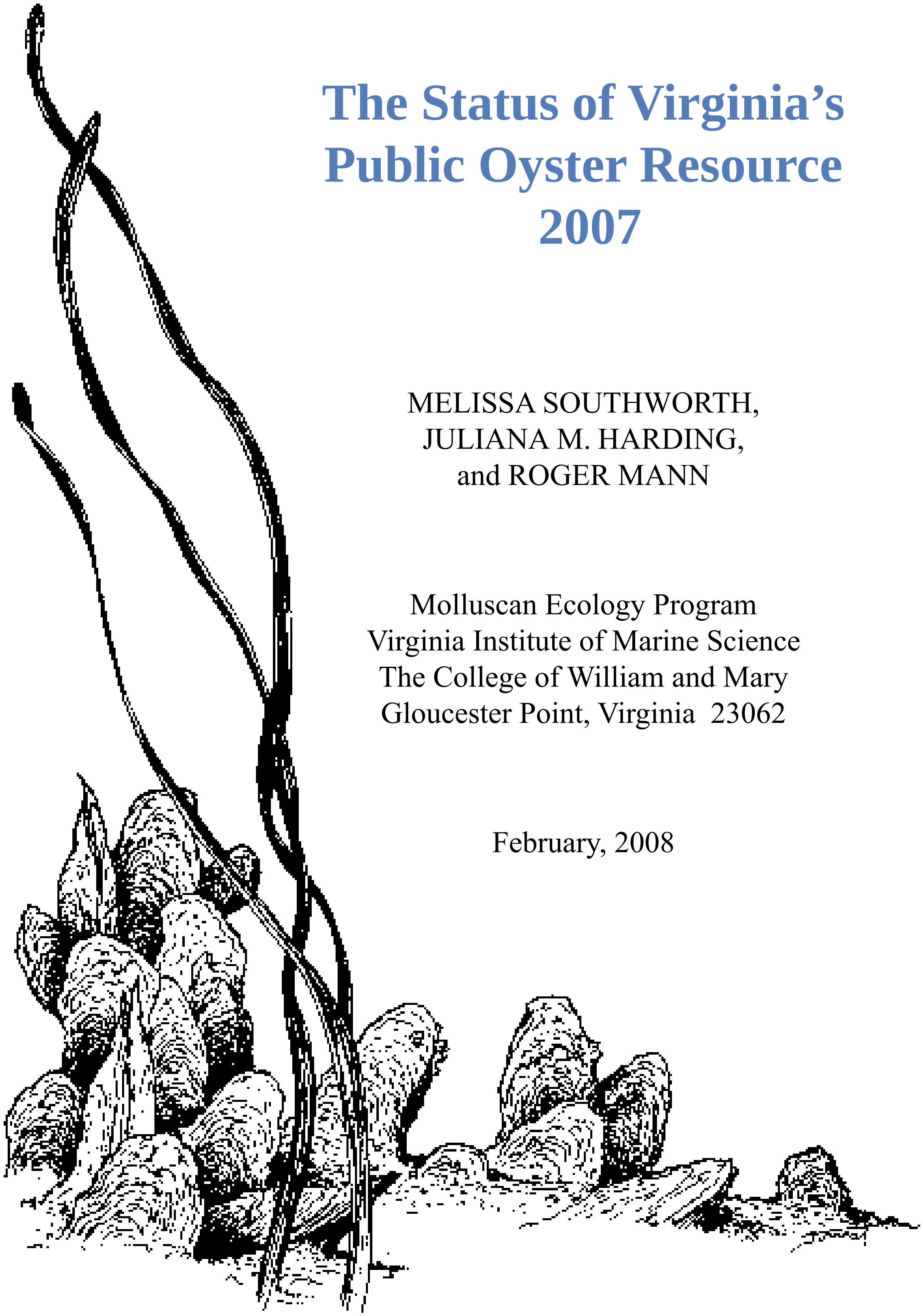
The Status of Virginia's Public Oyster Resource 2007



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Part I.

Oyster Spatfall In Virginia During 2007

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 2007 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2007 was monitored from the first week of June through the first week of October in the James, Piankatank and Great Wicomico Rivers. Spatfall stations included eight historical sites in the James River, three historical and five new sites in the Piankatank River and five historical and four new sites in the Great Wicomico River (Figure S1). In this report, historical sites refer to those that have been monitored yearly for at least the past 15 years whereas "new" sites are stations that were added during 1998 to monitor the effects of replenishment efforts by the Commonwealth of Virginia. The new 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 and on reefs in the Piankatank and Great Wicomico Rivers during winter 1997. 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 six to fourteen 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} / week 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 2007 is summarized in Table S1 and is discussed below for each river system monitored. Table S2 includes a summary of settlement for the past fifteen years at the historical stations in all three-river systems and the past nine years for the new stations 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 stations were used. All of the stations 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 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 2007. Comparisons were made over the past nine years for the new sites whereas the historical sites include fifteen 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 June 24 at Point of Shoal and Day's Point (Table S1). Beginning the week of July 29, settlement was consistently observed throughout the system and continued until the third week of September. There was only one peak in settlement observed system-wide in James River during 2007. This spanned the two-week time period between the last week of August and the first week of September (Figure S3). At all of the sites except Deep Water Shoal, settlement during this two-week time period accounted for greater than 50% of the total settlement for the year. A smaller localized peak in settlement occurred at the two most downriver southern shore sites (Rock Wharf and Day's Point) during the week of August 5 (Figure S3).

Settlement in the James River during 2007 was moderate to heavy ranging from a low of 4.14 (Wreck Shoal) to a high of 30.77 (Day's Point) cumulative spat shell^{-1} week^{-1}. As has often been observed in the past (Haven & Fritz 1985), settlement during 2007 was highest in the Burwell Bay area and along the southern shore.

Settlement in the James River during 2007 showed an increase from the previous year (2006) at all of the stations monitored except Dry Shoal (decrease) and Wreck Shoal (no change: Table S2; Figure S4). Spatfall during 2007 was higher than the 5, 10 and 15-year means at both Rock Wharf and Day's Point and was the third highest observed at those sites since 1993 (Table S2; Figure S4). Settlement at Deep Water Shoal was also among the highest (fourth) observed at that site during the past 15 years.

Average river water temperatures reached a maximum in early August (29 degrees C: Figure S5A). Water temperature was within 1 degree C of the 5, 10 and 15-year means (Figure S5A) throughout most of the sampling period. However, there were two pronounced drops in temperature during 2007. The first drop occurred during the first week of July (1.2 degrees C below average) and the second occurred during the third week of July (2 degrees C below average). Salinity was at least 2 ppt higher than the previous 5, 10 and 15-year means throughout most of the 2007 sampling season (Figure S5B). The difference in salinity between the most upriver station (Deep Water Shoal) and the most downriver station (Day's Point; Figure 1) ranged from 5 to 12 ppt, with the largest differences occurring in June, the first month of the sampling season.

Piankatank River

Settlement in the Piankatank River during the week of August 5 at all eight stations. Settlement was consistent throughout the system from early August through the third week of September with the largest pulse occurring during the week of August 26 (Table S1; Figure S6). Approximately 50% of the total settlement in the Piankatank River during 2007 occurred during the week of August 26. Cumulative spat shell^{-1} week^{-1} for the year was moderate to heavy ranging from a low of 2.90 at Wilton Creek to a high of 23.47 at Heron Rock.

Spatfall during 2007 showed an increase when compared with 2006 at all stations monitored, except Wilton Creek and marked the fourth year in a row that showed an increase at Ginney Point, Bland Point, Cape Toon and Stove Point (Table S2: Figure S7). Settlement during 2007 was also higher than the 5-year mean at all eight stations monitored and higher than the 10 and 15-year means at the three historical sites (Ginney Point, Palace Bar and Burton Point). Settlement during 2007 was the second highest observed over the past fifteen years at Ginney Point, the third highest at Burton Point and the fifth highest at Palace Bar. Settlement during 2007 was the highest observed at Cape Toon and the second highest observed at Bland Point, Heron Rock, and Stove Point since monitoring began at those stations in 1998.

The average water temperature ranged from 23 to 29 degrees C throughout the sampling period, reaching a maximum the first week of August.

Water temperature was similar to the 5, 10 and 15-year means until a three week period from late August into early September when it was approximately 2 degrees C higher than average (Figure S8A). Similar to what was observed in the James River, there was approximately a 1 degree C decrease in temperature during the first week of July and a 2 degrees C decrease during the third week of July (Figure S8A). Salinity ranged from 13 to 20 ppt throughout the sampling period. Salinity was similar to the 5, 10 and 15-year means until early August when it began to steadily rise and was an average of 2 to 3 ppt higher than the salinities previously recorded in the system (1991-2006, Figure S8B). The difference recorded between Wilton Creek (the most upriver station) and Burton Point (the most downriver station: Figure S1) ranged between 1 and 3 ppt throughout the sampling period except during the first week of August when the salinity at Wilton Creek decreased by about 5 ppt and was 7 ppt lower than the rest of the system.

Great Wicomico River

June 17 at three out of the nine sites in the Great Wicomico River (Table S1) and was intermittent from then until the end of the sampling period with a three week period in July where there was little to no settlement at most of the stations monitored. There were two major pulses in setting in the Great Wicomico River during 2007. The first and larger pulse occurred during the first two weeks of July and accounted for 61 to 87% of the total settlement in the system for the year (Figure S9). The second, smaller pulse occurred during the first two weeks of August. These four weeks combined, accounted for 94 to 98% of the total settlement for the season.

Cumulative spat shell^{-1} week^{-1} for the year was heavy at all of the sites except Fleet Point and ranged from a low of 8.55 at Fleet Point to a high of 135.28 at Harcum Flats. Similar to years past, settlement at the two stations downriver of Sandy Point, Whaley's East and Fleet Point, was among the lowest observed in the system with settlement generally increasing in an upriver fashion. Settlement during 2007 was higher than the previous year (2006) at all of the stations except Glebe Point (Table S2: Figure S10). Settlement during 2007 was also higher than the previous 5-year mean at all stations sampled and higher than both the 10 and 15-year means at the five historical stations (Table S2). Settlement was the highest observed during the past fifteen years at four out of the five historical sites. Settlement at all four new sites was the highest observed since monitoring began at those sites in 1998.

Average river water temperatures ranged between 23 and 30 degrees C throughout the sampling period reaching a maximum the week of August 5 (Figure S11A). Given the lack of historical data for the Great Wicomico River, temperature and salinity data during 2007 could only be compared with the previous 5 and 9-year means instead of the 5, 10 and 15-year means as in the James and Piankatank Rivers. Water temperature was similar to the 5 and 9-year means during the month of June, and then it fluctuated throughout the rest of the sampling period (Figure S11). As in the James and Piankatank Rivers, there was a pronounced decrease in temperature during the first week of July (2 degrees C difference) and then again during the third week (1.5 degrees C difference). Salinity ranged from 12 to 19 ppt during the sampling period comparable to that observed in the Piankatank, and was similar to the average for the system until early August when it began to steadily rise and was an average of 2 ppt higher than the previous nine-year mean (Figure S11B). There was less than a 1 ppt difference in salinity between the most upriver station (Glebe Point) and the most downriver station (Fleet Point: Figure S1) throughout most the sampling period.

DISCUSSION

With few exceptions in each of the rivers during various years, low or moderate spatfall (< 10 spat shell^{-1}) has been common in Virginia since 1993. Settlement during 2007 however, was relatively high in all three systems and among the highest observed over the past fifteen years of monitoring at several of the sites examined. Settlement in the Great Wicomico River was exceptionally high for the second year in a row and among the highest settlement event observed in the system since the mid 1980s.

While settlement in the James River was higher than the previous 5, 10 and 15-year means at several of the sites monitored, overall it was still typical of what has been observed in the system since the early 1990s with a cumulative seasonal average of less than 10 spat shell^{-1}. Two sites however, (Rock Wharf and Day's Point) had moderate to high settlement. These two sites are located along the southern shore in the downriver region of the seed area (Figure S1). This is not completely unexpected, after the onset of MSX in 1960, this area along with the Burwell Bay region often received the highest spat sets in the system (Andrews 1982). The circulation in the system is such that oysters spawned on the entire northern shore and in the more upriver seed area become entrained in the gyre and eventually are transported along the southern shore (Ruzecki & Hargis 1989).

The bulk of the settlement in the James River occurred during the month of September, more closely mimicking what was observed prior to the drought in the mid 1980s (Southworth & Mann 2004) than more recent settlement patterns. Salinities in the James River were several ppt higher than the long-term average throughout most of the season and this became especially evident from mid-July onward. Ulanowitz et al. (1980) showed that sustained high salinity contributed to greater spat production in the Maryland portion of the Chesapeake Bay.

With the exception of 1999 and 2002, settlement during 2007 in the Piankatank River was among the highest observed since the 1980s. 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 settlement in recent years in the Piankatank 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 exponentially with an increase in biomass (Cox & Mann 1992, Mann & Evans 1998). The numbers of oysters in the Piankatank River have been slowly increasing since the die-off and there was a relatively large increase in the number of small oysters in 2007 when compared with 2006 (Part II, this report). The timing of the set in the Piankatank River, was similar to that observed in the James River. The majority of the settlement occurred in late August into September with an associated increase in salinity (when compared with the long-term average) from early August onward.

Settlement in the Great Wicomico River was exceptionally high for the second year in a row and among the highest settlement event observed in the system since the mid 1980s. The bulk of the settlement in the Great Wicomico River occurred during the first two weeks of July. Both temperature and salinity were comparable to the 5 and 9-year means prior to the onset of the first settlement pulse. Winter salinities during the 2006/2007 season were lower than the previous few years (http://www.vims.edu/mollusc/NORM/index.htm), which may have reduced disease levels in the broodstock oysters. The parasite Perkinsus marinus is intolerant of salinities below 8 to 9 ppt and 12 ppt is described as the salinity required for a full epizootic (Mackin 1956). The salinity in the Great Wicomico River was below 12 ppt for several months during early 2007, dropping down to almost 10 ppt in early May before sharply increasing during the latter half of May. Infection by the parasite may be delayed at lower salinities (Ford & Tripp 1996), thus allowing the animal to develop and spawn prior to the onset of infection.

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.

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STATION	5/27 147	6/3 154	6/10 161	6/17 168	6/24 175	7/1 182	7/8 189	7/15 196	7/22 203	7/29 210	8/5 217	8/12 224	8/19 231	8/26 238	9/2 245	9/9 252	9/16 259	9/23 266	9/30 273	YEAR TOTAL
James River																				
Deep Water Shoal	D	0	0	0	0	0	0	0	0	0.25	0	0.10	0.15	0.05	1.34	2.39	0.05	0.25	0.70	5.28
Horsehead	D	0	0	0	0	0	0	0	0	0	0.05	0.30	0	1.25	1.50	0.25	0.40	0.45	0	4.20
Point of Shoal	D	0	0	0	0.06	0	0	0	0.05	0.15	0.05	0.80	0.15	4.00	2.45	0.24	0.15	0.50	0	8.60
Swash	D	0	0	0	0	0	0	0	0.10	0.15	0.10	0.30	0.10	1.45	3.30	0.25	0.20	0.35	0	6.30
Dry Shoal	D	0	0	0	0	0	0	0	0.10	0.10	0.10	1.05	0.20	1.73	0.72	0.15	0.30	0.40	0	4.85
Rock Wharf	D	0	0	0	0	0	0	0	0	0.15	2.60	0.95	0.20	5.30	8.45	0.15	0.50	1.40	0.06	19.8
Wreck Shoal	D	0	0	0	0	0	0.04	0	0.05	0.40	0.15	0.45	0.20	0.50	1.90	0.10	0.15	0.20	0	4.14
Day's Point	D	0	0	0	0.06	0	0.04	0	0	0.25	4.30	1.15	0.15	6.15	16.45	0.95	0.10	1.05	0.12	30.8
Piankatank River																				
Wilton Creek	D	0	0	0	0	0	0	0	0	0	0.20	0.70	0.75	0.80	0	0.10	0.30	0.05	0	2.90
Ginney Point	D	0	0	0	0	0	0	0	0	0	1.01	1.95	2.50	0.80	0.05	0.10	0.60	0.10	0	7.11
Palace Bar	D	0	0	0	0	0	0	0	0	0	0.50	0.80	1.65	0.90	0	0.35	0.20	0.10	0.12	4.62
Bland Point	D	0	0	0	0	0	0	0	0	0	0.35	0.60	2.10	6.30	0.40	0.20	0.90	0.10	0	11.0
Heron Rock	D	0	0	0	0	0	0	0	0	0	0.50	0.85	1.55	4.55	0.20	0.45	1.75	0.05	0	9.90
Cape Toon	D	0	0	0	0	0	0	0	0	0	2.74	1.90	4.10	11.7	0.30	0.55	1.35	0.65	0.18	23.5
Stove Point	D	0	0	0	0	0	0	0	0	0	0.95	0.85	1.50	11.4	1.25	0.35	3.10	0.25	0.23	19.9
Burton Point	D	0	0	0	0	0	0	0	0	0	0.05	0.80	2.75	6.40	0.15	0.05	0.30	0.10	0.04	10.6
Great Wicomico River																				
Glebe Point	D	0	0	0	1.27	57.2	45.7	0	0	0.60	4.90	22.9	0.10	0	0	0.10	0.05	0	0	132.9
Rogue Point	D	0	0	0.06	0.74	53.5	15.3	0.05	0	0.20	35.2	5.15	0.35	1.10	0.10	0.10	0.05	0.05	0	112
Hilly Wash	D	0	0	0.12	1.40	87.8	23.3	0	0	0	9.95	3.15	0.25	0.75	0.10	0.10	0	0.05	0	126.9
Harcum Flats	D	0	0	0.12	1.62	82.5	30.1	0	0	0	16.9	2.30	0.10	1.10	0.40	0.05	0.05	0.10	0	135.3
Hudnall	D	0	0	0	0.53	28.7	14.8	0.05	0.10	0	5.05	1.94	0	0.30	0.05	0.15	0.05	0	0	51.7
Shell Bar	D	0	0	0	1.27	12.6	13.1	0	0	0.05	1.70	1.05	0.20	0.20	0.10	0.05	0.05	0	0	30.3
Haynie Point	D	0	0	0	0.53	10.1	7.47	0.05	0	0	4.15	1.90	0.20	0.30	0.05	0.05	0	0	0	24.8
Whaley's East	D	0	0	0	0.62	5.15	13.1	0	0	0	1.50	0.65	0.05	0	0.30	0.15	0	0	0.06	21.6
Fleet Point	D	0	0	0	0.15	4.65	2.10	0.05	0	0	0.95	0.45	0	0	0.05	0.10	0.05	0	0	8.55

Table S2: Spatfall totals for historical sites (1992-2007) and for 1998-2007 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 2007 in reference to 2006 and to the five, ten, and fifteen-year means. Blank cells for a site indicate years where data are not available. “ND” indicates that there was no difference between values.

