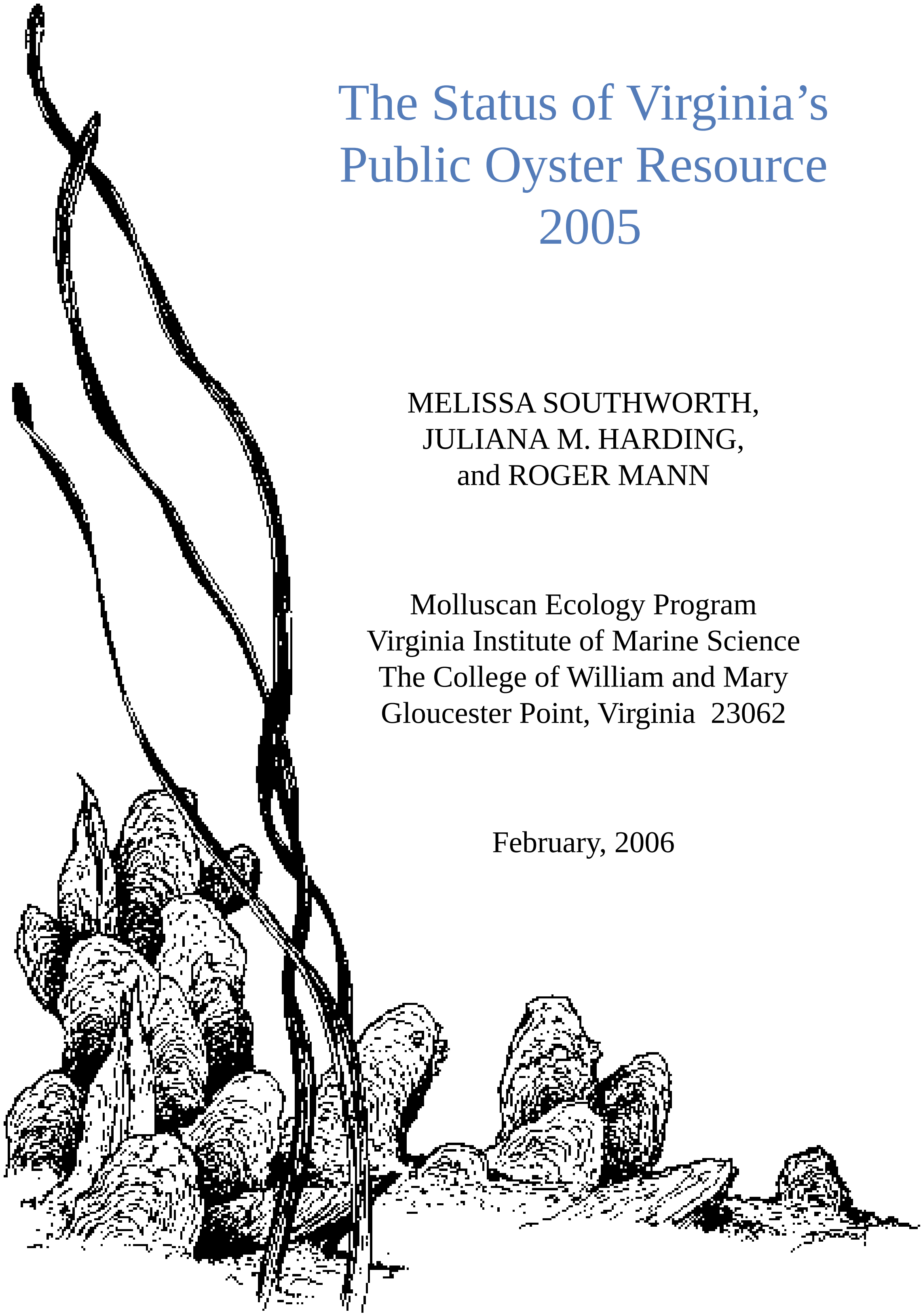

The Status of Virginia's Public Oyster Resource 2005

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Part I.

Oyster Spatfall In Virginia During 2005

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 2005 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2005 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 late February through December 2005, oysters (DEBY stock, 25-90 mm shell height; average 45 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:

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

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

Spatfall on shellstring collectors for 2005 is summarized in Table S1 and is discussed below for each river system monitored. Table S2 includes a summary of settlement for the past 16 years at the historical stations in all three river systems and the past 8 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 2005 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 2005. Comparisons were made over the past 5 years for the new sites whereas the historical sites include 15 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 22 at Dry Shoal (Table S1). There was consistent settlement at that site throughout the rest of the season with a small peak occurring in early August. Settlement at the other seven sites in the river was intermittent throughout the month of August and became more consistent during September. There was a peak in settlement during the last two weeks of September throughout the system (Figure S3). This peak accounted for greater than 60% of the total spatfall for the year six out of the eight stations monitored and was more prominent at the more down river sites along the southern shore (Rock Wharf and Day's Point).

Overall settlement in the James River during 2005 was moderate ranging from a low of 1.03 (Deep Water Shoal) to a high of 4.35 (Rock Wharf) cumulative spat shell^{-1} week^{-1}. During 2005 (as in 2004), there was a slightly higher percentage of settlement at the more downriver sites when compared with the upriver sites. This is in contrast to the previous five to six year pattern during which time settlement tended to be more evenly dispersed throughout the system (Figure S1 and Table S2) but instead more closely reflects historical settlement patterns observed in the system (Haven and Fritz, 1985).

Settlement in the James River during 2005 showed a decrease from the previous year (2004) at all of the stations monitored (Table S2; Figure S4). Spatfall during 2005 was also lower than the 5, 10 and 15-year means at all of the stations monitored. Overall settlement during 2005 was on the lower end of the range when compared with that observed over the past 15 years of monitoring.

Average river water temperatures reached a maximum in late July (30 degrees C: Figure S5A). Water temperature was similar to the 5, 10 and 15-year means (Figure S5A) except at the very beginning of the sampling period. There was also a brief two to three week period in mid August when temperature neared 30.0 degrees C before it dropped again to values more similar to the long-term averages. For the first two weeks of the sampling period salinity was slightly lower than previously recorded in the system. Salinity then increased from 7 ppt to 13 ppt within a week and remained within normal ranges, albeit slightly on the high side, until early August (Figure S5B). From early August to mid September salinity in the James River was 2 to 3 ppt higher than the previous 5, 10 and 15 year means. There was a 6 to 9 ppt salinity difference between Deep Water Shoal (the most upriver station) and Day's Point (the most downriver station: Figure S1).

Piankatank River

Settlement in the Piankatank River was first observed during the week of July 29 at five out of the eight stations. This marked the smaller of two peaks in settlement observed in the system during 2005 (Table S1; Figure S6). The second, larger peak in settlement occurred during the last two weeks of September and accounted for greater than 56% of the total settlement for the year at all eight stations monitored. The two peaks combined accounted for greater than 75% of the total settlement for the year and settlement in between the two peaks was light and intermittent throughout the system (Figure S6).

Cumulative spat shell^{-1} week^{-1} for the year ranged from a low of 0.24 at Palace Bar to a high of 2.64 at Cape Toon.

Spatfall during 2005 showed a small increase when compared with 2004 at five out of the eight stations monitored, and marked the second year in a row with an increase for Wilton Creek, Bland Point, Cape Toon and Stove Point (Table S2: Figure S7). Settlement at Ginney Point and Palace Bar during 2005 was low, an order of magnitude lower than the previous 5, 10 and 15-

year means and among the lowest observed at those stations in years when there was at least some settlement observed at those sites. Settlement at the other five (new) stations was lower than the previous 5 year mean and while higher during 2005 than during 2004, settlement at Heron Rock and Bland Point was still among the lowest observed at those sites since monitoring began in 1998.

