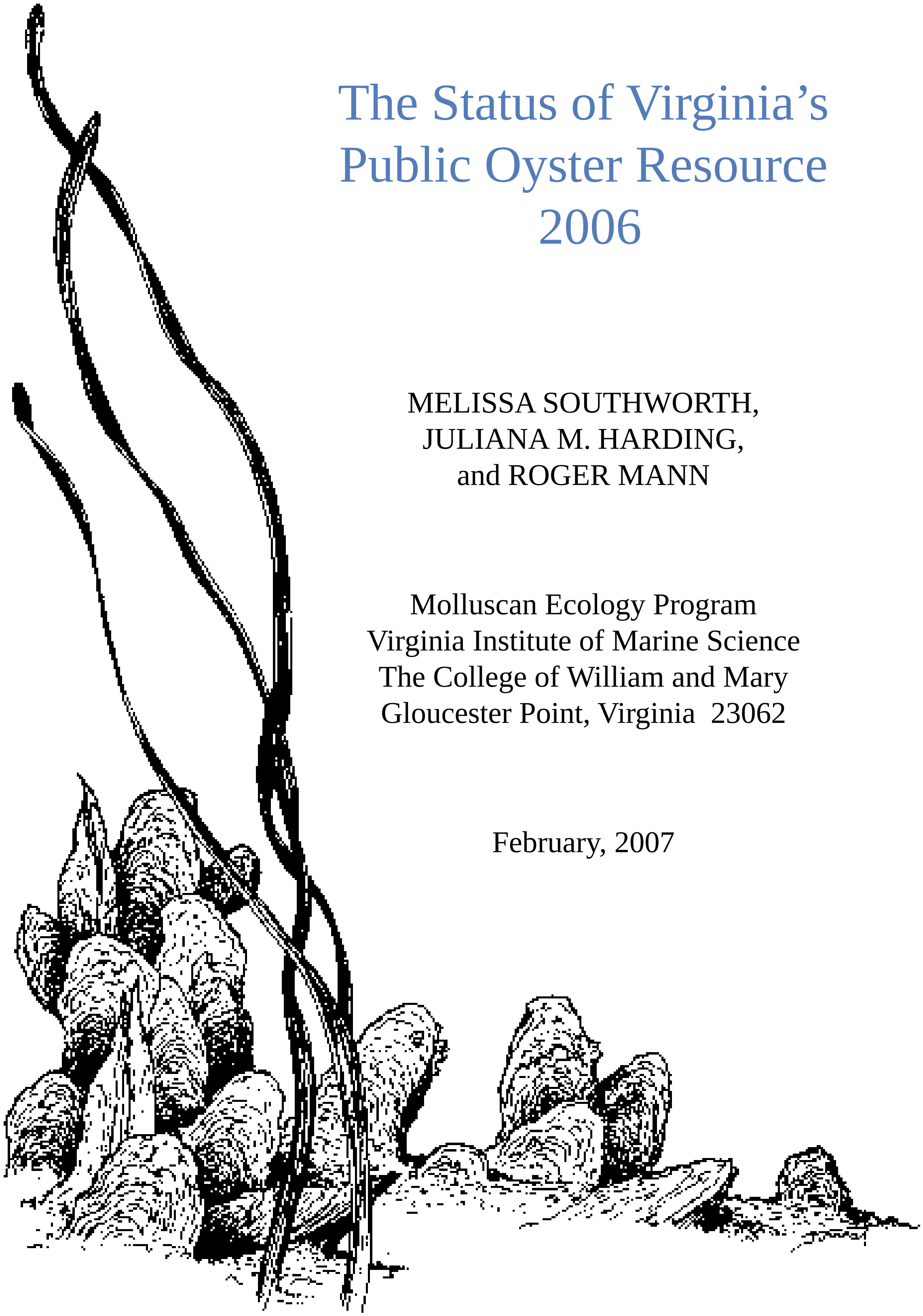
The Status of Virginia's Public Oyster Resource 2006



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Proper citation for this report:

Southworth, M., J.M. Harding, and R. Mann. 2007. The status of Virginia's public oyster resource 2006. Molluscan Ecology Program, Virginia Institute of Marine Science, Gloucester Point, Virginia. 49 pp.

Part I.

Oyster Spatfall In Virginia During 2006

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) monitors the recruitment activity of the Eastern oyster, *Crassostrea virginica* (Gmelin), annually from late spring through early fall, by deploying spatfall (settlement of larval oysters or 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. 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 system. 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 2006 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2006 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. From early January through late September, 2006 oysters (DEBY stock, 20-120 mm shell height; average 50 mm) were periodically planted on Shell Bar Reef in the Great Wicomico River (http://www.vims.edu/mollusc/NORM/NORMdatahub/NORMplantDEBYscs.htm).

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 2006 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 eight 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 2006 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

2006. Comparisons were made over the past eight 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 July 1 at Dry Shoal and Wreck Shoal (Table S1). Beginning the week of July 22, settlement was consistently observed throughout the system and continued until the end of September, with the exception of the first two weeks of September when there was little or no settlement at most of the sites monitored. This coincided with Tropical Storm Ernesto, which entered the Chesapeake Bay on September 1, dropping between 4 and 8 inches of rain in the region. As a result of the storm several shellstrings were lost (Table S1). There were two peaks in settlement in the James River during 2006 (Figure S3). The first longer peak lasted approximately four weeks from the end of July through the third week in August and the second shorter peak occurred the week of September 16. Settlement during these two periods accounted for greater than 76% of the total spatfall that occurred in the system during 2006.

Overall settlement in the James River during 2006 was moderate ranging from a low of 1.92 (Rock Wharf) to a high of 8.53 (Dry Shoal) cumulative spat shell^{-1} week^{-1}. Settlement was relatively evenly distributed throughout the river system (with the exception of Dry Shoal) and this pattern is in contrast to the historical pattern of increasing spatfall as one moves in a downriver direction (Haven & Fritz, 1985).

Settlement in the James River during 2006 showed an increase from the previous year (2005) at all of the stations monitored except Rock Wharf (Table S2; Figure S4). Spatfall during 2006 was lower than the 5 and 10-year means at all of the sites monitored except Dry Shoal, and lower than the 15-year mean at all eight sites monitored. Overall settlement during 2006 was typical of what has been observed in the system during the past ten years and slightly on the low side compared with that observed in the early 1990s.

Average river water temperatures reached a maximum in late July (29 degrees C: Figure S5A). Water temperature was within one degree C of the 5, 10 and 15-year means (Figure S5A) throughout the sampling period. Salinity was an average of 2 to 5 ppt higher than previously recorded in the system throughout most of June (Figure S5B). There was approximately a three week period in late July into early August when salinity was again higher than that previously recorded in the system. There was a slight drop in salinity in early September following Tropical Storm Ernesto (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 6 to 15 ppt, a slightly higher difference than normal.

Piankatank River

Settlement in the Piankatank River was first observed during the week of June 24 at Cape Toon. There were no discrete peaks in settlement observed in the Piankatank River during 2006; settlement was consistent throughout the system from the first week of July through the second week of September (Table S1; Figure S6). Cumulative spat shell^{-1} week^{-1} for the year was moderate ranging from a low of 1.11 at Heron Rock to a high of 8.21 at Cape Toon.

Spatfall during 2006 showed an increase when compared with 2005 at all eight stations monitored, and marked the third year in a row with an increase for Wilton Creek, Bland Point, Cape Toon and Stove Point (Table S2: Figure S7). Settlement during 2006 was also higher than the 5-year mean at all stations except Heron Rock (slight decrease) and Stove Point (no difference). Settlement at Palace Bar was lower than both the 10 and 15-year means. At Ginney Point settlement during 2006 was higher than the 10-year mean, but lower than the 15-year mean and at Burton Point it was lower than the 15-year mean with no observed difference when compared with the 10-year mean.

The average water temperature ranged from 22 to 30 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 throughout most of the sampling period except in mid June when it decreased by several degrees and was 3 degrees C lower than normal and during the maximum in early August when temperature was slightly higher than normal (Figure S8A). Salinity ranged from 14 to 18 ppt throughout the sampling period. Salinity was approximately 2 ppt higher than the 5, 10 and 15-year means from the beginning of the sampling period through mid July and approximately 1 ppt higher from mid July through late August. Salinity dropped slightly in the beginning of September following Tropical Storm Ernesto, whereas typically salinity begins to increase at this time. The difference recorded between Wilton Creek (the most upriver station) and Burton Point (the most downriver station: Figure S1) ranged between 1 and 2 ppt throughout the sampling period except immediately following Ernesto when the salinity at Wilton Creek dropped 5 ppt lower than the more downriver sites and remained lower for two weeks.

Great Wicomico River

Settlement began the week of June 24 at all nine sites in the Great Wicomico River (Table S1). The majority of settlement occurred during a five-week period from late June through mid July, with a smaller peak at the upriver sites the week of August 12 (Figure S9). Settlement during this six week time frame accounted for greater than 90% of the settlement for the season. Settlement from the second week of August through the end of the sampling period was light and intermittent.

Cumulative spat shell^{-1} week^{-1} for the year was heavy at the seven sites located upriver of the Sandy Point (Figure S1) ranging from a low of 17.14 at Haynie Point and generally increasing in an upriver fashion to a high of 150.29 at Glebe Point. 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 at 4.92 and 5.99 cumulative spat shell^{-1} week^{-1} respectively. Settlement during 2006 was higher than the previous year (2005) at all of the stations sampled (Table S2: Figure S10). Settlement during 2006 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 at Rogue Point, Hilly Wash, Harcum Flats and Shell Bar was the highest observed since monitoring began at those sites in 1998. At the historical sites, settlement during 2006 was the highest observed in the past fifteen years at Haynie Point and the second highest observed at Glebe Point, Fleet Point and Whaley's East (Table S2).

Average river water temperatures ranged between 21 and 30 degrees C throughout the sampling period reaching a maximum the week of August 3 (Figure S11A). Given the lack of historical data for the Great Wicomico River, temperature and salinity during 2006 could only be compared with the previous 5 and 8-year means instead of the 5, 10 and 15-year means as it was in the James and Piankatank Rivers. Water temperature was lower (2 to 3(C) than the long-term averages for most of June into mid July, higher than the long-term averages (3 degrees C) when it reached its maximum in early August, then lower again (1 to 2 degrees C) for the latter part of the sampling period (Figure S11A). Salinity ranged from 11 to 18 ppt during the sampling period and was higher than the 5 and 8-year means throughout June, into early July (Figure S11B). Salinity was similar to the long-term averages throughout most of July and August, and then similar to that observed in the Piankatank River dropped below average toward the beginning of September around the time of Tropical Storm Ernesto. There was a 1 to 3 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 2006 in the James River was higher than 2005, but similar overall to numbers observed in the system over the past decade. Settlement in the Piankatank River was good compared with the past 5 years, but still not as good as that observed prior to the 1990s. Settlement in the Great Wicomico River, on the other hand, was exceptionally high and among the highest settlement events observed in the system since the mid 1980s.

Settlement began in the Great Wicomico River in late June and the bulk of the settlement occurred throughout the month of July. Environmental conditions in the Great Wicomico in the early part of the sampling season in 2006 were similar to those observed in 2002, also an exceptionally high settlement year (Southworth et al. 2003). During 2006, salinity was several ppt higher than the long-term average for the entire month of June, into early July. Gametogenesis or fecundity (Thomson et al., 1996), larval survival and growth in the plankton (Kennedy, 1996), quantity and quality of food (Kennedy, 1996) and success of metamorphosis are all affected by salinity (Kennedy, 1996). Although spring salinity data in the Great Wicomico are not available for comparison prior to 2006 it is reasonable to assume that salinity in the Great Wicomico was higher than normal for at least part of the spring season given that salinities were 2 to 3 ppt higher than normal when sampling began in early June. Ulanowitz et al. (1980) showed that sustained high salinity contributed to greater spat production in the Maryland portion of the Chesapeake Bay. In addition to high spring/early summer salinities, winter temperatures were also higher than normal (VIMS, unpublished data). The combination of relatively "warm" winters followed by saline summers generally characterizes good settlement years (Mann et al., manuscript in preparation) and this combination is often intensified in smaller systems.

One other factor that should be considered in the Great Wicomico River is the ongoing restoration efforts (www.vims.edu/mollusc/NORM) and the effects that they may have on the system. Broodstock oysters (DEBY strain) have been planted on Shell Bar Reef at various intervals since 2002 and as of September 2006, there were approximately 2.6 million oysters on the reef of which 2.4 million were DEBYs (VMRC, unpublished data). It is possible that these oysters contributed to the settlement observed in the system to some extent although to date, genetics data has shown no increase in the number of DEBY spat in the system (Dr. Jens Carlsson, VIMS, personal communication).

While settlement in the Piankatank River, was not as high as that observed in the Great Wicomico River it was still higher than that recorded in the previous three years and higher than the previous 5-year means at six out of the eight sites monitored in that system. Salinity in the Piankatank River was higher than normal from the beginning of the sampling period throughout the month of June. This was similar to what was observed in the Great Wicomico River, but the difference in salinity was not as great in the Piankatank River. The oyster population in the Piankatank River has been in decline over the past several years and only five out of the past fifteen years have been heavy settlement years (at least one station with greater than 10 cumulative spat shell-1) and system wide heavy settlement has not been observed since the early 1990s. The lack of settlement in recent years in the Piankatank when compared with historical numbers could be due to a decline in the number of broodstock in the system. 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). Both oyster population densities and sizes in the Piankatank River have been in serious decline over the past three to four years and, while there was a small increase in the number of small oysters in the Piankatank when compared with 2005, overall the number of oysters in the Piankatank remains low (Part II of this report).

With the exception of 2002 and a few sites in various other years, settlement in the James River in recent years has been characterized by low to moderate sets. These low to moderate sets have been prevalent in the system since the early 1990s and settlement in the James River in 2006 was typical of these low to moderate sets. As was observed in the Piankatank and Great Wicomico Rivers, salinity was higher than normal throughout the month of June, but in contrast to the two smaller systems this did not result in a higher than average set. The James River also differed from the other two systems in that the settlement that did occur was several weeks later in the season, more closely mimicking what was observed prior to the drought in the mid 1980s (Southworth & Mann, 2004) than more recent settlement patterns.