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STATION	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Mean 02-06	Mean 97-06	Mean 92-06	Ref. 2006	Ref. 5-yr	Ref. 10-yr	Ref. 15-yr
James River																							
Deep Water Shoal	0.7	15.7	0.6	1.7	0.5	1.3	1.2	5.7	0.7	2.0	33.8	0.1	1.6	1.0	2.1	5.3	7.7	4.9	4.6	+	-	+	+
Horsehead	3.6	43.7	3.2	0.3	3.6	2.4	1.1	3.8	2.3	4.0	24.4	0.0	3.6	1.3	2.2	4.2	6.3	4.5	6.6	+	-	-	-
Point of Shoal	5.4	73.7	15.0	4.8	2.3	2.3	1.5	3.5	0.7	4.0	31.3	0.1	3.1	1.1	2.2	8.6	7.6	5.0	10.1	+	+	+	-
Swash		46.2	4.8	1.8	2.2	1.7	1.6	6.8	2.6	3.5	26.0	0.5	11.9	1.4	1.8	6.3	8.3	5.8	8.1	+	-	+	-
Dry Shoal	14.2	119.0	25.8	2.8	11.0	1.1	1.1	6.1	3.7	2.1	16.5	0.6	8.7	3.1	8.5	4.9	7.5	5.1	15	-	-	-	-
Rock Wharf	11.4	34.3	10.7	0.2	2.4	5.6	2.1	8.0	1.0	8.5	22.7	0.1	10.0	4.4	1.9	19.8	7.8	6.4	8.2	+	+	+	+
Wreck Shoal	3.3	15.5	2.2	2.6	10.0	0.7	0.7	3.1	0.9	3.2	8.3	1.3	21.6	3.1	4.1	4.1	7.7	4.7	5.4	ND	-	-	-
Day's Point	14.2	131.5	42.2	3.0	4.6	5.6	0.4	7.3	4.3	1.6	10.5	0.1	3.6	1.6	1.9	30.8	3.5	3.7	15.5	+	+	+	+
Piankatank River																							
Wilton Creek							1.9	5.9	3.6	0.2	6.5	0.1	0.2	0.4	3.9	2.9	2.2			-	+		
Ginney Point	11.4	1.7	0.0	0.5	1.3	0.0	2.2	6.4	6.8	1.2	5.9	0.2	0.2	0.3	3.9	7.1	2.1	2.7	2.8	+	+	+	+
Palace Bar	24.9	5.0	0.8	1.0	1.6	0.0	5.5	10.1	3.9	0.2	3.1	0.1	0.5	0.2	2.1	4.6	1.2	2.6	3.9	+	+	+	+
Bland Point							2.3	44.1	2.7	1.3	6.7	0.2	0.4	1.0	3.7	11	2.4			+	+		
Heron Rock							10.1	9.3	3.2	0.6	5.1	0.2	0.7	0.4	1.1	9.9	1.5			+	+		
Cape Toon							4.5	12.3	1.2	1.8	9.1	0.1	2.0	2.6	8.2	23.5	4.4			+	+		
Stove Point							1.0	7.1	1.8	1.6	31.0	0.1	0.7	1.7	7.0	19.9	8.1			+	+		
Burton Point	11.7	6.5	0.1	1.0	1.0	0.7	1.3	14.9	2.7	0.8	4.9	0.2	1.9	0.9	2.9	10.6	2.2	3.1	3.4	+	+	+	+
Great Wicomico River																							
Glebe Point	0.5	0.2	0.0	1.5	0.6	21.2	0.6	2.4	4.2	1.1	283.3	4.9	1.6	2.0	150.3	132.9	88.4	47.2	31.6	-	+	+	+
Rogue Point							0.9	2.0	2.6	0.7	16.6	7.0	0.5	2.6	88.1	112	23			+	+		
Hilly Wash							0.6	1.6	3.2	0.8	24.1	2.9	0.5	1.9	43.9	126.9	14.7			+	+		
Harcum Flats							0.1	1.3	0.8	1.1	33.7	3.7	0.7	1.5	110.7	135.3	30.1			+	+		
Hudnall	0.5	0.8	0.0	0.1	0.2	39.1	0.5	0.9	1.0	1.4	12.7	3.1	0.6	0.9	37.4	51.7	10.9	9.8	6.6	+	+	+	+
Shell Bar							0	2.9	0.8	0.8	17.8	1.9	0.3	0.9	29.6	30.3	10.1			+	+		
Haynie Point	0.6	1.4	0.0	1.0	3.7	4.4	0.7	1.1	1.1	0.9	15.4	1.6	0.3	0.8	17.1	24.8	7	4.3	3.3	+	+	+	+
Whaley's East	0.1	0.2	0.0	0.3	2.1	1.0	0.4	1.8	0.2	0.7	2.4	0.9	0.1	0.4	6.0	21.6	1.9	1.4	1.1	+	+	+	+
Fleet Point	2.9	2.0	0.0	0.3	2.6	3.4	0.3	0.5	0.6	1.0	3.9	0.4	0.3	0.4	4.9	8.6	2	1.6	1.6	+	+	+	+

Figure S1: Map showing the location of the 2007 shellstring sites. An N following the site name indicates a new 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 (N), 10) Ginney Point, 11) Palace Bar, 12) Bland Point (N), 13) Heron Rock (N), 14) Cape Toon (N), 15) Stove Point (N), 16) Burton Point.

Great Wicomico River: 17) Glebe Point, 18) Rogue Point, 19) Hilly Wash (N), 20) Harcum Flats (N), 21) Hudnall, 22) Shell Bar (N), 23) Haynie Point, 24) Whaley's East, 25) Fleet Point.

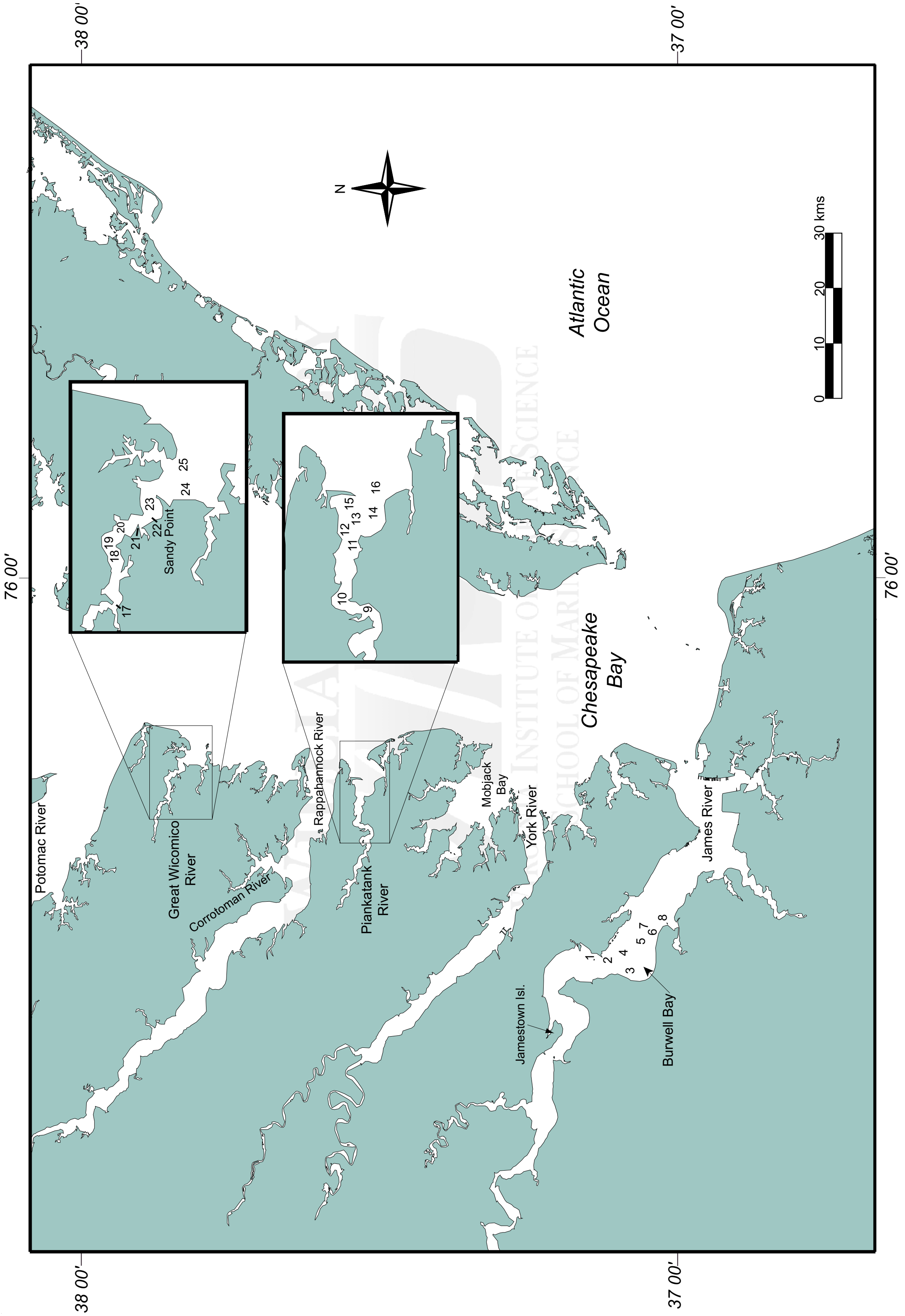
38 00'
37 00'
76 00'
N
Atlantic Ocean
Chesapeake Bay
0 10 20 30 kms
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Jamestown Isl.
Burwell Bay
Sandy Point
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Figure S2: Diagram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

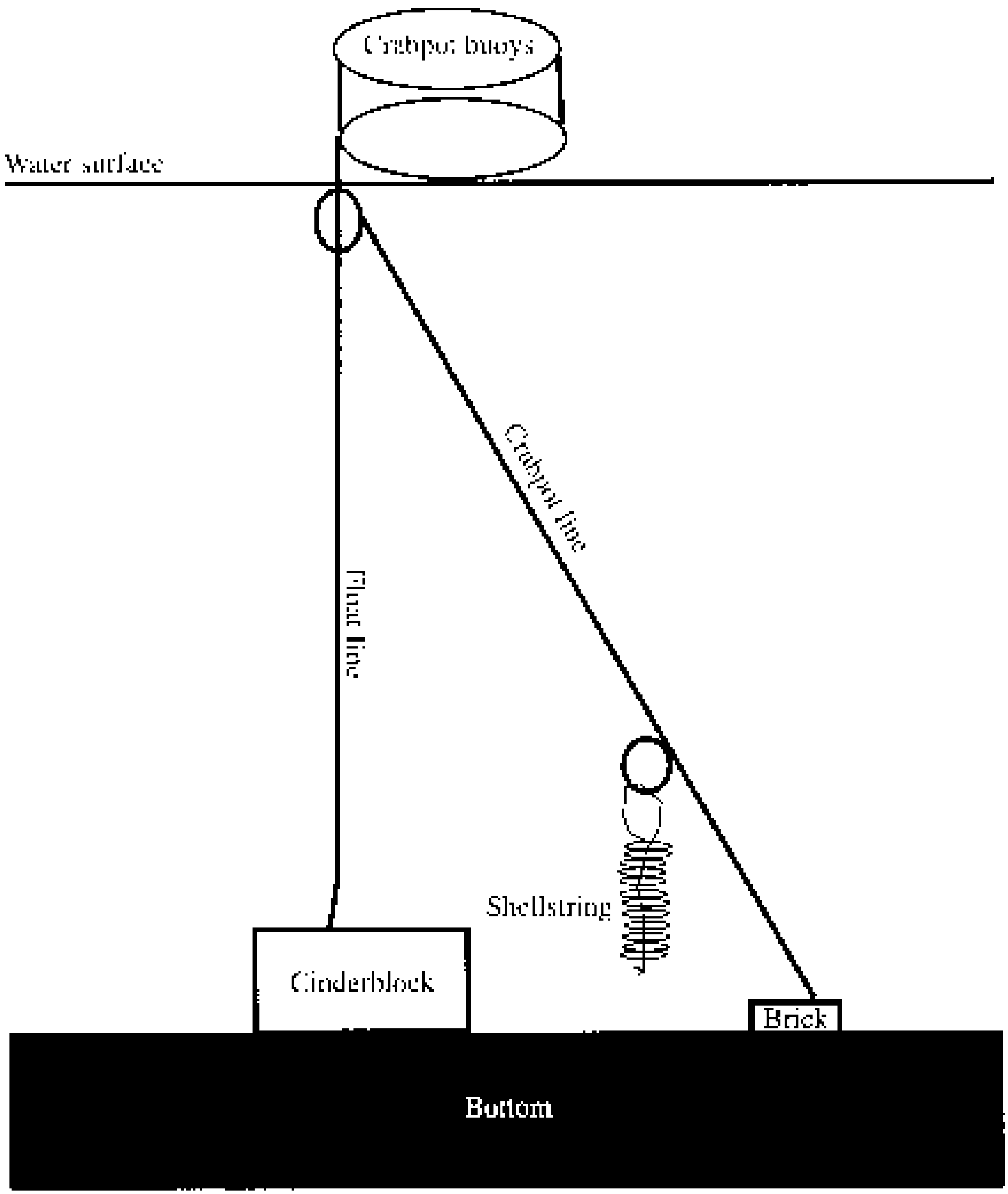


FIGURE S3: JAMES RIVER (2007) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$

