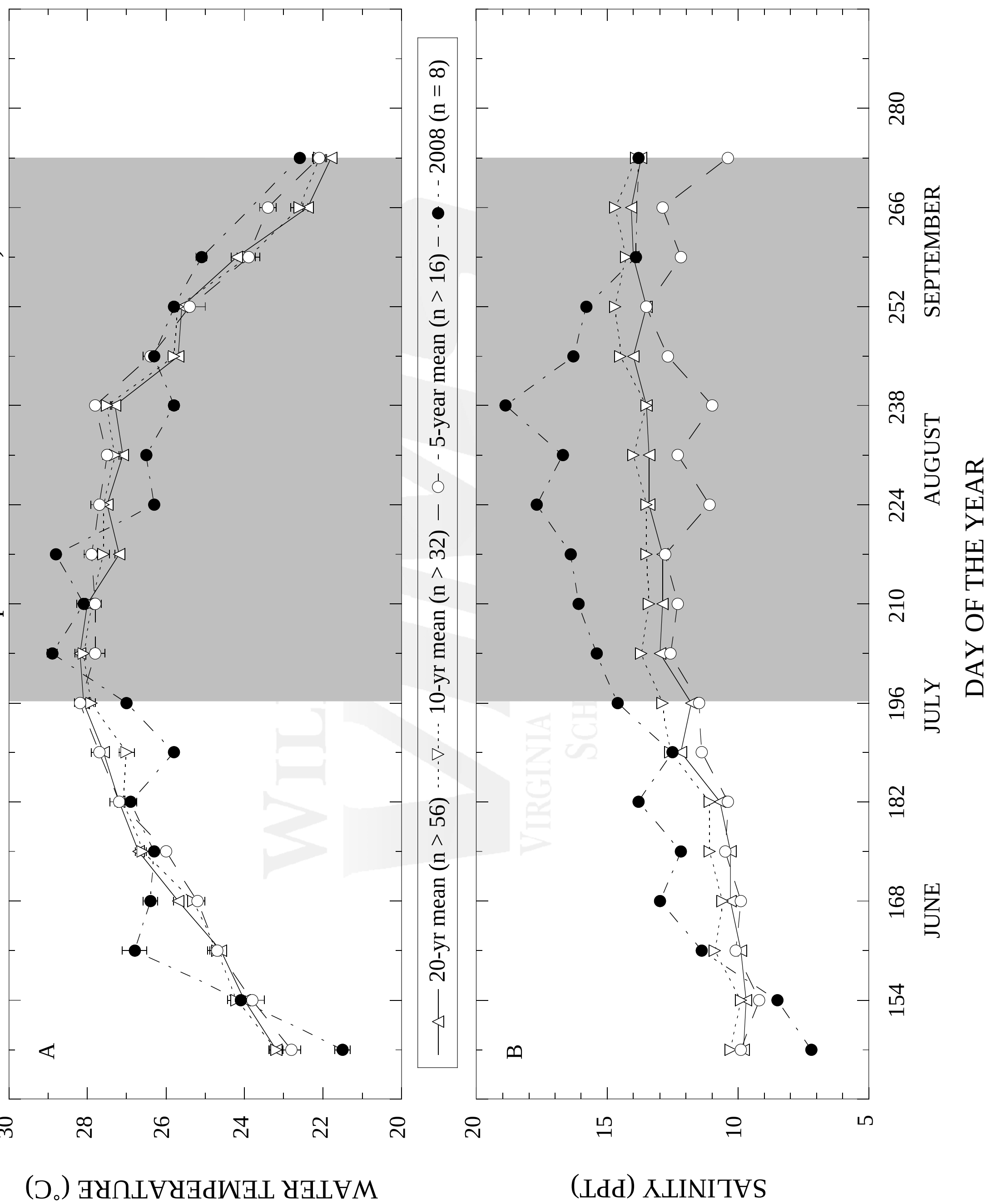


FIGURE S6: PIANKATANK RIVER (2008) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: M = modern station as described in text)

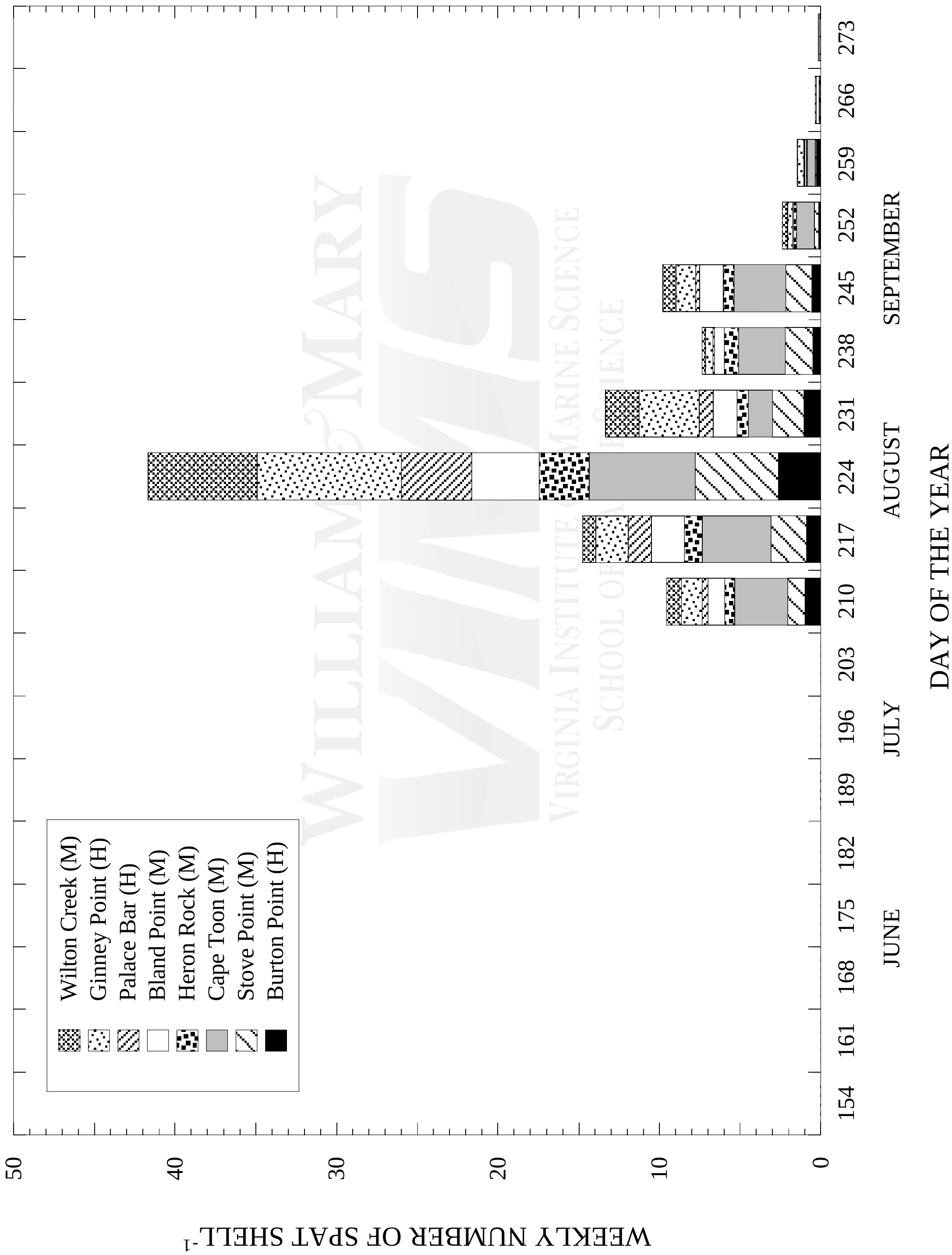


FIGURE S7: SPATFALL TRENDS IN THE PIANKATANK RIVER AT THE 3 HISTORICAL SITES (panel A: 20 years) AND THE 5 MODERN SITES (panel B: 10 years)
(Expressed as cumulative weekly spatfall)

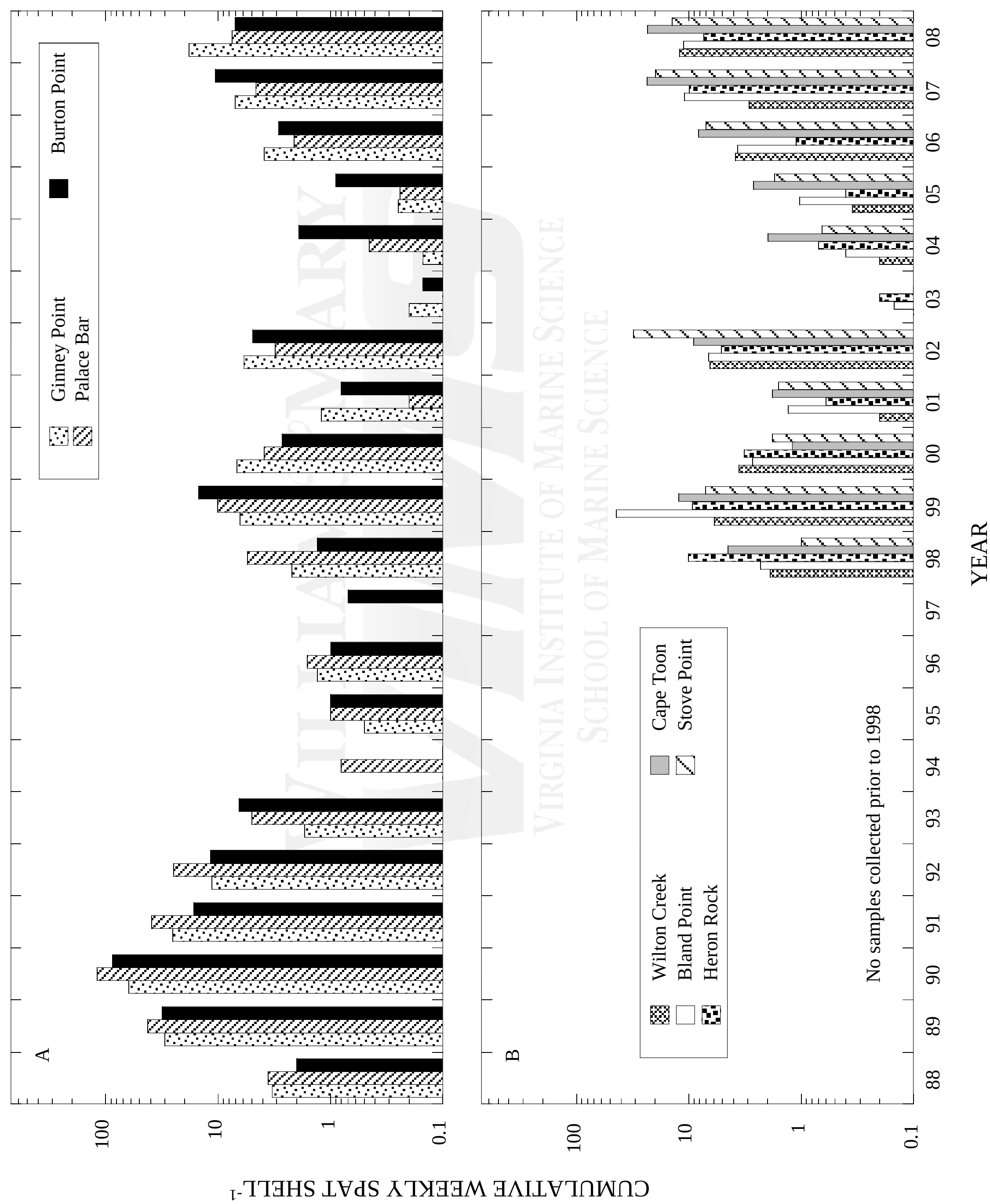


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 19-YEAR MEANS COMPARED WITH 2008
(Error bars represent standard error of the mean; shaded area represents the bulk of settlement during 2008; n is the number of data points used to calculate the mean)