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

STATION	5/27	6/3	6/10	6/17	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/2	9/9	9/16	9/23	9/30	YEAR
	147	154	161	168	175	182	189	196	203	210	217	224	231	238	245	252	259	266	273	TOTAL
James River																				
Deep Water Shoal	D	0	0	0	0	0	0	0.05	0.15	0.16	0.20	1.25	0.05	0.05	0	0	0.09	0.10	0	2.10
Horsehead	D	0	0	0	0	0	0	0	0.45	0.20	0.05	0.65	0.41	0.05	-	-	0.35	0	0.06	2.22
Point of Shoal	D	0	0	0	0	0	0	0	0.60	0.25	0.60	0.20	0.10	0.05	0	0	0.26	0.05	0.12	2.23
Swash	D	0	0	0	0	0	0.06	0	0.10	1.00	0.30	0.15	0	0.05	0.05	0	0.04	0.05	0	1.80
Dry Shoal	D	0	0	0	0	0.04	0.06	0.15	1.05	3.55	0.65	0.70	0.10	0.05	0.10	0	1.93	0.15	0	8.53
Rock Wharf	D	0	0	0	0	0	0	0	0.50	0.35	0.15	0.15	0.05	0.10	0	0	0.57	0.05	0	1.92
Wreck Shoal	D	0	0	0	0	0.22	0.18	0	0.70	0.60	0.55	0.65	0.15	0.25	-	-	0.61	0.10	0	4.03
Day's Point	D	0	0	0	0	0	0	0	0.70	0.20	0.60	0.05	0.10	0.05	-	0	0.18	0.05	0	1.93
Piankatank River																				
Wilton Creek	D	0	0	0	0	0.22	0.29	0.45	0.45	0.50	0.35	0.50	0.35	0.60	0.10	0	0	0	0.05	3.86
Ginney Point	D	0	0	0	0	0.09	0.12	0.20	1.00	0.40	0.65	0.63	0.35	0.15	0.10	0.09	0.05	0.05	0	3.88
Palace Bar	D	0	0	0	0	0.04	0.12	0.05	0.20	0.45	0.30	0.30	0.10	0.40	0.15	0	0	0	0	2.11
Bland Point	D	0	0	0	0	0.18	0.29	0.45	0.45	0.10	0.30	0.35	0.35	1.10	0.05	0.04	0	0	0	3.66
Heron Rock	D	0	0	0	0	0	0.06	0	0.05	0.10	0.10	0.11	0.05	0.40	0	0.18	0.06	0	0	1.11
Cape Toon	D	0	0	0	0.05	0.39	0.18	0.40	1.55	0.60	1.60	0.27	0.50	1.05	0.80	0.67	0.05	0.05	0.05	8.21
Stove Point	D	0	0	0	0	0.22	0.76	0.40	0.85	0.20	0.35	0.55	0.90	2.50	0.20	0.09	0	0	0	7.02
Burton Point	D	0	0	0	0	0.22	0.29	0.15	0.95	0.05	0.20	0	0.45	0.50	0.05	0.04	0	0	0	2.90
Great Wicomico River																				
Glebe Point	D	0	0	0	56.7	30.8	27.3	11.1	14.8	0.85	0.25	8.20	0.05	0	0.15	0.05	0	0	0	150.29
Rogue Point	D	0	0	0	36.4	14.6	14.1	1.45	9.60	0.10	0.60	10.6	0.05	0	0.40	0.20	0.10	0	0	88.11
Hilly Wash	D	0	0	0	5.05	4.77	11.3	1.95	12.7	0.25	0.40	7.10	0.05	0.15	0.10	0.10	0	0	0	43.88
Harcum Flats	D	0	0	0	16.5	21.2	16.5	3.80	35.4	0.05	0.62	16.4	0.10	0	0.10	0	0.05	0	0	110.65
Hudnall	D	0	0	0	7.05	3.28	3.91	2.60	15.2	0.25	1.10	3.95	0	0	0.05	0.05	0	0	0	37.39
Shell Bar	D	0	0	0	4.70	4.73	3.62	2.55	11.5	0.15	0.35	1.80	0.10	0.05	0.05	0	0	0	0.06	29.61
Haynie Point	D	0	0	0	1.75	2.67	2.10	1.35	4.90	0.10	0.40	3.50	0.05	0	0.15	0	0.05	0	0.12	17.14
Whaley's East	D	0	0	0	0.80	1.79	0.30	0.10	1.75	0	0.45	0.60	0.10	0	0	0.10	0	0	0	5.99
Fleet Point	D	0	0	0	1.15	1.23	0.18	0.16	1.60	0	0.05	0.45	0	0	0	0.10	0	0	0	4.92

Table S2: Spatfall totals for historical sites (1991-2006) and for 1998-2006 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 2006 in reference to 2005 and to the five, ten, and fifteen-year means. Blank cells for a site indicate years where data are not available.

STATION	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Mean 01-05	Mean 96-05	Mean 91-05	Ref. 2005	Ref. 5-yr	Ref. 10-yr	Ref. 15-yr
James River																							
Deep Water Shoal	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	7.7	4.8	5.1	+	-	-	-
Horsehead	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	6.7	4.7	8.1	+	-	-	-
Point of Shoal	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	7.9	5.0	11.3	+	-	-	-
Swash	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	8.7	5.8	12.8	+	-	-	-
Dry Shoal	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	6.2	5.4	28.9	+	+	+	-
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	9.1	6.5	8.7	-	-	-	-
Wreck Shoal	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	7.5	5.3	7.5	+	-	-	-
Day's Point	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	3.5	4.0	25.1	+	-	-	-
Piankatank River																							
Wilton Creek								1.9	5.9	3.6	0.2	6.5	0.1	0.2	0.4	3.9	1.5			+	+		
Ginney Point	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	1.6	2.4	4.2	+	+	+	-
Palace Bar	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	0.1	2.5	6.4	+	+	-	-
Bland Point								2.3	44.1	2.7	1.3	6.7	0.2	0.4	1.0	3.7	1.9			+	+		
Heron Rock								10.1	9.3	3.2	0.6	5.1	0.2	0.7	0.4	1.1	1.4			+	-		
Cape Toon								4.5	12.3	1.2	1.8	9.1	0.1	2.0	2.6	8.2	3.1			+	-		
Stove Point								1.0	7.1	1.8	1.6	31.0	0.1	0.7	1.7	7.0	7.0			+	ND		
Burton Point	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	1.7	2.9	4.3	+	+	ND	-
Great Wicomico River																							
Glebe Point	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	58.6	32.2	21.7	+	+	+	+
Rogue Point								0.9	2.0	2.6	0.7	16.6	7.0	0.5	2.6	88.1	5.5			+	+		
Hilly Wash								0.6	1.6	3.2	0.8	24.1	2.9	0.5	1.9	43.9	6.0			+	+		
Harcum Flats								0.1	1.3	0.8	1.1	33.7	3.7	0.7	1.5	110.7	8.1			+	+		
Hudnall	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	3.7	6.0	4.4	+	+	+	+
Shell Bar								0	2.9	0.8	0.8	17.8	1.9	0.3	0.9	29.6	4.3			+	+		
Haynie Point	12.4	0.6	1.4	0.0	1.0	3.7	4.4	0.7	1.1	1.1	0.9	15.4	1.6	0.3	0.8	17.1	3.8	3.0	3.0	+	+	+	+
Whaley's East	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	0.9	1.0	1.2	+	+	+	+
Fleet Point	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	1.2	1.3	1.6	+	+	+	+

Figure S1: Map showing the location of the 2006 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.

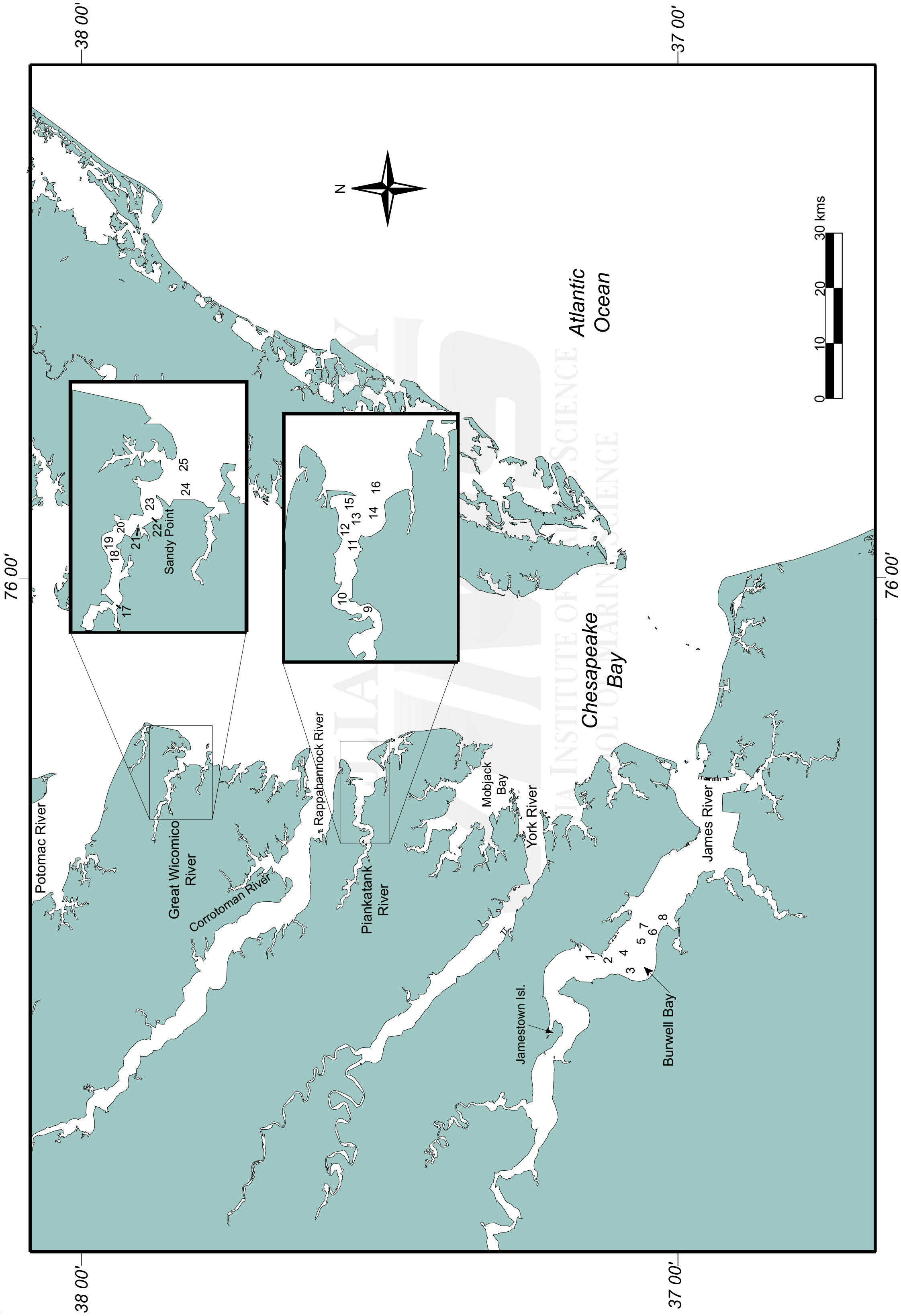

38 00'
37 00'
76 00'
N
Atlantic Ocean
Chesapeake Bay
0 10 20 30 kms
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Jamestown Isl.
Burwell Bay
Sandy Point
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25

Figure S2: Diagram of shellstring setup on buoys.

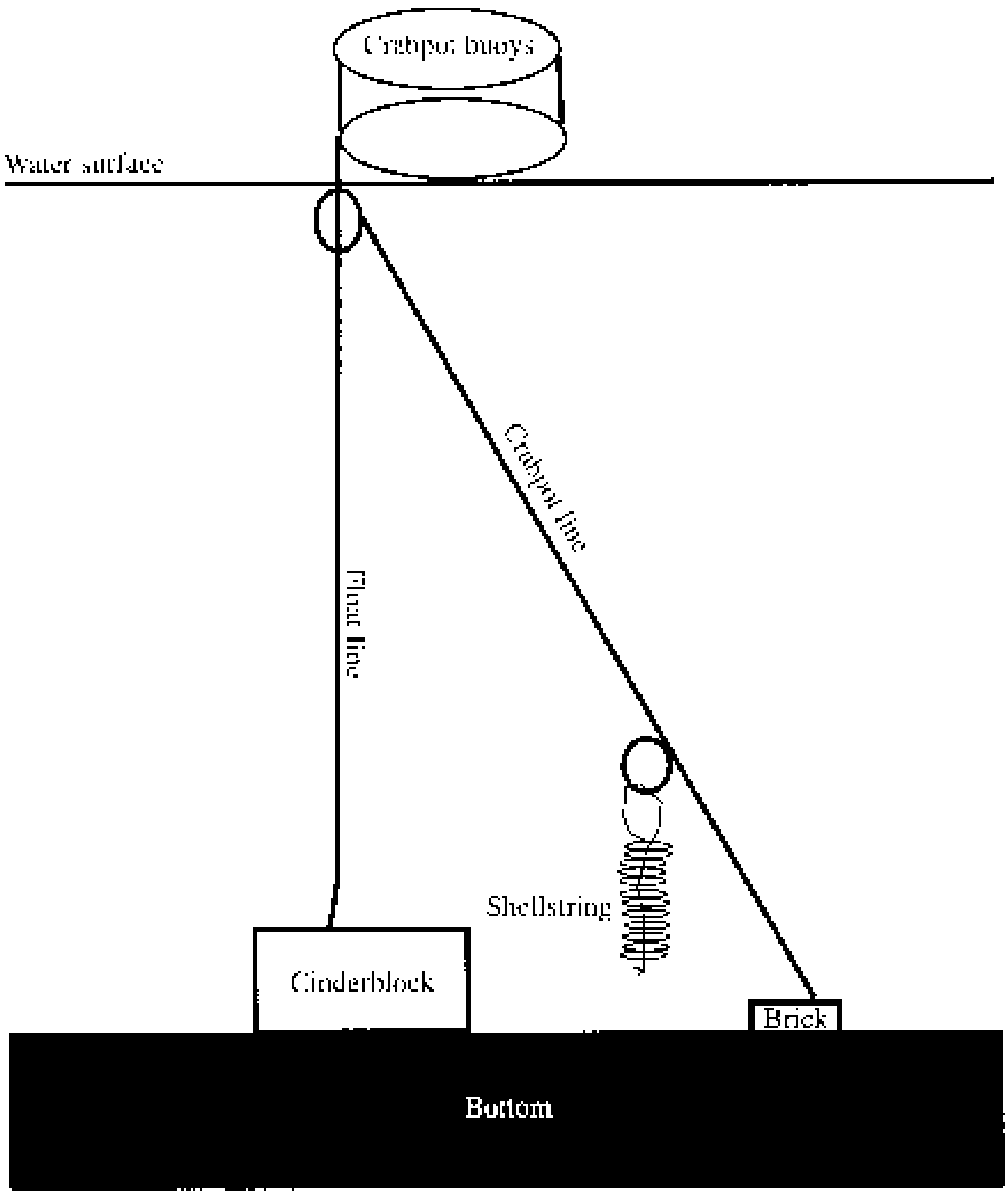


FIGURE S3: JAMES RIVER (2006) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(no sample for Horsehead or Wreck Shoal on DOY 245 and 252 and Day's Point on DOY 245)

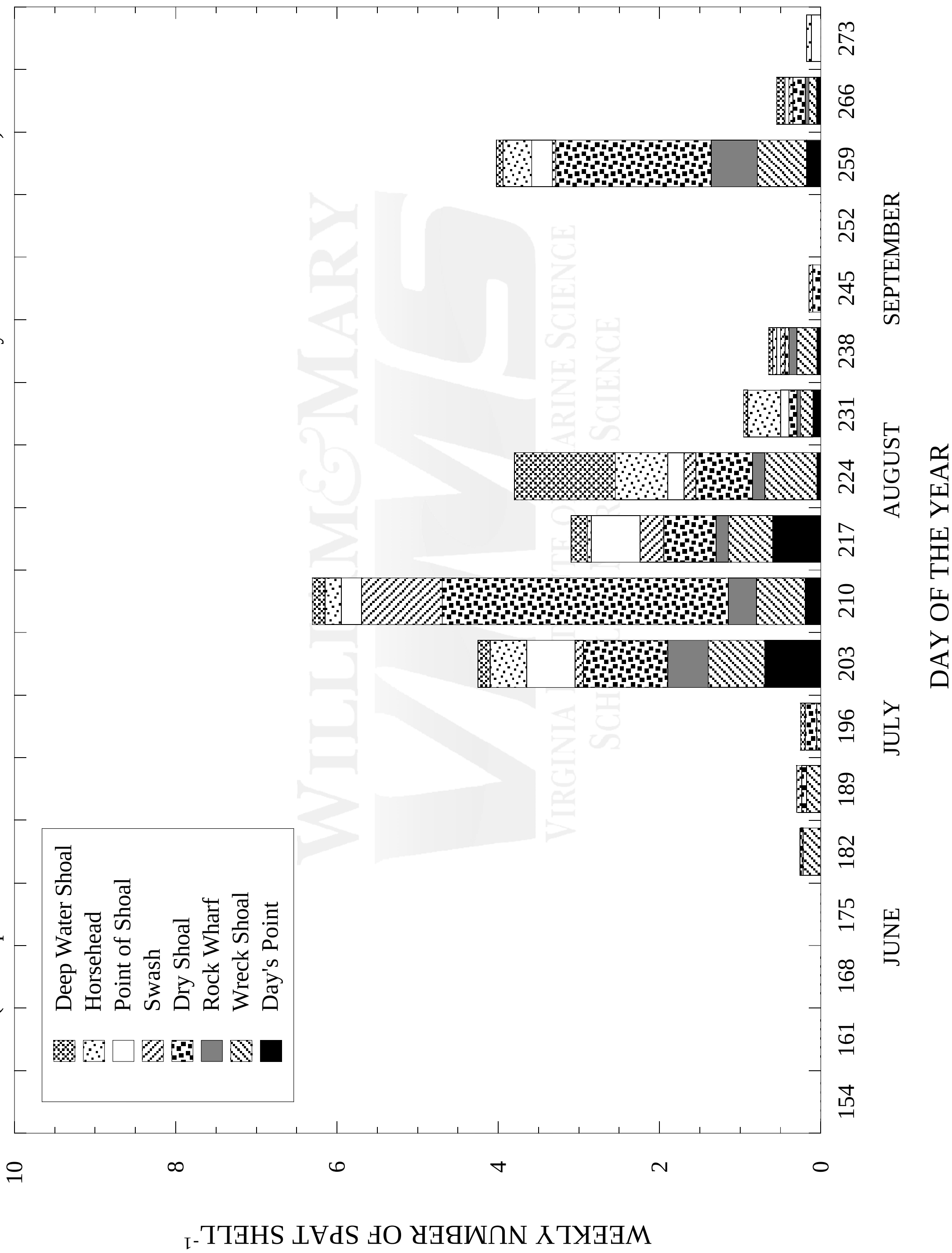


FIGURE S4: SPATFALL TRENDS OVER THE PAST 15 YEARS AT ALL 8 SITES IN THE JAMES RIVER (upriver sites in top panel; downriver sites in bottom panel) (expressed as cumulative weekly spatfall)