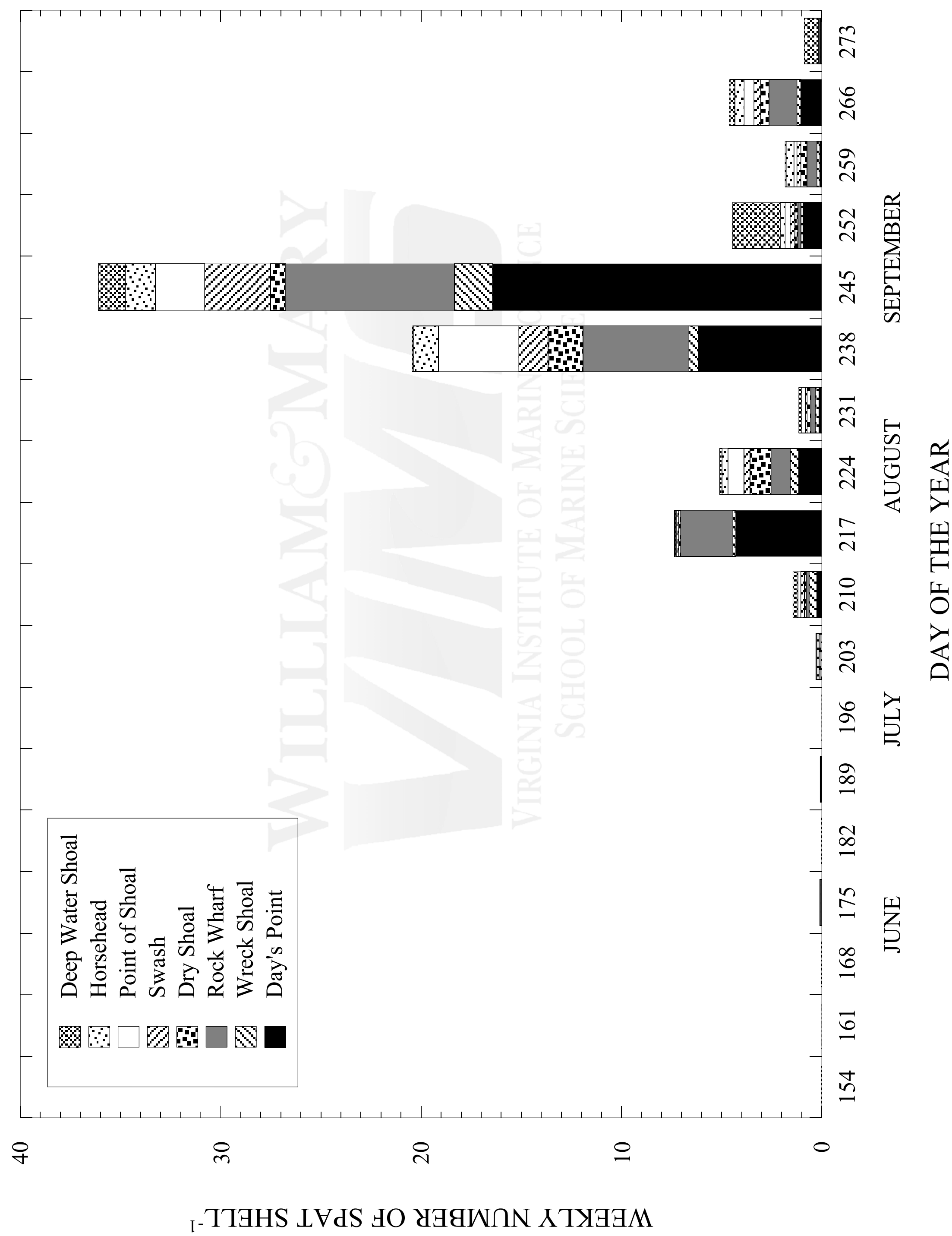


FIGURE S4: SPATFALL TRENDS OVER THE PAST 15 YEARS AT ALL 8 SITES IN THE JAMES RIVER (upriver sites in panel A; downriver sites in panel B) (expressed as cumulative weekly spatfall)

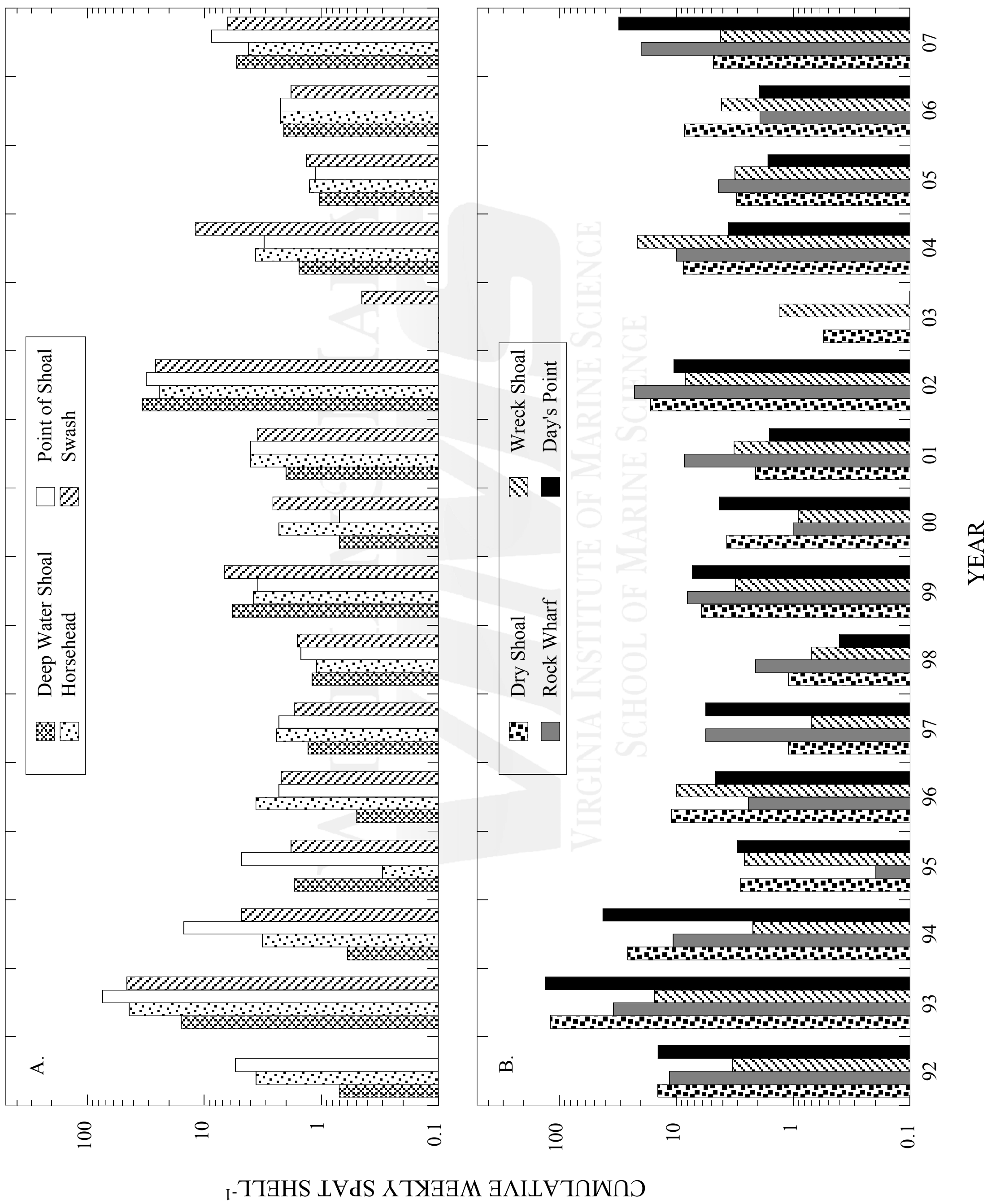
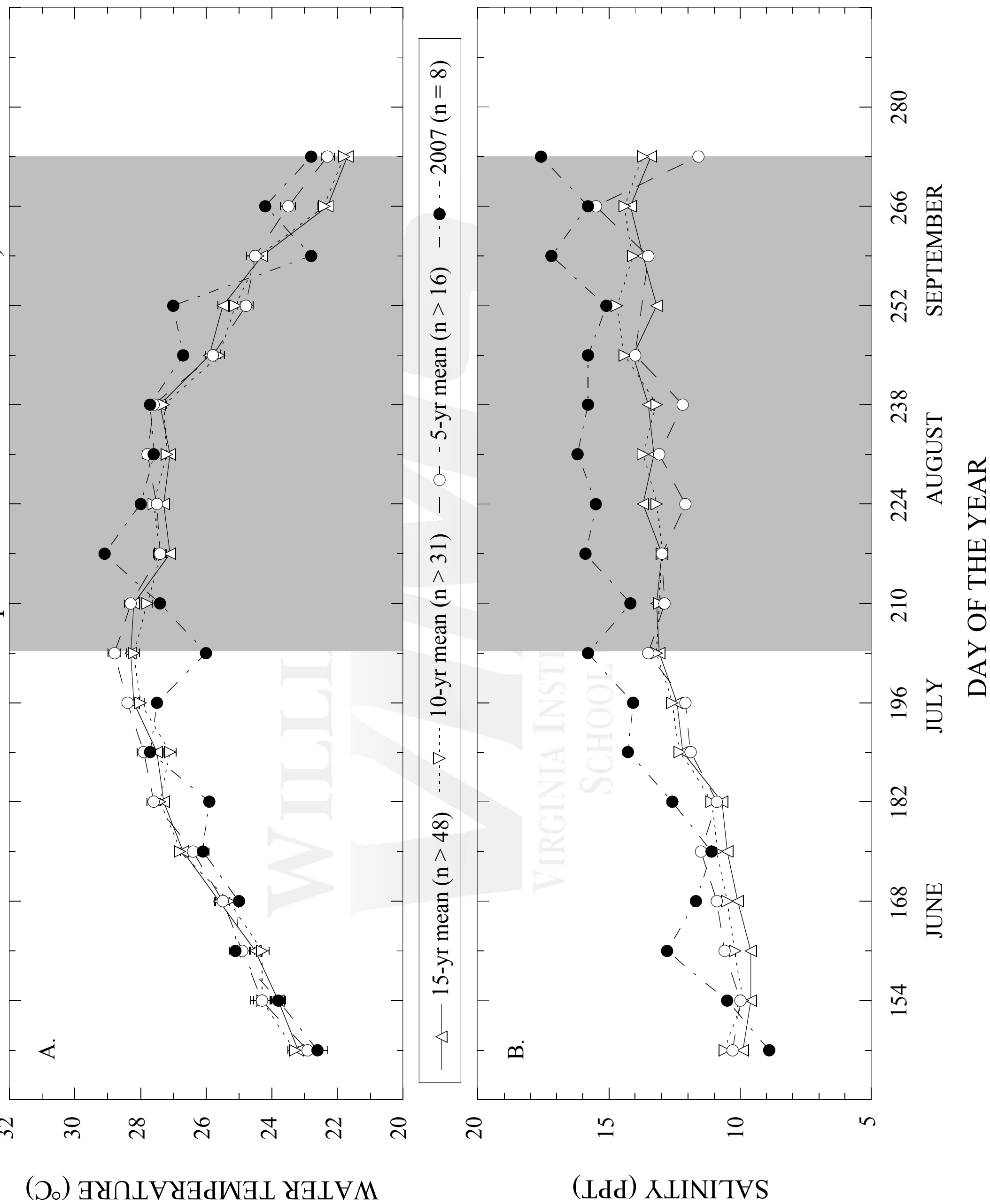


FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 15-YEAR MEANS COMPARED WITH 2007 (Error bars represent standard error of the mean; shaded area represents settlement during 2007; n is the number of data points used to calculate the mean)



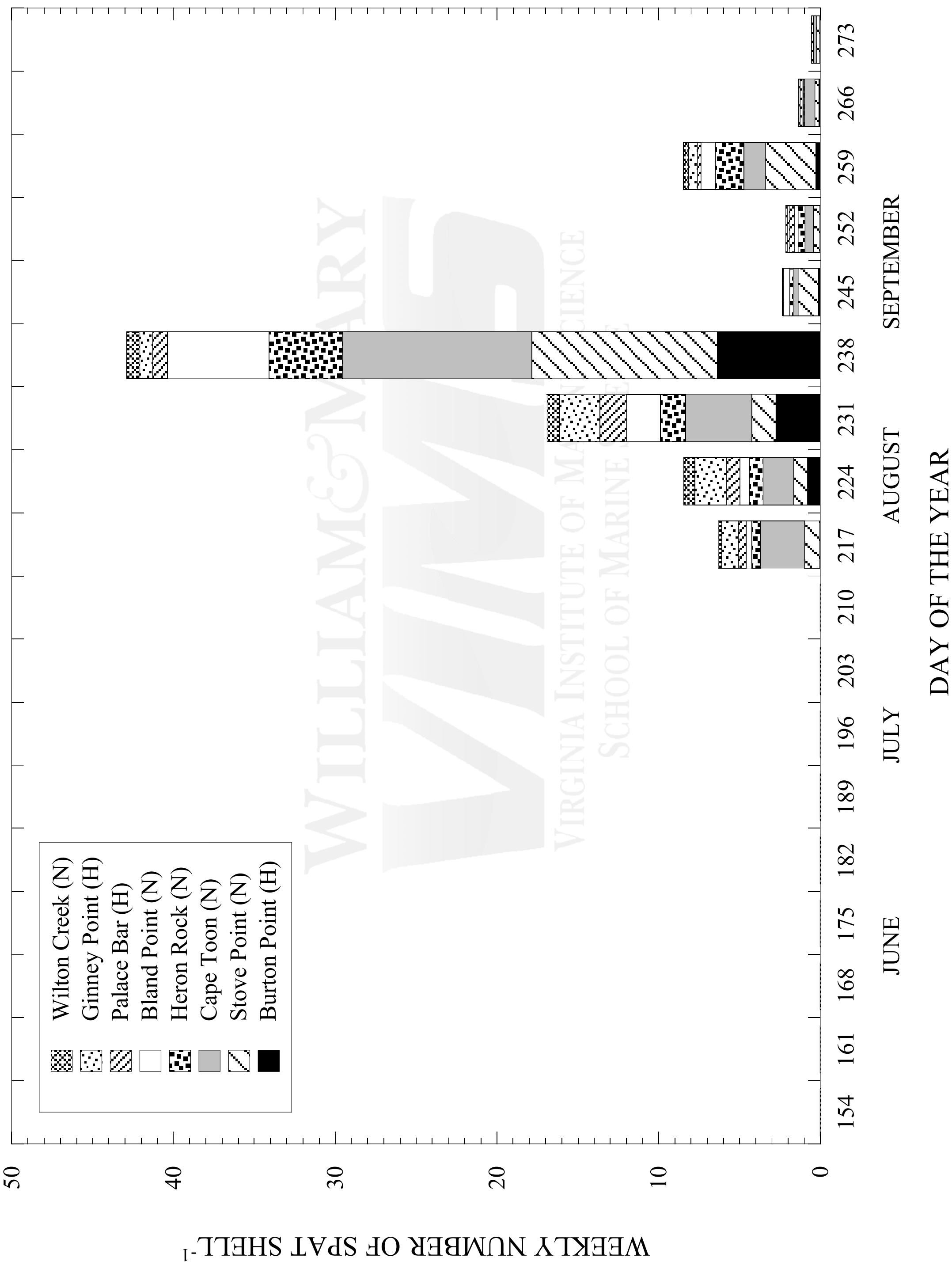


FIGURE S6: PIANKATANK RIVER (2007) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$ (H = historical station: N = new station as described in text)

FIGURE S7: SPATFALL TRENDS IN THE PIANKATANK RIVER AT THE 3 HISTORICAL SITES (panel A: 15 years) AND THE 5 NEW SITES (panel B: 9 years)
(Expressed as cumulative weekly spatfall)