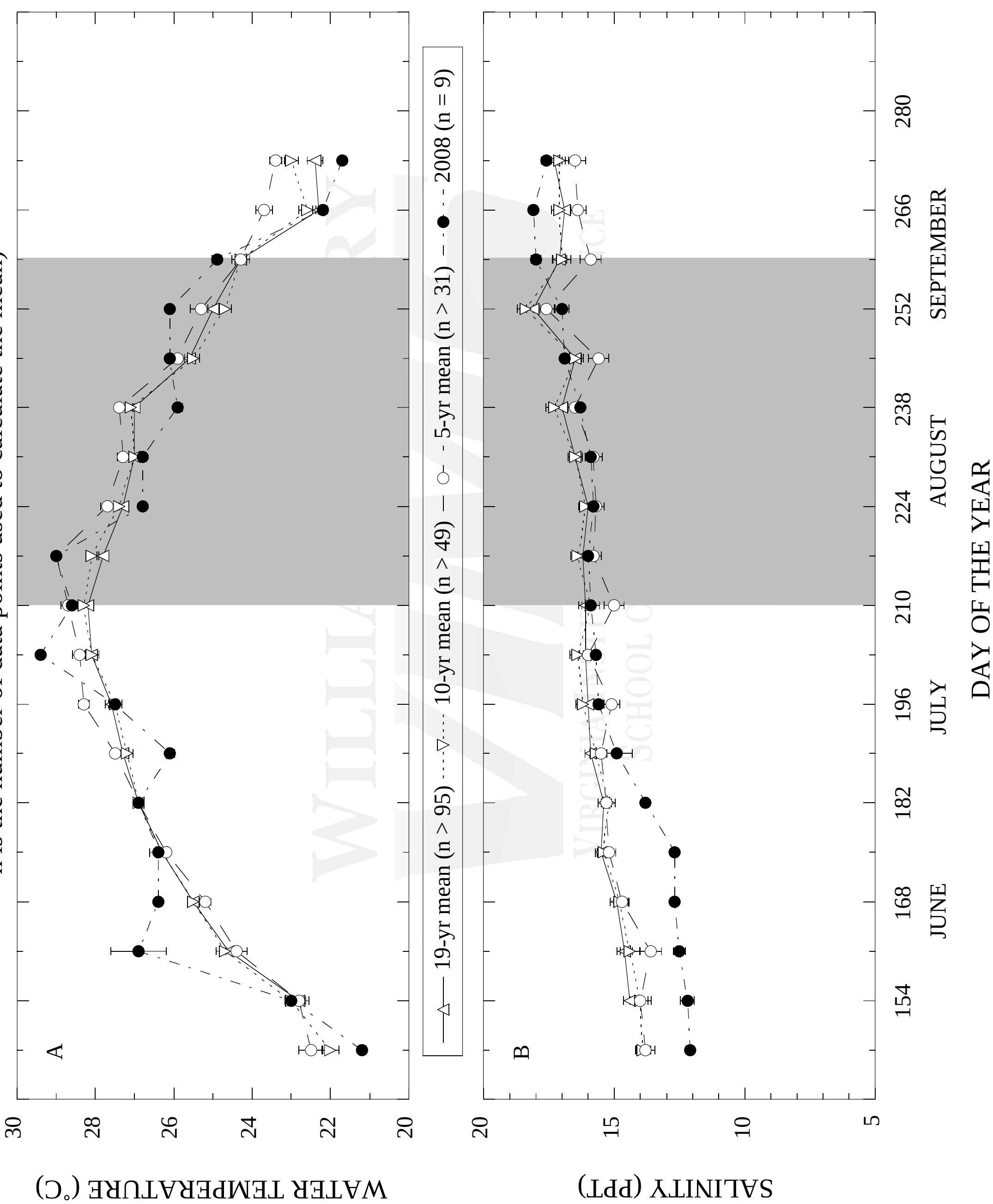
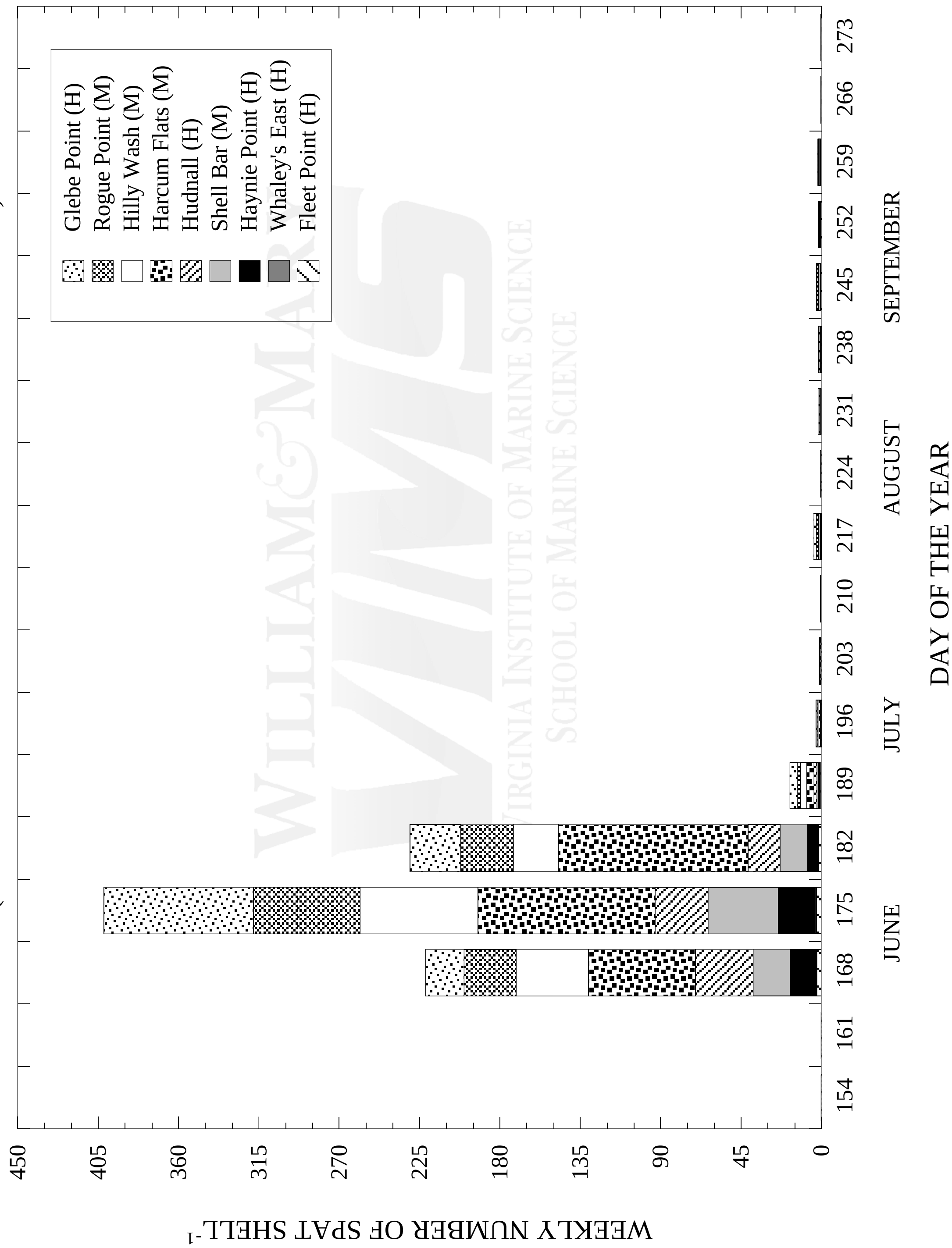


FIGURE S9: GREAT WICOMICO RIVER (2008) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: M = modern station as described in text)



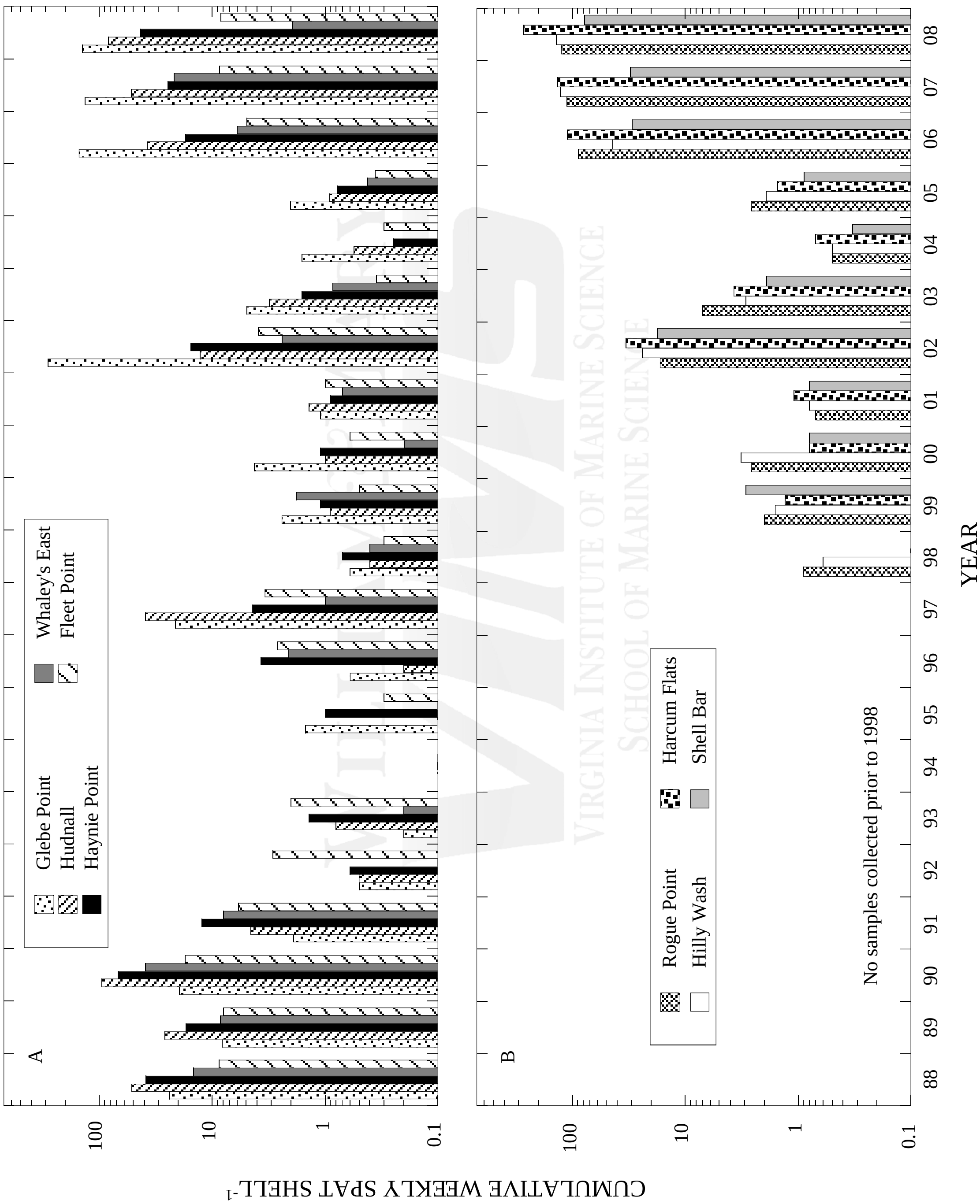
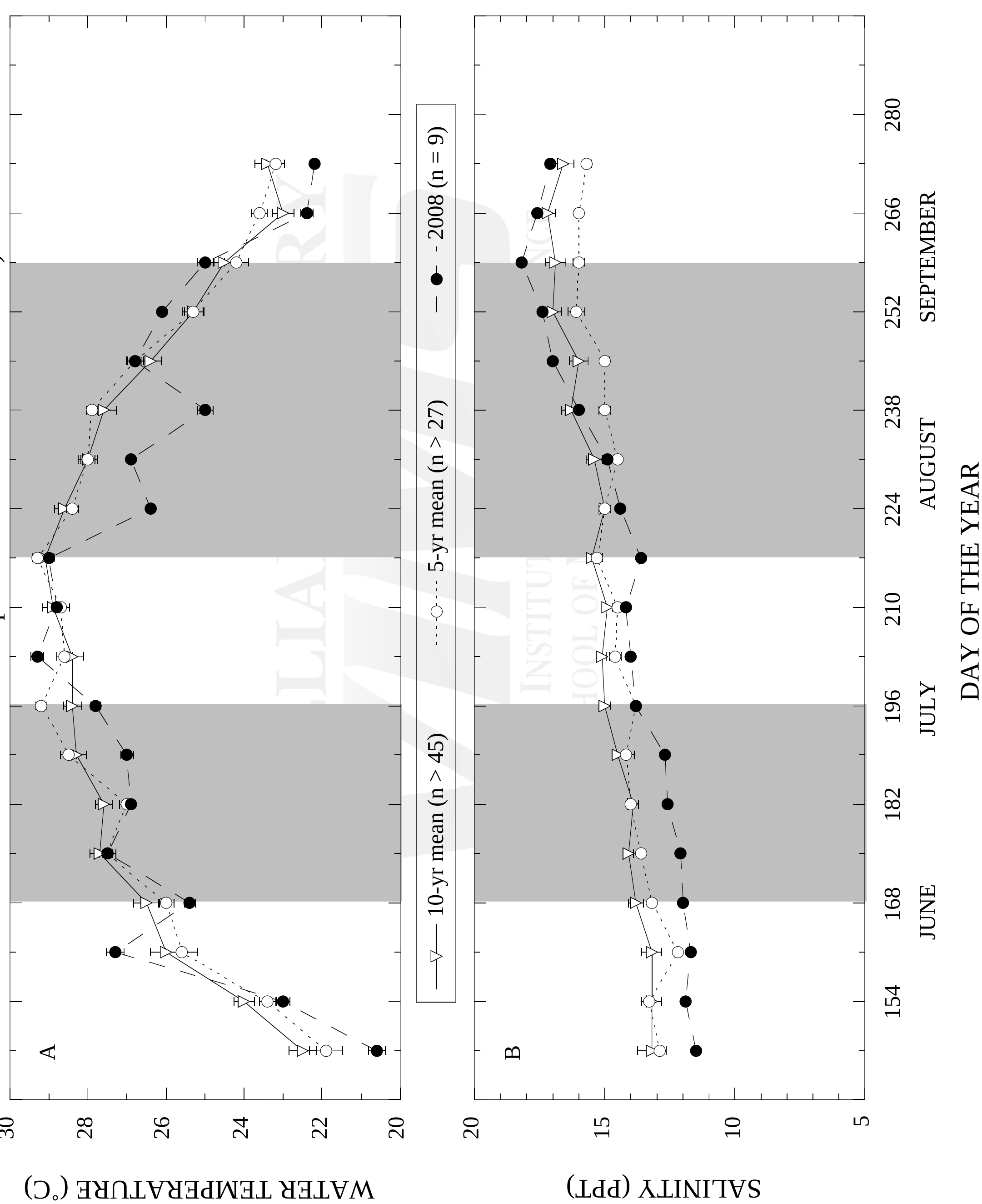


FIGURE S10: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER AT THE 5 HISTORICAL SITES (panel A: 20 years) AND THE 4 MODERN SITES (panel B: 10 years) (Expressed as cumulative weekly spatfall)

FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE SETTLEMENT PERIOD: 5 AND 10-YEAR MEANS COMPARED WITH 2008
(Error bars represent standard error of the mean; shaded area represents the bulk of settlement during 2008; n is the number of data points used to calculate the mean)



Part II. Dredge Survey of Selected Oyster Bars in Virginia During 2008

INTRODUCTION

The Eastern oyster, *Crassostrea virginica* (Gmelin), 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 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 2008.