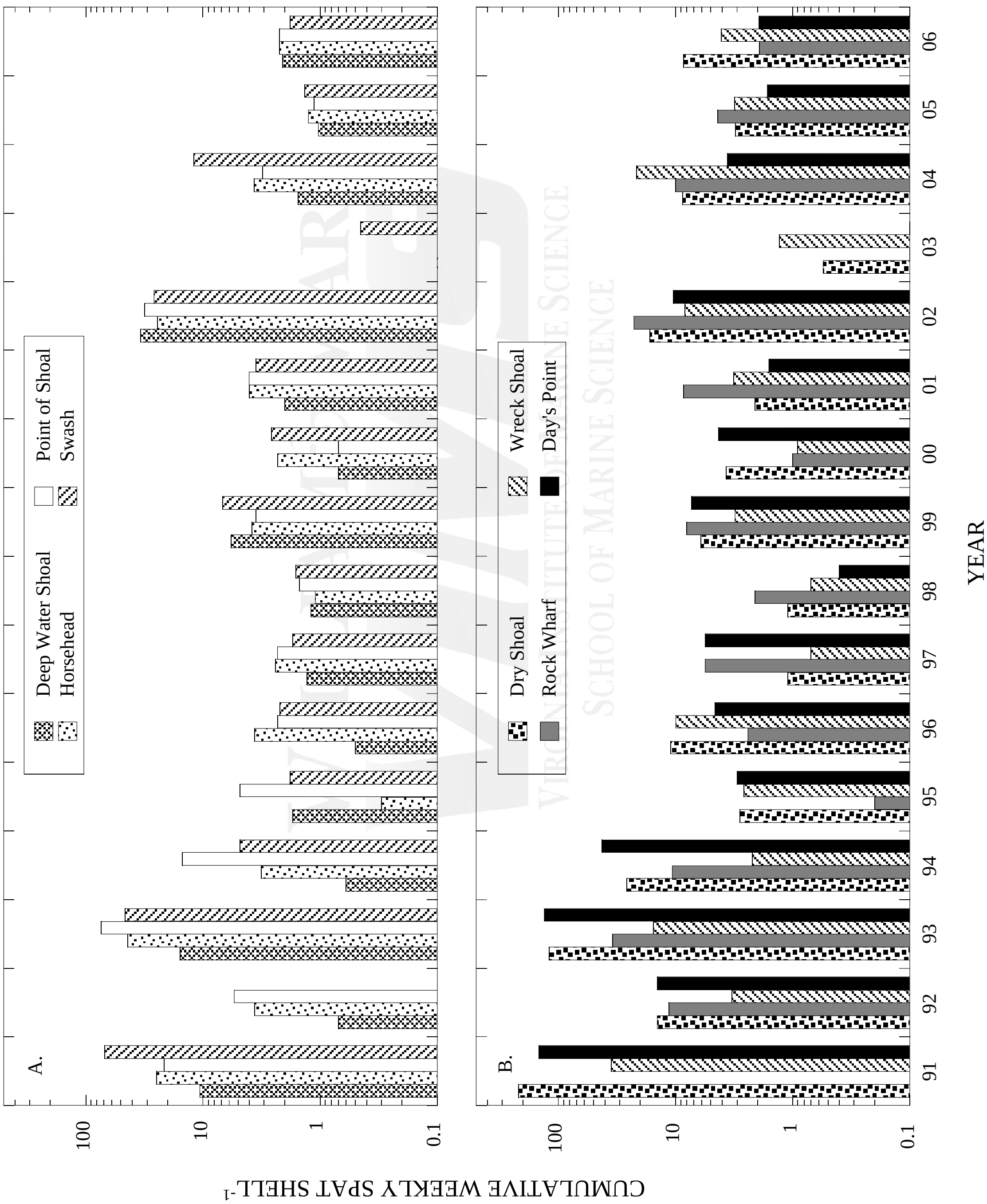


FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 15-YEAR MEANS COMPARED WITH 2006
(Error bars represent standard error of the mean; shaded area represents settlement during 2006; n is the number of data points used to calculate the mean)

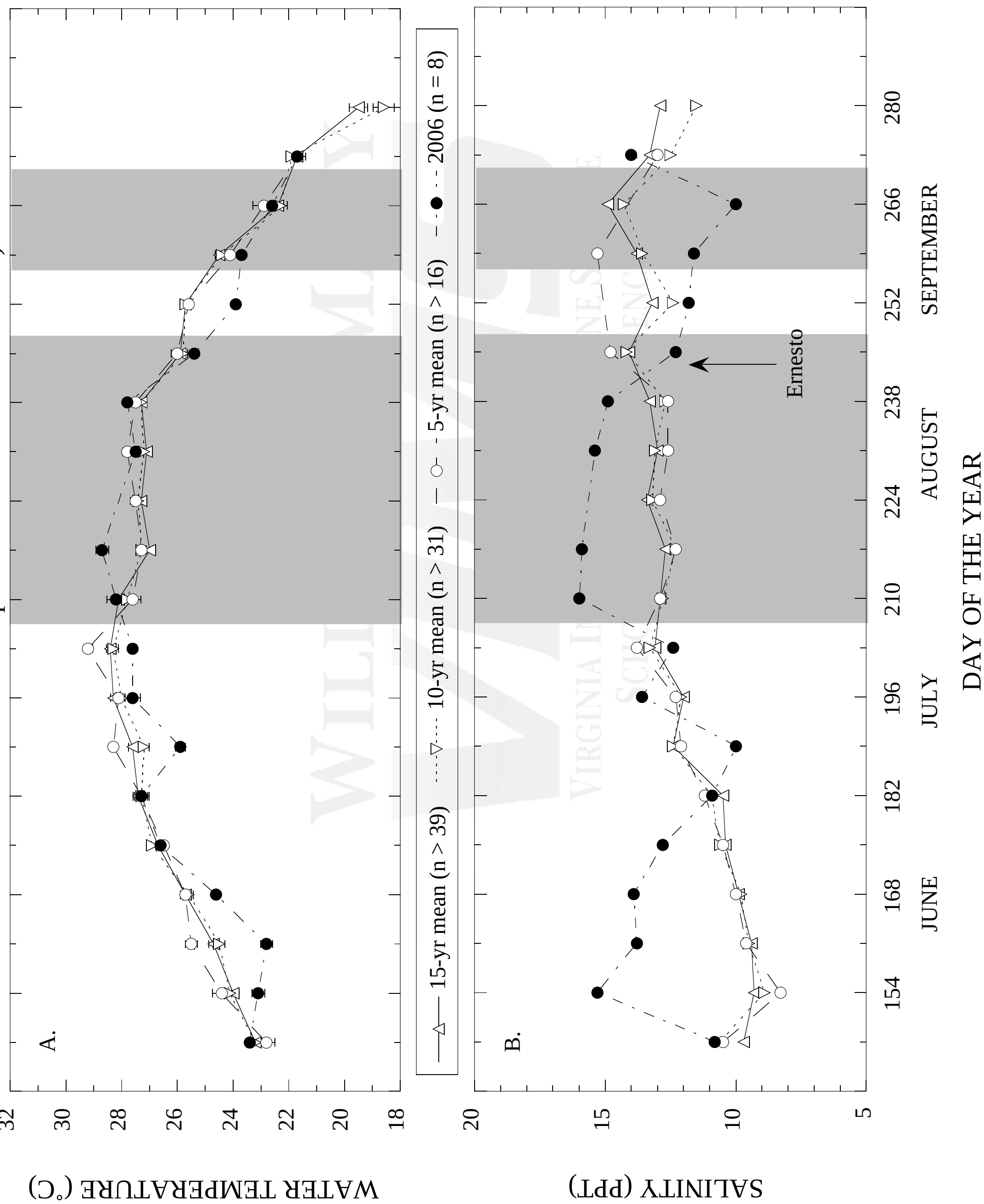


FIGURE S6: PIANKATANK RIVER (2006) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$ (H = historical station: N = new station as described in text)

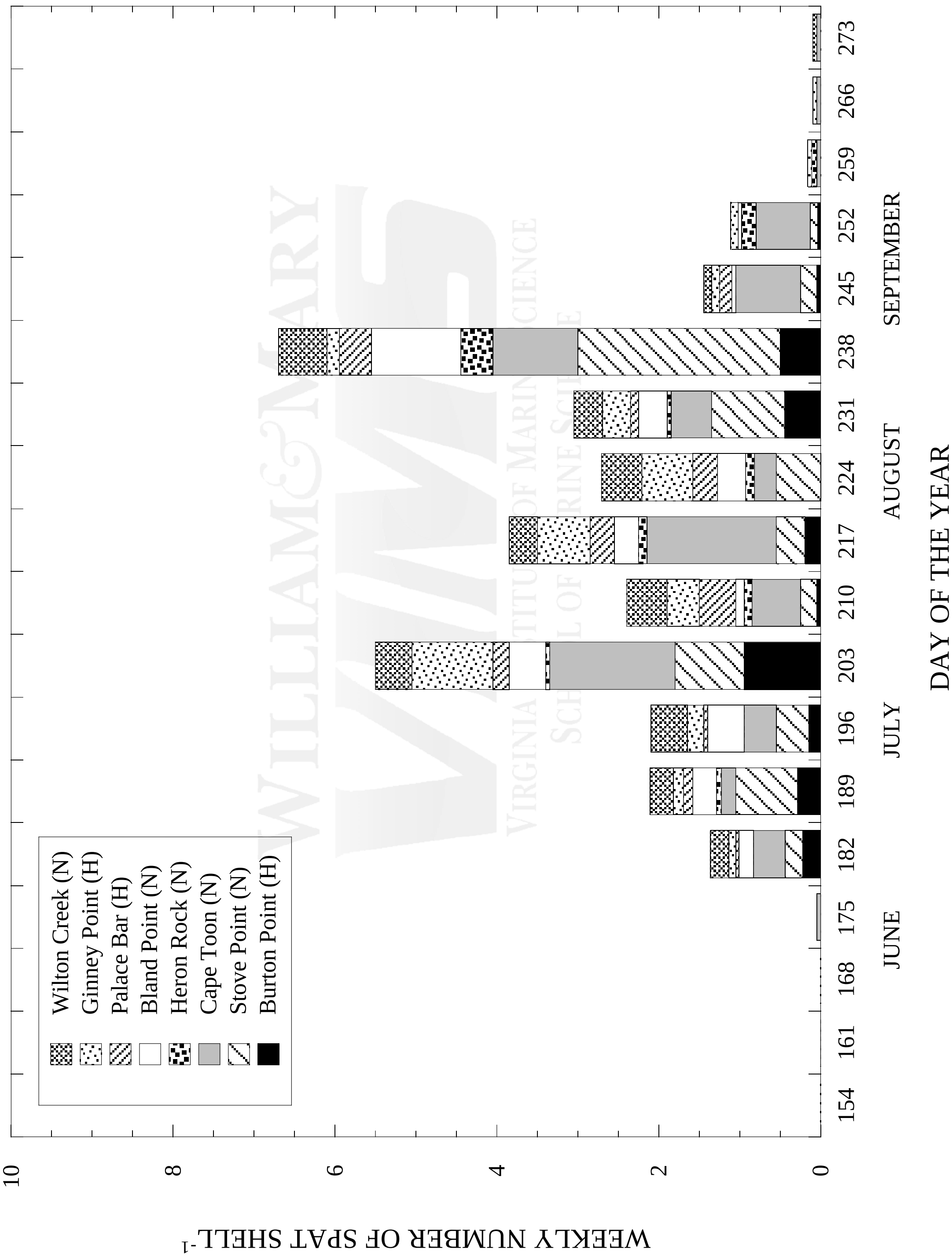


FIGURE S7: SPATFALL TRENDS IN THE PIANKATANK RIVER AT THE 3 HISTORICAL SITES (panel A: 15 years) AND THE 5 NEW SITES (panel B: 8 years)
(Expressed as cumulative weekly spatfall)

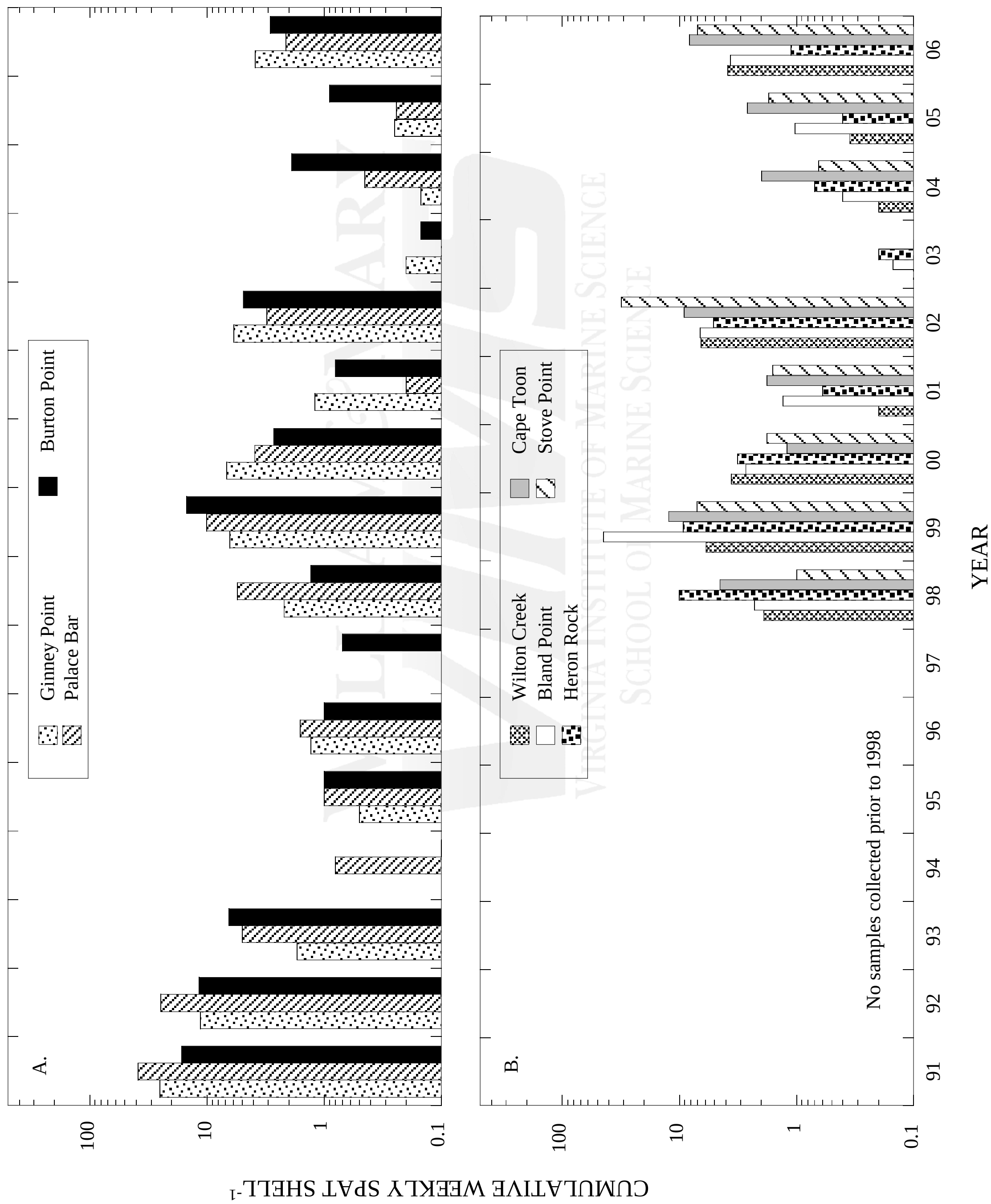


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 15-YEAR MEANS COMPARED WITH 2006
(Error bars represent standard error of the mean; shaded area represents settlement during 2006; n is the number of data points used to calculate the mean)