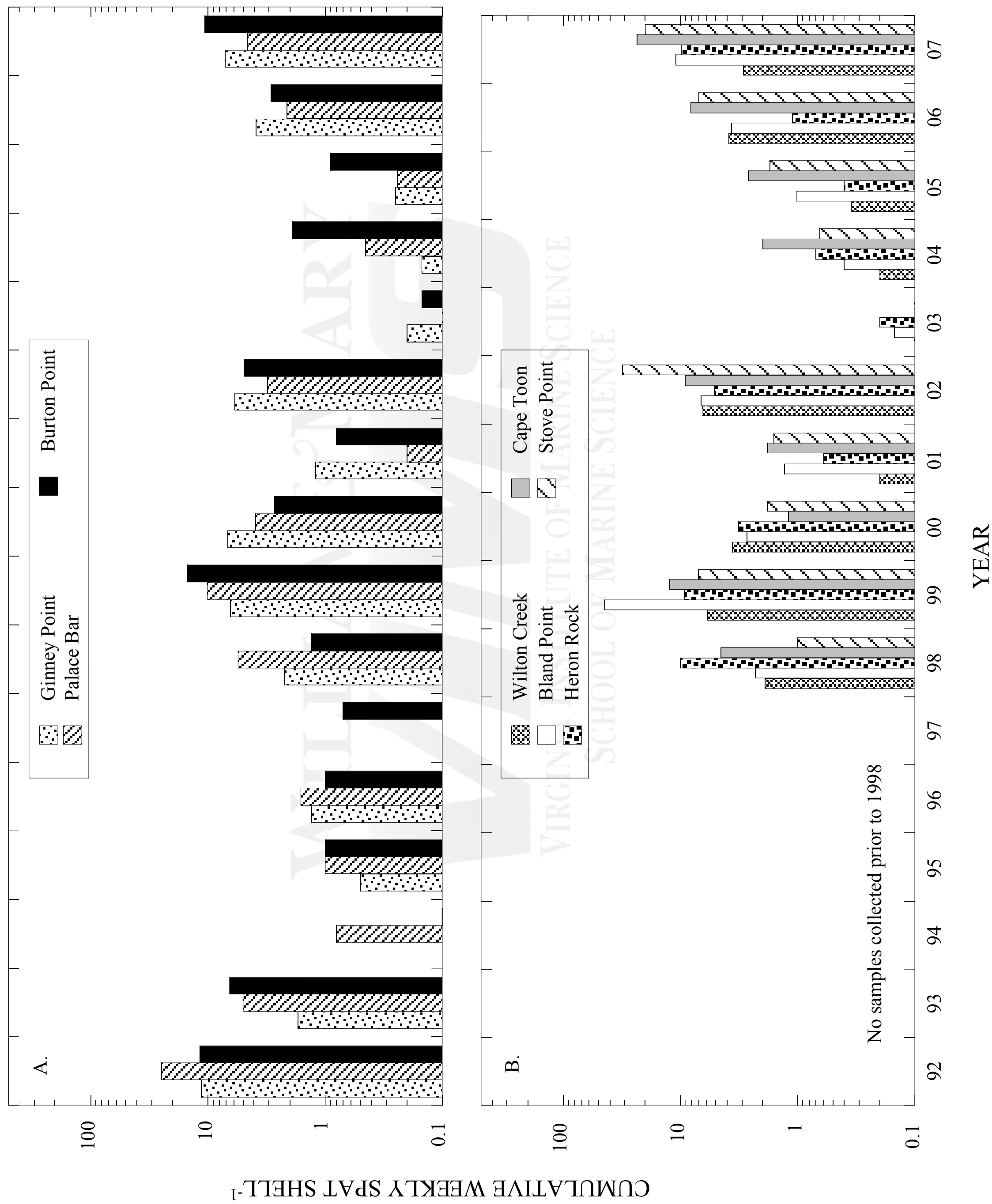


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 15-YEAR MEANS COMPARED WITH 2007
(Error bars represent standard error of the mean; shaded area represents settlement during 2007; n is the number of data points used to calculate the mean)

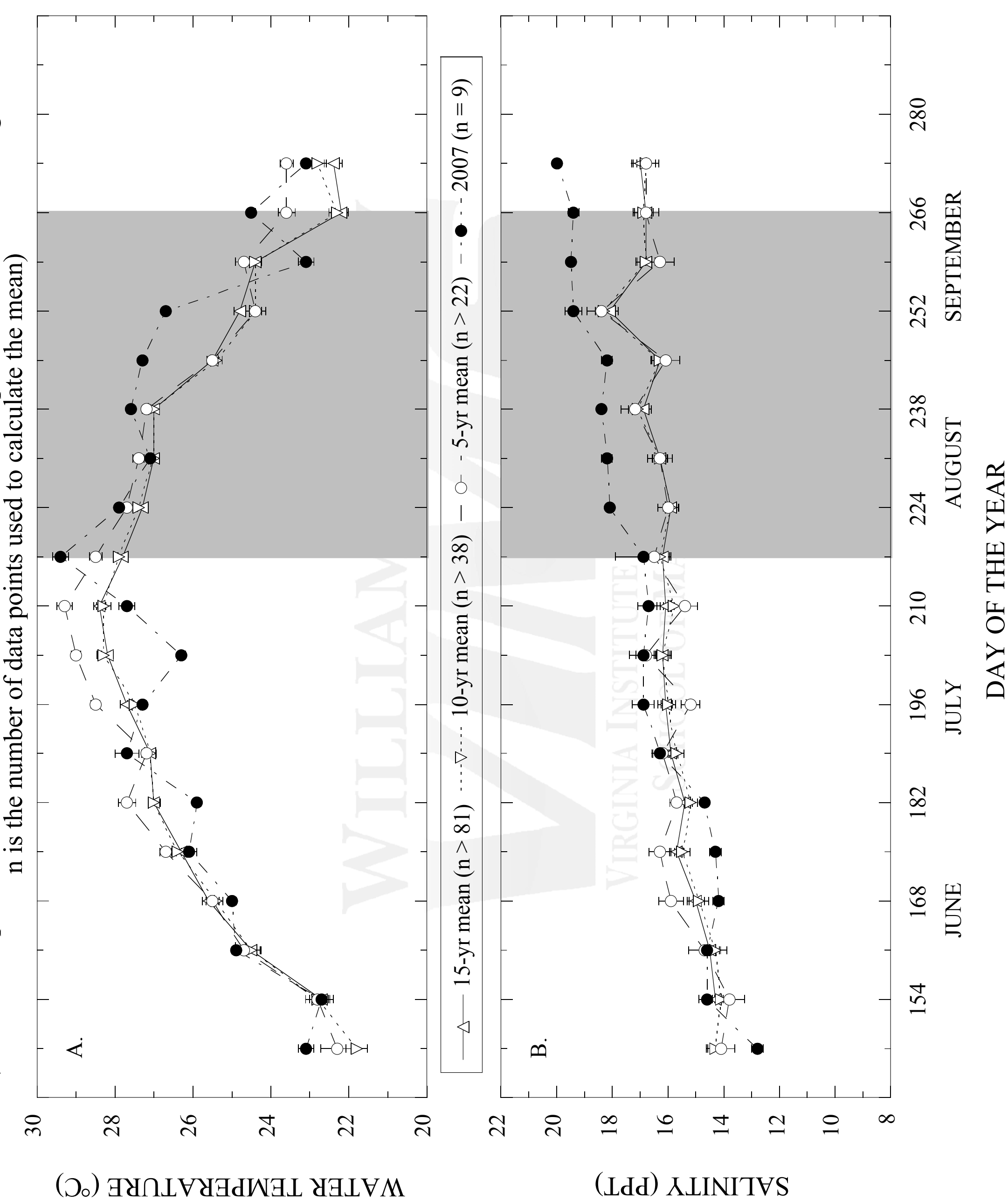


FIGURE S9: GREAT WICOMICO RIVER (2007) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: N = new station as described in text)

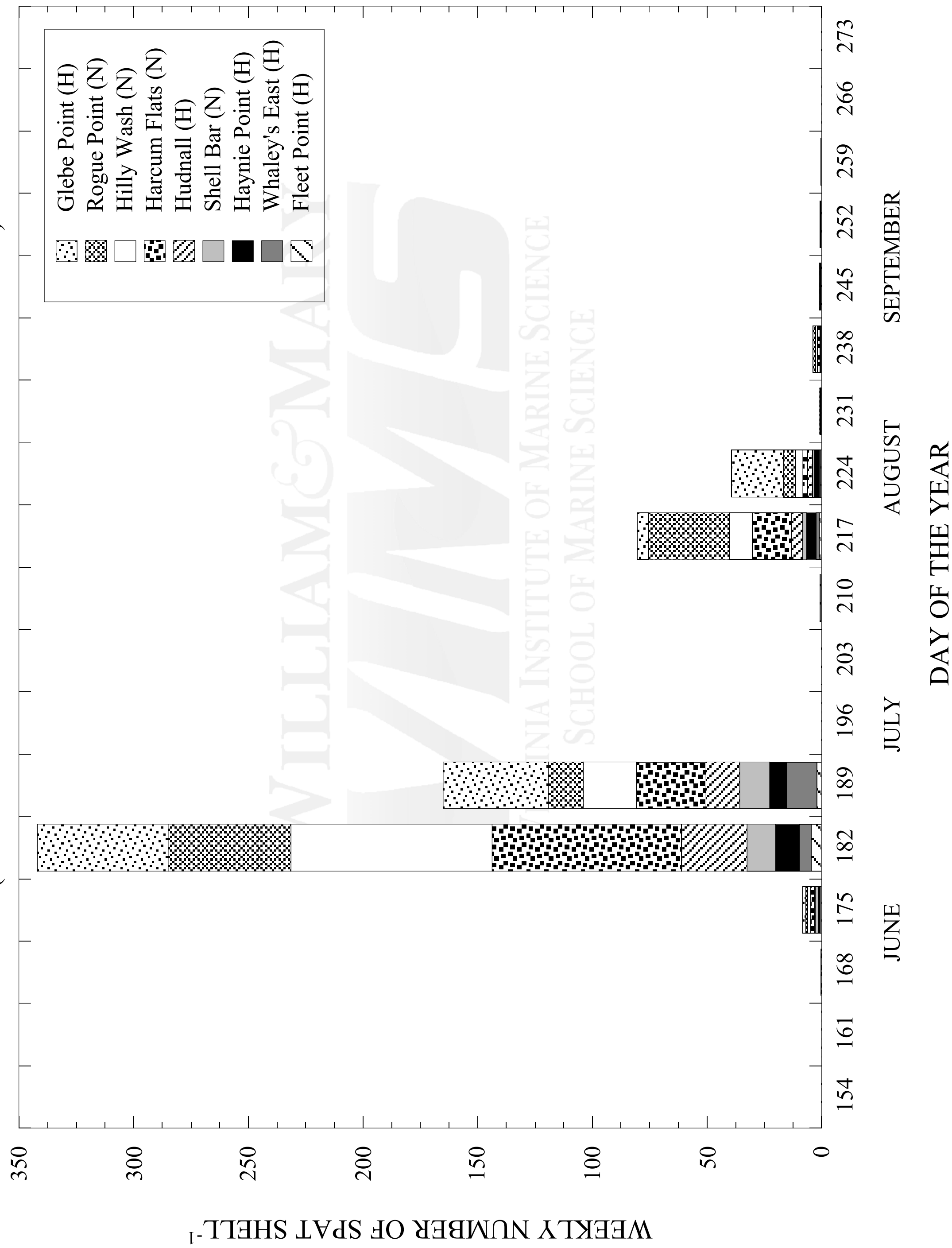


FIGURE S10: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER AT THE 5 HISTORICAL SITES (panel A: 15 years) AND THE 4 NEW SITES (panel B: 9 years) (Expressed as cumulative weekly spatfall)

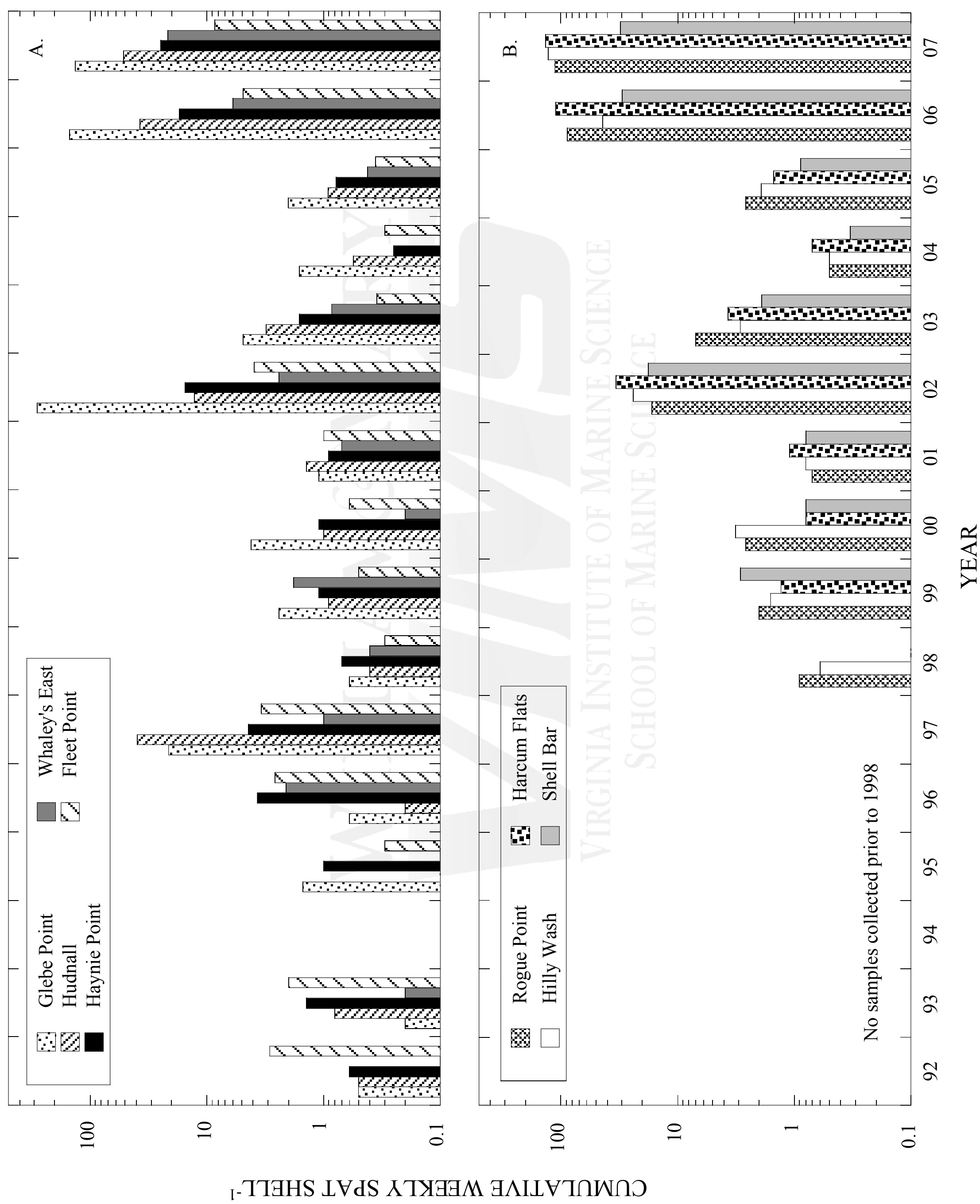
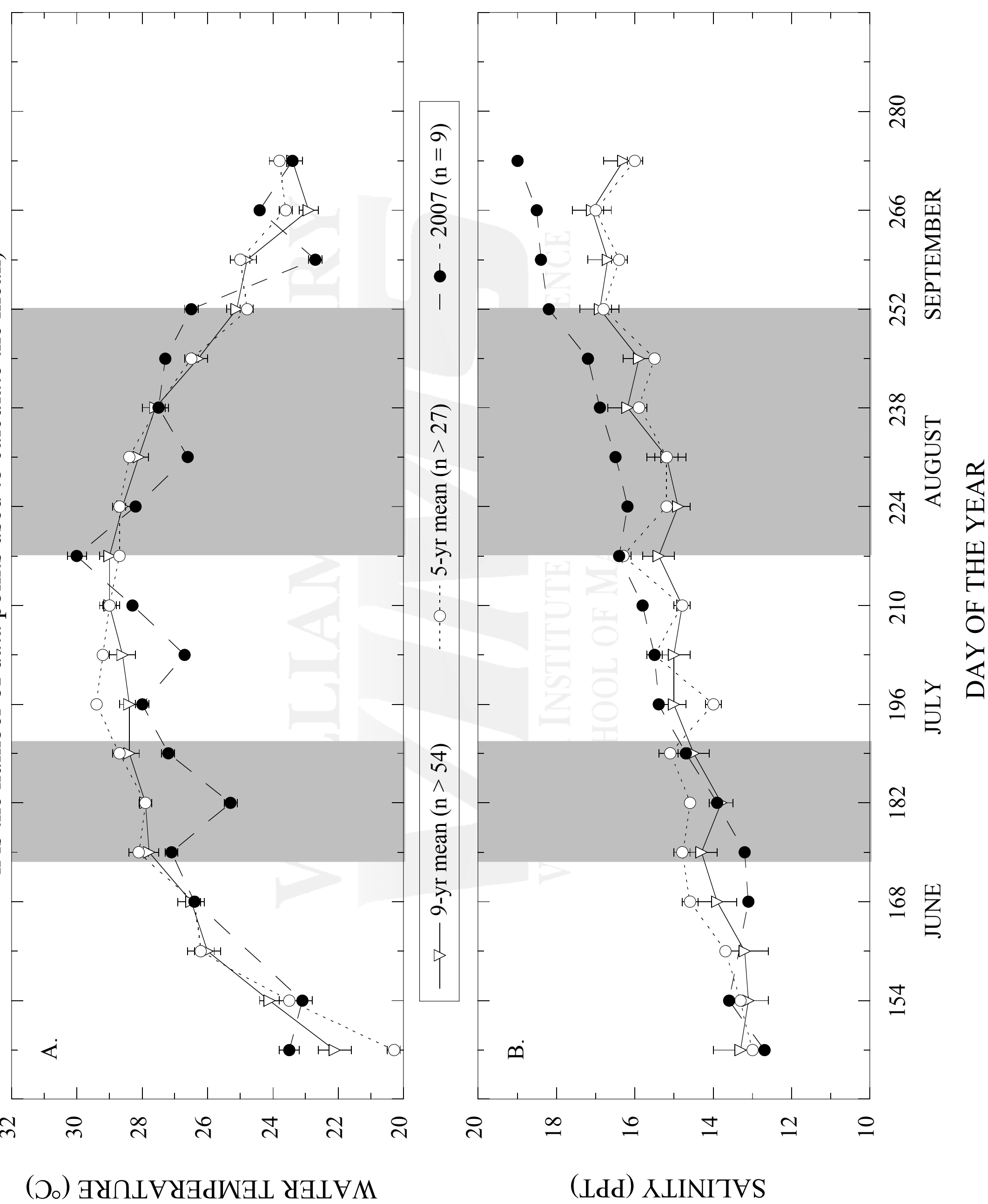


FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE SETTLEMENT PERIOD: 5 AND 9-YEAR MEANS COMPARED WITH 2007
(Error bars represent standard error of the mean; shaded area represents settlement during 2007; n is the number of data points used to calculate the mean)



Part II. Dredge Survey of Selected Oyster Bars in Virginia During 2007

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 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 from September through November.