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 site 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 by VIMS during Fall 2008 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 2008) 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 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, 2008 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. In spring 2008, cultch was planted on Fleet Point and Whaley's East in the Great Wicomico River, on Broad Creek in the Rappahannock River and on Palace Bar in the Piankatank River. 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 6 and October 21, 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.

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 70.5 bushel^{-1} (bu) at Nansemond Ridge to a high of 1,350 bu^{-1} at Long Shoal.

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 6 (Nansemond Ridge) to 75 bu^{-1} (Point of Shoal). There was an increase in the number of market oysters at Long Shoal, Dry Shoal and Nansemond Ridge when compared with 2007 (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 similarly high levels since (Figure D3C).

The average number of small oysters bu^{-1} ranged from a low of 29.0 at Nansemond Ridge to a high of 362.5 at Swash. When compared with 2007, there was an increase in the number of small oysters observed at Deep Water Shoal, Horsehead, Point of Shoal and Nansemond Ridge and a decrease at Wreck Shoal (Figure D2).

The average number of spat varied widely depending on location in the river. The average number of spat bu^{-1} ranged from a low of 35.5 at Nansemond Ridge to a high of 1,046.5 at Mulberry Point. There was a relatively large increase in the number of spat observed at the eight most upriver sites when compared with 2007, with the highest number of spat occurring on the more northern side of the river near and upriver of Jail Island (Figure D2; Figure D1 for location in river). Spatfall at the five most upriver sites has been steadily increasing since about 2003 (an extremely wet year with several summer freshets) and was among the highest observed in the past twenty years of monitoring (Figure D3). 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). As spatfall during the past several years (since the early 2000s) has been increasing at the more upriver sites, this pattern has not been seen as often. During 2008, the five most upriver sites all had a higher percentage of spat compared with small oysters.

The average number of boxes bu^{-1} ranged from a low of 15 (Nansemond Ridge) to a high of 124.5 (Dry Shoal). Boxes accounted for 6 (Deep Water Shoal) to 21% (Dry Shoal) of the total (live and dead) oysters observed. At the more upriver sites, the sites that had the largest spatfall numbers, the majority of observed boxes were spat boxes. There was a relatively high percentage of new boxes (23 to 36% of the total boxes observed) at Long Shoal, Dry Shoal, Wreck Shoal and Thomas Rock. An average of 27% of the total larger oysters (includes all categories except spat and spat boxes) were either new or old 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 15.8 to 18 degrees C (Table D2). Salinity was variable depending on location in the river, increasing in a downriver direction, from 11.9 ppt at Deep Water Shoal to 21.6 ppt at Thomas Rock and 18.8 ppt at Nansemond Ridge.

York River

The average total number of live oysters bu^{-1} in the York River was 58 at Aberdeen Rock and 72.5 at Bell Rock. The live oysters at Aberdeen Rock were primarily small (73%) with an increase in the number observed when compared with 2007 (Figure D4 and D5). When compared with 2007, there was a decrease in the number of spat observed at Aberdeen Rock. Oysters at Bell Rock were also primarily small (62%). While the number of market oysters at Bell Rock remains low, the population of market oysters at the site has been relatively stable since about 1997 (Figure D5) with a small increase observed in 2008 when compared with 2007 numbers (Figure D4). The average number of boxes (new and old) bu^{-1} was low (Aberdeen Rock; 9 bu^{-1} and Bell Rock; 11.5 bu^{-1}), accounting for approximately 13% of the total oysters (live and dead) at both sites. At both sites, the majority of the boxes (greater than 83%) were old boxes. Water temperature on the day of sampling was 18.8 degrees C at Aberdeen Rock and 19.4 degrees C at Bell Rock. There was a 3.7 ppt difference in salinity observed: 14.6 ppt at Bell Rock and 18.3 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters at Tow Stake and Pultz Bar were 159 and 264.5 oysters bu^{-1} respectively. There was an increase in the number of market oysters observed at both sites when compared with 2007 (Figure D4 and D6). Market oysters were observed at Pultz Bar for the first time since 2005 and the number of both small and market oysters at both bars were among the highest observed in the past twenty years of monitoring (highest at Pultz Bar, 3rd highest at Tow Stake; Figure D6). There was a decrease in the number of spat at both sites when compared with 2007. The live oysters were primarily small oysters at both sites. There were very few boxes at either site (less than 7% of the total live and dead), and of the boxes observed 83 (Pultz Bar) to 100% (Tow Stake) were old boxes. For the first time since 2002, there were no spat boxes attributed to oyster drills at either site in Mobjack Bay. Water temperature was between 20 and 21 degrees C and salinity was approximately 21 ppt at both sites (Table D2) on the day of sampling.

Piankatank River

The average total number of live oysters bu^{-1} in the Piankatank River ranged from 118 at Burton Point to 452.5 at Palace Bar. There was an increase in the number of market oysters observed at Ginney Point and Palace Bar when compared with 2007, and this marked the third 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 Ginney Point and Palace Bar during 2008 was the highest observed over the past twenty years of monitoring. The number of small oysters at all three sites was similar to that observed during 2007 and at Ginney Point this was the highest observed over the past twenty years (Figure D8).

There was a decrease in the number of spat at Ginney Point and Palace Bar, when compared with 2007. Settlement during 2008 was relatively good for the third year in a row following three years (2003-2005) of record low settlement. The composition of live oysters in the system was approximately 50/45 small oysters and spat (the remaining 5% were market oysters) with a slightly higher percentage of small oysters present at Ginney Point. The number of boxes observed was low at all three sites accounting for 8 (Ginney Point and Palace Bar) to 16% (Burton Point) of the total (live and boxes). Of these boxes, the majority (greater than 83%) were either old or spat boxes. At Burton Point, two out of the seven spat boxes observed had a drill hole, indicative of predation by one of the two oyster drills, *Eupleura caudata* and *Urosalpinx cinerea*, both of which are found in the Chesapeake Bay. Water temperature on the day of sampling was approximately 21 degrees C at all three sites. Salinity ranged between 17.5 (Ginney Point and Palace Bar) and 18.4 ppt (Burton Point).

Rappahannock River

The average total number of live oysters bu^{-1} in the Rappahannock River ranged from a low of 18.5 at Morattico Bar to a high of 364 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). Middle Ground had the second highest total number of oysters (197.5 bu^{-1}). This is especially promising considering the almost 100% die-off that occurred at this site in 2005 (Southworth et al. 2006).

The average number of market oysters bu^{-1} ranged from 8 (Middle Ground) to 47.5 (Ross Rock). For the most part, the greatest number of market oysters are found at the most upriver and most downriver sites with the sites located mid river having the fewest numbers of market oysters. There was a small increase in the number of market oysters observed at Bowler's Rock, Morattico Bar, Middle Ground and Parrot Rock (Figure D9 and D10) when compared with 2007. The small increase observed at Morattico Bar may have been a result of the planting of seed oysters from the Great Wicomico River in spring 2008 (VMRC, unpublished data).

For the seventh year in a row, Drumming Ground near the mouth of the Corrotoman River had the highest average number of small oysters bu^{-1} with 302.5. There was an increase in the number of small oysters at Smokey Point and Broad Creek when compared with 2007 numbers (Figure D9). As with the increase in market oysters at Morattico Bar, the increase observed at Smokey Point may have been a result of the planting of seed oysters from the Great Wicomico River in spring 2008 (VMRC, unpublished data).

For the third year in a row, there was at least one spat observed at all ten sites in the Rappahannock River, and spat numbers were similar to those observed during 2007 (Figure D9 and D10). Settlement throughout the system has been low (typically less than 100 spat bu^{-1}) since the early 1990s (Figure D10) and 2008 marked only the third year since 2002 with settlement at the three most upriver sites (Ross Rock, Bowler's Rock and Long Rock). For the third year in a row, Middle Ground had the largest average number of spat with 33.5 bu^{-1}.

The average total number of boxes bu^{-1} was low ranging from 1 (Long Rock) to 30 (Drumming Ground). Boxes accounted for less than 12% of the total (live and dead) at all of the sites monitored. The majority of the boxes observed were old boxes and 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 20.5 to 21.5 degrees C. Salinity increased moving from the most upriver site (Ross Rock: 10.8 ppt) toward the mouth (Broad Creek: 18.0 ppt).

Great Wicomico River

The average total number of live oysters bu-1 in the Great Wicomico River was moderate ranging from 233 at Whaley's East to 465 at Haynie Point. The live oysters found at all three sites were a mixture of spat and small oysters with very few market oysters. There was an increase in the number of market oysters at Whaley's East and a decrease in the number of small oysters at Fleet Point when compared with 2007 (Figure D11 and D12). The number of small oyster at Haynie Point and Whaley's East were among the highest observed during the past twenty years of monitoring. Despite a small decrease in settlement at Fleet Point when compared with 2007, settlement in the Great Wicomico River over the past three years has been relatively consistent, comparable to what was seen in the system during the late 1980s and early 1990s (Figure D12). The total number of boxes bu-1 was moderate ranging from 25.5 (Whaley's East) to 55.5 (Haynie Point). This accounted for 10 (Whaley's East) to 12% (Fleet Point) of the total (live and dead) number of oysters observed. Greater than 74% of the boxes were old with less than 3% spat boxes. Water temperature on the day of sampling was between 20 and 21 degrees C and salinity was approximately 17.5 ppt at all three sites monitored.

DISCUSSION

The abundance of market oysters throughout the Chesapeake Bay region has been in serious decline since the turn of the 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 River and Rappahannock River, 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 27.9 market oysters bu-1), but slightly higher than that observed during 2007.

For the past several decades, the bulk of Virginia's oyster population has been composed primarily of small oysters and spat. During 2008, small oysters dominated populations at sixteen out of the thirty sites and spat dominated at ten out of the remaining fourteen. The only four sites with predominately market oysters (Bowler's Rock, Long Rock, Morattico Bar and Hog House), all have extremely low (less than 50 oysters bu-1) oyster populations. The oyster populations in the upper 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). However, 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 2008 was moderate, but varied widely across and within river systems. In the Great Wicomico River, settlement at Haynie Point and Whaley's East were the second and third highest recorded in the past twenty years, respectively. For the third year in a row, settlement was observed at all ten sites in the Rappahannock River, but was low to moderate throughout the system when compared with historic numbers. Settlement in the York River and Mobjack Bay was relatively low with less than 21 spat bu-1 observed at all of the sites. In contrast to historical setting patterns (Haven & Fritz 1985), settlement in the James River was relatively high at the eight most upriver sites and low at the two most downriver sites.

Circulation in the James River is such that larvae from the lower reaches are swept upriver and retained in a gyre from Wreck Shoal to Burwell Bay (Haven & Fritz 1985, Ruzecki & Hargis 1989). Historically, the area between Wreck Shoal and Hampton Flats provided the most larvae to the seed area, which is defined as the area between Nansemond Ridge and Deep Water Shoal (Figure D1); thus it covers the entire area that is currently sampled (Haven & Fritz 1985). With the onset of Dermo in the early 1950s and MSX in the late 1950s, many of the downriver oyster populations, (including those in the lower reaches of the seed area) have been in decline. Due to this decline, over the past several decades most of the broodstock has been located in the mid to upper section of the seed area (the Burwell Bay region). As a result, the majority of the spatfall during the past several decades has occurred in the more mid to upriver section of the seed area. However, there were several years during the early 1990s when spatfall was higher downriver (between Dry Shoal and Wreck Shoal, Figure D1; Part I of this report, Table S2) and this coincided with a period of low (3 to 4 ppt below the long-term means) salinity and an increase in the populations of the adults located in the more downriver seed area (Figure D13). A second increase occurred in these more downriver areas following 2002, a year with relatively high salinity and good settlement. While the populations of larger oysters on these three bars have experienced some fluctuations over the past few years, the numbers remain elevated when compared with the mid 1990s and early 2000s. These numbers have remained elevated despite the harvesting that has been allowed since 2004 at the two most downriver sites, Nansemond Ridge and Thomas Rock (Figure D13). The oysters from these sites most likely have served as broodstock, providing some larvae to the upriver portion of the seed area.

The average total number of boxes observed during 2008 was relatively low, accounting for less than 21% of the total (live and dead) at all thirty sites monitored. On a system basis, the James River had the highest number of boxes for the third 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 26 and 28%). This may be indicative of increased mortality during 2008 caused by disease, which one would expect given the elevated salinities in the system throughout much of June, July and August (Part I of this report).

Drill holes have become more prevalent in spat boxes since the early 2000s. During 2008 however, drill holes were only present in the spat boxes observed at Burton Point in the Piankatank River. For the first time since 2002, there were no spat boxes with drill holes present in 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 (< 10 adult drills of either species observed across all bars per year) 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 2008 dredge survey, it should be noted that drill holes were observed at multiple sites in both the Piankatank River and Mobjack Bay during the annual VIMS/VMRC oyster patent tong survey in November of 2008 (Southworth, personal observation), so the predation of spat by oyster drills in these systems remains a concern.