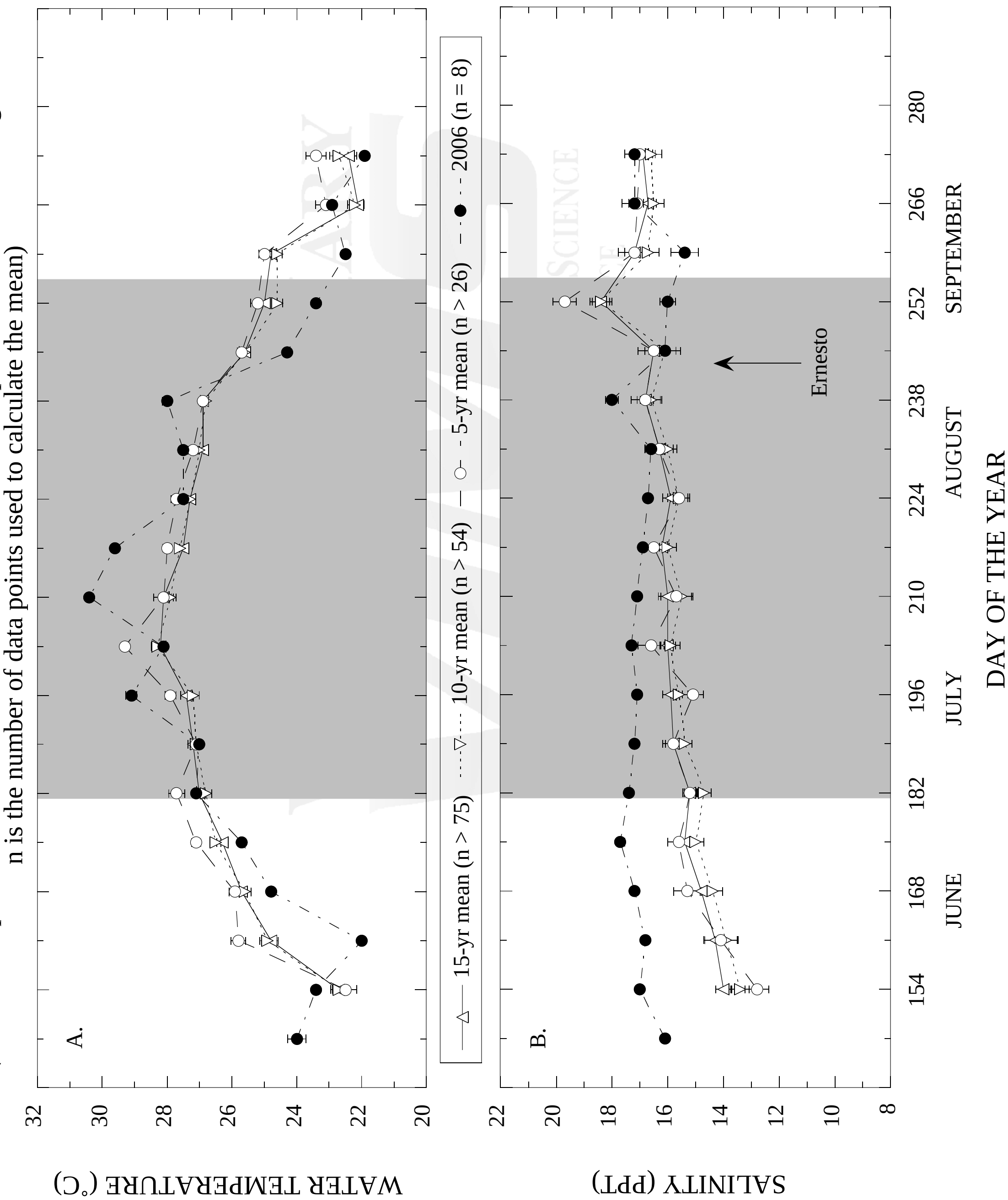


FIGURE S9: GREAT WICOMICO RIVER (2006) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: N = new station as described in text)

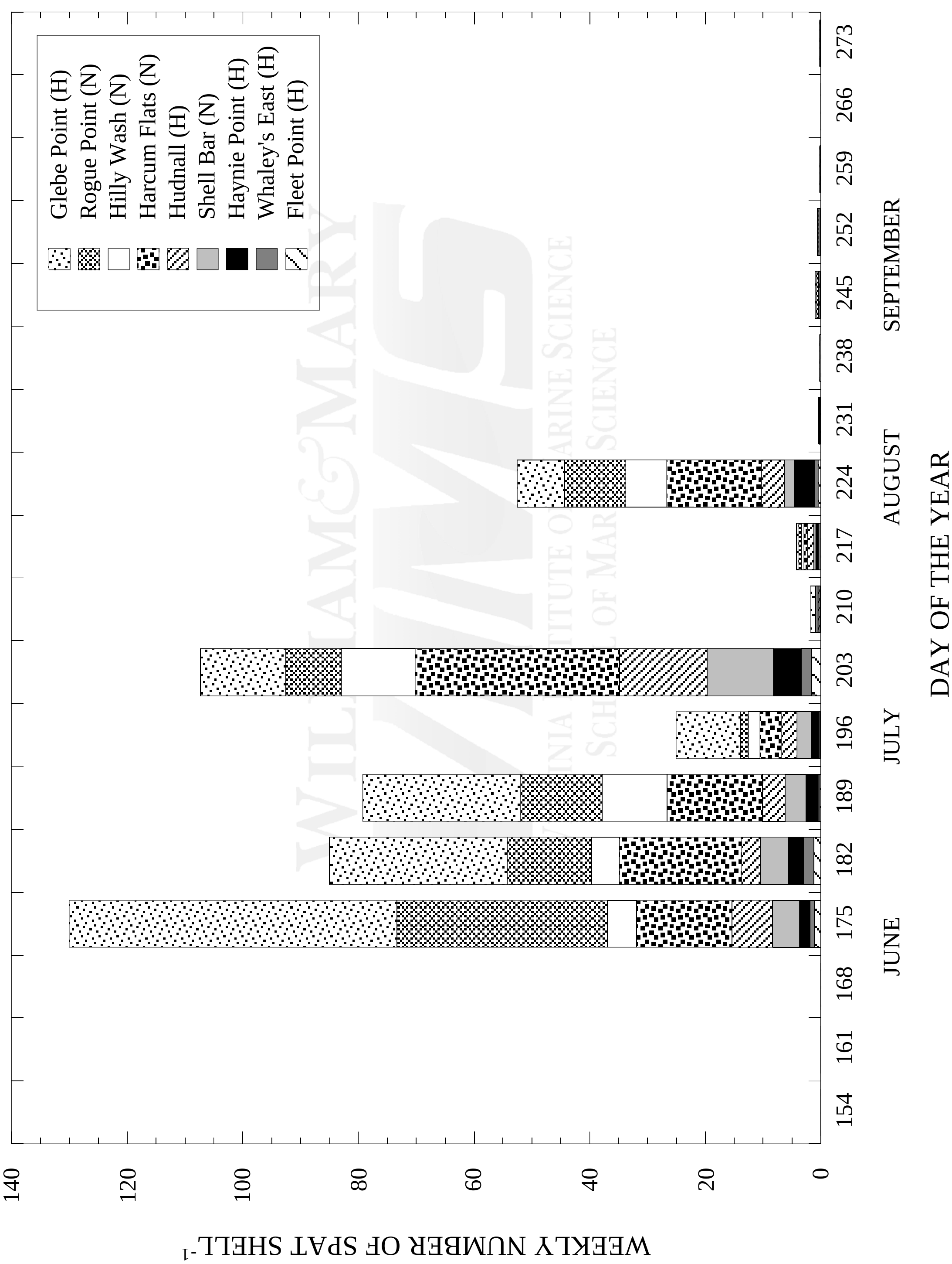


FIGURE S10: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER AT THE 5 HISTORICAL SITES (panel A: 15 years) AND THE 4 NEW SITES (panel B: 8 years) (Expressed as cumulative weekly spatfall)

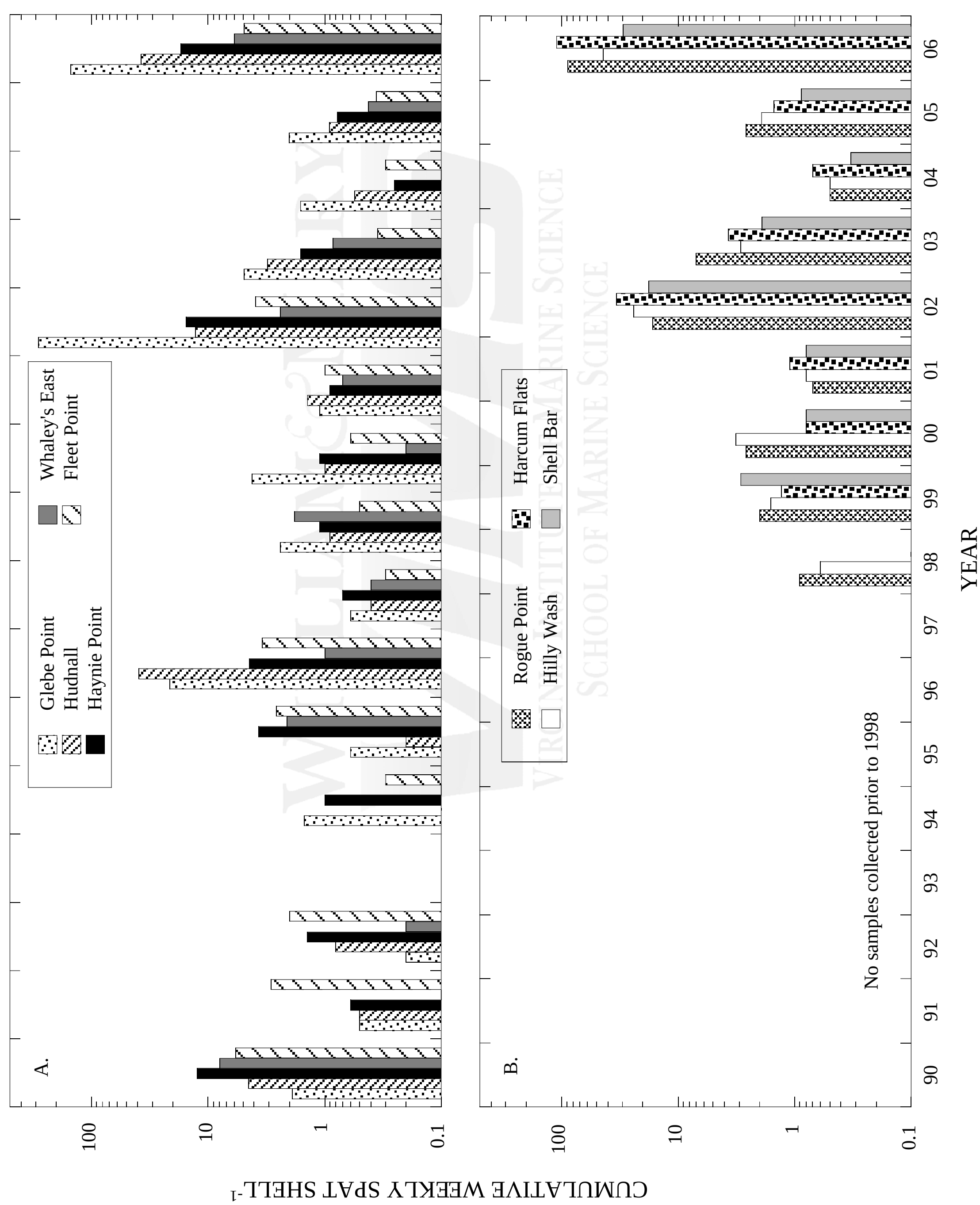
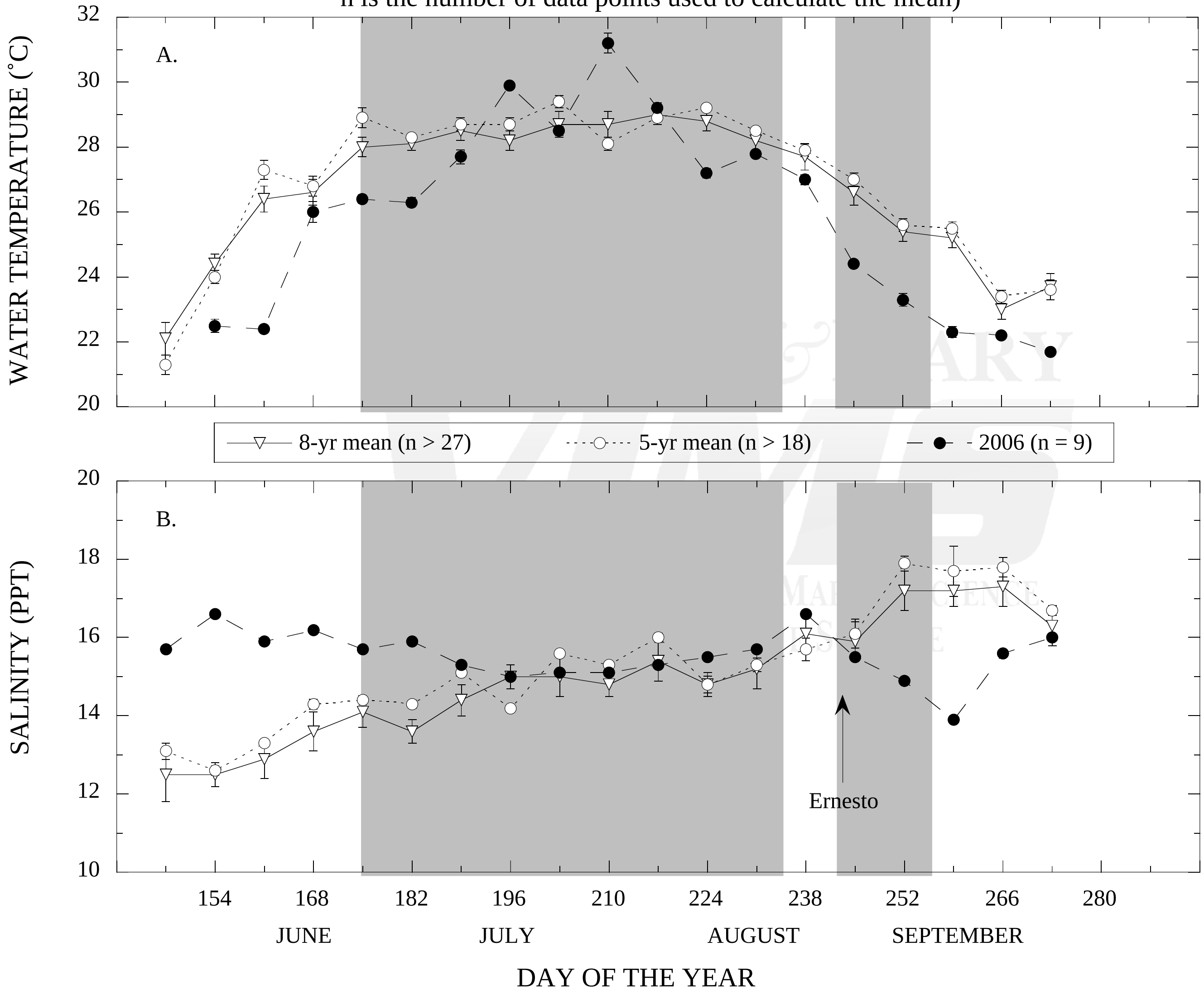


FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE SETTLEMENT PERIOD: 5 AND 8-YEAR MEANS COMPARED WITH 2006
(Error bars represent standard error of the mean; shaded area represents settlement during 2006; n is the number of data points used to calculate the mean)



Part II. Dredge Survey of Selected Oyster Bars in Virginia During 2006

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 2006 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 2006) 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).