The average water temperature ranged from 20 to 30 degrees C throughout the sampling period, reaching a maximum in mid July. Water temperature was about 2 degrees C lower than the previous 5, 10 and 15-year means for two weeks in June, and then increased to within normal range for three weeks (Figure S8A). With the exception of two weeks at the end of August water temperature was approximately 2 to 4 degrees C higher than the 5, 10 and 15-year means from mid July through the end of the sampling season. Salinity ranged from 11 to 18 ppt throughout the sampling period. Salinity was 1 to 2 ppt higher than the 5, 10 and 15-year means from the beginning of the sampling period through early July. Salinity slowly increased throughout the sampling period and was similar to salinities previously recorded in the river from early July onward. 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.

Great Wicomico River

There was only one major peak in settlement in the Great Wicomico River during 2005. This was during the first two weeks of July when greater than 54% of the cumulative spatfall for the year settled at eight out of the nine stations monitored (Table S1; Figure S9). Settlement for the rest of the sampling period was light and intermittent throughout the river (Figure S9).

Cumulative spat shell^{-1} week^{-1} for the year ranged from a low of 0.36 at Fleet Point to a high of 2.61 at Rogue 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. Settlement during 2005 was higher than the previous year (2004) at all of the stations sampled (Table S2: Figure S10). Settlement was lower during 2005 than the previous 5-year mean at all stations sampled and lower than both the 10 and 15-year means at the five historical stations (Table S2). The pattern of an increase in spatfall with increasing distance from the river mouth was once again observed in the Great Wicomico, with the highest spatfall occurring at Glebe Point and Rogue Point (the two most upriver stations).

Average river water temperatures ranged between 20 and 30 degrees C throughout the sampling period reaching a maximum in late July (Figure S11A). Given the lack of historical data for the Great Wicomico River, temperature and salinity during 2005 could only be compared with the previous 5 year mean 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 degrees C) than the long term average for most of June into mid July, higher (1 degree C) than the long term average for the latter half of July, became similar to the long term average for the entire month of August then was higher (1 to 3 degrees C) for the month of September (Figure S11A). Salinity ranged from 10 to 18 ppt during the sampling period and rose continuously throughout the season. Low salinities prevailed from early June through late July (Figure S11B). During the months of June and July, salinity was between 1 and 4 ppt lower than the previous 5-year mean (Figure S11B). Salinity was higher (1 to 2 ppt) than the long-term average for most of August into the first part of September. There was a 1 to 2 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, a slightly lower difference than that observed in past years.

DISCUSSION

With few exceptions in each of the rivers during various years, low spatfall (< 10 spat shell^{-1}) has been common in Virginia since 1993. Settlement during 2005 in the James River was lower than

2004 and among the lowest observed over the past 15 years at several of the stations monitored. While settlement in the Piankatank River was higher during 2005 than 2004 at five out of the eight sites, 2004 marked the third year in a row with low settlement. The Great Wicomico River was marginally better and settlement during 2005 was within the middle of the range for what has been observed in the system over the past 15 years.

In both the James and Piankatank Rivers, the settlement that was observed, did not occur until very late in the season with the majority of the settlement occurring during the last two weeks of September. Both of these systems had slightly lower than normal temperatures and salinities in the early part of the sampling period. Settlement didn't begin in either system until salinities reached average or slightly higher than average (James River) and temperatures reached around 30(C. The interesting thing is that the Great Wicomico River showed similar patterns in both temperature and salinity, as that observed in the Piankatank River throughout the season except with even greater differences in salinity when compared with the long-term mean. Despite this the majority of the settlement in the Great Wicomico River occurred early in the season while both salinity and water temperatures were below average.

One 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. Oysters were moved from Sarah's Creek off the York River and placed on Shell Bar Reef in the Great Wicomico River on a weekly or bi-weekly basis throughout the sampling period. The majority of these oysters were in the 40-50 mm size range, but there were several times during summer 2005, when larger (> 60 mm) oysters were moved. The first occurred approximately two weeks before the big pulse in settlement was observed in the system (VIMS Molluscan Ecology Lab, unpublished data). During that time the salinity in the York River was several parts per thousand higher and the temperature was several (C lower than in the Great Wicomico River. Changes in water temperature has long been recognized as a means of manipulating oysters to spawn in hatchery conditions (Loosanoff & Davis 1963) and Butler (1956) postulated that rapid changes in temperature may be just as important as some "critical" level being obtained. While variations in salinity do not appear to stimulate spawning in C. virginica, some oyster species that live in monsoon climates have been shown to spawn in response to a decrease in salinity (Joseph & Madhyastha 1984). It is possible the combination of these two factors, an increase in temperature and a decrease in salinity, stimulated the oysters that were moved into the Great Wicomico River to spawn. There was a second movement of larger oysters into the system later in the season, but by that time temperature and salinity in the York and Great Wicomico Rivers were similar.

The oyster population in the Piankatank River has been in serious decline over the past several years and only six out of the past 15 years have been heavy settlement years (at least one station with greater than 10 cumulative spat shell-1. The lack of settlement in the Piankatank could be due to a lack 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 or the number of eggs produced per oyster increases exponentially with an increase in biomass (Cox & Mann 1992, Mann & Evans 1998). Both oyster population numbers and sizes in the Piankatank River have been in decline over the past three to four years (Part II of this report).

Settlement in the James River during 2005 was also among the lowest observed over the past 15 years. There are several possible reasons for this. For one, water temperatures were lower than average during the first few weeks of observations. Gametogenesis (gonadal development) and water temperature are directly correlated (Shumway 1996). Lower spring water temperatures may have delayed gonadal development. Monthly examination of oysters at Horsehead during the spawning season revealed that the meats of the oysters were watery and generally in poor condition (Southworth, unpublished data). Disease levels during 2005 were also higher than they were in the previous few years (Dr. Ryan Carnegie, VIMS, personal communication). Despite low salinity during 2004, there was still moderate settlement in the James River. This was thought to be due to the large number of 2002 spat surviving at the more downriver sites (Southworth et al. 2005). While there were still a good number of oysters at these more downriver sites during 2005, disease levels had increased such that 50% of the oysters had moderate to heavy Perkinsus infections (Dr. Ryan Carnegie, VIMS, personal communication). Choi et al. (1994) found a negative correlation between the intensity of Perkinsus infection and the rate of gonadal development suggesting that Perkinsus retards gamete development. This disease aspect may also help explain why despite good temperatures and salinities throughout the season, what little settlement was observed was in the latter part of the season.