Table D1: Station locations for the 2008 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 2008. 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	10/21	17.7	11.9	37.5	327	711	1075.5	7.5	8.5	56.5	72.5
Mulberry Point	10/21	17	13.7	51.5	201.5	1046.5	1299.5	5	29	56.5	90.5
Horsehead	10/21	17.5	14.6	66	355.5	564	985.5	20.5	54	24	98.5
Point of Shoal	10/21	17.9	13.8	75	349.5	576	1000.5	10.5	40	25	75.5
Swash	10/21	17.8	14.8	41	362.5	946.5	1350	15.5	58.5	35	109
Long Shoal	10/21	16.9	15.9	71	344.5	408	823.5	30.5	44.5	11	86
Dry Shoal	10/21	16.7	17.3	44	287.5	152	483.5	37	80	7.5	124.5
Wreck Shoal	10/20	17.9	20.5	43	58	133	234	10	30	3.5	43.5
Thomas Rock	10/20	18	21.6	10	30	67	107	5.5	8.5	1.5	15.5
Nansemond Ridge	10/20	15.8	18.8	6	29	35.5	70.5	2.5	10	2.5	15
York River											
Bell Rock **	10/8	19.4	14.6	20	45	7.5	72.5	0.5	11	0	11.5
Aberdeen Rock	10/8	18.8	18.3	8	42.5	7.5	58	1.5	7.5	0	9
Mobjack Bay											
Tow Stake	10/6	20.6	20.7	13	125	21	159	0	11.5	0	11.5
Pultz Bar	10/6	20.3	21	20	230	14.5	264.5	2	10	0	12
Piankatank River											
Ginney Point	10/16	21	17.5	31.5	277.5	101.5	410.5	6	28.5	1.5	36
Palace Bar	10/16	21	17.5	28	238	186.5	452.5	4	29	7.5	40.5
Burton Point	10/16	20.5	18.4	7	66	45	118	2.5	16	3.5	22
Rappahannock River											
Ross Rock	10/15	21.3	10.8	47.5	38.5	2	88	0	3.5	0	3.5
Bowler's Rock	10/15	21.3	12.6	27	16.5	1	44.5	1	3.5	0	4.5
Long Rock	10/15	21.3	13.9	22.5	4.5	1.5	28.5	0	1	0	1
Morattico Bar	10/15	21.3	15.8	11.5	5	2	18.5	0	2.5	0	2.5
Smokey Point	10/15	21.4	16	17.5	79	2	98.5	1.5	5.5	0	7
Hog House	10/15	21.2	16.2	16	15	2	33	0	2.5	0	2.5
Middle Ground #	10/15	21.5	17	8	156	33.5	197.5	4	14	1	19
Drumming Ground	10/15	21.4	17.5	33	302.5	28.5	364	9	19.5	1.5	30
Parrot Rock	10/15	20.5	17.4	20	71	24.5	115.5	3	11.5	0	14.5
Broad Creek	10/15	20.5	18	14	94.5	11	119.5	1.5	11.5	0	13
Great Wicomico River											
Haynie Point	10/14	21	17.5	22.5	332	110.5	465	8.5	45.5	1.5	55.5
Whaley's East	10/14	20.2	17.6	19.5	81.5	132	233	6	19	0.5	25.5
Fleet Point	10/14	20	17.5	6.5	205	173.5	385	8	43	1.5	52.5

Figure D1: Map showing the location of the oyster bars sampled during the 2008 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.

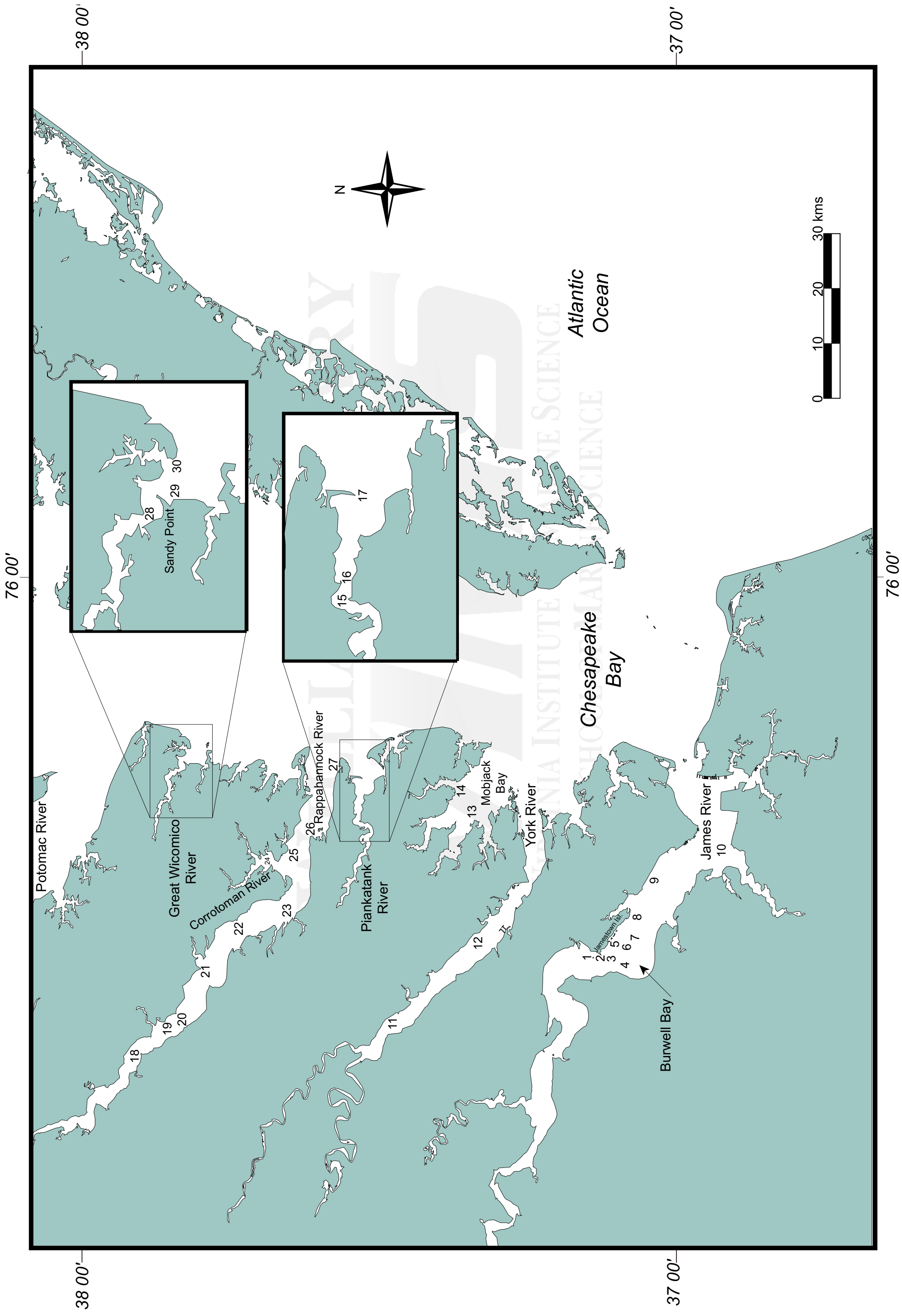

38 00'
37 00'
76 00'
N
Atlantic Ocean
Chesapeake Bay
0 10 20 30 kms
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Burwell Bay
Sandy Point
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 25 26 27 28 29 30

FIGURE D2: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE JAMES RIVER (2007-2008)
(Error bars represent standard error of the mean)

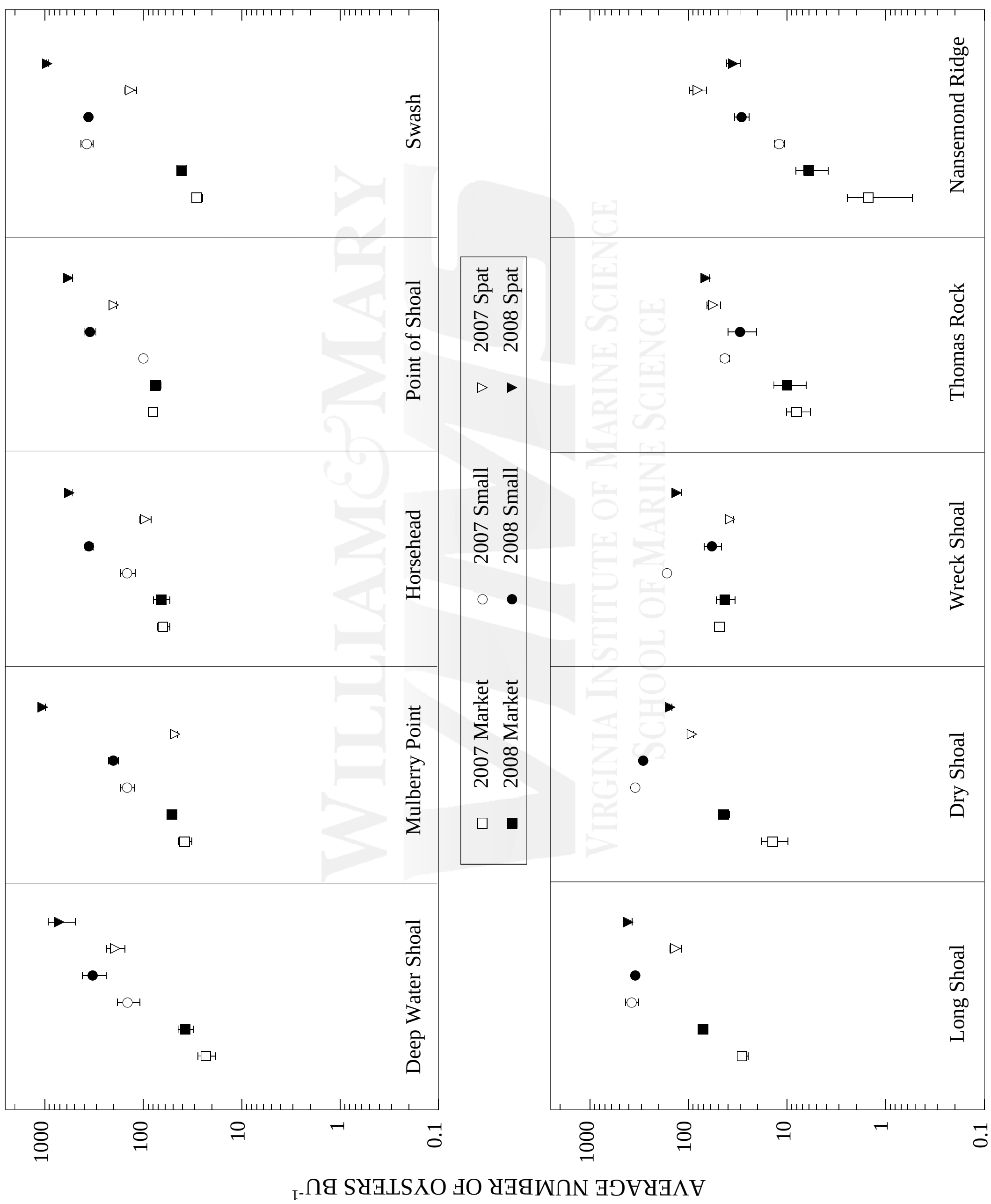
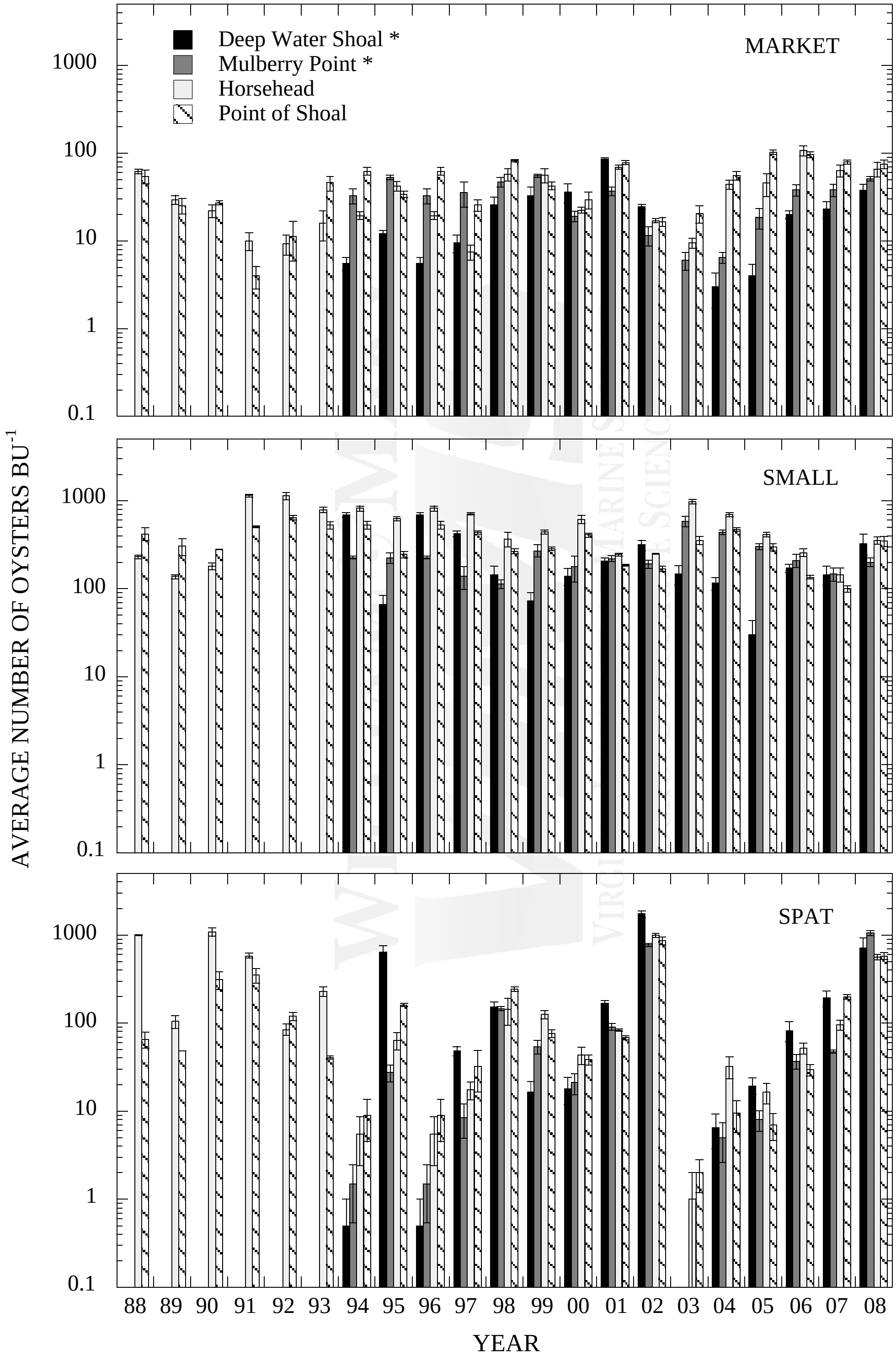
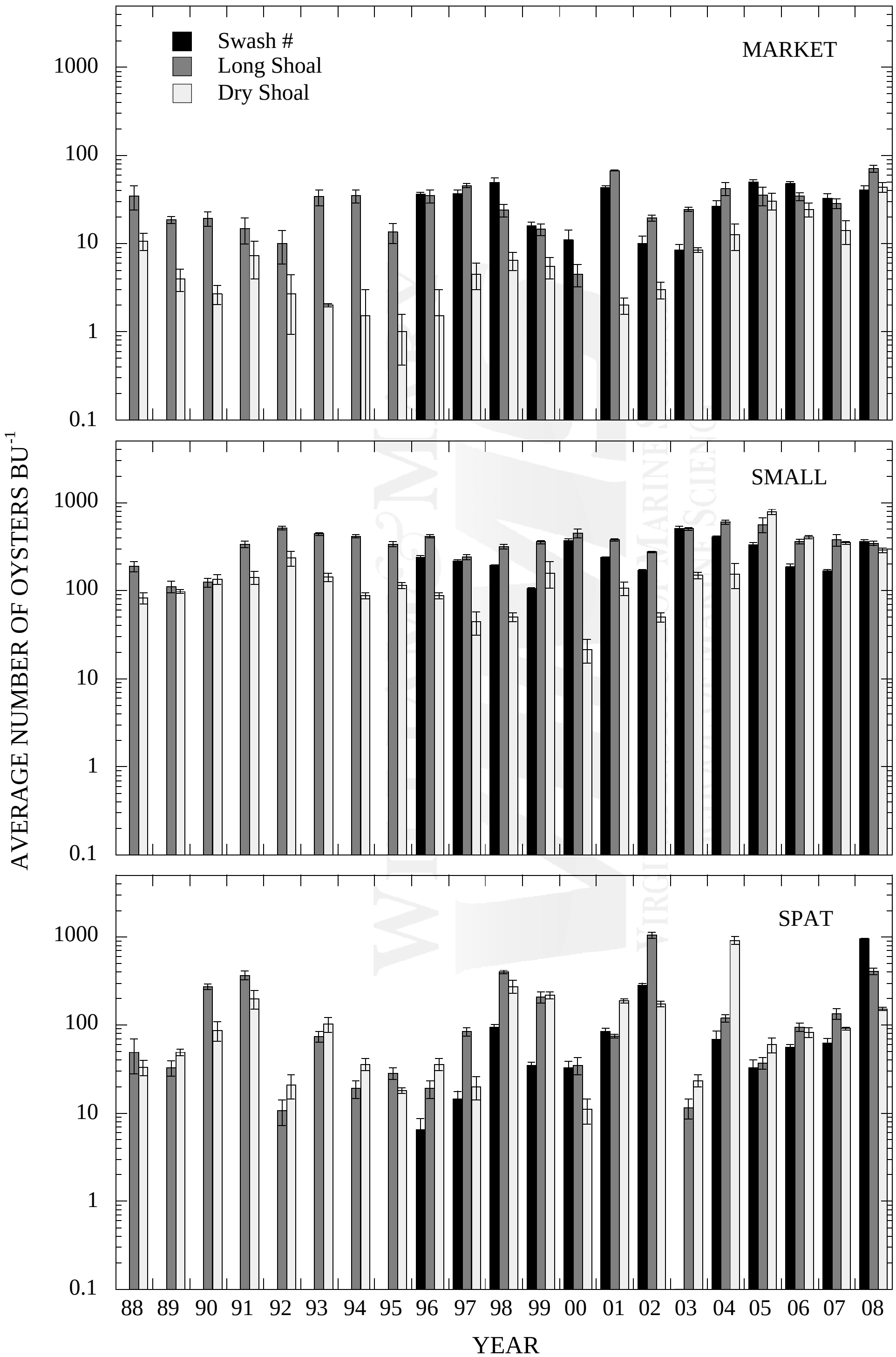