Broodstock oysters were periodically planted on Shell Bar Reef in the Great Wicomico River from January through September 2006 (www.vims.edu/mollusc/NORM). In Spring 2006, clean shell or cultch was planted on Burton Point in the Piankatank River and Broad Creek in the Rappahannock River. In the Mobjack Bay, both Tow Stake and Pultz Bar were cleaned of oysters and then received a planting of clean cultch in late Spring 2006. Seed (mixture of all size-classes of oysters) was planted on Bowler's Rock in the Rappahannock River in early 2006.

RESULTS

Thirty oyster bars were sampled between October 10 and October 26, 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 141 bushel^{-1} at Thomas Rock to a high of 513 bushel $^{-1}$ at Dry Shoal. When compared with 2005, the total number of oysters increased at the most upriver site, Deep Water Shoal, which has had persistent low numbers of oysters since the occurrence of several freshets during the summer months in 2003. The total number of oysters observed at Thomas Rock and Nansemond Ridge during 2006 was similar to 2005, whereas at the other seven sites, there was a substantial decrease when compared with 2005 (Figure D3).

The average number of market oysters in the James River remains low when compared with historical numbers. Horsehead had an average of 107 market oysters bushel^{-1}, a relatively high number compared to past years. The rest of the sites had low to moderate numbers of market oysters ranging from 3 (Nansemond Ridge) to 96.5 bushel^{-1} (Point of Shoal). There was a slight increase in the number of market oysters at the three most upriver sites (Deep Water Shoal, Mulberry Point and Horsehead) and a slight decrease at the three most downriver sites (Wreck Shoal, Thomas Rock and Nansemond Ridge; Figure D2).

Numbers of small oysters bushel^{-1} ranged from a low of 15 at Nansemond Ridge to a high of 405.5 at Dry Shoal. When compared with 2005, there was a notable increase in small oysters observed at Deep Water Shoal and a notable decrease at eight out of the other nine sites monitored (Figure D2 and D3).

The average number of spat varied depending on location in the river, but tended to be higher at the more downriver sites. The average number of spat bushel^{-1} ranged from a low of 29.5 at Point of Shoal to a high of 173.5 at Nansemond Ridge. There was an increase in the number of spat at all ten sites when compared with 2005 (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. This pattern was somewhat apparent during 2006, but not as evident as in some recent years.

The average number of boxes bushel^{-1} ranged from a low of 7 (Deep Water Shoal) to a high of 198.5 (Thomas Rock). Boxes at all but the two most upriver sites (Deep Water Shoal and Mulberry Point) and the most downriver site (Nansemond Ridge) accounted for greater than 16% of the total (live and dead) oysters observed. This is not unexpected given the decrease in the total number of oysters at most of these sites as previously mentioned. The boxes at the more upriver sites were composed of both new and old boxes (approximately 60/40 split) whereas the more downriver sites were predominately old boxes (approximately 20/80 split).

Water temperature during the sampling period ranged from 12.8 to 15.4 degrees C (Table D2). Salinity was variable depending on location in the river, increasing in a downriver direction, from 5.8 ppt at Deep Water Shoal to 15.5 ppt at Nansemond Ridge.

York River

In the York River, the average total number of live oysters bushel $^{-1}$ in was 92 at Aberdeen Rock and 119.5 at Bell Rock. The live oysters at Aberdeen Rock were primarily spat accounting for 82% of the total with a substantial increase in the number of spat when compared with 2005 (Figure D4). There was also a notable, but smaller increase in the number of spat at Bell Rock compared with 2005, but the live oysters at Bell Rock were predominately small oysters accounting for 75% of the total (Figure D4). There was a notable decrease in the number of small oysters at Bell Rock, and the number of market oysters has remained relatively stable since about 1997 (Figures D4 and D5). The average number of boxes (new and old) bushel^{-1} was low at Aberdeen Rock (17 bushel^{-1}) and moderately high at Bell Rock (82 bushel^{-1}), accounting for 16 and 41% of the total oysters (live and dead) respectively. At Bell Rock, approximately 24% of the boxes were new boxes, a relatively high number compared to most years. Water temperature on the day of sampling was 22.3 degrees C at both sites. There was a 4.3 ppt difference in salinity observed: 13.0 ppt at Bell Rock and 17.3 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters at Tow Stake and Pultz Bar were 42.5 and 51.5 oysters bushel^{-1} respectively. There was a notable increase in spat at both sites when compared with 2005 (Figure D4) and settlement at Pultz Bar was among the highest observed in the past 15 years (Figure D6). Despite the cleaning that occurred on both bars in Spring 2006 (see above text), there was little change in the numbers of small or market size oysters when compared with 2005 at either site (Figure D4). The live oysters at Pultz Bar were almost 100% spat whereas the live oysters at Tow Stake were composed of about 55% spat, 35% small and 10% markets. There were very few boxes observed at either station, and of the boxes observed half of them were spat boxes. Of the three total spat boxes observed at Tow Stake two of them had drill holes and three out of the four at Pultz Bar 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 22 degrees C and salinity was approximately 20 ppt at both stations (Table D2) on the day of sampling.

Piankatank River

In the Piankatank River, the average total number of live oysters bushel^{-1} ranged from 99 at Burton Point to 253 at Ginney Point. There was a notable increase in the number of spat observed when compared with 2005, and spat accounted for greater than 81% of the total oysters observed at all three sites (Figure D7). Settlement during 2006 was among the highest observed in the system over the past fifteen years and the first relatively good settlement year recorded since 2002 (Figure D8). In addition to the increase in spat, there was also a notable increase in the number of small oysters observed at all three sites. Overall however, the numbers of oysters in the Piankatank River are among the lowest observed during the past fifteen years of monitoring (Figure D7 and D8). For the first time in three years there were market oysters observed at Ginney Point. There have been a high number of boxes observed in the Piankatank River during the past several years and 2006 was the first in three years with a low number of boxes. The number of boxes ranged from 6 (Ginney Point and Palace Bar) to 12 (Burton Point) boxes bushel^{-1}. There were at least one spat box found at each station and one of the four spat boxes at Ginney Point had a flatworm (*Stylochus* sp.) in it. There are two species of *Stylochus* (also known as oyster leeches) common to the Chesapeake Bay and they have been associated with incidences of high mortality in eastern oyster populations, particularly among spat (Webster & Medford, 1961). At Burton Point, one of the four 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 was approximately 19.5 degrees C at all three sites. Salinity ranged between 16 and 16.6 ppt increasing in an upriver direction, in contrast to what one would expect.

Rappahannock River

The average total number of live oysters bu^{-1} in the Rappahannock River ranged from a low of 16.5 at Morattico Bar to a high of 279 at Middle 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 seen in the James River. 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 bushel^{-1} ranged from 1 (Middle Ground) to 28.5 (Parrot Rock). The greatest number of market oysters was observed at the three most upriver sites and the three most downriver sites, the other four sites had very few market size oysters. There was a small decrease in the number of market oysters at both Bowler's Rock and Smokey Point when compared with 2005 (Figure 9). The number of market oysters at Ross Rock has remained relatively stable since about 2002 and since about 1994 at Broad Creek (Figure D10).

For the fifth year in a row, Drumming Ground near the mouth of the Corrotoman River had the highest average number of small oysters bu^{-1} with 55.5, which was very similar to that observed during 2005 (Figure D9 and D10). When compared with 2005 numbers, there was a notable increase in small oysters at Bowler's Rock and Smokey Point and a notable decrease at Long Rock and Morattico Bar (Figure D9). The increase observed at Bowler's Rock can most likely be attributed to the seed that was planted on it in Spring 2006, as previously mentioned.

There were at least a few spat observed at all ten stations in the Rappahannock which was a notable increase when compared with 2005 numbers (Figure D9). Settlement throughout the system has been low for the past several years (Figure D10) and 2006 marked the first 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 271.5 bushel^{-1}, accounting for 97% of the total number of oysters at that site.

The average total number of boxes bushel^{-1} ranged from 0 (Ross Rock) to 25.5 (Middle Ground). Boxes accounted for less than 21% 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 Smokey Point (one spat box out of all four samples) had spat boxes.

Water temperature during the sampling period ranged from 19.0 to 19.8 degrees C. Salinity increased moving from the most upriver station (Ross Rock: 7.5 ppt) toward the mouth (Broad Creek: 16.5 ppt).

Great Wicomico River

The average total number of live oysters bu^{-1} in the Great Wicomico River was moderate at the two sites downriver of Sandy Point (Figure 1 for location) averaging 275.5 (Fleet Point) and 329.5 (Whaley's East) and high at Haynie Point (627 oysters $bushel^{-1}$), the one site located upriver of Sandy Point. The live oysters found at all three sites were predominately spat, accounting for greater than 80% of the total. Compared with 2005 numbers, this equated to a relatively large increase in the number of spat observed (Figure D11). Settlement during 2006 was among the highest observed in the system during the past fifteen years, comparable to 1997 and 2002 numbers (Figure D12). There was also a notable increase in the number of small oysters observed at all three sites when compared with 2005 and an increase in the number of market oysters at Haynie Point and Fleet Point (Figure D11). The total number of boxes $bushel^{-1}$ was low ranging from 3 (Whaley's East) to 26.5 (Haynie Point). This accounted for less than 4% of the total (live and dead) number of oysters observed. Despite the large number of spat observed at all three sites there were very few spat boxes observed at any of the sites. Water temperature ranged between 18.2 (Fleet Point and Whaley's East) and 19.2 degrees C (Haynie Point) and salinity was between 16.4 (Fleet Point and Whaley's East) and 17.0 ppt (Haynie Point) on the day of sampling.

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 21 market oysters $bushel^{-1}$).

For the past 15 to 20 years, the bulk of Virginia's oyster population has been composed primarily of small oysters (> 65%). Over the past four to five years however this trend has been less apparent. During 2006, only four sites (three in the James River and Bell Rock in the York River) had oyster populations that consisted of greater than 65% small oysters. Spat dominated the oyster populations in the Piankatank and Great Wicomico Rivers with greater than 80% of the oysters observed being spat. In the Rappahannock River, the more downriver stations tended to have a higher percentage of spat than the more upriver sites and overall, populations at the mid river sites were low with a mixture of all size classes. The oyster population at Pultz Bar in Mobjack Bay consisted almost entirely of spat. The population at Pultz Bar has been consistently low for the past several years, the settlement observed there during 2006 is encouraging and is most likely due to the shell plant that was received on Pultz Bar in spring 2006, which provided clean substrate for the larvae to settle on.

Overall settlement during 2006 was good with an increase at all thirty sites monitored when compared with 2005. Settlement in both the Piankatank and Great Wicomico Rivers was among the highest observed during the past fifteen years. In the upper Rappahannock River, settlement was observed for the first time since 2002 and settlement at all of the sites except the two most downriver (Parrot Rock and Broad Creek) was among the highest observed during the past fifteen years of monitoring. In the James River, settlement at the three most upriver sites was low compared to the 1990s, but was the highest observed since 2002. Settlement at the remaining sites in the James River was typical for that observed during 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 in these downriver areas is again on the decline most likely due to a combination of disease and fishing mortality. In both 2005 and 2006, disease levels at the more downriver stations were higher than they have been in the past few years with half of the oysters at Nansemond Ridge, Thomas Rock and Wreck Shoal having moderate to heavy Perkinsus infections (Dr. Ryan Carnegie, VIMS, personal communication).

The average total number of boxes observed during 2006 was relatively low at all sites, accounting for less than 20% of the total (live and dead) at twenty-three out of the thirty sites monitored. On a system basis, the James River had the highest number of boxes with five out of the ten sites in the James having greater than 20% boxes. These sites were primarily located in the mid to lower portion of the sampling area. This is in direct contrast to 2005, when the James River was the only system that had a low number of 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 1989 to 2005 averages (Dr. Ryan Carnegie, VIMS, personal communication), but 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.

Despite the high numbers of spat observed throughout the Great Wicomico River, at Ginney Point and Palace Bar in the Piankatank River and at Middle Ground and Drumming Ground in the Rappahannock River, there were a relatively low number of spat boxes observed at all of the sites monitored. Drill holes were present in the spat boxes observed at both sites in the Mobjack Bay and at Burton Point in the Piankatank 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 found in recent years in the mouths of the Piankatank and Rappahannock Rivers, and in Mobjack Bay.

Table D1: Station locations for the 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

* Denotes stations with coordinates that were slightly different from the 2005 coordinates.

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.	Salinity	Average number of oysters per bushel				Average number of boxes per bushel			
		(deg C)	(ppt)	Market	Small	Spat	Total	New	Old	Spat	Total
James River											
Deep Water Shoal	11/6	12.9	5.8	20	172	82	274	2.5	3	1.5	7
Mulberry Point	11/6	12.8	7.4	38	210.5	37	285.5	4.5	9.5	2.5	16.5
Horsehead	11/6	12.8	8.5	107	258	52	417	37	44	0	81
Point of Shoal	11/6	13.2	9.4	96.5	15.5	29.5	141.5	25.5	42	0	67.5
Swash	11/6	13.1	12.9	48	187	55.5	290.5	30.5	45	0	75.5
Long Shoal	11/6	12.8	10.2	34.5	361.5	95	491	19	87	1.5	107.5
Dry Shoal	11/6	13.5	12.6	24.5	405.5	83	513	41.5	146.5	5	193
Wreck Shoal	11/2	14.5	14.7	18.5	144	98.5	261	31.5	164	3	198.5
Thomas Rock	11/2	15.0	14.5	10	38	93	141	5.5	65	4	74.5
Nansemond Ridge	11/2	15.4	15.5	3	15	173.5	191.5	1	19	5.5	25.5
York River											
Bell Rock **	9/29	22.3	13.0	18.5	89	12	119.5	19.5	62.5	0	82
Aberdeen Rock	9/29	22.3	17.3	7.5	9.5	75	92	2	12.5	2.5	17
Mobjack Bay											
Tow Stake	9/28	22.3	19.5	4.5	14.5	23.5	42.5	0	1.5	1.5	3
Pultz Bar	9/28	22.3	20.5	0	1	50.5	51.5	0	1	2	3
Piankatank River											
Ginney Point	10/13	19.7	16.6	2.5	43	207.5	253	0.5	3.5	2	6
Palace Bar	10/13	19.7	16.4	3	33	179	215	1	4.5	0.5	6
Burton Point	10/13	19.4	16.0	3.5	15	80.5	99	0	10	2	12
Rappahannock River											
Ross Rock	10/20	19.3	7.5	22.5	42	4	68.5	0	0	0	0
Bowler's Rock	10/20	19.5	11.0	18.5	16.5	2.5	37.5	1	3.5	0	4.5
Long Rock	10/20	19.6	11.3	25.5	1.5	5	32	0	2.5	0	2.5
Morattico Bar	10/20	19.8	13.0	7	6.5	3	16.5	0.5	1.5	0	2
Smokey Point	10/20	19.7	14.2	8.5	5	7.5	21	0	1	0.5	1.5
Hog House	10/20	19.6	15.3	3	2	16.5	21.5	0	0.5	0	0.5
Middle Ground #	10/20	19.4	15.2	1	6.5	271.5	279	0.5	15.5	9.5	25.5
Drumming Ground	10/20	19.4	16.3	13.5	55.5	150.5	219.5	4	12.5	0	16.5
Parrot Rock	10/13	19.0	15.6	28.5	22.5	60	111	4	9	0	13
Broad Creek	10/13	19.7	16.5	22.5	13	38	73.5	2	17	0	19
Great Wicomico River											
Haynie Point	10/16	19.2	17.0	17	59	551	627	2	20.5	4	26.5
Whaley's East	10/16	18.2	16.4	0	20	309.5	329.5	0	2	1	3
Fleet Point	10/16	18.2	16.4	16	38	221.5	275.5	0.5	8.5	1.5	10.5

Figure D1: Map showing the location of the oyster bars sampled during the 2006 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.