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

STATION	5/27	6/3	6/10	6/17	6/24	7/1	7/8	7/15	7/22	7/29	8/5	8/12	8/19	8/26	9/2	9/9	9/16	9/23	9/30	YEAR
	147	154	161	168	175	182	189	196	203	210	217	224	231	238	245	252	259	266	273	TOTAL
James River																				
Deep Water Shoal	D	0	0	0	0	0	0	0	0	0	0	0	0.18	-	0.08	-	0.3	0.29	0.18	1.03
Horsehead	D	0	0	0	0	0	0	0	0	0	0.05	0	0	-	0.05	-	0.10	0.88	0.18	1.26
Point of Shoal	D	0	0	0	0	0	0	0	0	0	0	0	0.09	-	0.05	-	0.03	0	0.96	1.13
Swash	D	0	0	0	0	0	0	0	0	0.06	0.10	0.10	0.09	-	0.05	-	0	0.65	0.35	1.35
Dry Shoal	D	0	0	0	0	0	0	0	0.09	0.12	1.22	0.2	0.66	-	0.11	-	0.03	0.35	0.35	3.08
Rock Wharf	D	0	0	0	0	0	0	0	0	0	0.05	0.05	0.09	-	0.22	-	0	1.05	2.89	4.35
Wreck Shoal	D	0	0	0	0	0	0	0	0	0	0.75	0	0.35	-	0.03	-	0.10	1.11	0.79	3.13
Day's Point	D	0	0	0	0	0	0	0	0	0	0	0	0	-	0	-	0	1.34	0.30	1.64
Piankatank River																				
Wilton Creek	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.20	0.35
Ginney Point	D	0	0	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0.05	0.15	0.25
Palace Bar	D	0	0	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0.10	0.10	0.24
Bland Point	D	0	0	0	0	0	0	0	0	0.18	0	0.05	0	0.13	0	0.06	0	0.40	0.21	1.03
Heron Rock	D	0	0	0	0	0	0	0	0	0	0	0.05	0	0	0.05	0	0	0.25	0.05	0.40
Cape Toon	D	0	0	0	0	0	0	0	0	0.66	0	0.05	0	0.13	0	0	0	1.60	0.20	2.64
Stove Point	D	0	0	0	0	0	0	0	0	0.13	0	0	0	0.18	0.05	0.12	0	0.80	0.45	1.73
Burton Point	D	0	0	0	0	0	0	0	0	0.31	0	0	0	0.09	0	0	0	0.25	0.25	0.90
Great Wicomico River																				
Glebe Point	D	0	0	0	0	0.97	1.00	0	0	0	0	0.05	0	0	0	0	0	0	0	2.02
Rogue Point	D	0	0	0	0	1.05	1.15	0.05	0	0.13	0.05	0	0	0.18	0	0	0	0	0	2.61
Hilly Wash	D	0	0	0	0	0.96	0.45	0	0	0	0.10	0	0	0.09	0	0	0	0.05	0.27	1.92
Harcum Flats	D	0	0	0	0	0.36	0.45	0	0	0.09	0	0	0	0.09	0.20	0.12	0	0.20	0	1.51
Hudnall	D	0	0	0	0	0.44	0.15	0.11	0	0.04	0	0	0	0	0	0.12	0	0.05	0	0.91
Shell Bar	D	0	0	0	0	0.18	0.40	0.10	0	0	0.10	0	0	0.04	0	0.06	0	0	0	0.88
Haynie Point	D	0	0	0	0	0.22	0.35	0	0	0	0.06	0	0	0.09	0	0.06	0	0	0	0.78
Whaley's East	D	0	0	0	0	0.18	0.10	0	0	0.04	0	0	0	0	0	0	0	0.10	0	0.42
Fleet Point	D	0	0	0	0	0.04	0.05	0	0	0	0	0.05	0	0	0.05	0.12	0	0	0.05	0.36

Table S2: Spatfall totals for historical sites (1988-2005) and for 1998-2005 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 2005 in reference to 2004 and to the five, ten, and fifteen-year means. Blank cells for a site indicate years where data are not available.