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 one bar between seasons in the same year or between counts for the same season 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 2007 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 2007) 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, 2006 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 at each of the dredge stations using a handheld electronic probe (YSI 85).

In Spring 2007, clean shell or cultch was planted on Parrot Rock in the Rappahannock River.

RESULTS

Thirty oyster bars were sampled between September 28 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.

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 94.5 bushel^{-1} (bu) at Nansemond Ridge to a high of 540 bu^{-1} at Long Shoal. Overall the total number of oysters during 2007 was similar to that observed during 2006 at all ten sites (Figures D2 and D3).

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 1.5 (Nansemond Ridge) to 79.5 bu^{-1} (Point of Shoal). There was a slight increase in the number of market oysters at Wreck Shoal (Figure D2). The number of market oysters at the other nine sites remained relatively stable when compared with 2006 numbers.

Numbers of small oysters bu^{-1} ranged from a low of 12 at Nansemond Ridge to a high of 376 at Long Shoal. When compared with 2006, there was very little change in the number of small oysters at all of the sites monitored.

The average number of spat varied depending on location in the river. The average number of spat bu^{-1} ranged from a low of 56 at Thomas Rock to a high of 199 at Point of Shoal. There was a relatively large increase in the number of spat observed at Point of Shoal when compared with 2006 and a slightly smaller increase at Deep Water Shoal and Horsehead (Figure D2). In the past, there has been a relationship between location in the river and the composition of live oysters in terms of size distribution. As one moves from the most upriver station (Deep Water Shoal) to the most downriver station (Nansemond Ridge: Figure D1), the percentage of small oysters tends to decrease while the percentage of spat tends to increase. In most recent years, this pattern has not been as apparent. While the two most downriver sites (Nansemond Ridge and Thomas Rock) both had greater than 50% spat, Deep Water Shoal, the most upriver site, was also composed of greater than 50% spat. The number of spat at the four most upriver sites, Deep Water Shoal, Mulberry Point, Horsehead and Point of Shoal, was the highest observed since 2002. Settlement at those stations has been steadily increasing since hitting a low during 2003 (an extremely wet year with several summer freshets).

The average number of boxes bu^{-1} ranged from a low of 7.5 (Nansemond Ridge) to a high of 107.5 (Dry Shoal). Boxes accounted for 4 (Deep Water Shoal) to 22% of the total (live and dead) oysters observed. This was a decrease at most sites when compared with 2006. Between 52 and 79% of the boxes observed were old.

Water temperature during the sampling period ranged from 21.4 to 22.6 degrees C (Table D2). Salinity was variable depending on location in the river, increasing in a downriver direction, from 15.2 ppt at Deep Water Shoal to 22.3 ppt at Nansemond Ridge.

York River

In the York Rier, the average total number of live oysters bu^{-1} was 72.5 at Aberdeen Rock and 51 at Bell Rock. The live oysters at Aberdeen Rock were approximately 61% spat, 32% small and the rest market (Figure D4). There was a notable increase in the number of small oysters at Aberdeen Rock when compared with 2006 Figure D4). Oysters at Bell Rock were primarily small (75%), with a notable decrease in the number of small oysters observed when compared with 2006 (Figures D4 and D5). There was also a notable decrease in the number of market oysters at Bell Rock (Figures D4 and D5). The average number of boxes (new and old) bu^{-1} was low at both sites; Aberdeen Rock (4.5 bu^{-1}) and Bell Rock (21 bu^{-1}), accounting for 6 and 29% of the total oysters (live and dead) respectively. At both sites, the majority of the boxes (greater than 67%) were old boxes. Water temperature on the day of sampling was 24 degrees C at Aberdeen Rock and 25 degrees C at Bell Rock. There was a 4.1 ppt difference in salinity observed: 16.5 ppt at Bell Rock and 20.6 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters at Pultz Bar and Tow Stake were 69.5 and 253.5 oysters bu^{-1} respectively. There was a notable, relatively large increase in small oysters at both sites when compared with 2006 (Figure D4). For the second year in a row, settlement at Pultz Bar was among the highest observed during the past 15 years of monitoring (Figure D6). Once again, there were no market size oysters present at Pultz Bar and very few at Tow Stake. The live oysters were primarily spat (77%) at Pultz Bar and small oysters (78%) at Tow Stake. There were very few boxes observed at either station, and of the boxes observed 80% were either old or spat boxes. Four out of the five total spat boxes observed between the two stations had drill holes. The presence of a drill hole is indicative of predation by one of the two oyster drills, *Eupleura caudata* and *Urosalpinx cinerea* both of which are commonly found in the Chesapeake Bay. Water temperature was approximately 24 degrees C and salinity was approximately 22.5 ppt at both stations (Table D2) on the day of sampling.

Piankatank River

In the Piankatank River, the average total number of live oysters bu^{-1} ranged from 131 at Burton Point to 544.5 at Palace Bar. There was a notable increase in the number of small oysters observed when compared with 2006, and this marked the second year in a row that showed an increase at all three sites (Figures D7 and D8). Settlement during 2007 was again among the highest observed in the system over the past fifteen years (Figure D8), with a notable increase in the number of spat observed at Palace Bar when compared with 2006 (Figure D7). Settlement during 2007 was relatively good for the second year in a row following three years (2003-2005) of record low settlement. The composition of live oysters in the system was approximately 50/50 small oysters and spat with a slightly higher percentage of spat present at Palace Bar. The number of boxes observed was very low at all three sites accounting for less than 3% of the total (live and boxes). The number of boxes ranged from 4.5 (Ginney Point) to 8.5 (Burton Point) boxes bu^{-1}. Of these boxes, the majority (greater than 78%) were either old or spat boxes. At Burton Point, five out of the seven spat boxes observed had a drill hole, indicative of predation by one of the two previously mentioned oyster drill species commonly found in the Chesapeake Bay. Water temperature on the day of sampling ranged from 23 degrees C at Burton Point to 21.1 degrees C at Palace Bar. Salinity ranged between 19.8 and 20.6 ppt increasing in a downriver (Ginney Point to Burton Point) direction.

Rappahannock River

The average total number of live oysters bu^{-1} in the Rappahannock River ranged from a low of 13.5 at Morattico Bar to a high of 310.5 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 over the past few 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).

The average number of market oysters bu^{-1} ranged from 1 (Hog House and Middle Ground) to 20 (Long Rock). For the most part the greatest number of market oysters are at the most upriver sites and the most downriver sites. There was a slight notable decrease in the number of market oysters observed at Broad Creek. The number of market oysters at Broad Creek has remained relatively stable for the past eight years and this decrease marked the first notable one since 1998 (Figure D9 and D10). There was no change observed in the number of market oysters at the other nine sites monitored.

For the sixth year in a row, Drumming Ground near the mouth of the Corrotoman River had the highest average number of small oysters bu^{-1} with 238, a relatively large increase when compared with 2006 (Figures D9 and D10). There was also a notable increase in the number of small oysters at Long Rock, Smokey Point, Hog House, Middle Ground, Parrot Rock and Broad Creek when compared with 2006 numbers (Figure D9). Similar to Drumming Ground, the increase in the number of small oysters at Middle Ground was relatively large; 6.5 small oysters bu^{-1} in 2006 versus 145 small oysters bu^{-1} in 2007.

For the second year in a row, there was at least one spat observed at all ten stations in the Rappahannock. However there was a notable decrease in the number of spat at seven out of the ten stations when compared with 2006. Broad Creek was the only site that showed an increase in spat from 2006 to 2007(Figure D9). Settlement throughout the system has been low for the past several years (Figure D10) and 2007 marked only the second year with settlement observed at the three most upriver sites (Ross Rock, Bowler's Rock and Long Rock) since 2002. Middle Ground had the largest average number of spat with 121 bu^{-1}, for the second year in a row.

The average total number of boxes bu^{-1} was relatively low ranging from 2 (Long Rock) to 25 (Drumming Ground). Boxes accounted for less than 18% of the total (live and dead) at all of the sites monitored. The majority of the boxes observed were old boxes and only Middle Ground (the site with the highest settlement) and Broad Creek had spat boxes. One out of the two spat boxes observed at Broad Creek had a drill hole, indicative of predation by one of the oyster drills as previously mentioned.

Water temperature during the sampling period ranged from 20.5 to 21.8 degrees C. Salinity increased moving from the most upriver station (Ross Rock: 12.1 ppt) toward the mouth (Broad Creek: 20.2 ppt).

Great Wicomico River

The average total number of live oysters bu^{-1} in the Great Wicomico River was moderate to high ranging from 462 at Fleet Point to 636.5 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 a notable, large increase in the number of small oysters for the second year in a row at all three sites when compared with 2006 (Figure D11 and D12). Settlement during 2007 was among the highest observed in the system during the past fifteen years, comparable to 1997, 2002 and 2006 numbers (Figure D12). The total number of boxes bu^{-1} was low ranging from 6.5 (Whaley's East) to 16.5 (Fleet Point). This accounted for less than 4% of the total (live and dead) number of oysters observed. The boxes were approximately a 60/30 split of old boxes and new boxes with the remaining 10% being spat boxes. Water temperature on the day of sampling was approximately 21 degrees C and salinity was approximately 20 ppt at all three stations 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). 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 16.5 market oysters bu^{-1}).

For the past several decades, the bulk of Virginia's oyster population has been composed primarily of small oysters and spat. Small oysters dominated at eighteen out of the thirty stations and spat dominated at ten out of the remaining twelve. The only two sites with predominately market oysters (Long Rock and Smokey Point), both have extremely low oyster populations.

Overall settlement during 2007 was moderate. Settlement in both the Piankatank and Great Wicomico Rivers was among the highest observed during the past fifteen years. For the second year in a row, settlement was observed at all ten stations in the Rappahannock River. Settlement at the more upriver sites was among the highest observed during the past fifteen years of monitoring. Settlement at the four most upriver sites (Deep Water Shoal, Mulberry Point, Horsehead and Point of Shoal) in the James River has been steadily increasing since 2003. Settlement at the remaining six sites was moderate compared with the past fifteen years.

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 (located downriver of the seed area) 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 MSX and *Perkinsus*, many of these downriver oyster populations, those downriver of the seed area as well as those in the lower reaches of the seed area, disappeared such that most of the broodstock for the past several decades has been located in the mid to upper section of the seed area (the Burwell Bay region). As such over the past several decades, the majority of the spatfall 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; Part I of this report, Table S2) and this coincided with a period of low (3 to 4 ppt below the 5, 10 and 15-year 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. The population of larger oysters on these three bars, especially Wreck Shoals, has remained higher for several years, despite the harvesting that has been allowed at the two most downriver sites, Nansemond Ridge and Thomas Rock (Figure D13) and the oysters from these sites most likely have served as broodstock, providing larvae to the upriver portion of the seed area.

average total number of boxes observed during 2007 was relatively low at all sites, accounting for less than 20% of the total (live and dead) at twenty-six out of the thirty sites monitored. On a system basis, the James River had the highest number of boxes for the second year in a row with two (Swash and Wreck Shoal) out of the ten sites in the James having greater than 20% boxes. In the York River, the most upriver site (Bell Rock) had a large number of boxes whereas the more downriver site had a low number of boxes. Both sites were on the high side in terms of disease when compared with the 1989 to 2005 averages (Dr. Ryan Carnegie, VIMS, personal communication). However, it would appear that at Bell Rock the lower salinity and, therefore most likely the more disease naïve population, was more affected by disease than the Aberdeen population, located at the higher salinity site.

Drill holes have become more prevalent in spat boxes over the past few years. During 2007, drill holes were present in the spat boxes observed at both sites in the Mobjack Bay, at Burton Point in the Piankatank River and at Broad Creek in the mouth of the Rappahannock River. These holes were most likely caused by the oyster drills Urosalpinx cinerea or Eupleura caudata which are often 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 been observed more frequently during recent years in the mouths of the Piankatank and Rappahannock Rivers, and in Mobjack Bay.

Table D1: Station locations for the 2007 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 2006. 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	22.0	15.2	23	145.5	193	361.5	3	8	4.5	15.5
Mulberry Point	10/23	21.6	16.5	38	147	47.5	232.5	13.5	36	1	50.5
Horsehead	10/23	21.8	18.0	63	146	96	305	24.5	50.5	0.5	75.5
Point of Shoal	10/23	21.6	17.6	79.5	100	199	378.5	15	57	1	73
Swash	10/23	21.4	17.5	32.5	167	62.5	262	16	57	0	73
Long Shoal	10/23	22.6	16.6	28.5	376	135.5	540	18	65	2	85
Dry Shoal	10/23	22.0	19.0	14	348.5	92	454.5	33	73	1.5	107.5
Wreck Shoal	10/23	22.1	18.5	48.5	164	38	250.5	14	55	1	70
Thomas Rock	10/23	21.9	20.7	8	43	56	107	2.5	19	0.5	22
Nansemond Ridge	10/23	21.4	22.3	1.2	12	81	94.5	0.5	5	2	7.5
York River											
Bell Rock **	10/4	25.0	16.5	9	38	4	51	1	20	0	21
Aberdeen Rock	10/4	24.0	20.6	5.5	23	44	72.5	1.5	3	0	4.5
Mobjack Bay											
Tow Stake	9/28	24.1	22.4	2	198	53.5	253.5	2	6	1	9
Pultz Bar	9/28	24	22.6	0	16	53.5	69.5	1	2.5	1.5	5
Piankatank River											
Ginney Point	10/17	21.0	19.8	2	230	247	479	1	2.5	1	4.5
Palace Bar	10/17	21.1	20.3	3.5	203.5	337.5	544.5	1	3	3	7
Burton Point	10/17	20.3	20.6	2	72	57	131	1.5	3.5	3.5	8.5
Rappahannock River											
Ross Rock	10/16	21.8	12.1	18.5	37.5	9	65	0	2.5	0	2.5
Bowler's Rock	10/16	20.8	14.5	7.5	22.5	0.5	30.5	0.5	4	0	4.5
Long Rock	10/16	20.9	15.2	20	7	1	28	0	2	0	2
Morattico Bar	10/16	20.5	17.0	5	7.5	1	13.5	0	2.5	0	2.5
Smokey Point	10/16	21.1	18.3	11.5	11	1	23.5	0.5	2.5	0	3
Hog House	10/16	21.2	19.2	1	10	4	15	0	2.5	0	2.5
Middle Ground #	10/16	20.9	19.1	1	145	121	267	2.5	4.5	0.5	7.5
Drumming Ground	10/16	21.3	19.8	7	238	65.5	310.5	7.5	17.5	0	25.5
Parrot Rock	10/16	21.0	19.9	21	41	32.5	94.5	4.5	16.5	0	21
Broad Creek	10/15	21.4	20.2	6.5	55.5	85.5	147.5	4	14	1	19
Great Wicomico River											
Haynie Point	10/15	20.6	19.8	21.5	447.5	167.5	636.5	5	9	2	16
Whaley's East	10/15	20.7	19.8	1	331.5	166	498.5	1.5	4	1	6.5
Fleet Point	10/15	20.7	20.1	12.5	196.5	253	462	5.5	10	1	16.5

Figure D1: Map showing the location of the oyster bars sampled during the 2007 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.