FIGURE D3A: JAMES RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* 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)

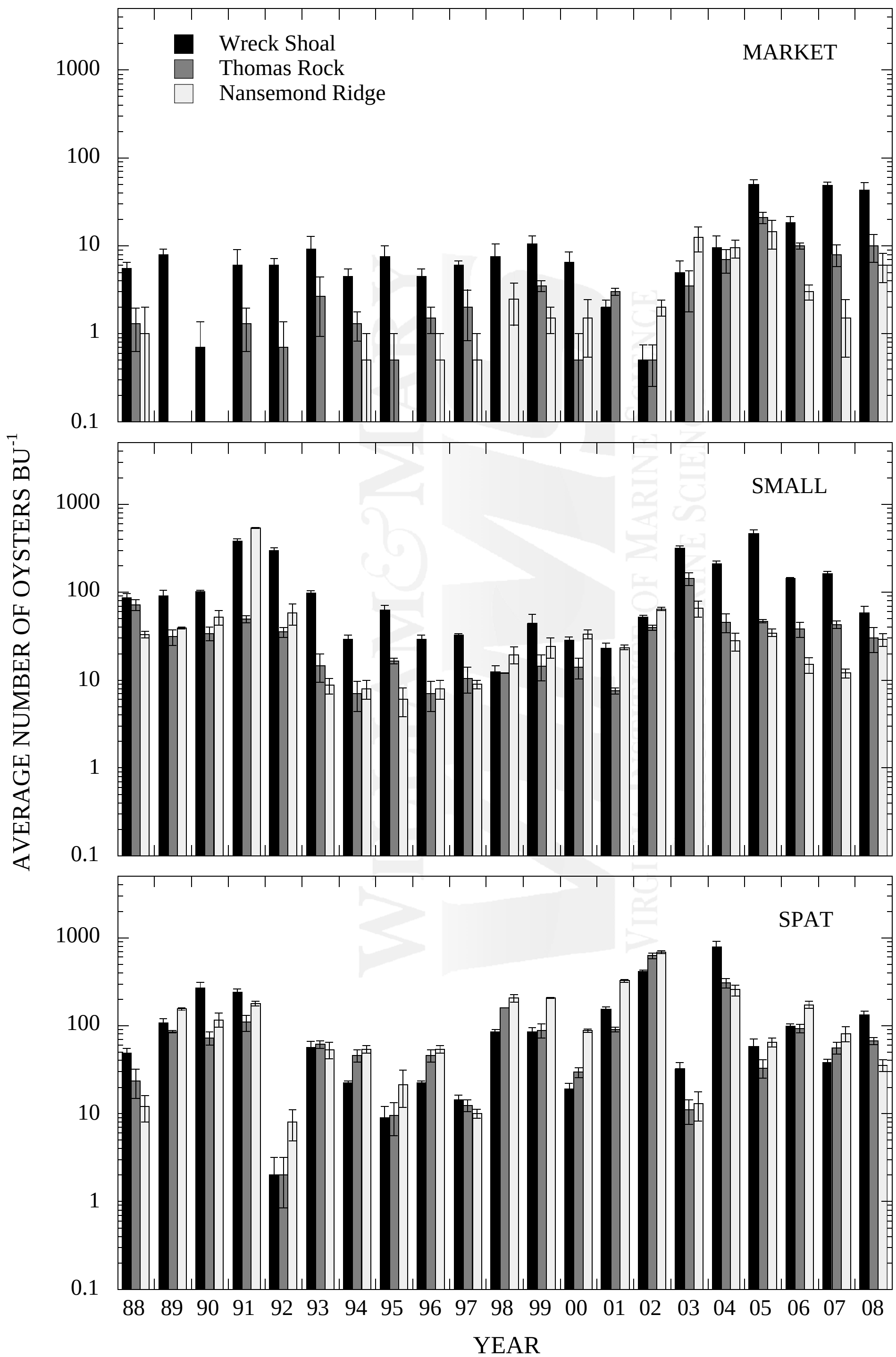


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE YORK RIVER AND MOBJACK BAY (2007-2008)
(Error bars represent standard error of the mean)