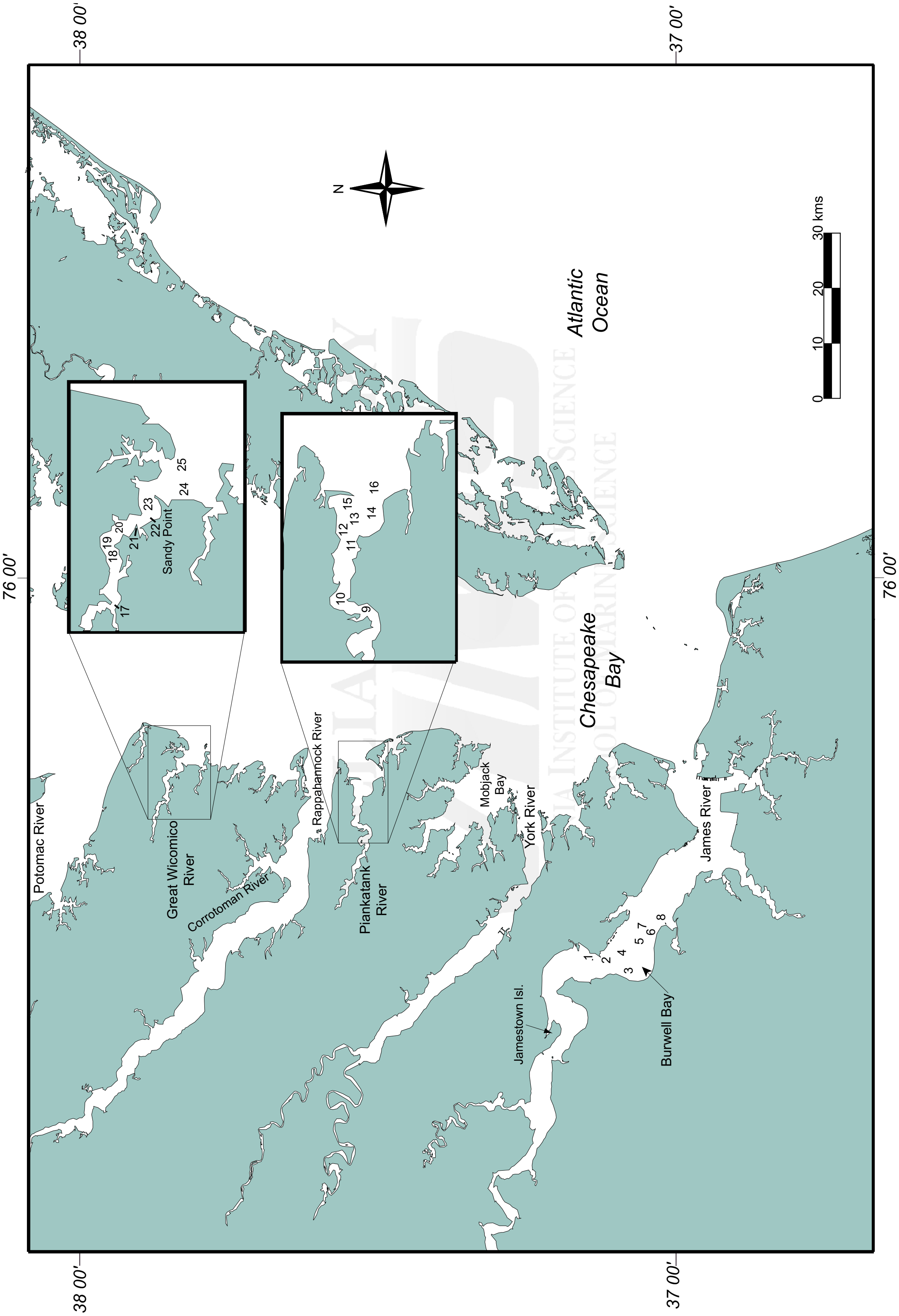
STATION	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Mean 00-04	Mean 95-04	Mean 90-04	Ref. 2004	Ref. 5-yr	Ref. 10-yr	Ref. 15-yr
James River																							
Deep Water Shoal	2.6	10.6	0.7	15.7	0.6	1.7	0.5	1.3	1.2	5.7	0.7	2.0	33.8	0.1	1.6	1.0	7.6	4.9	5.2	-	-	-	-
Horsehead	0.9	24.7	3.6	43.7	3.2	0.3	3.6	2.4	1.1	3.8	2.3	4.0	24.4	0.0	3.6	1.3	6.9	4.6	8.1	-	-	-	-
Point of Shoal	14.3	21.4	5.4	73.7	15.0	4.8	2.3	2.3	1.5	3.5	0.7	4.0	31.3	0.1	3.1	1.1	7.8	5.4	12.2	-	-	-	-
Swash	3.3	68.7		46.2	4.8	1.8	2.2	1.7	1.6	6.8	2.6	3.5	26.0	0.5	11.9	1.4	8.9	5.9	13.0	-	-	-	-
Dry Shoal	30.9	217.1	14.2	119.0	25.8	2.8	11.0	1.1	1.1	6.1	3.7	2.1	16.5	0.6	8.7	3.1	6.3	5.4	30.7	-	-	-	-
Rock Wharf	1.8		11.4	34.3	10.7	0.2	2.4	5.6	2.1	8.0	1.0	8.5	22.7	0.1	10.0	4.4	8.5	6.1	8.5	-	-	-	-
Wreck Shoal	4.0	35.3	3.3	15.5	2.2	2.6	10.0	0.7	0.7	3.1	0.9	3.2	8.3	1.3	21.6	3.1	7.1	5.2	7.5	-	-	-	-
Day's Point	22.4	145.6	14.2	131.5	42.2	3.0	4.6	5.6	0.4	7.3	4.3	1.6	10.5	0.1	3.6	1.6	4.0	4.1	26.5	-	-	-	-
Piankatank River																							
Wilton Creek									1.9	5.9	3.6	0.2	6.5	0.1	0.2	0.4	3.3			+	-		
Ginney Point	62.6	25.4	11.4	1.7	0.0	0.5	1.3	0.0	2.2	6.4	6.8	1.2	5.9	0.2	0.2	0.3	4.1	2.5	9.0	+	-	-	-
Palace Bar	119.2	38.9	24.9	5.0	0.8	1.0	1.6	0.0	5.5	10.1	3.9	0.2	3.1	0.1	0.5	0.2	3.5	2.6	15.3	-	-	-	-
Bland Point									2.3	44.1	2.7	1.3	6.7	0.2	0.4	1.0	11.0			+	-		
Heron Rock									10.1	9.3	3.2	0.6	5.1	0.2	0.7	0.4	3.7			-	-		
Cape Toon									4.5	12.3	1.2	1.8	9.1	0.1	2.0	2.6	4.9			+	-		
Stove Point									1.0	7.1	1.8	1.6	31.0	0.1	0.7	1.7	8.3			+	-		
Burton Point	87.4	16.4	11.7	6.5	0.1	1.0	1.0	0.7	1.3	14.9	2.7	0.8	4.9	0.2	1.9	0.9	4.7	2.8	10.7	-	-	-	-
Great Wicomico River																							
Glebe Point	19.5	1.9	0.5	0.2	0.0	1.5	0.6	21.2	0.6	2.4	4.2	1.1	283.3	4.9	1.6	2.0	59.2	32.0	24.4	+	-	-	-
Rogue Point									0.9	2.0	2.6	0.7	16.6	7.0	0.5	2.6	5.8			+	-		
Hilly Wash									0.6	1.6	3.2	0.8	24.1	2.9	0.5	1.9	6.5			+	-		
Harcum Flats									0.1	1.3	0.8	1.1	33.7	3.7	0.7	1.5	8.1			+	-		
Hudnall	94.8	4.5	0.5	0.8	0.0	0.1	0.2	39.1	0.5	0.9	1.0	1.4	12.7	3.1	0.6	0.9	3.8	5.9	11.4	+	-	-	-
Shell Bar									0	2.9	0.8	0.8	17.8	1.9	0.3	0.9	4.8			+	-		
Haynie Point	68.2	12.4	0.6	1.4	0.0	1.0	3.7	4.4	0.7	1.1	1.1	0.9	15.4	1.6	0.3	0.8	4.0	3.0	8.0	+	-	-	-
Whaley's East	39.1	7.9	0.1	0.2	0.0	0.3	2.1	1.0	0.4	1.8	0.2	0.7	2.4	0.9	0.1	0.4	1.2	1.0	4.1	+	-	-	-
Fleet Point	17.4	5.8	2.9	2.0	0.0	0.3	2.6	3.4	0.3	0.5	0.6	1.0	3.9	0.4	0.3	0.4	1.3	1.3	2.9	+	-	-	-

Figure S1: Map showing the location of the 2005 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
30 kms
0
10
20
30
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Jamestown Isl.
Burwell Bay
Sandy Point
1
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3
4
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Figure S2: Diagram of shellstring setup on buoys.