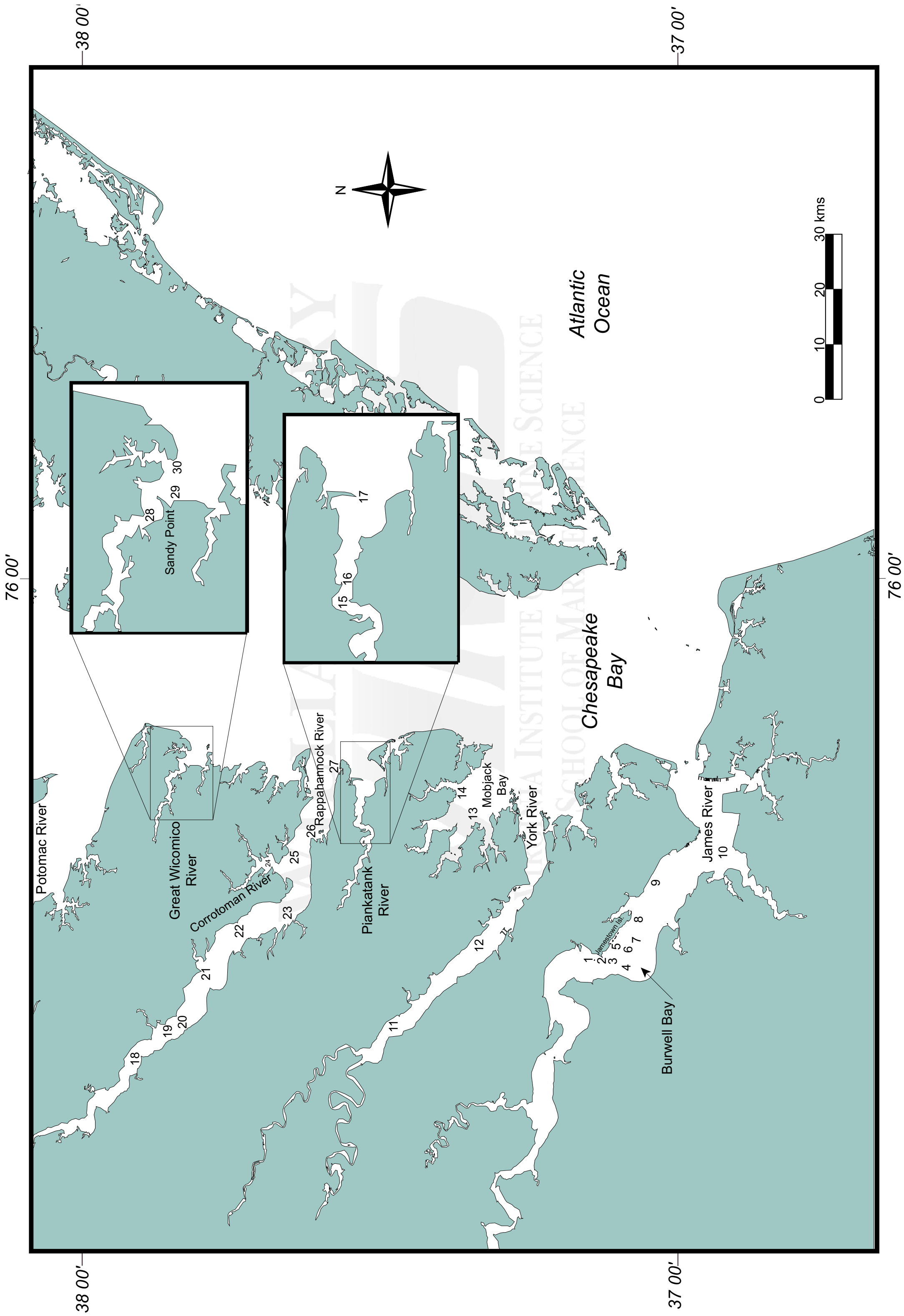

38 00'
37 00'
76 00'
N
0 10 20 30 kms
Atlantic Ocean
Chesapeake Bay
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Burwell Bay
Sandy Point
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 25 26 27 28 29 30

FIGURE D2: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE JAMES RIVER (2005-2006)
(Error bars represent standard error of the mean)

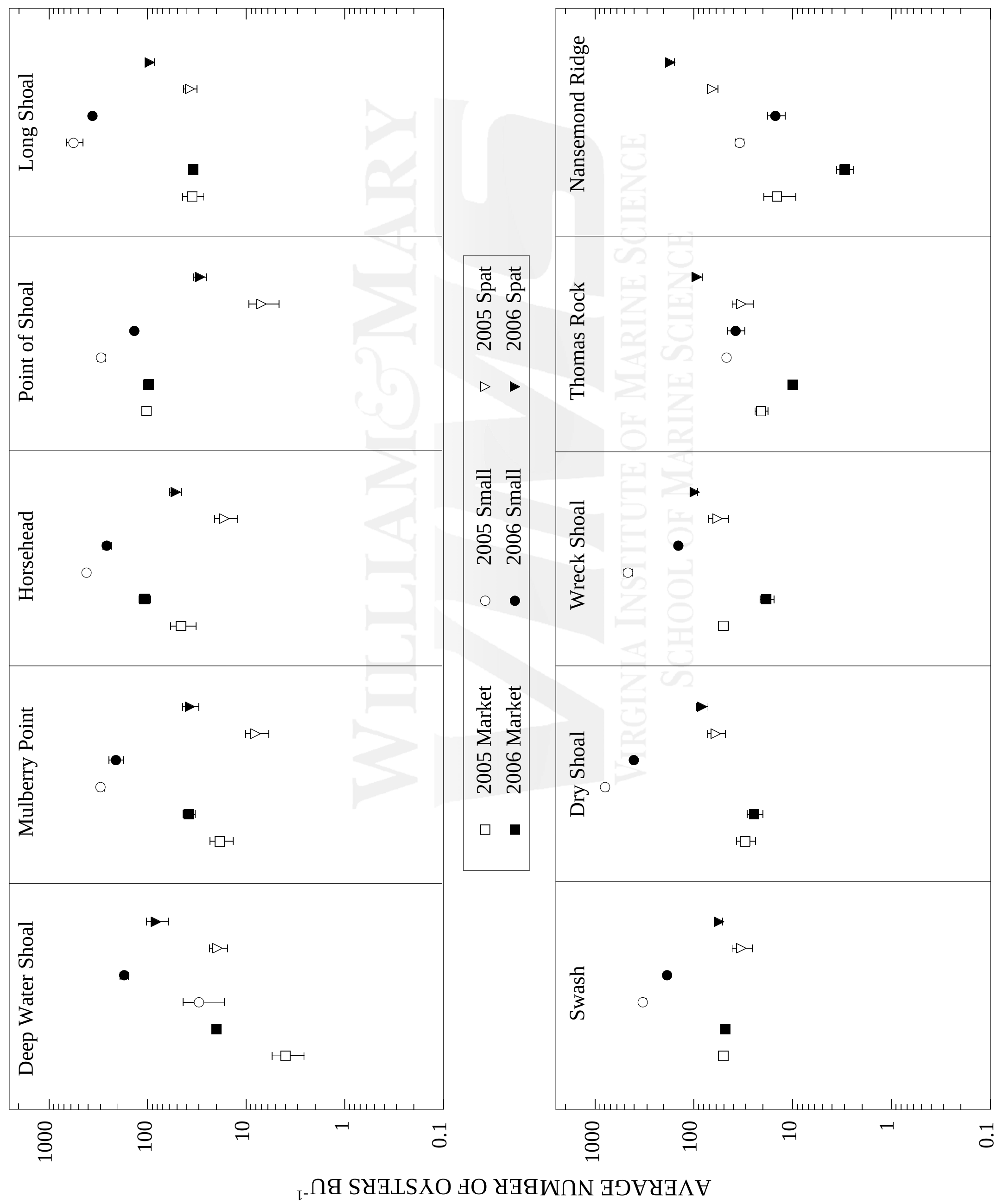
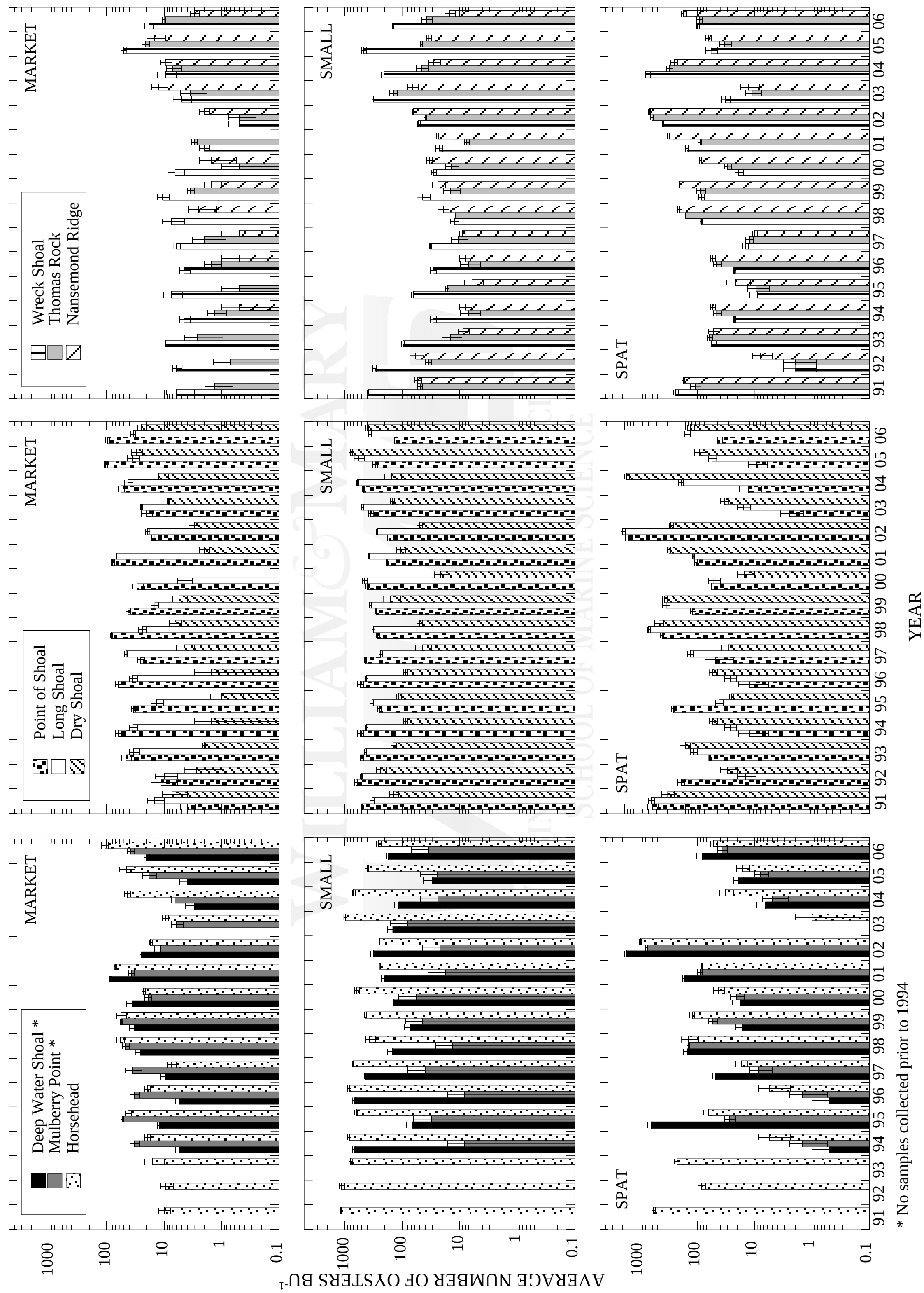


FIGURE D3: JAMES RIVER OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)



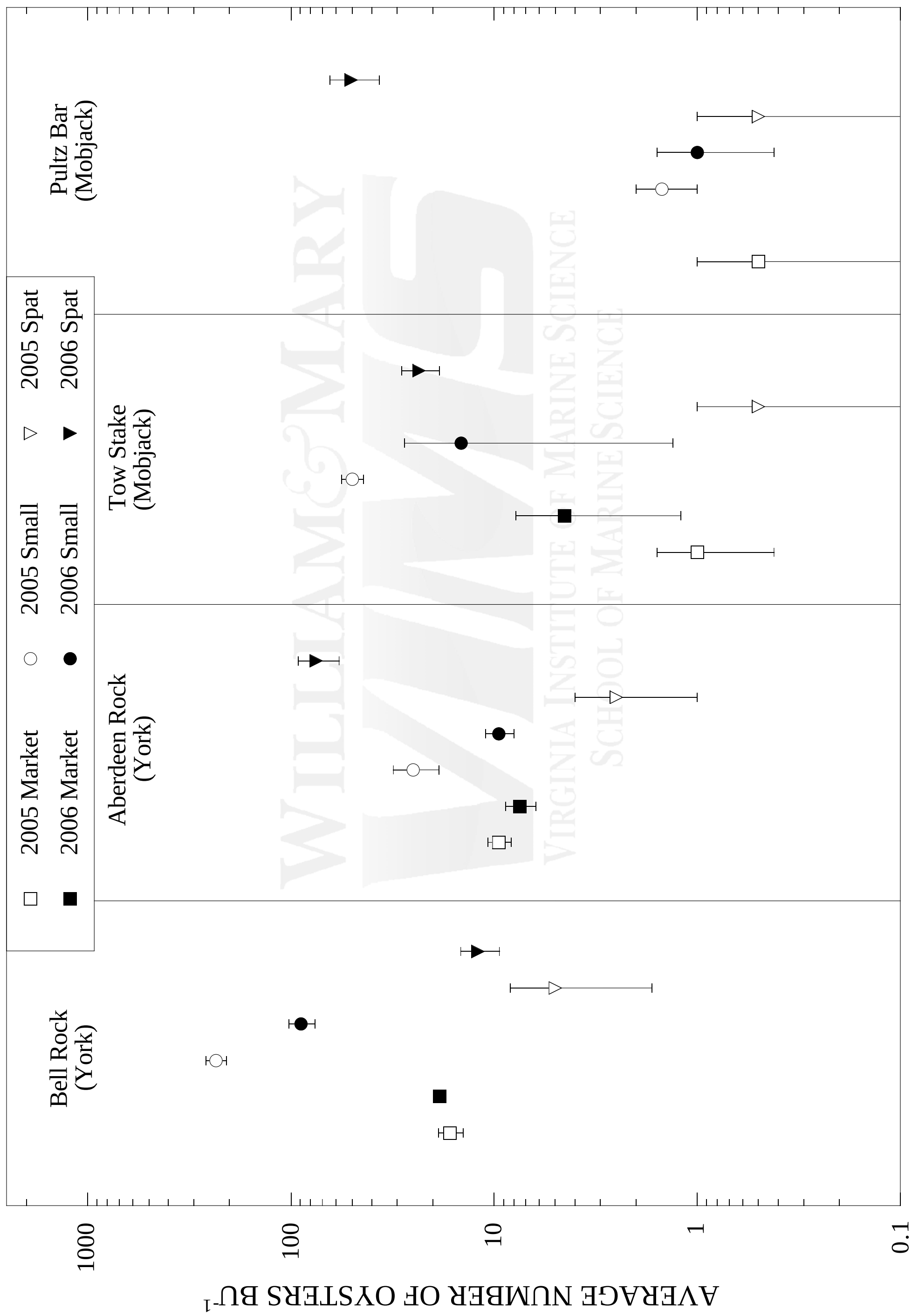


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE YORK RIVER AND MOBJACK BAY (2005-2006)
(Error bars represent standard error of the mean)