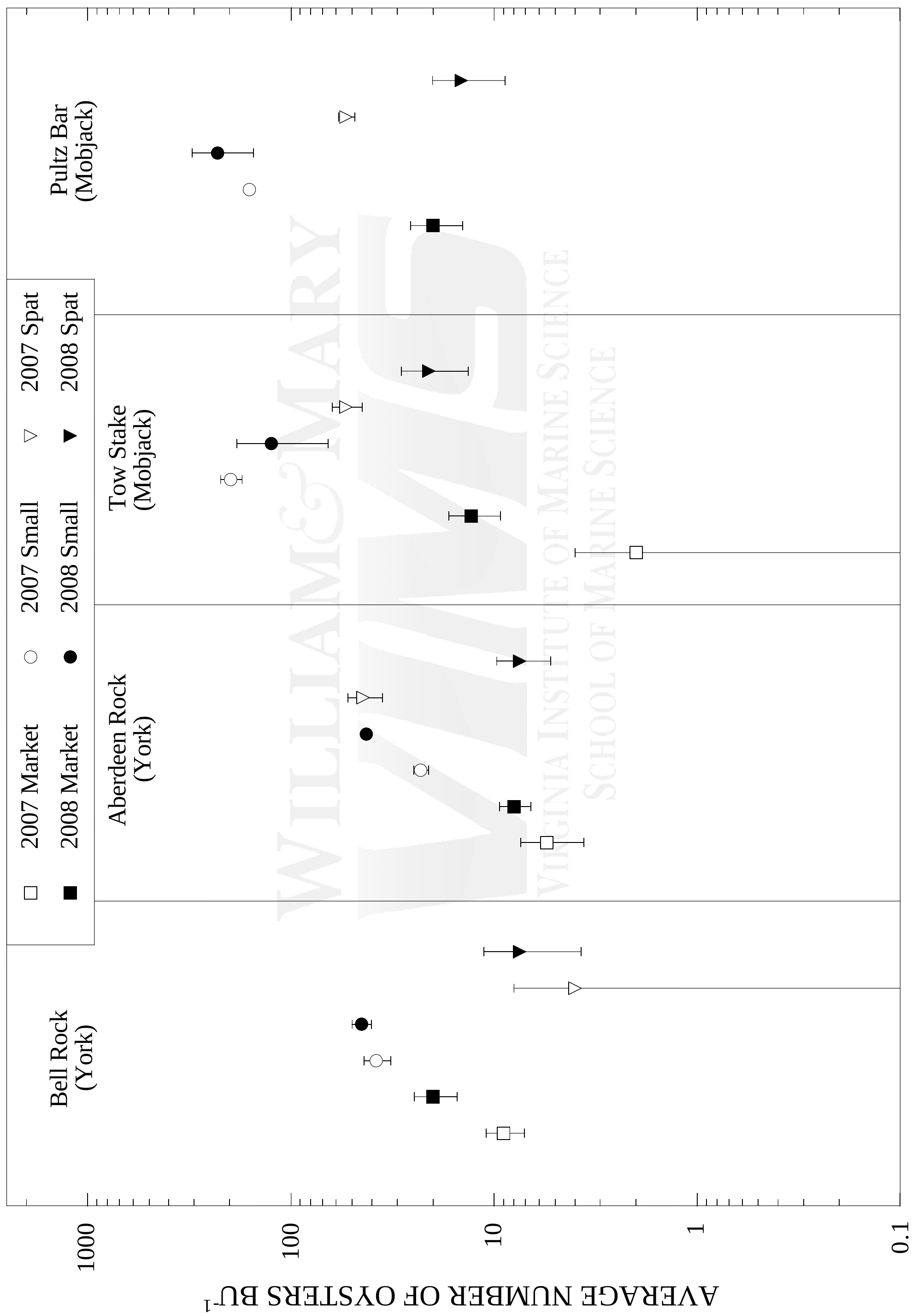
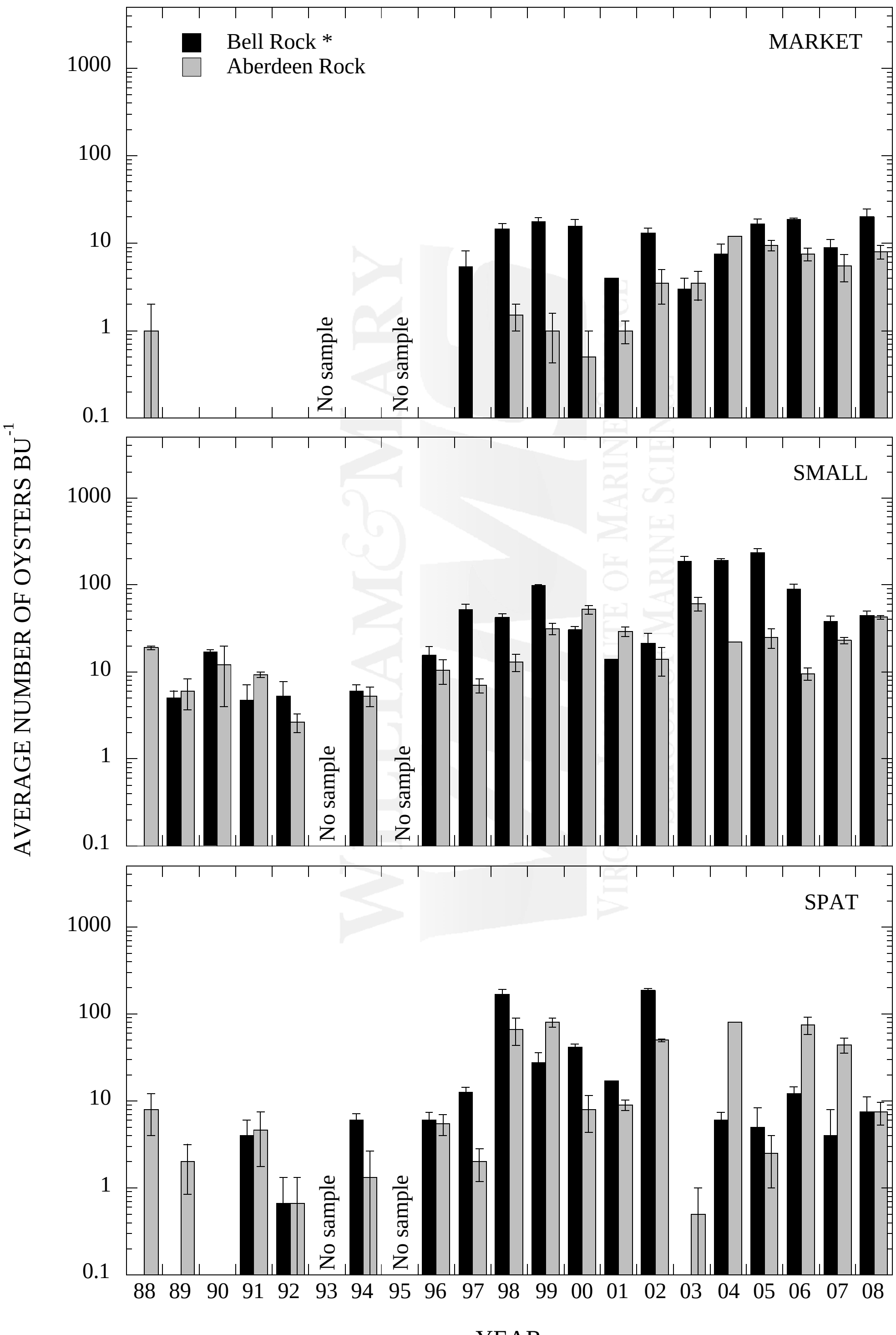
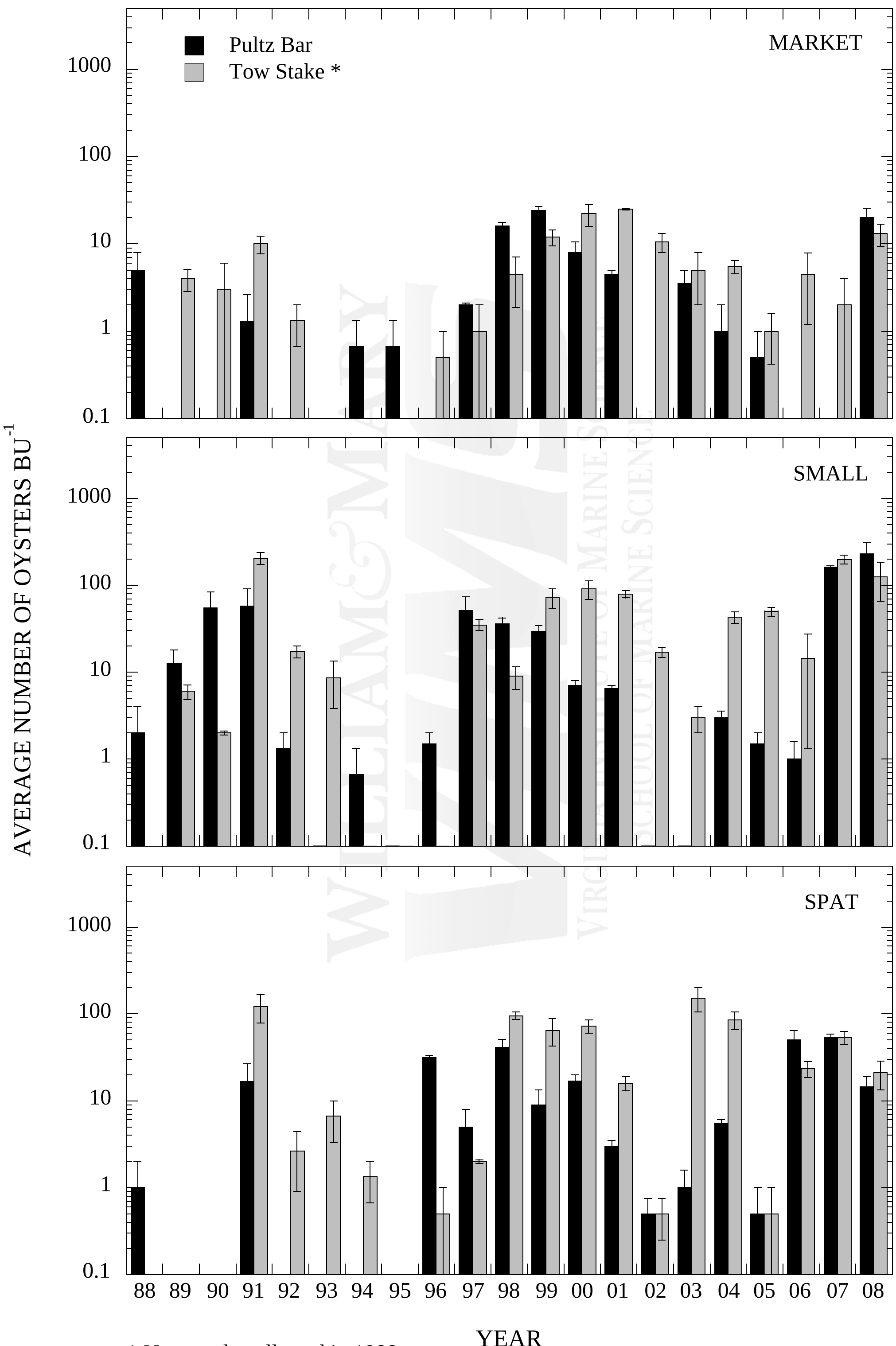


FIGURE D5: YORK RIVER OYSTER TRENDS OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No sample collected in 1988

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



* No sample collected in 1988

FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE PIANKATANK RIVER (2007-2008)
(Error bars represent standard error of the mean)

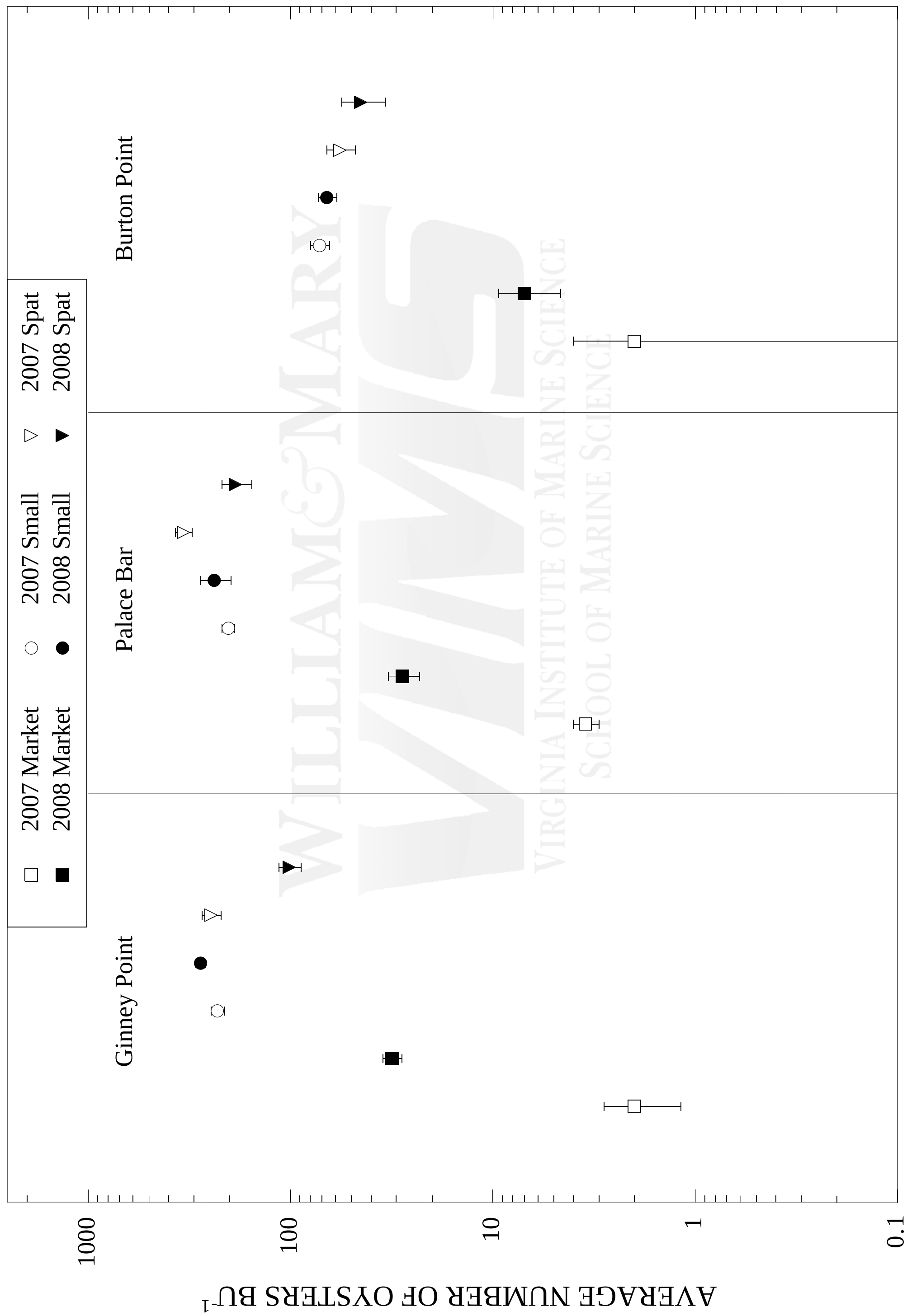


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

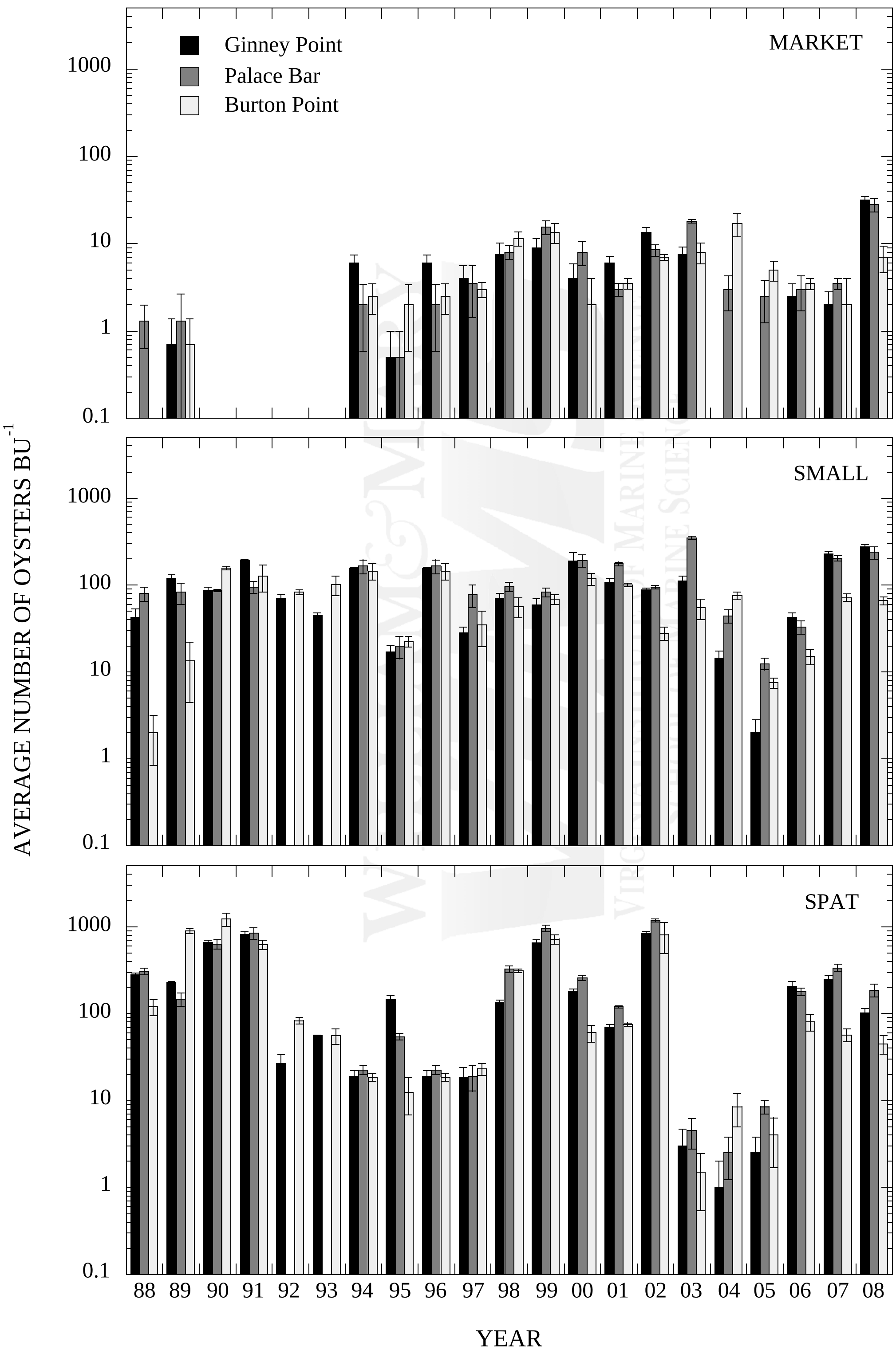


FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2007-2008)
(Error bars represent standard error of the mean)