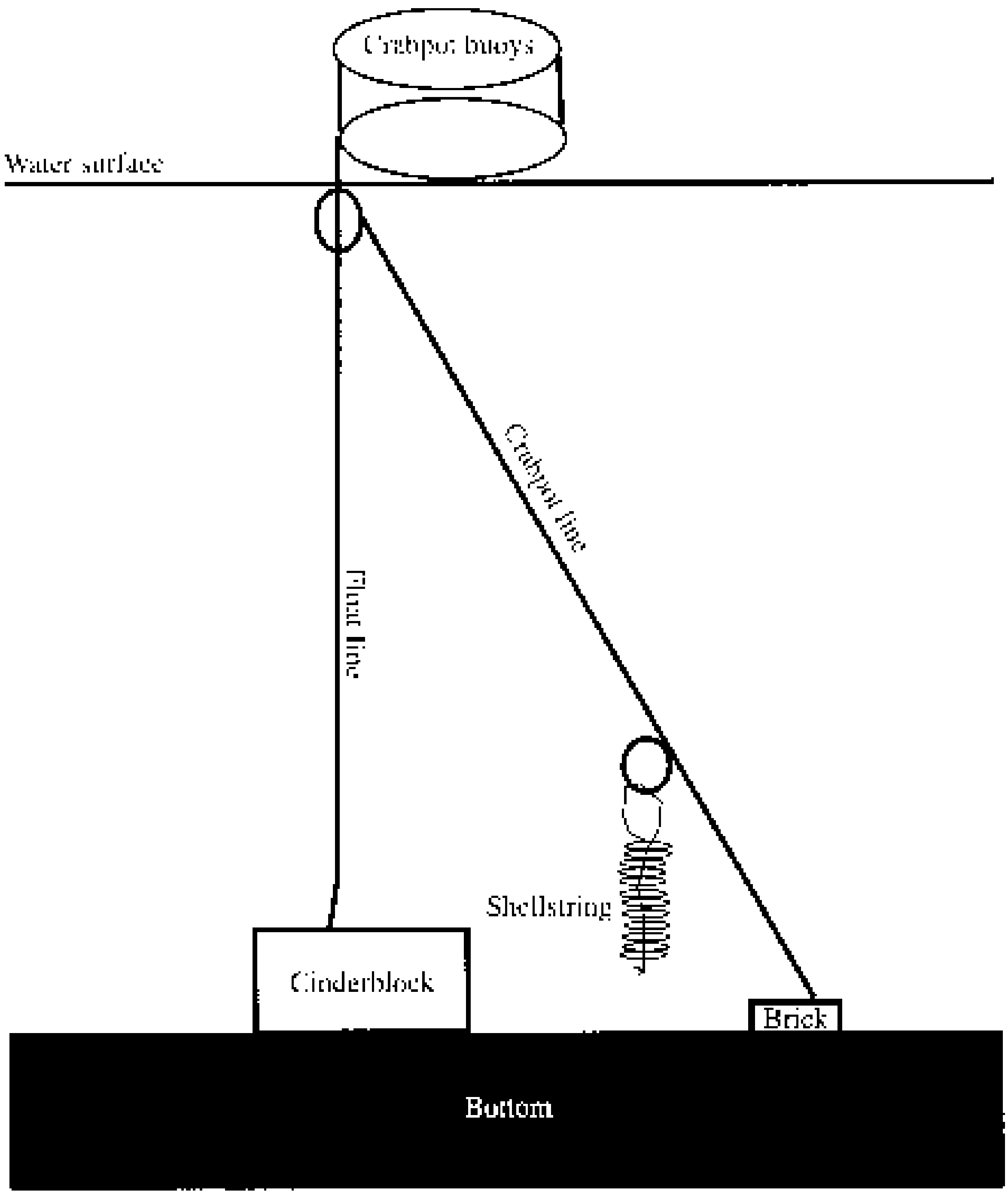


FIGURE S3: JAMES RIVER (2005) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$

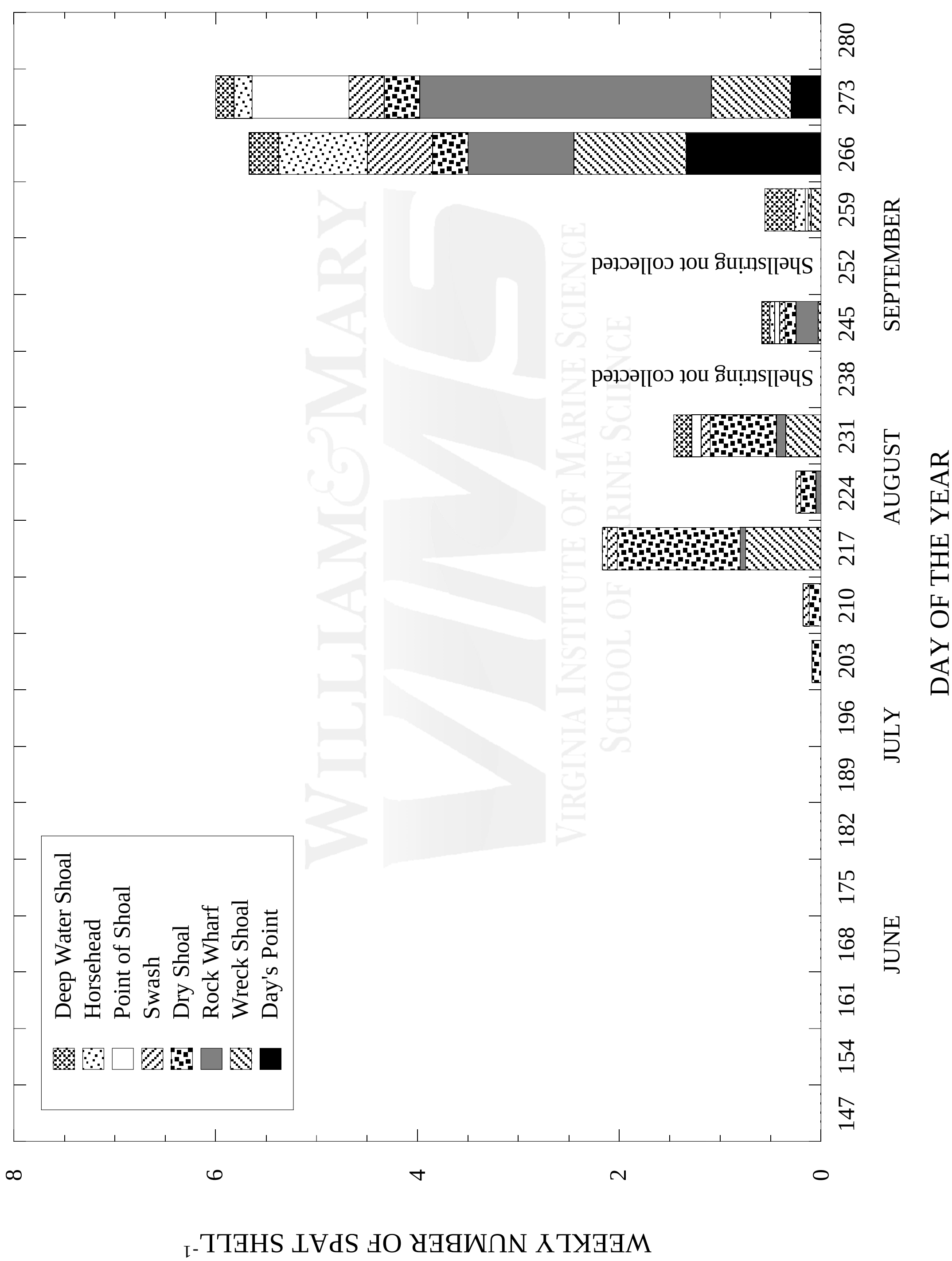


FIGURE S4: SPATFALL TRENDS OVER THE PAST 15 YEARS AT ALL 8 SITES IN THE JAMES RIVER (upriver sites in top panel; downriver sites in bottom panel) (expressed as cumulative weekly spatfall)