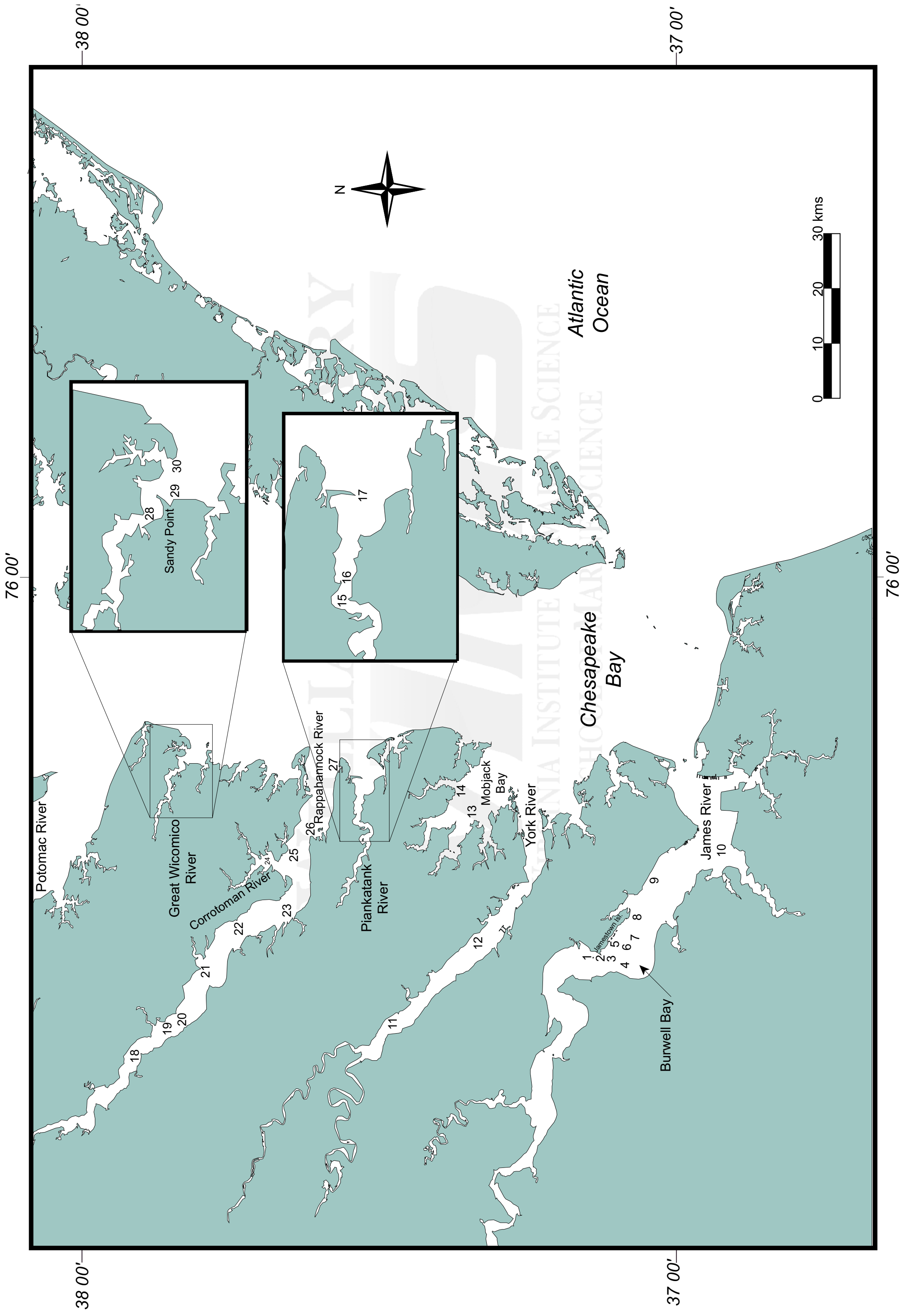
York River: 11) Bell Rock, 12) Aberdeen Rock.

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'
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Atlantic
Ocean
Chesapeake
Bay
0
10
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Potomac River
Great Wicomico
River
Corrotoman River
Rappahannock River
Piankatank
River
Mobjack
Bay
York River
James River
Burwell Bay
Sandy Point
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FIGURE D2: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE JAMES RIVER (2006-2007)
(Error bars represent standard error of the mean)

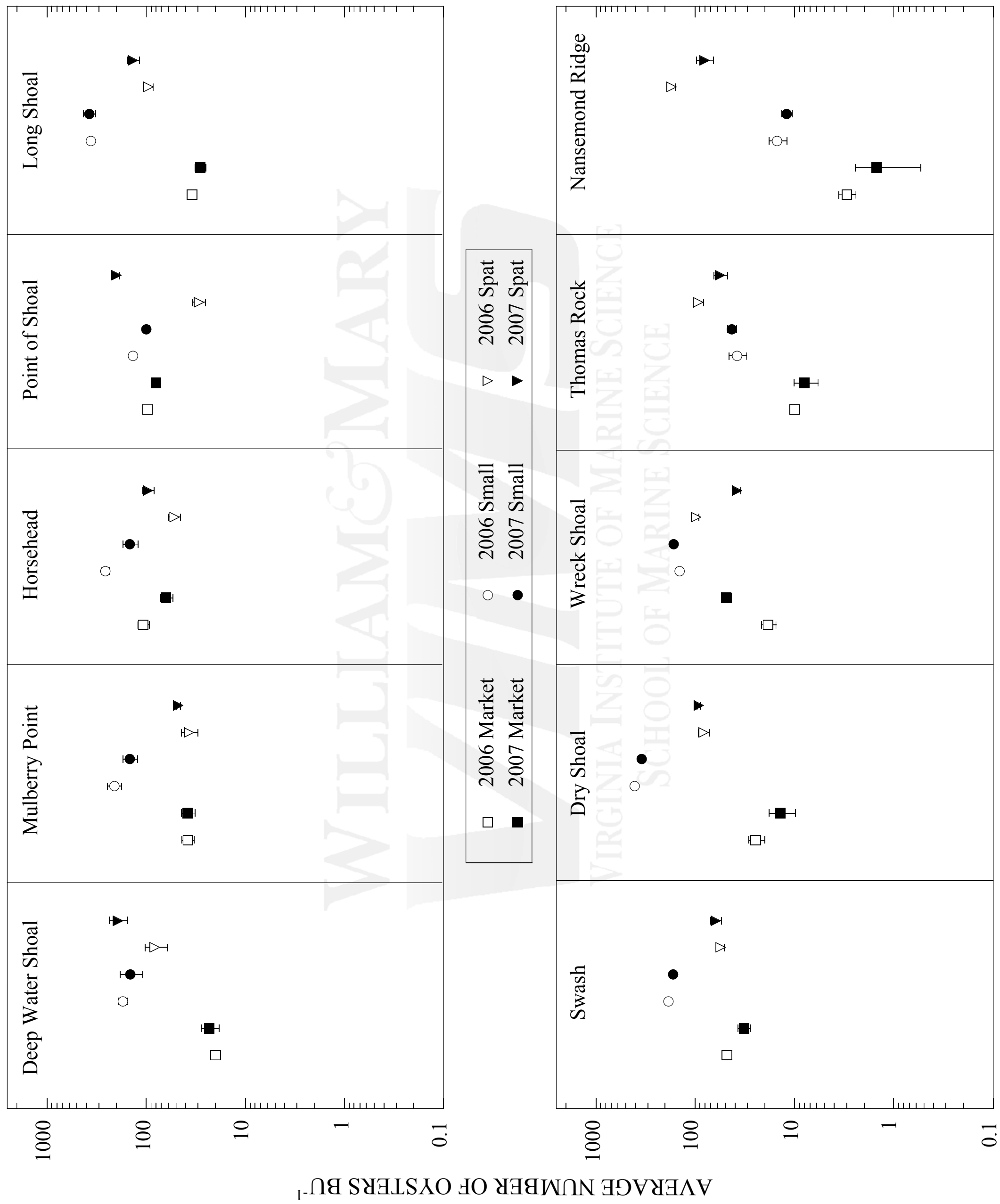


FIGURE D3: JAMES RIVER OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

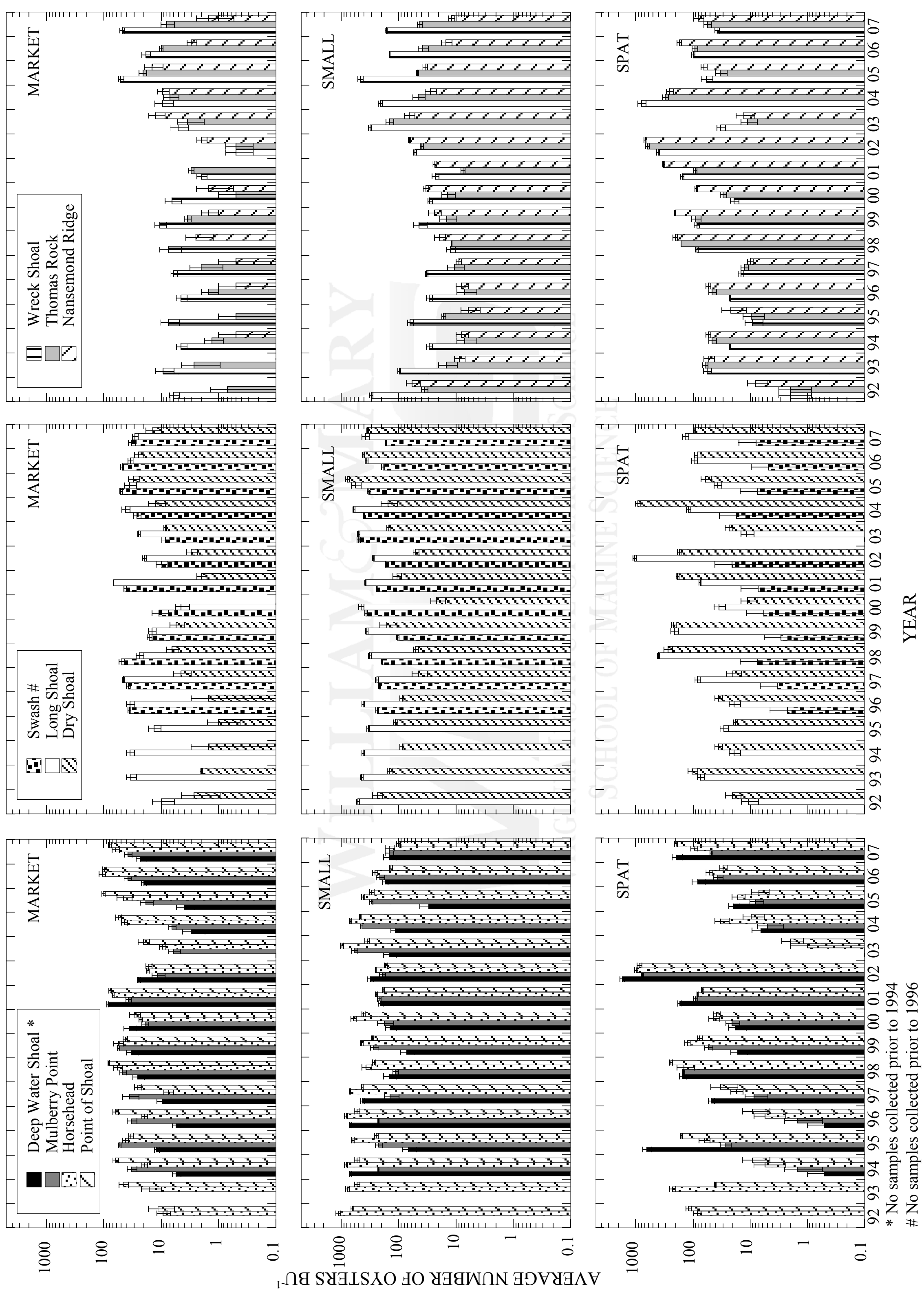


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE YORK RIVER AND MOBJACK BAY (2006-2007)
(Error bars represent standard error of the mean)