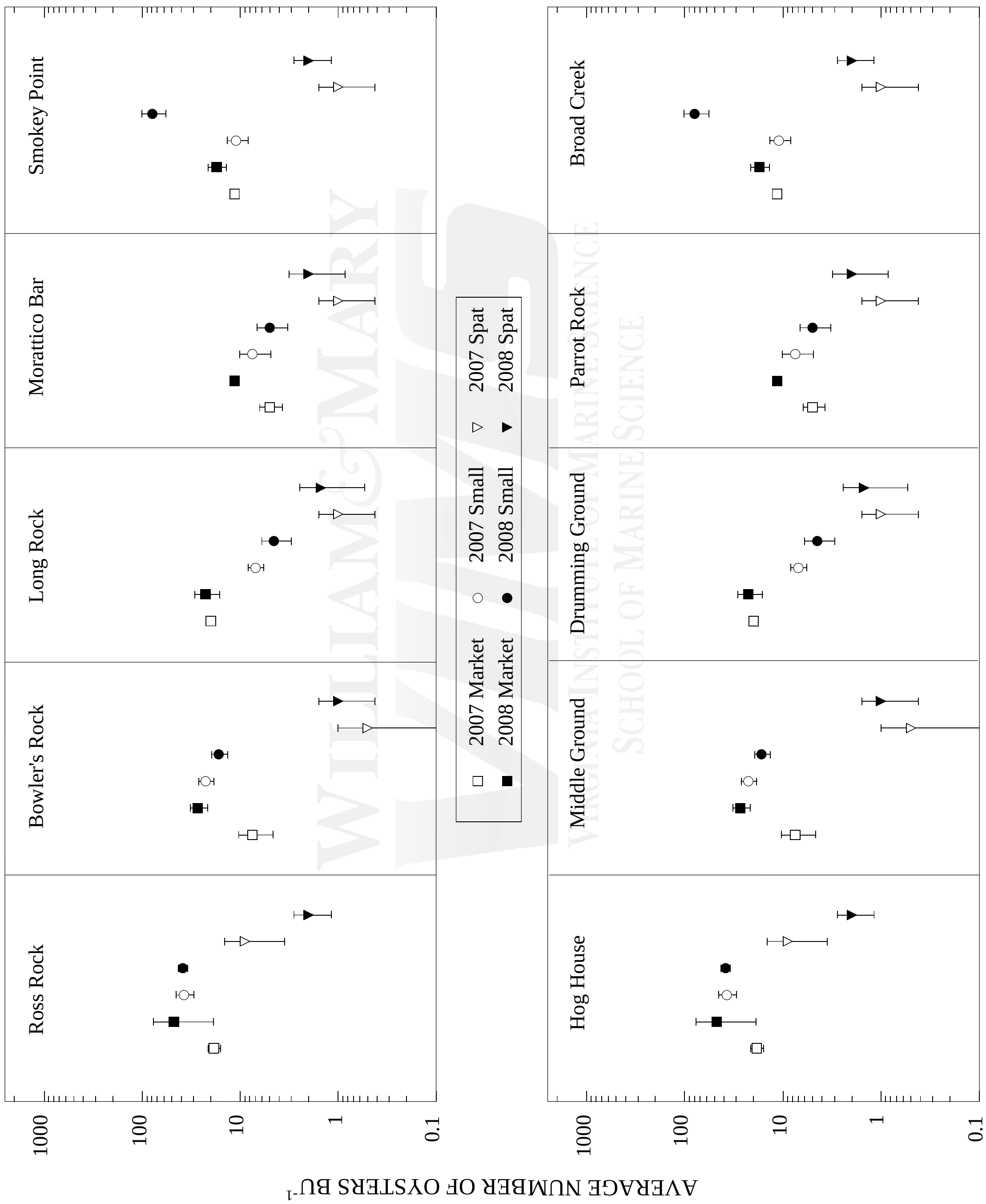
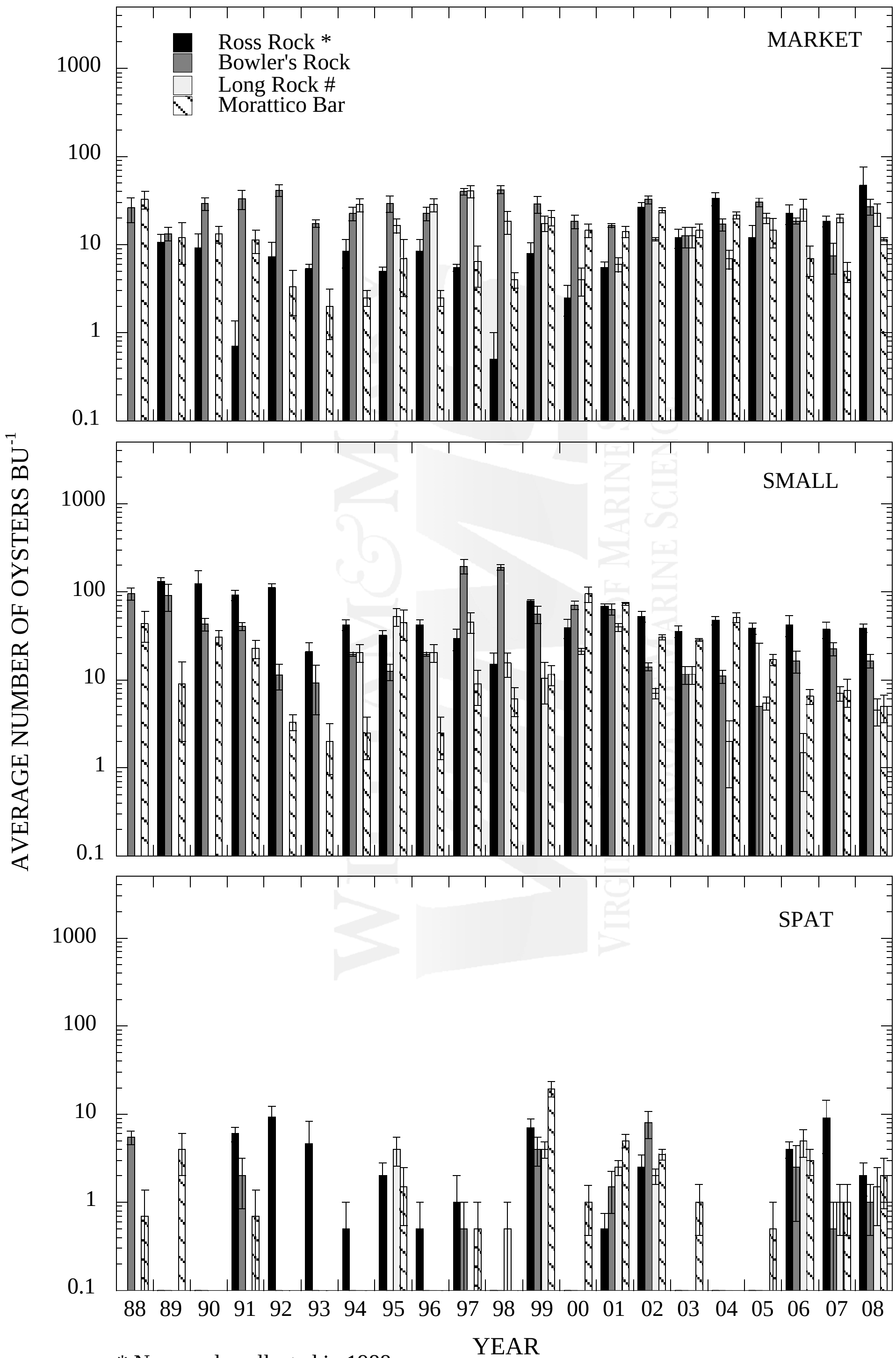


FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No sample collected in 1988
\# 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)

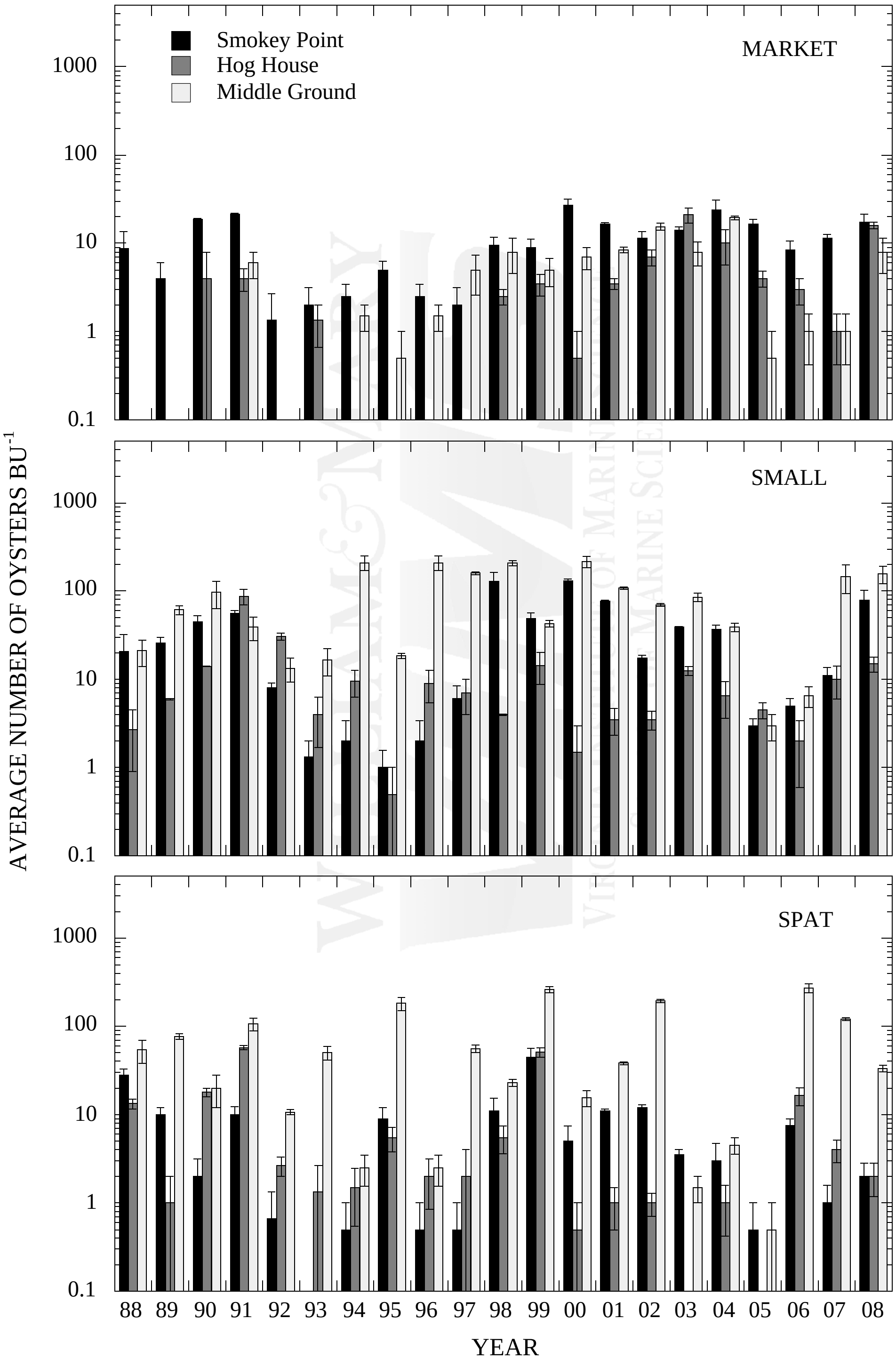
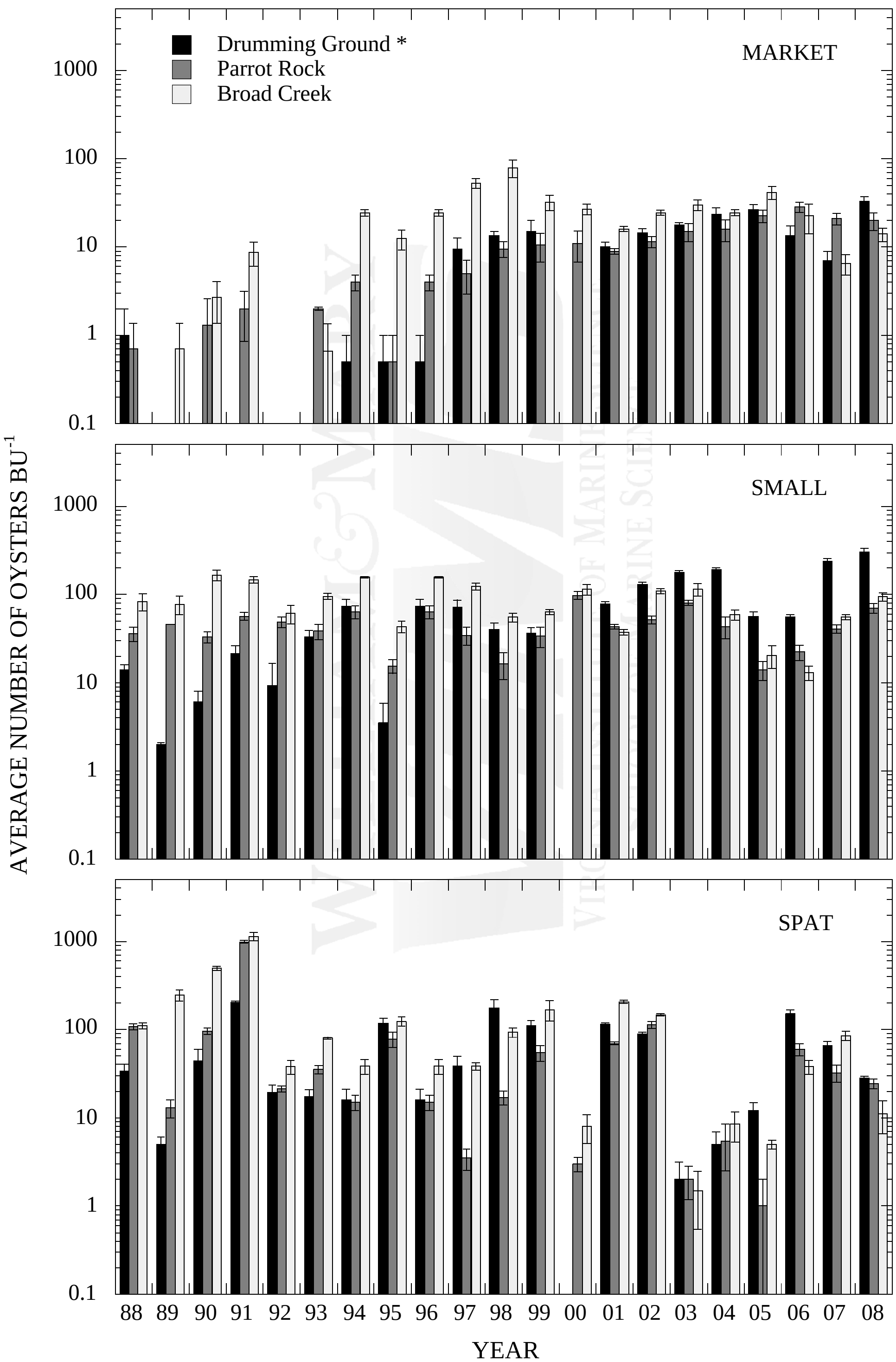