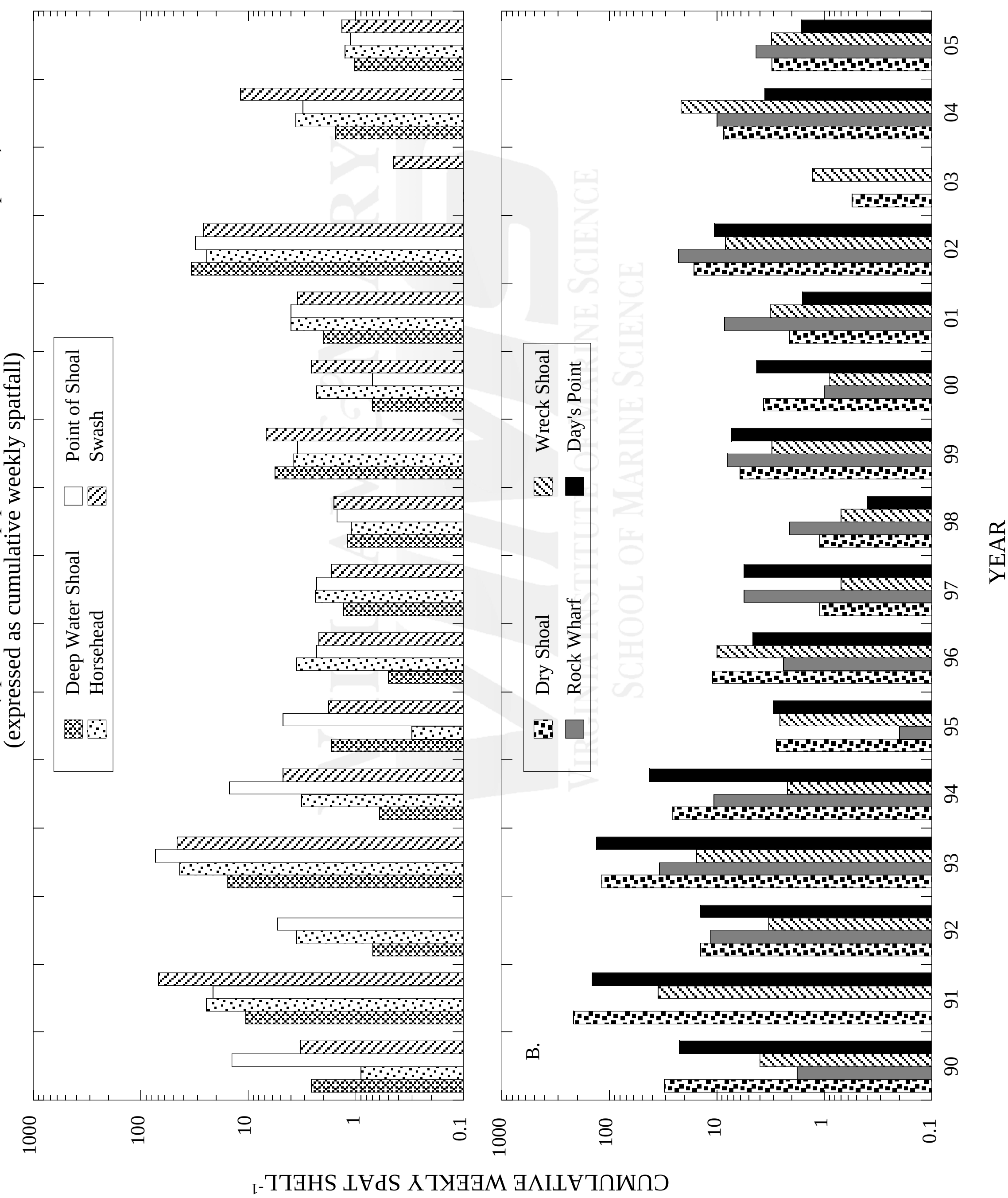


FIGURE S5: TEMPERATURE AND SALINITY IN THE JAMES RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 15-YEAR MEANS COMPARED WITH 2005 (Error bars represent standard error of the mean; shaded area represents settlement during 2005; n is the number of data points used to calculate the mean)

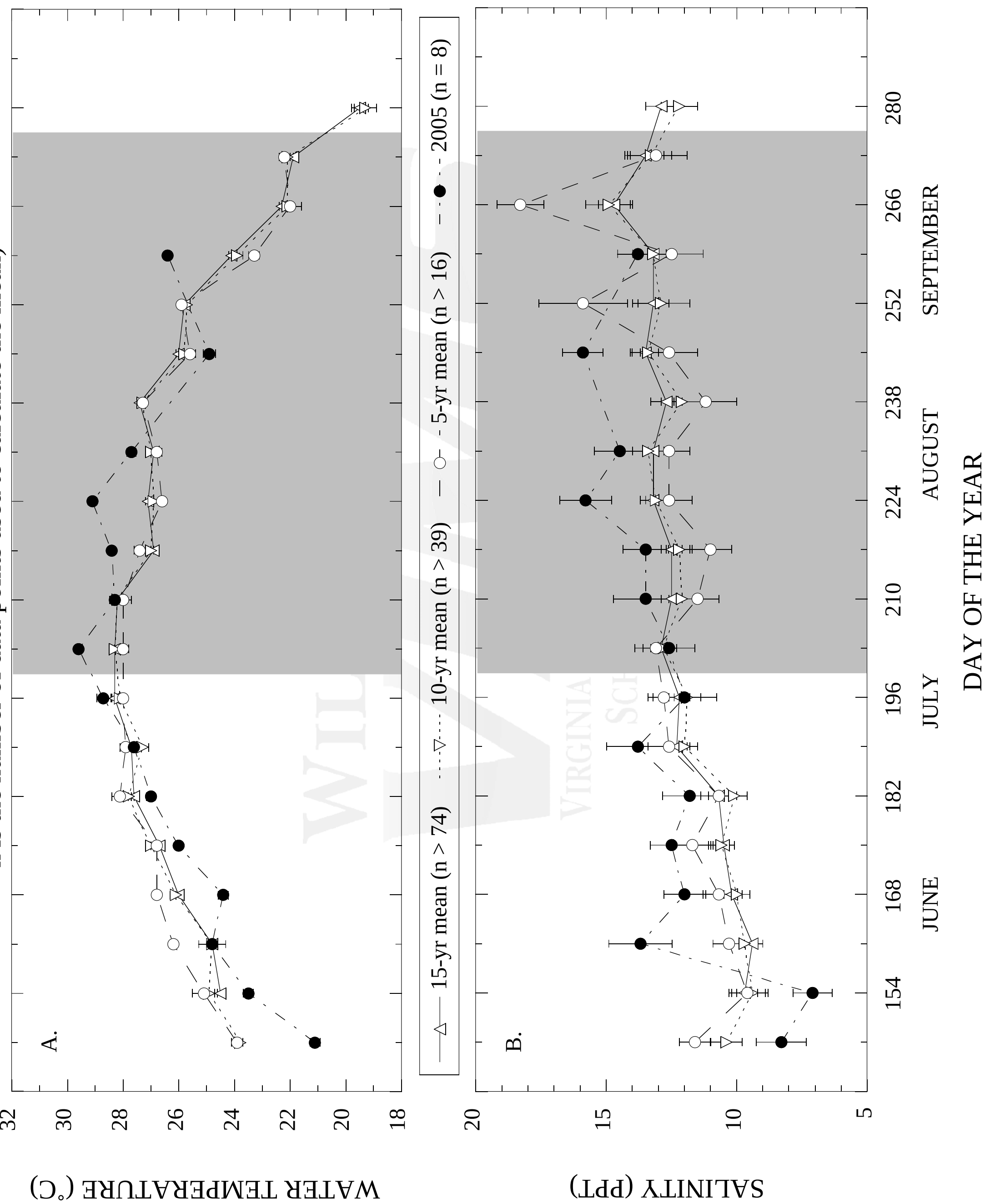


FIGURE S6: PIANKATANK RIVER (2005) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: N = new station as described in text)