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

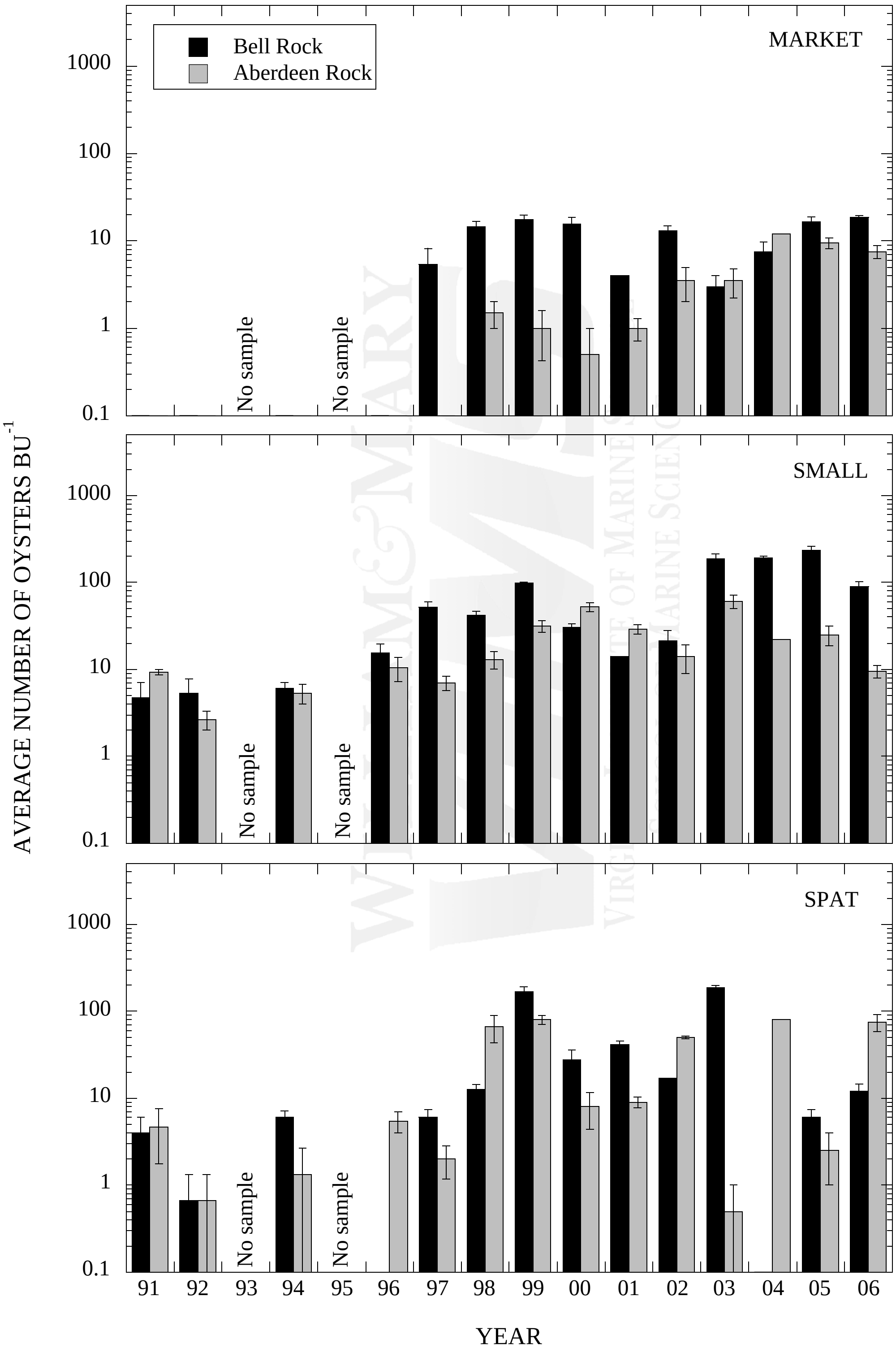


FIGURE D6: MOBJACK BAY OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

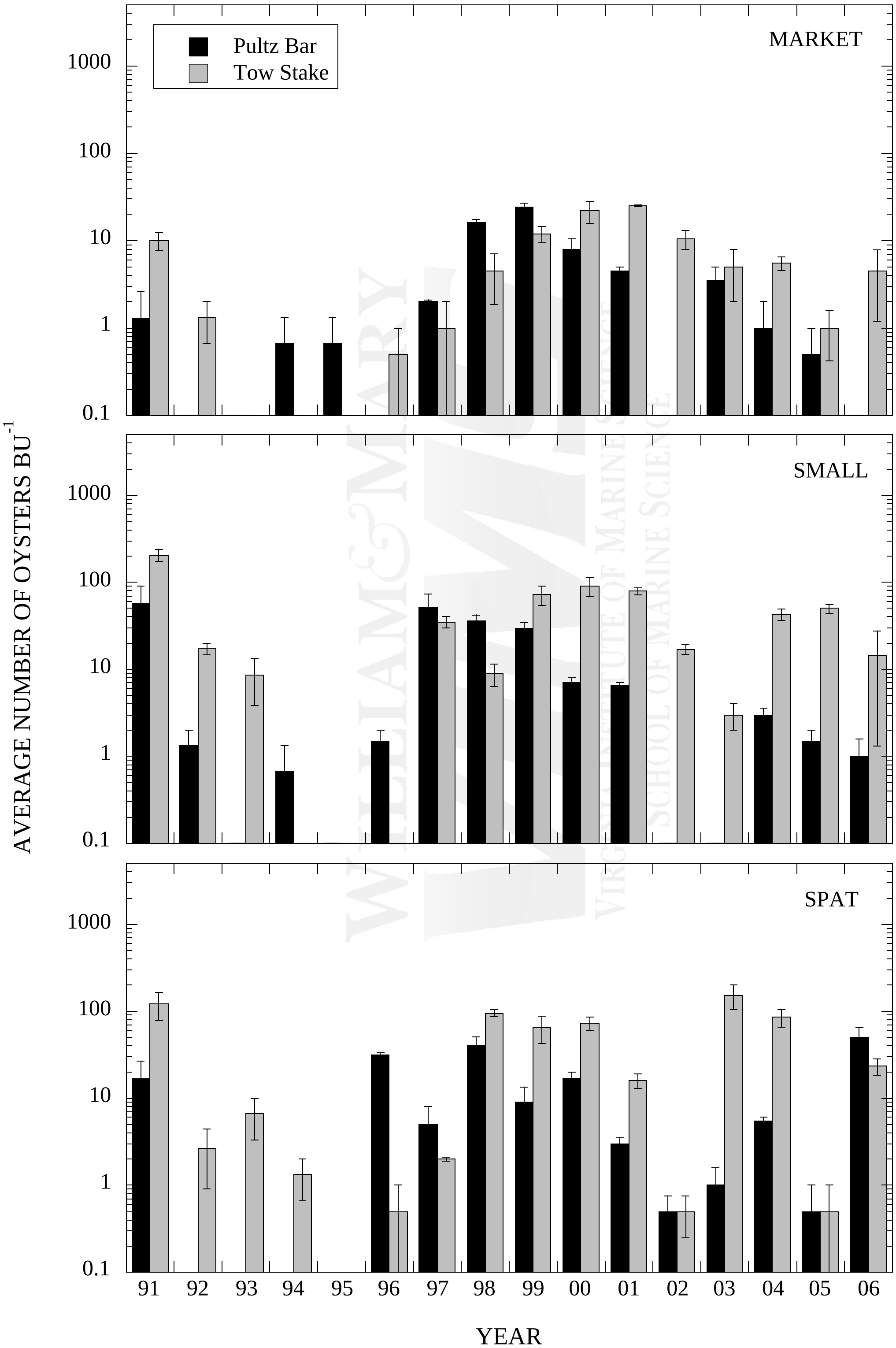


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE PIANKATANK RIVER (2005-2006)
(Error bars represent standard error of the mean)

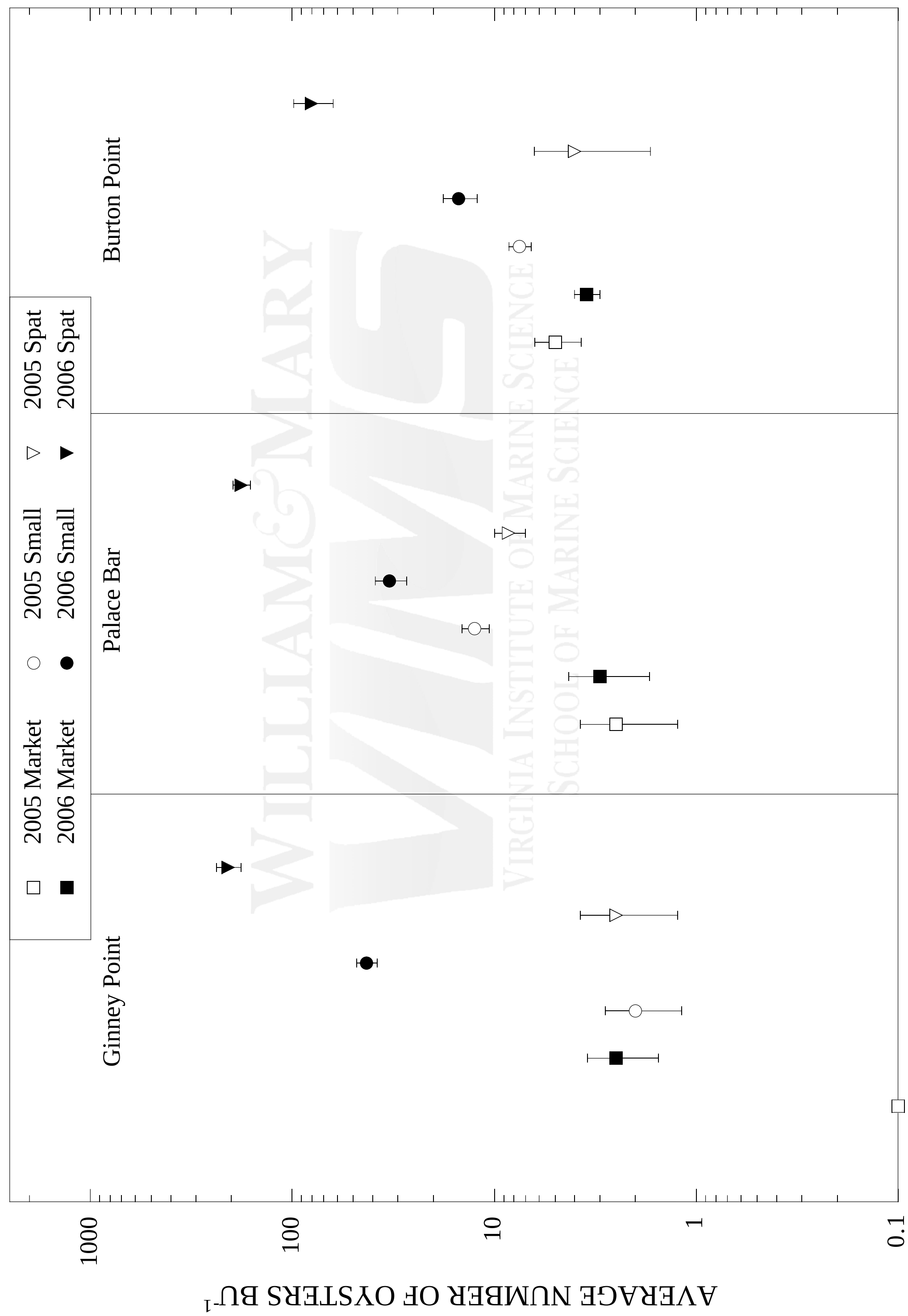


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

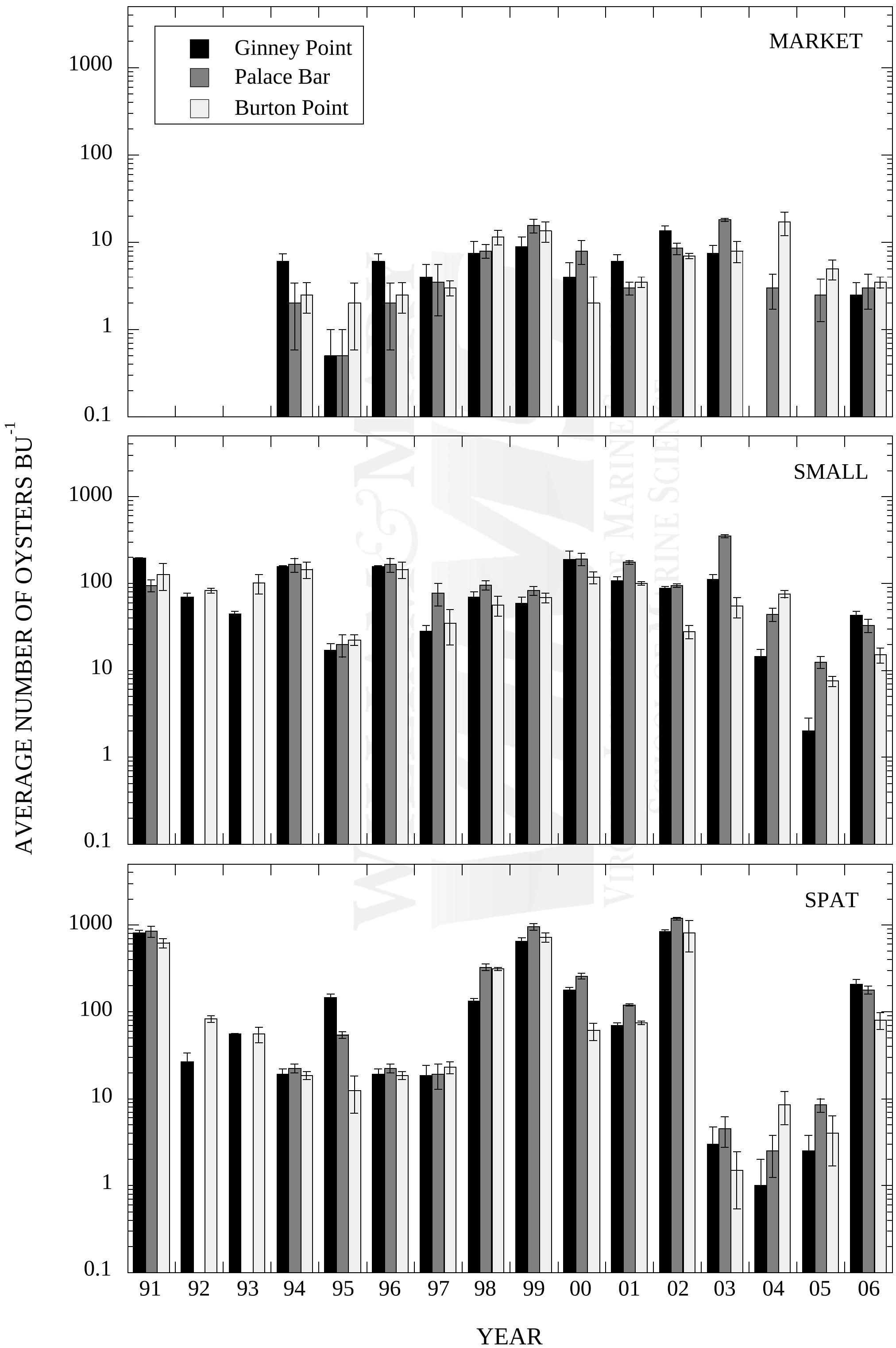


FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2005-2006)
(Error bars represent standard error of the mean)