FIGURE D10C: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)



* No sample collected in 2000

FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE GREAT WICOMICO RIVER (2007-2008)
(Error bars represent standard error of the mean)

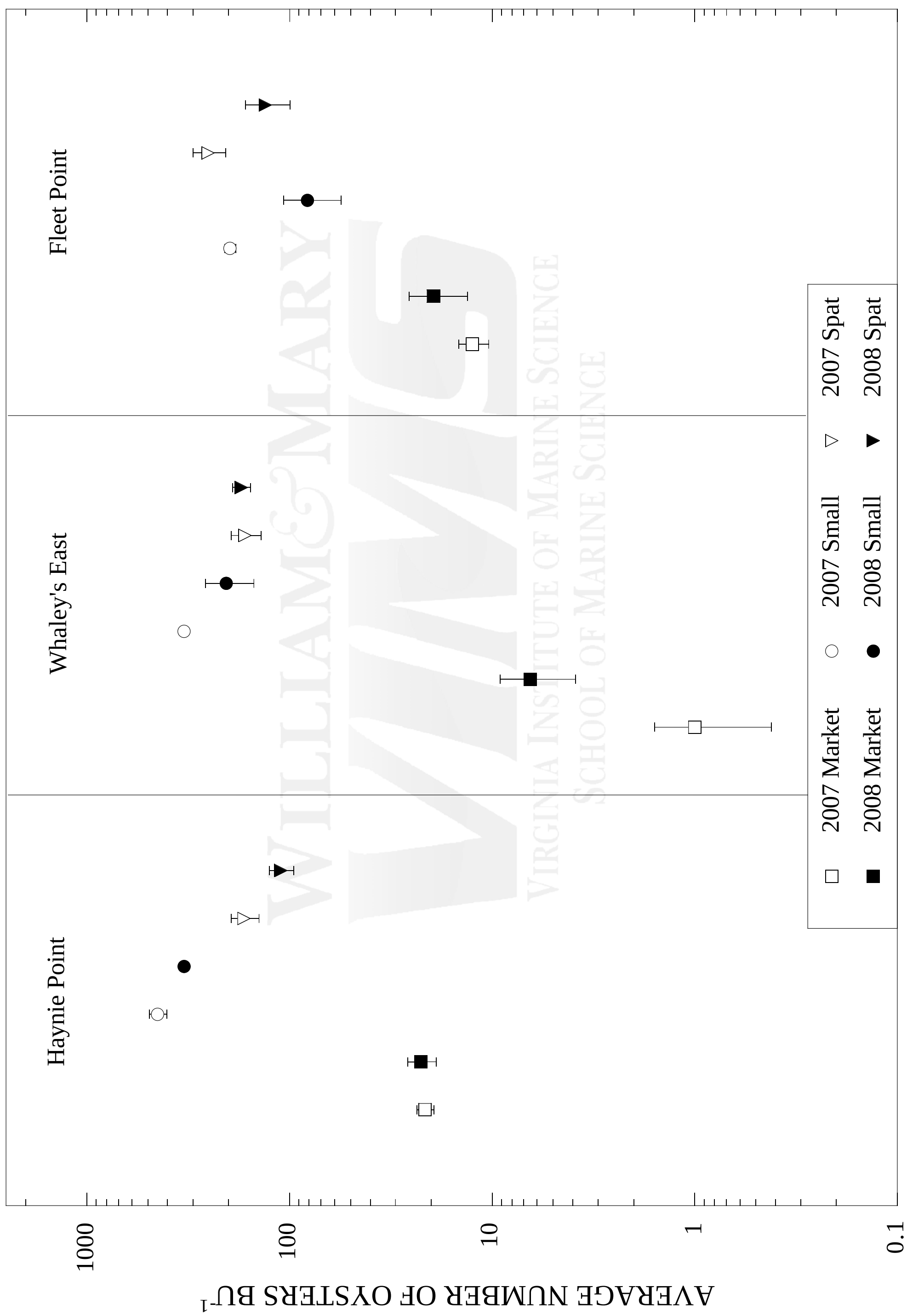


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 20 YEARS
(Error bars represent standard error of the mean)

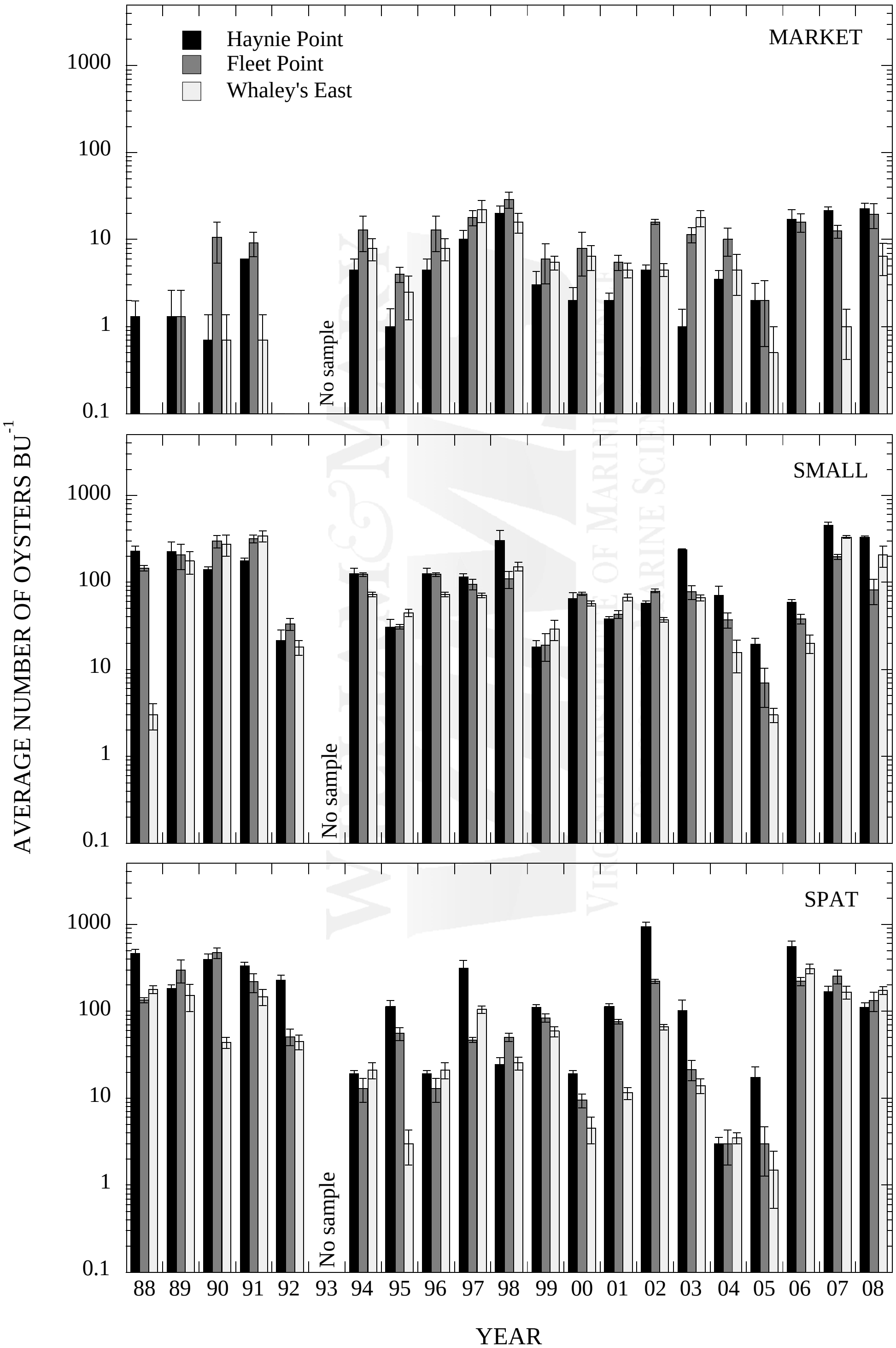
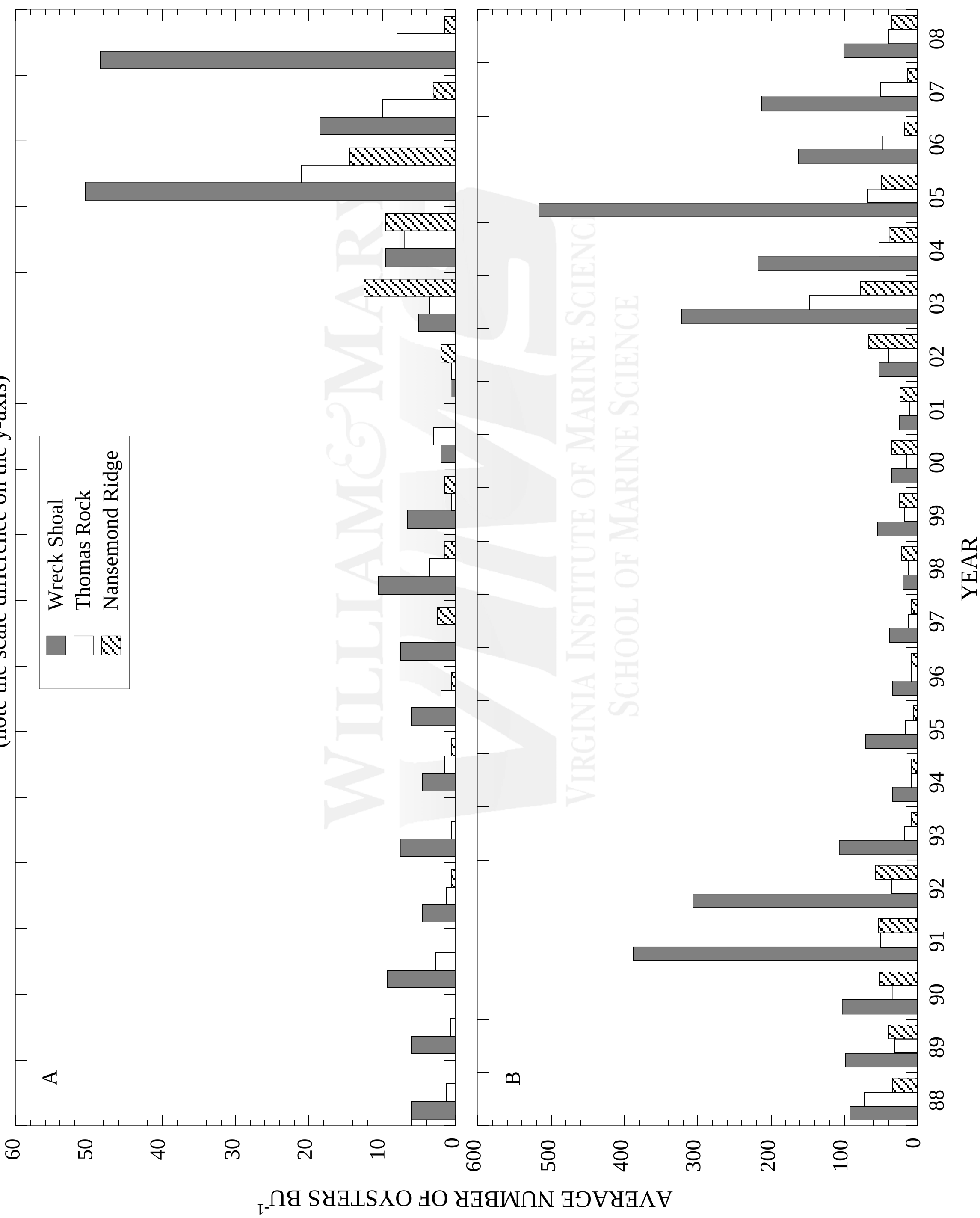


FIGURE D13: AVERAGE NUMBER OF MARKET (panel A) AND MARKET PLUS SMALL OYSTERS COMBINED (panel B) AT THE 3 MOST DOWNRIVER SITES IN THE JAMES RIVER (note the scale difference on the y-axis)



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