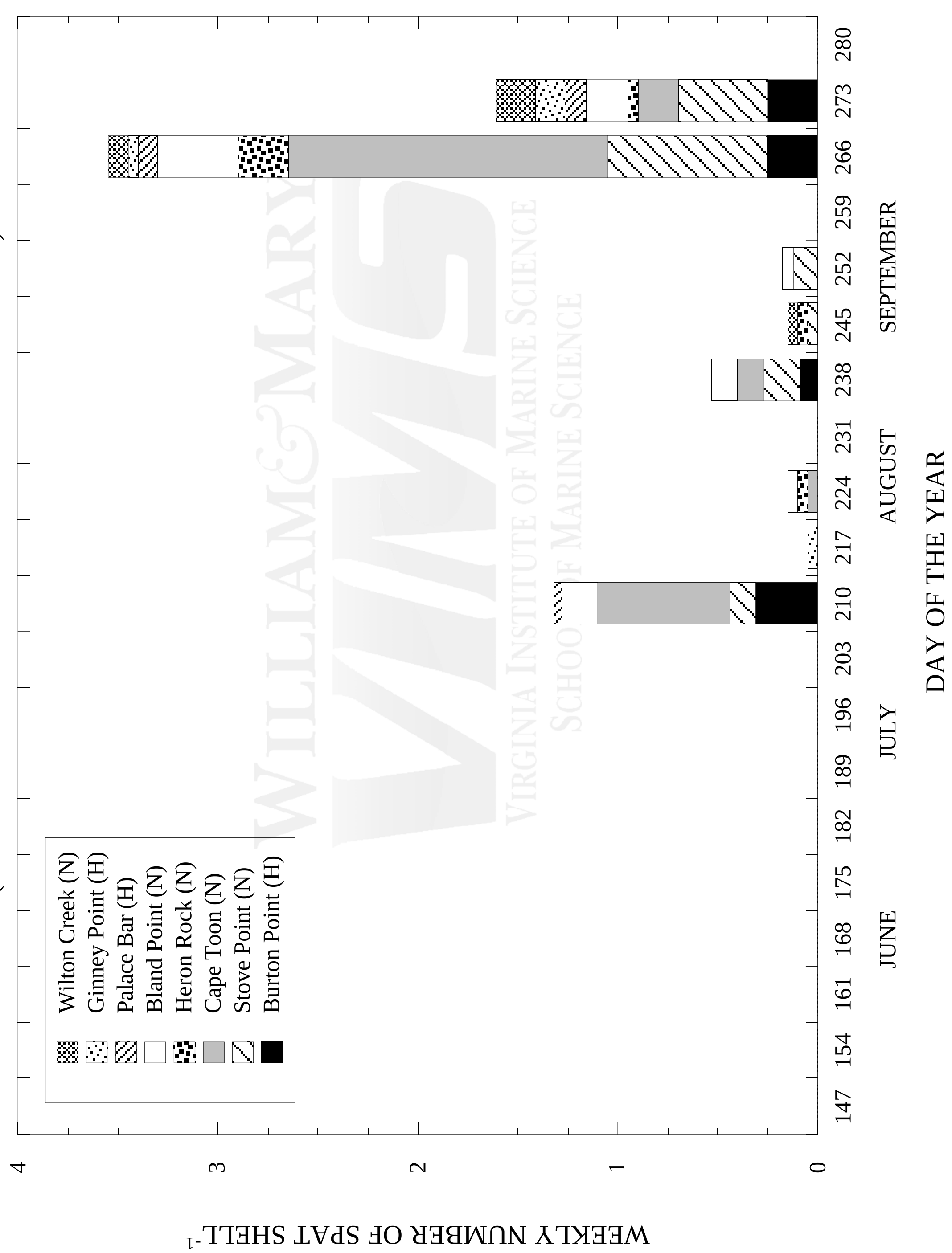


FIGURE S7: SPATFALL TRENDS IN THE PIANKATANK RIVER AT THE 3 HISTORICAL SITES (panel A: 15 years) AND THE 5 NEW SITES (panel B: 7 years)
(Expressed as cumulative weekly spatfall)

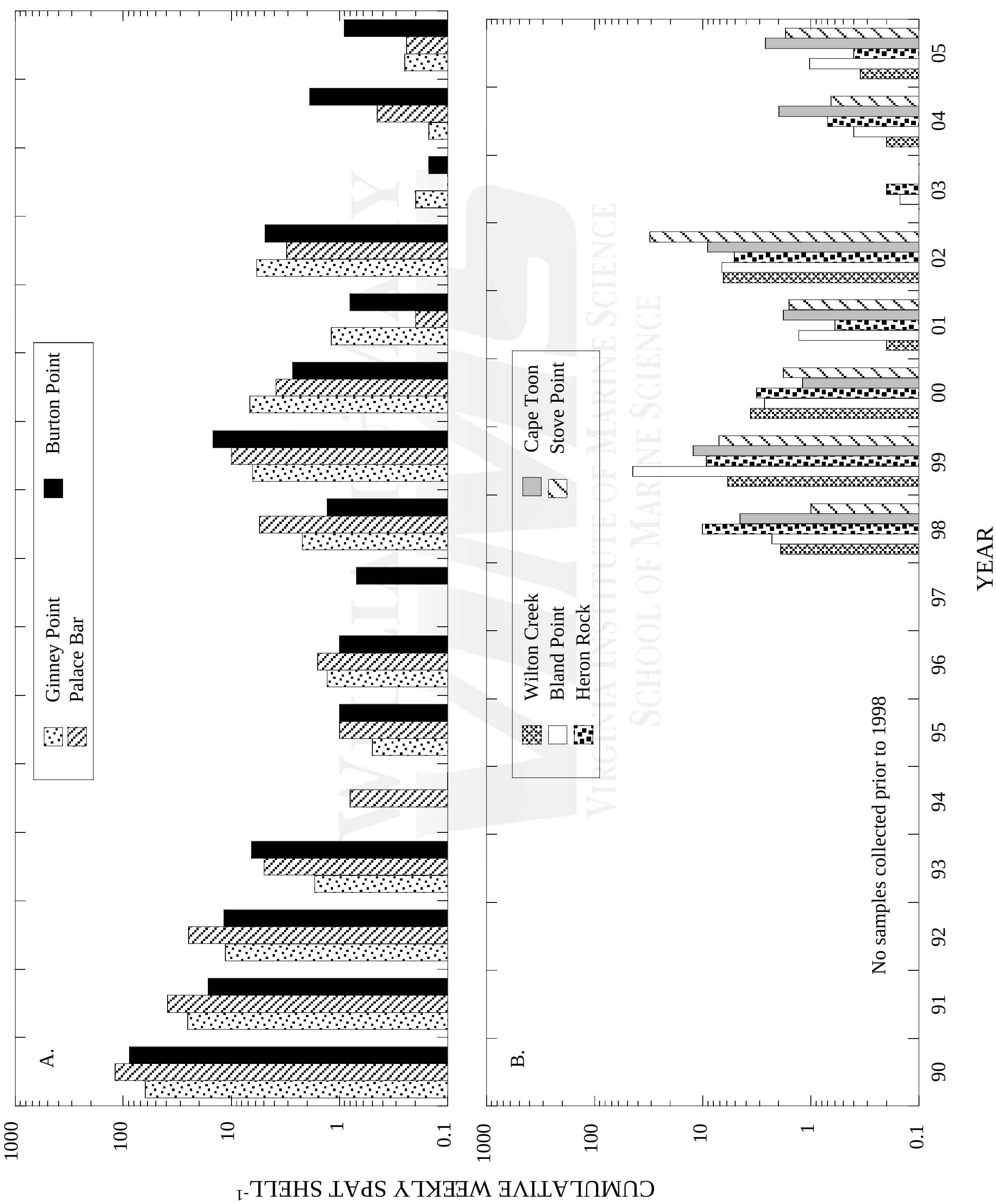


FIGURE S8: TEMPERATURE AND SALINITY IN THE PIANKATANK RIVER DURING THE SETTLEMENT PERIOD: 5, 10 AND 15-YEAR MEANS COMPARED WITH 2005
(Error bars represent standard error of the mean; shaded area represents settlement during 2005; n is the number of data points used to calculate the mean)