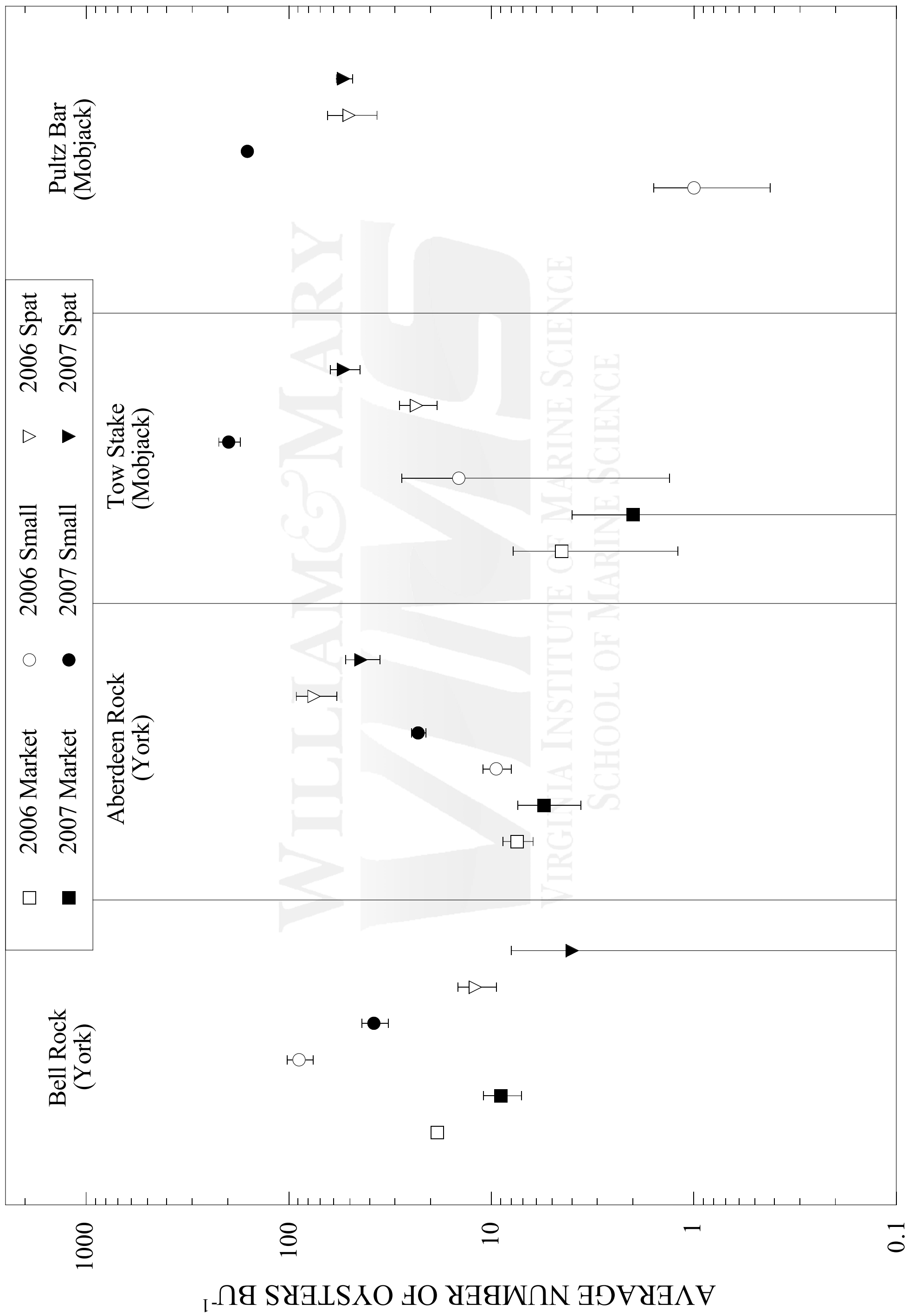


FIGURE D5: YORK RIVER OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

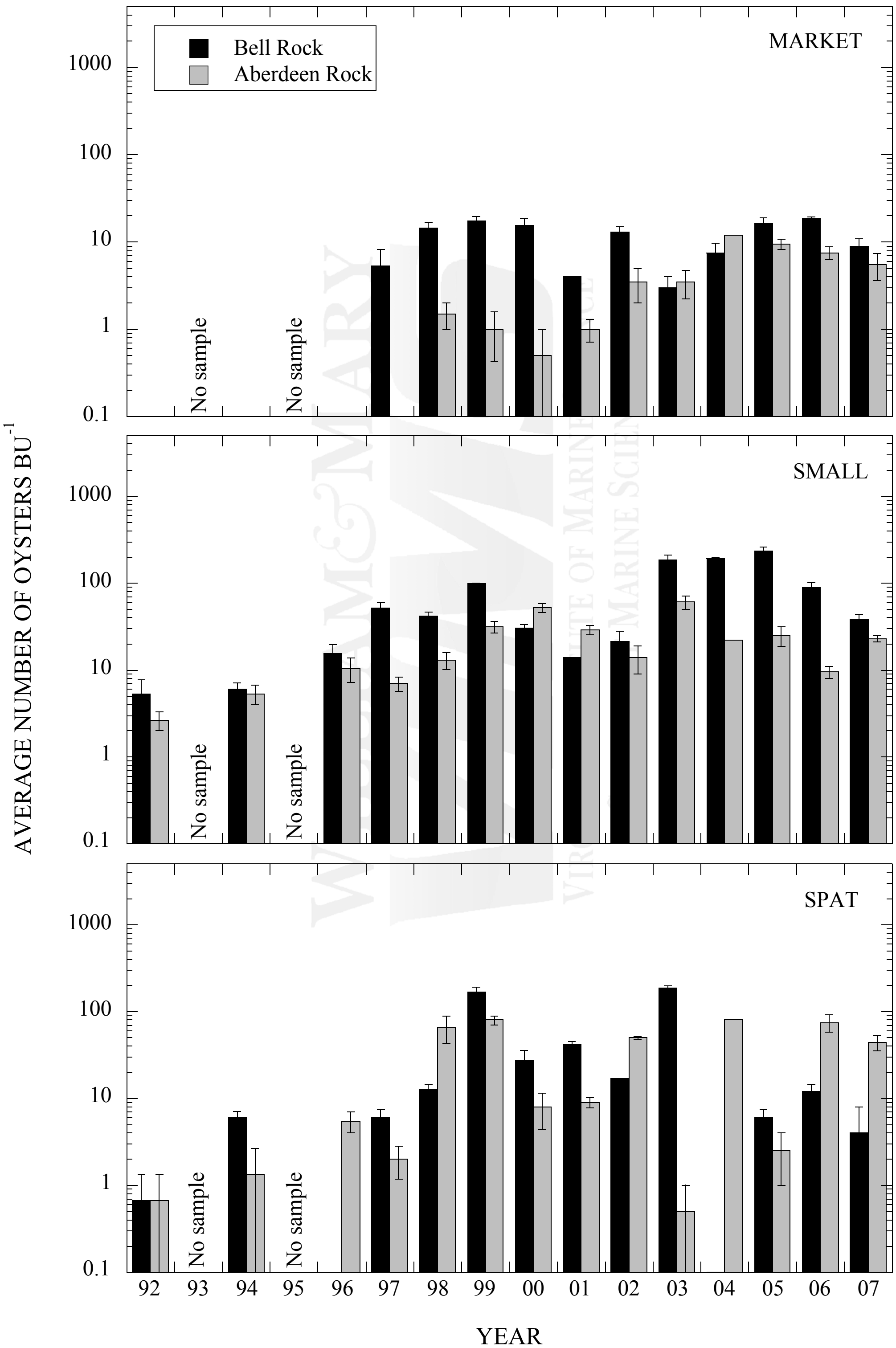


FIGURE D6: MOBJACK BAY OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

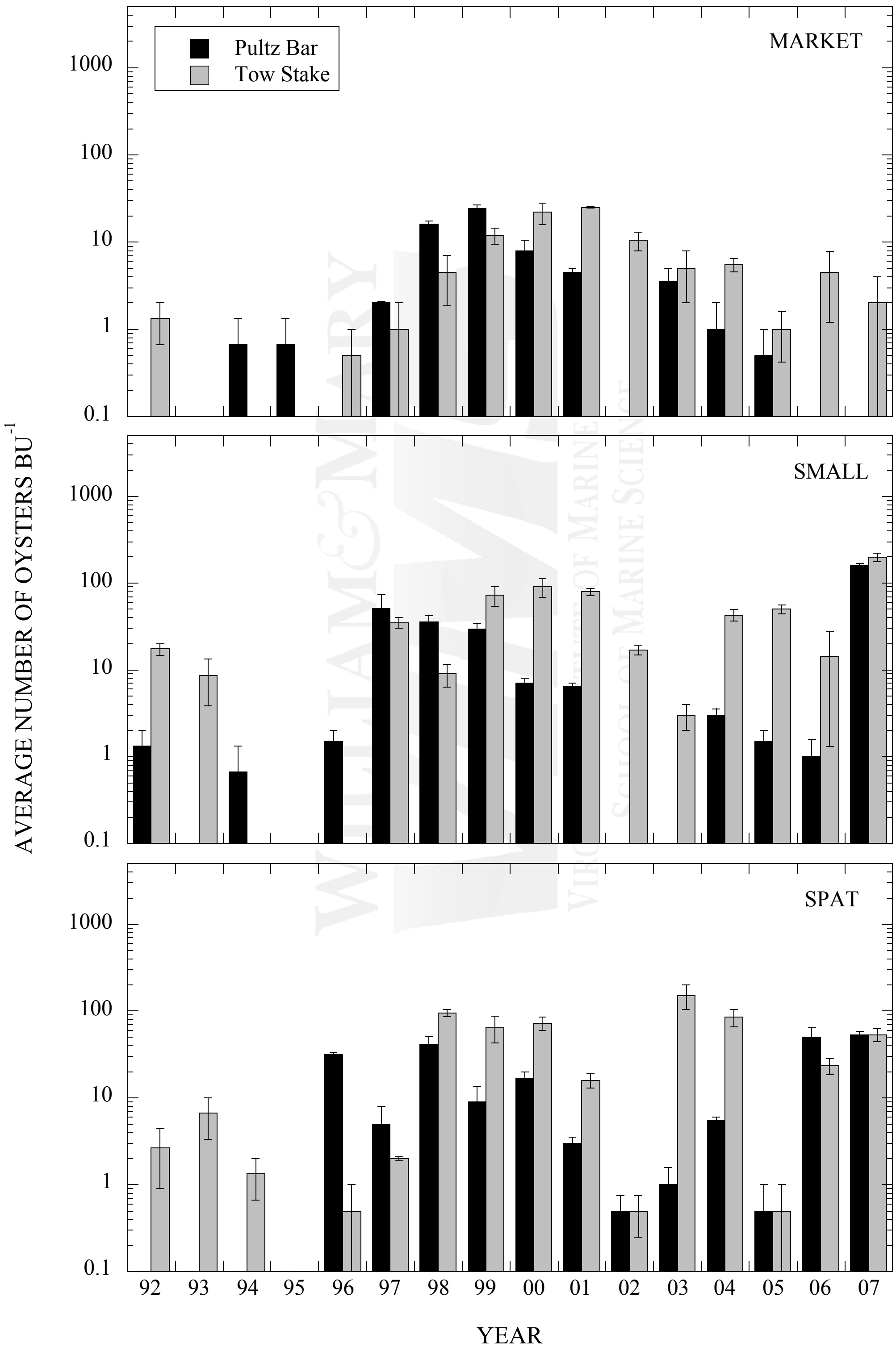


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE PIANKATANK RIVER (2006-2007)
(Error bars represent standard error of the mean)

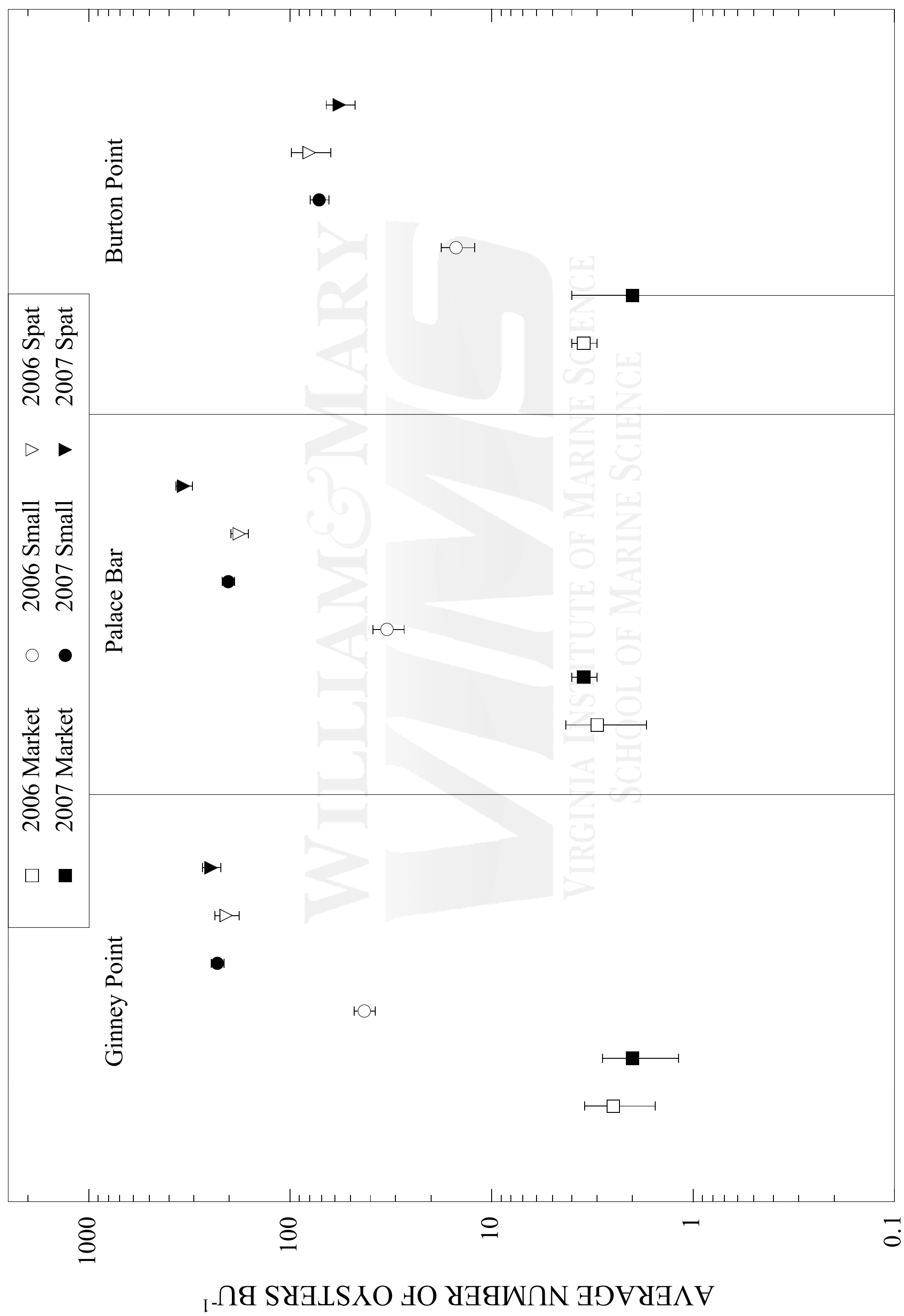


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

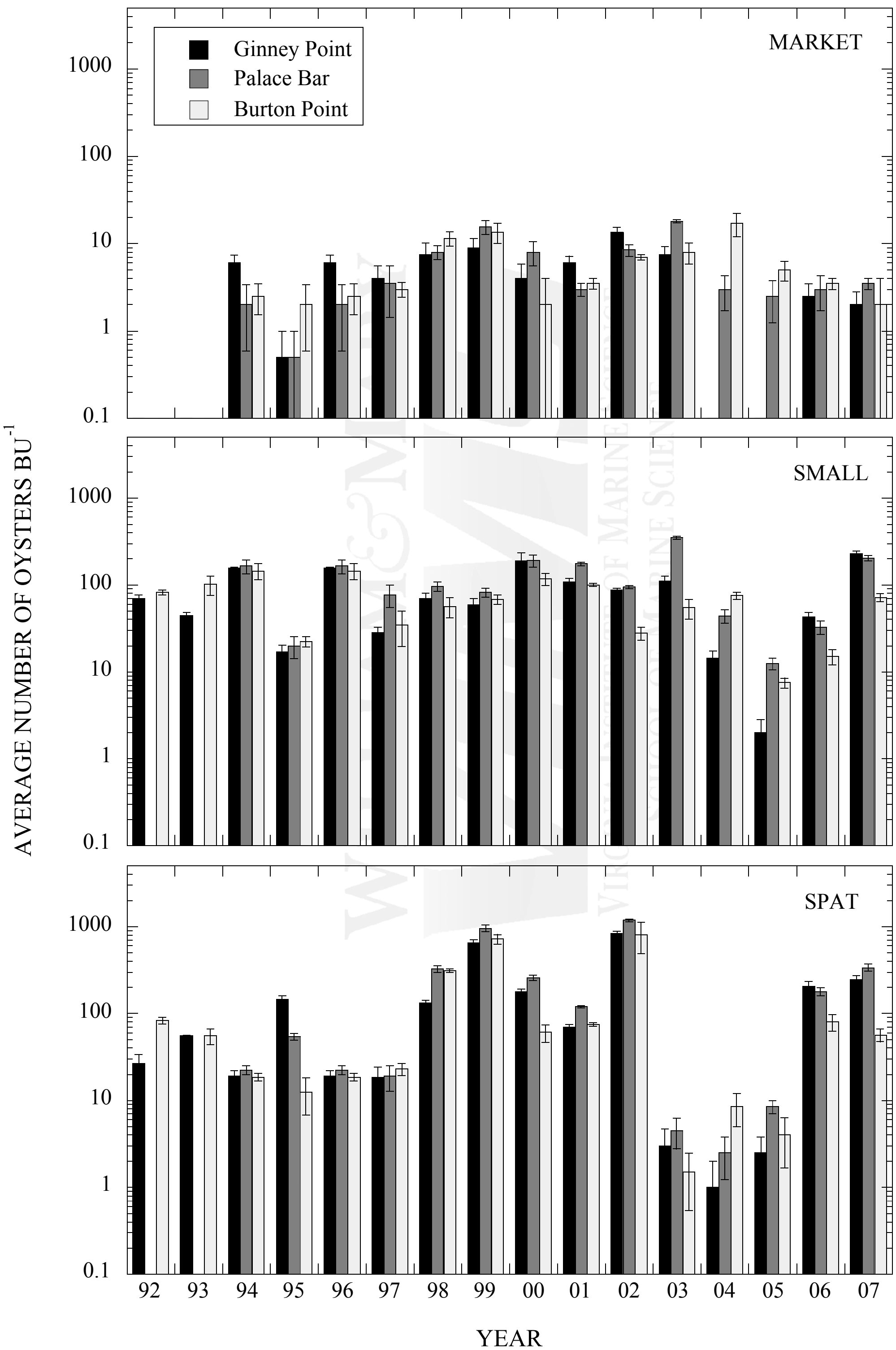


FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2006-2007)
(Error bars represent standard error of the mean)