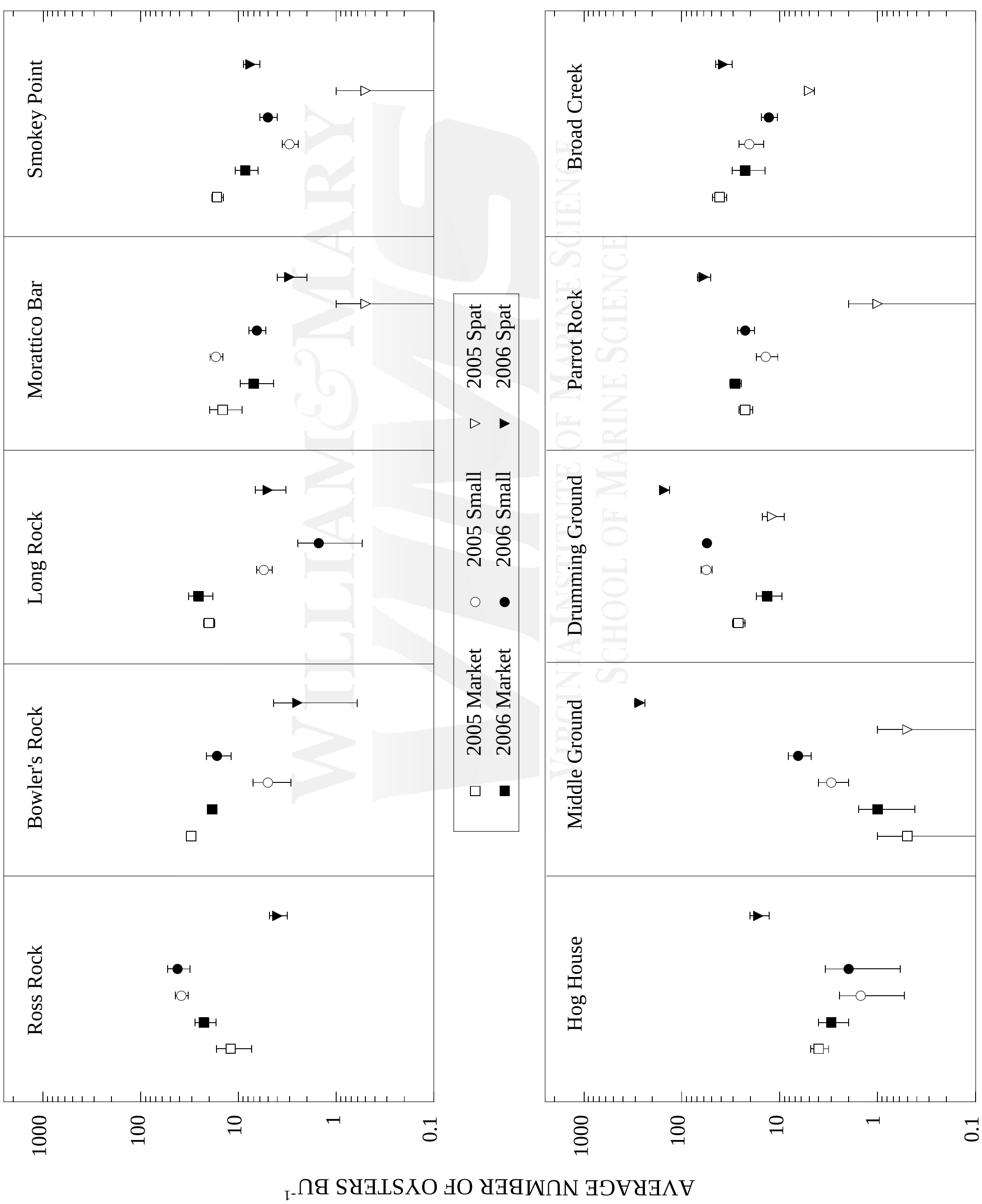


FIGURE D10: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

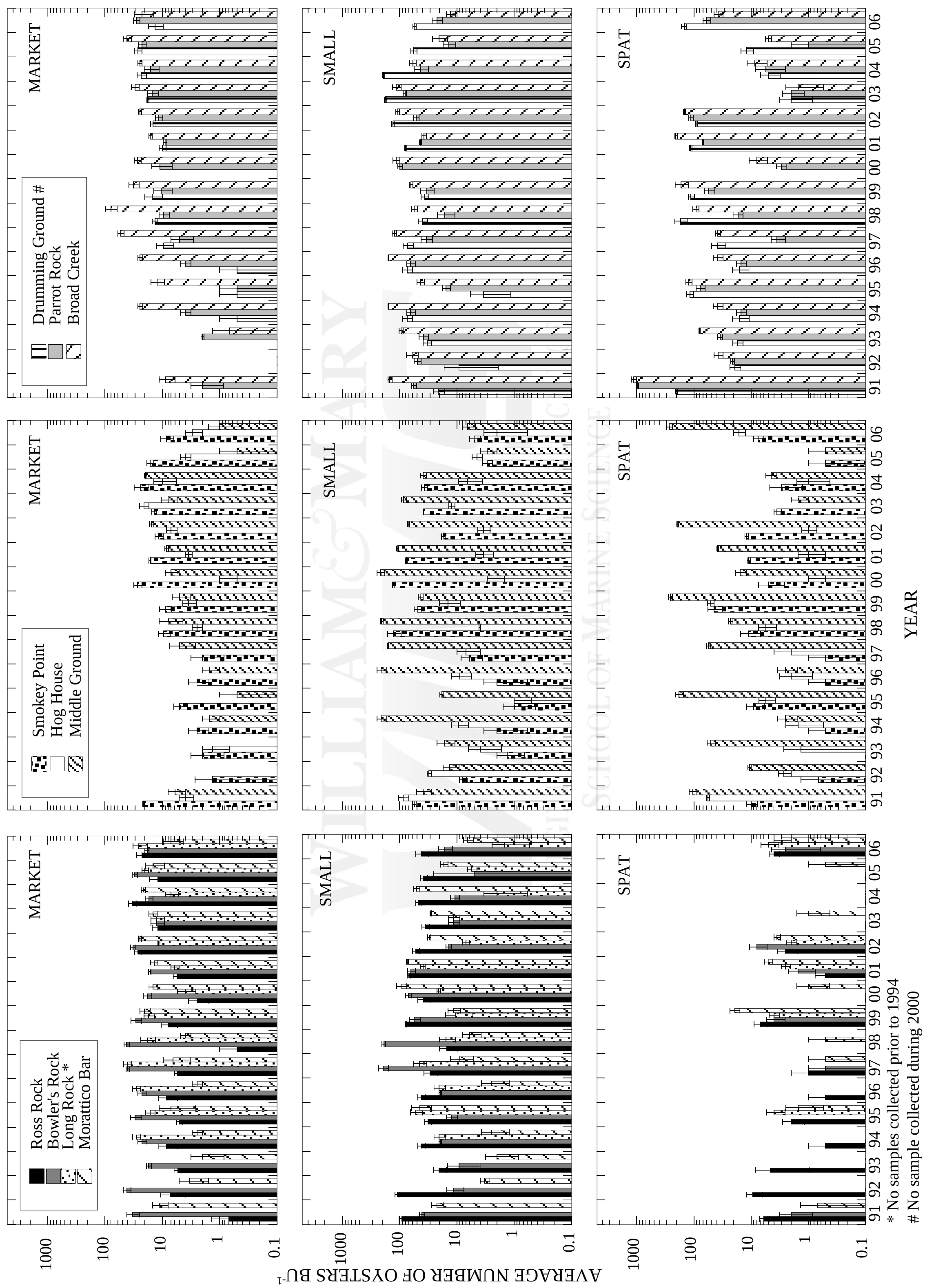


FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE GREAT WICOMICO RIVER (2005-2006)
(Error bars represent standard error of the mean)

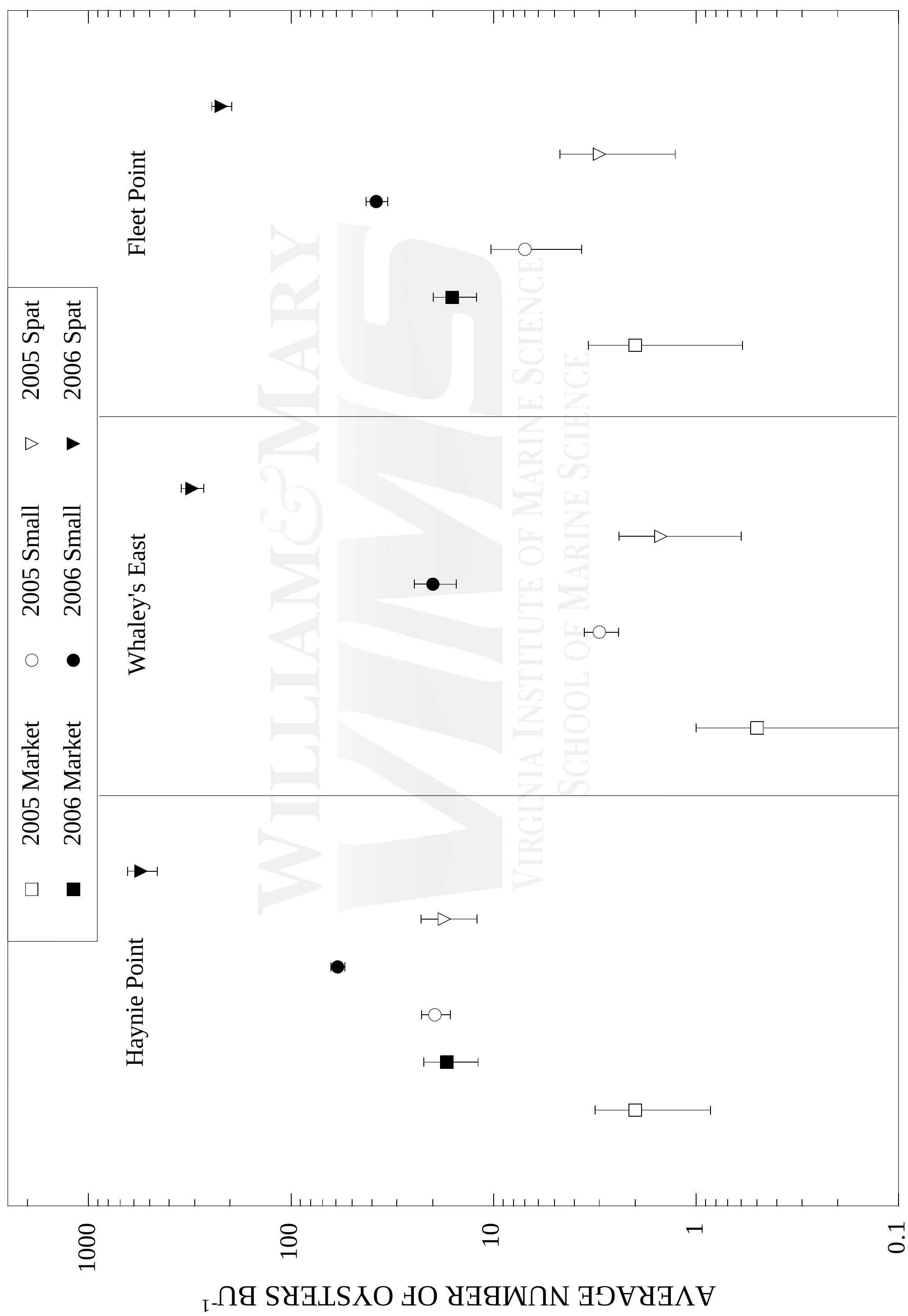
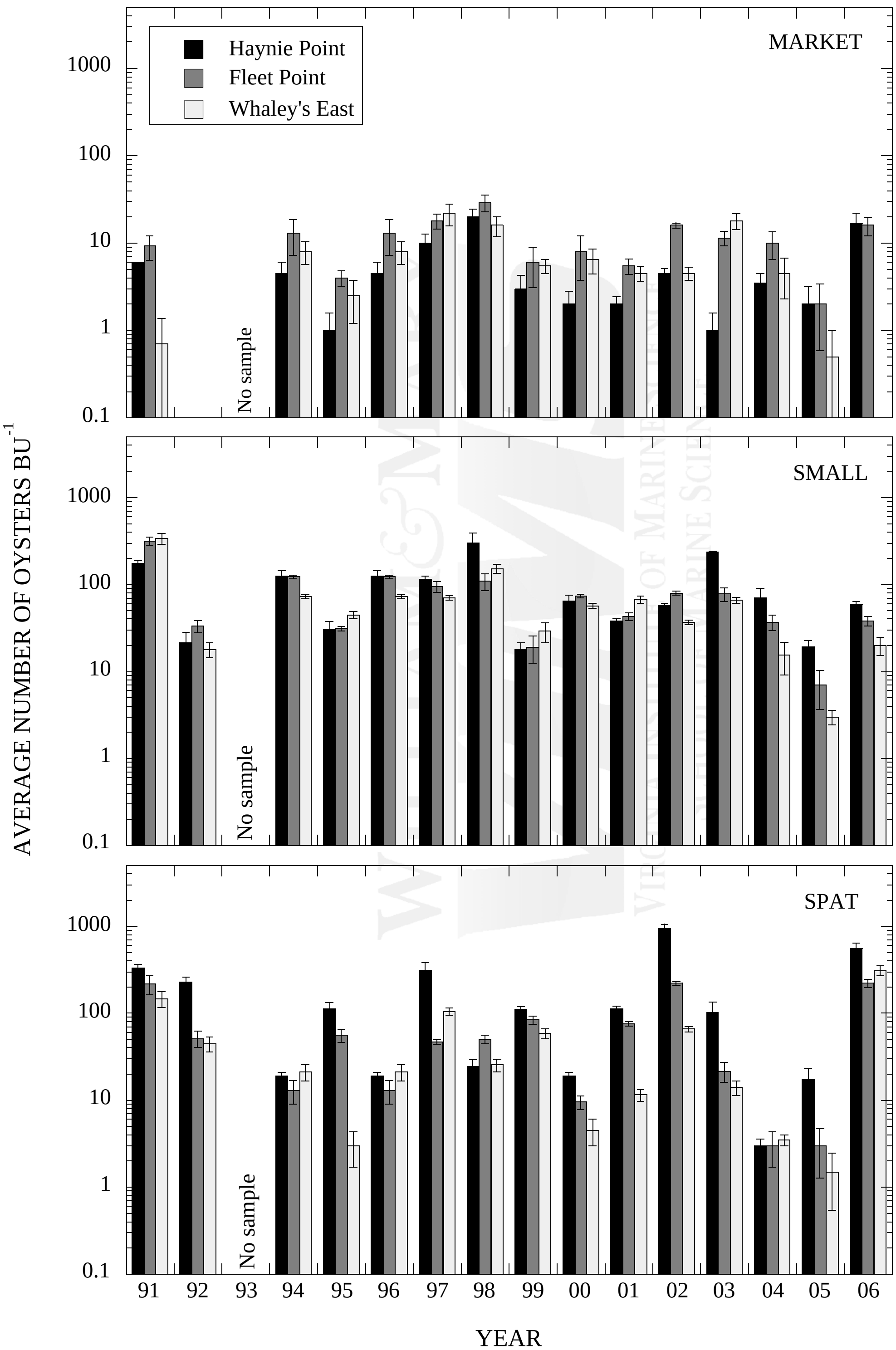


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)



ACKNOWLEDGMENTS

These monitoring programs required the assistance of many people, without whose contributions they could not have been successfully completed. We are deeply grateful to the following: Tim Gass, Wayne Reisner and Bob Gammish for help with vessel operations. Matthew Robinson assisted in making and examining the shellstrings as well as helping out with fieldwork. Cindy Forrester (Department of Fisheries Science, Budget Manager) and Gail Reardon, Grace Walser, and Heidi Fischer (Department of Fisheries Science, Purchasing Agents). VIMS Vessel Operations Department provided assistance with boat scheduling and operation throughout the year, namely George Pongonis (superintendent), Raymond Forrest and Susan Rollins. Roland Billups and Barbara West from VIMS Vehicle Operations Department provided assistance with truck scheduling and operation. Dr. James A. Wesson, Division Head, Conservation and Replenishment Division of the Virginia Marine Resources Commission for use of the *J. B. Baylor* vessel, his assistance during the fall survey and data on shell replenishment during 2006. Adam Crocket, John Ericson and Vernon Rowe of the VMRC for their assistance during the fall 2006 dredge survey.

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