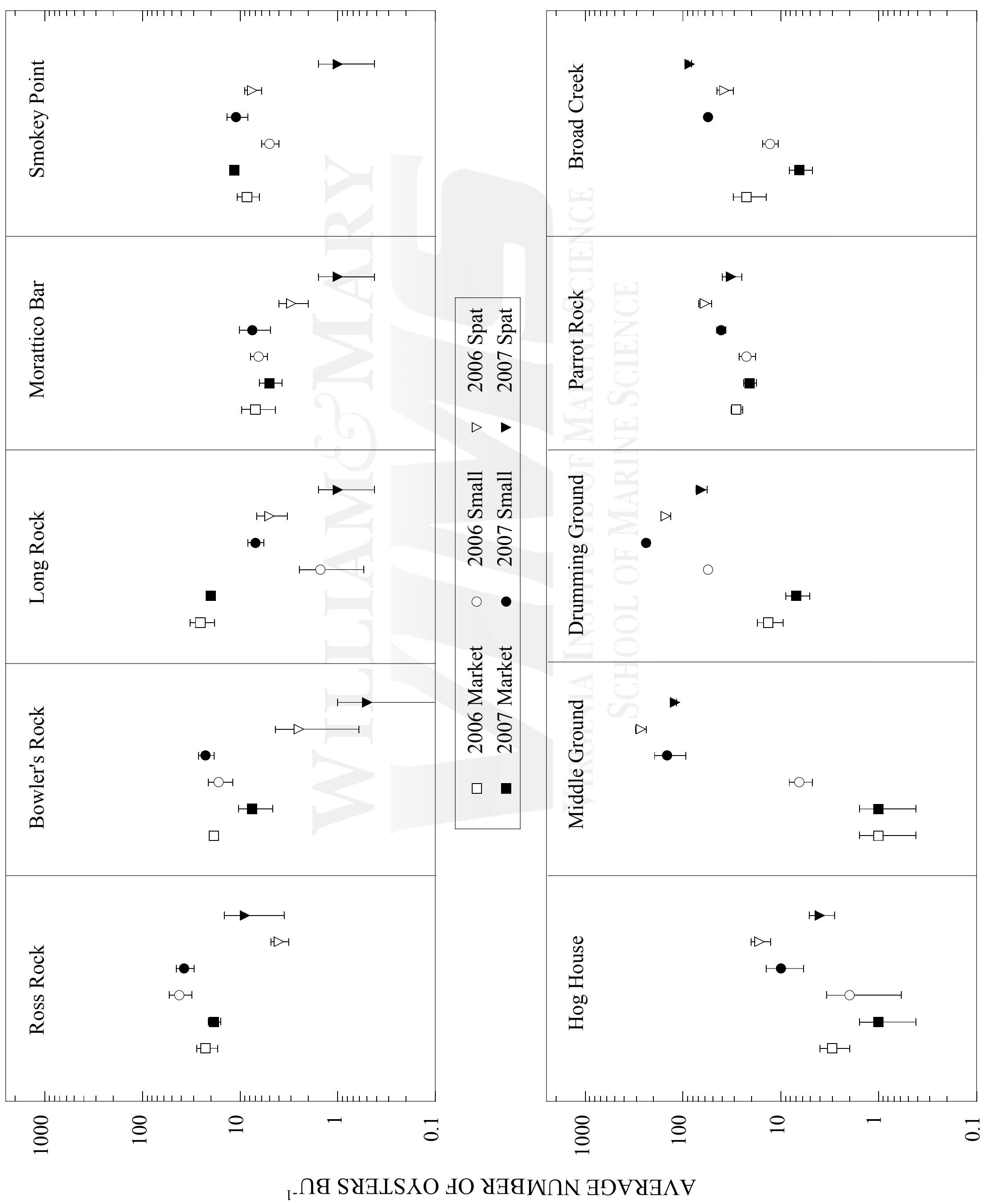


FIGURE D10: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

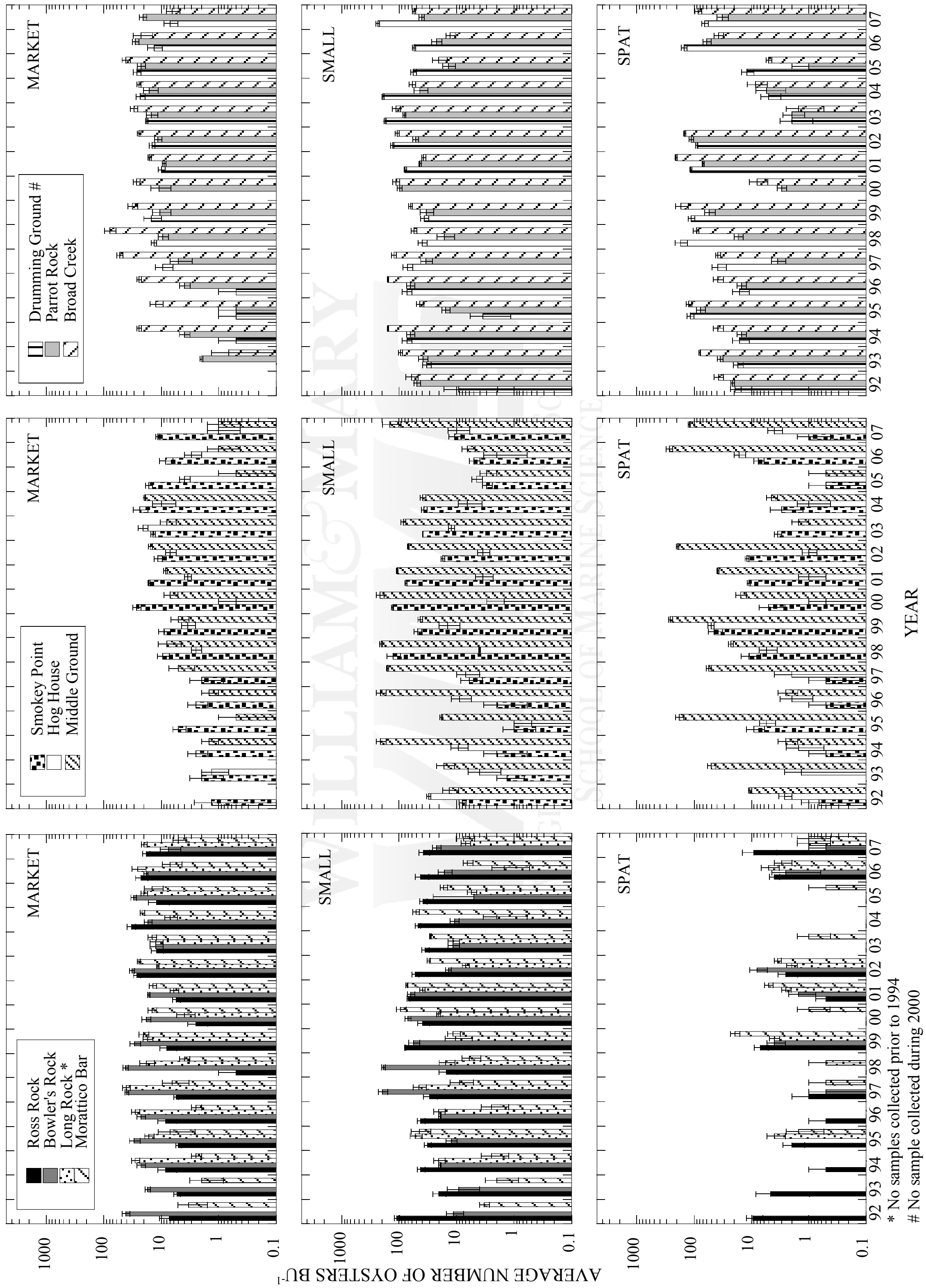


FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE GREAT WICOMICO RIVER (2006-2007)
(Error bars represent standard error of the mean)

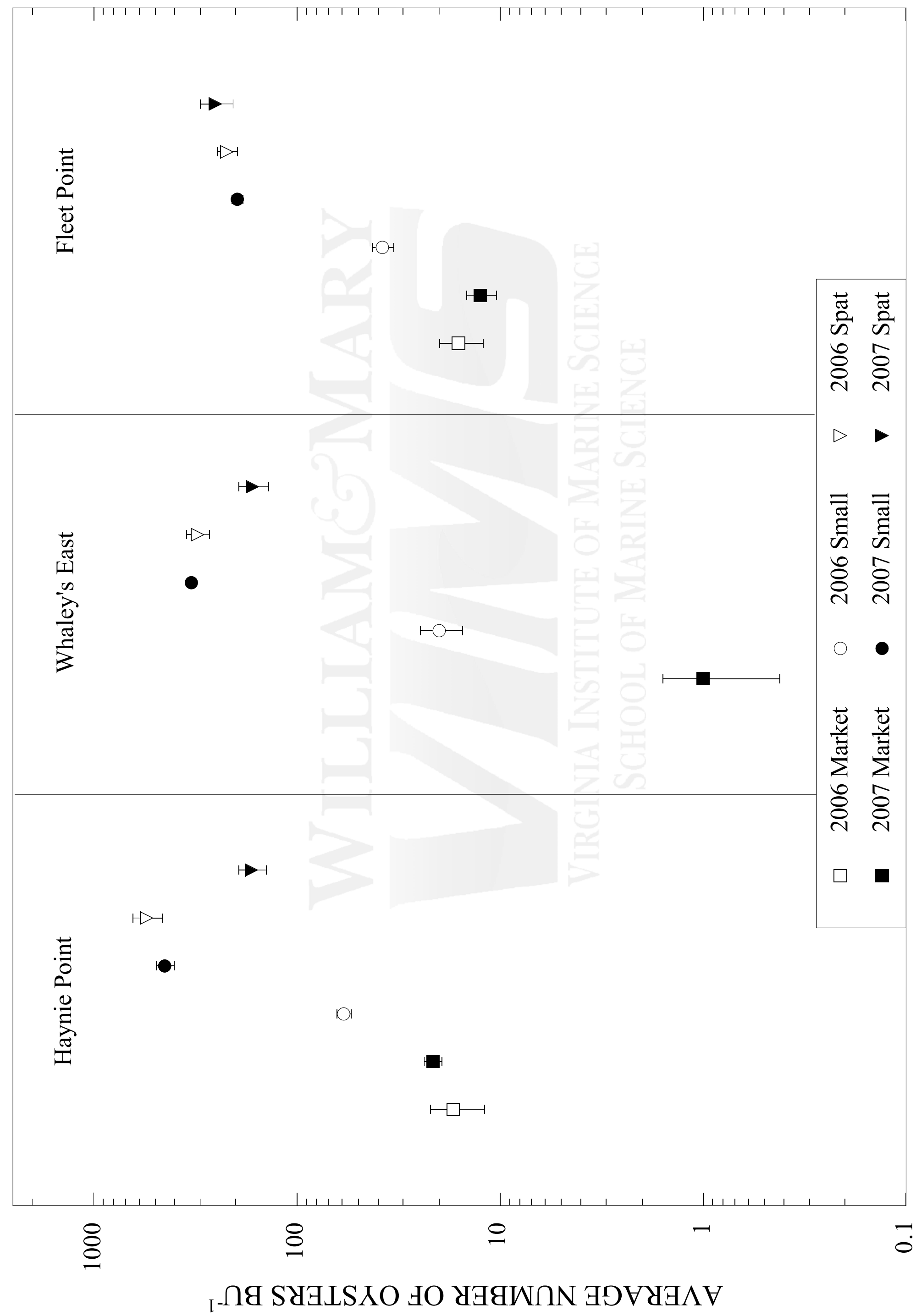


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

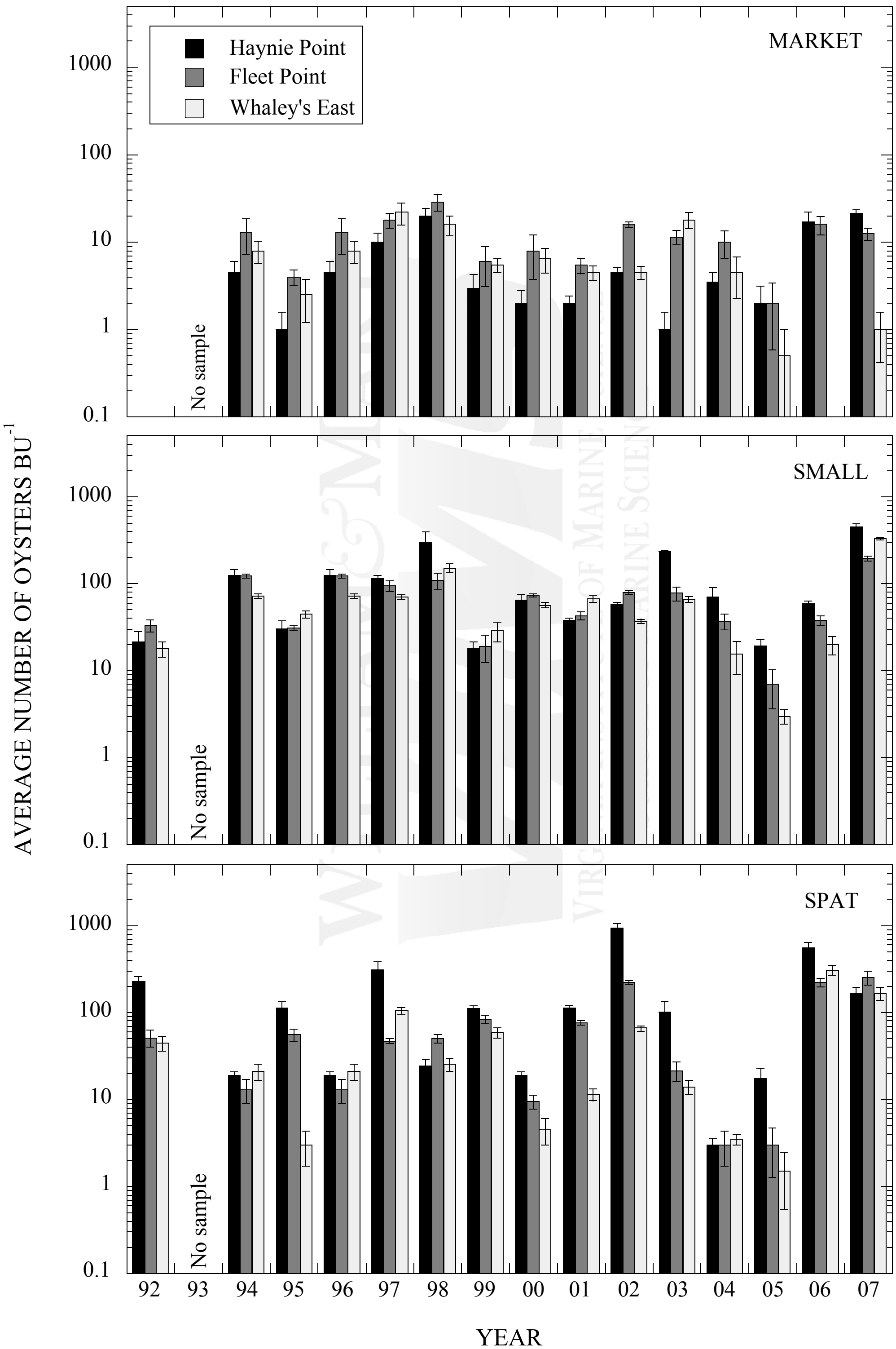
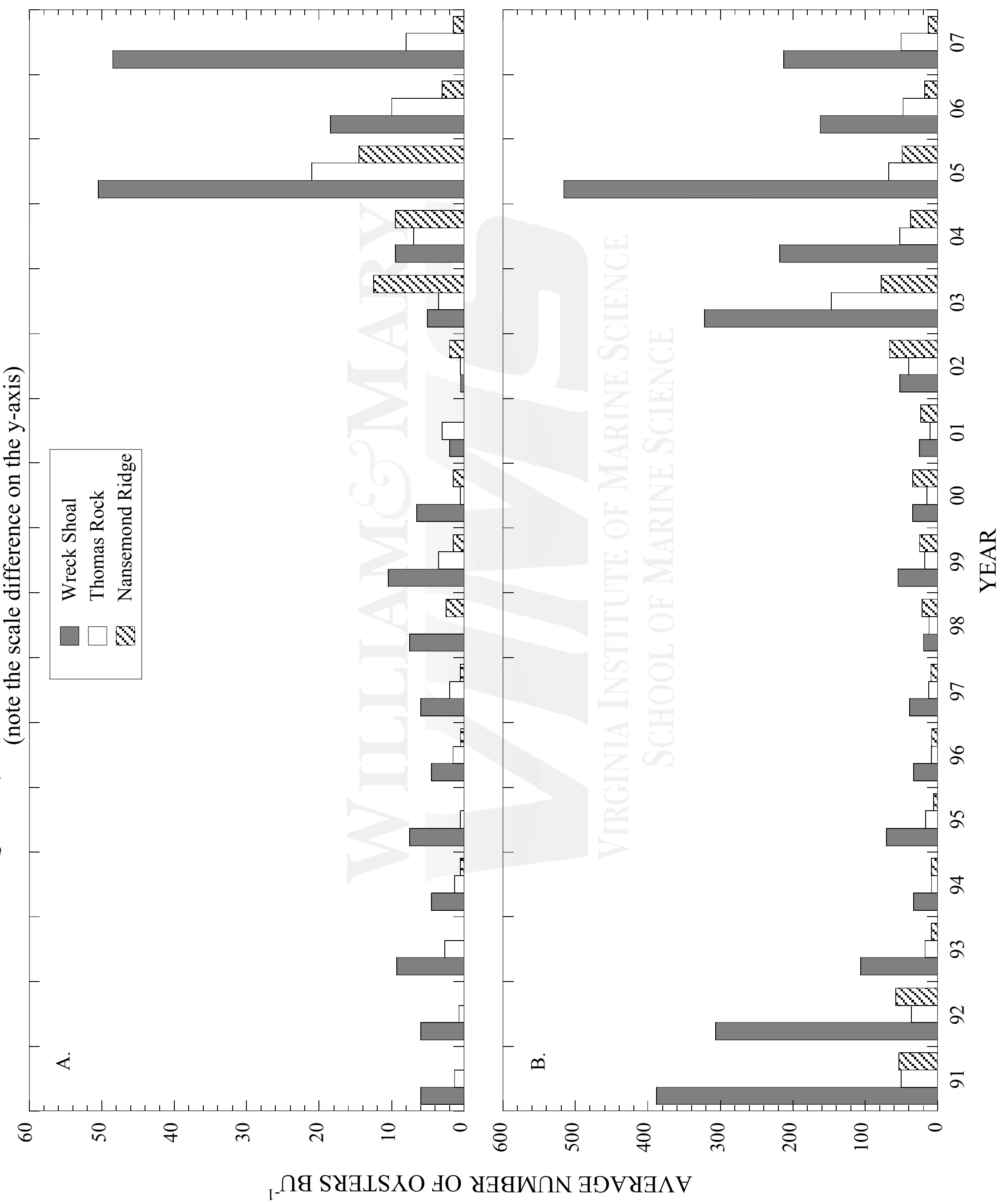


FIGURE D13: AVERAGE NUMBER OF MARKET (panel A) AND MARKET PLUS SMALL OYSTERS COMBINED (panel B) AT THE 3 MOST DOWNRIVER SITES IN THE JAMES RIVER (note the scale difference on the y-axis)



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