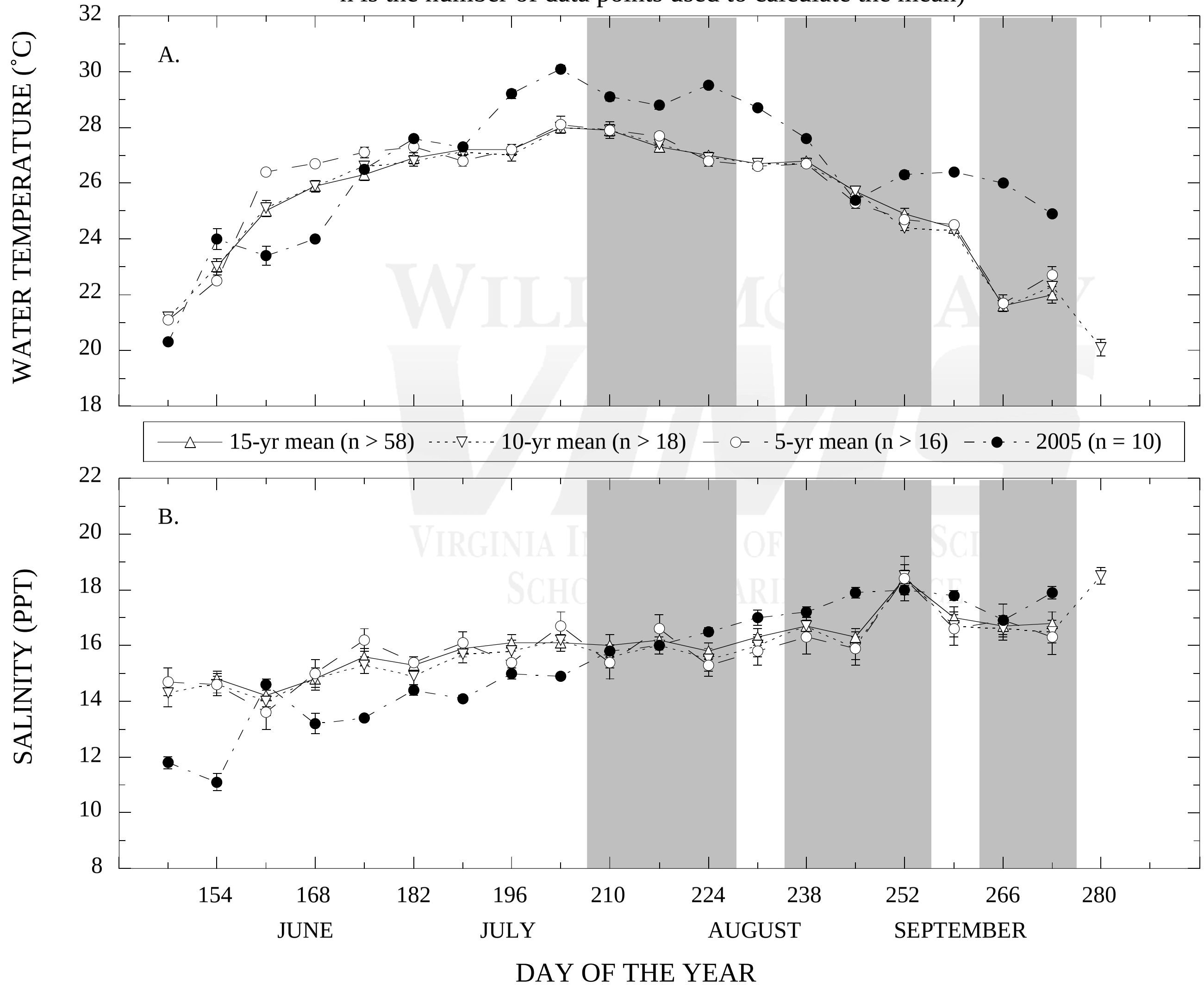


FIGURE S9: GREAT WICOMICO RIVER (2005) WEEKLY SPATFALL INTENSITY
EXPRESSED AS NUMBER OF SPAT SHELL $^{-1}$
(H = historical station: N = new station as described in text)

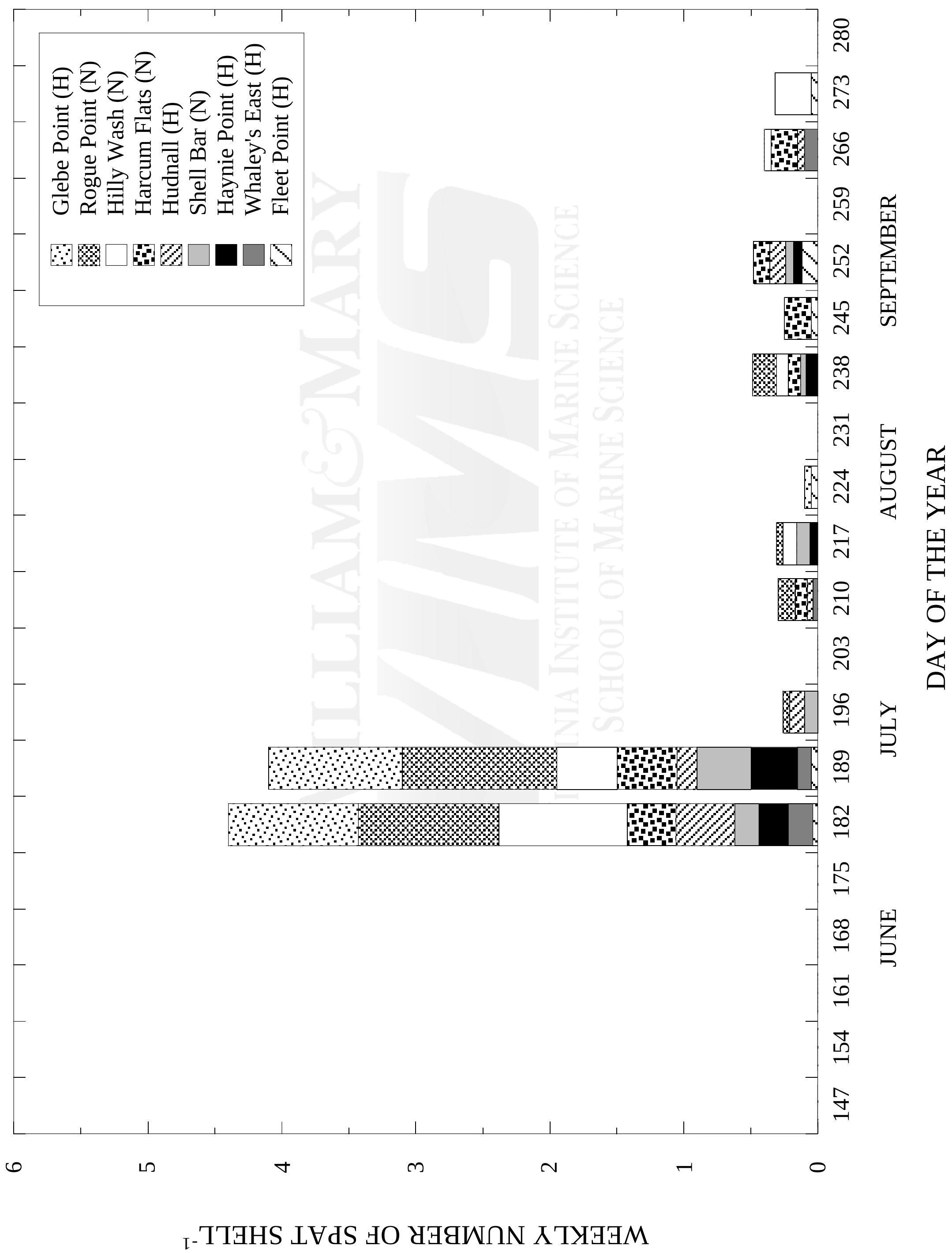


FIGURE S10: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER AT THE 5 HISTORICAL SITES (panel A: 15 years) AND THE 4 NEW SITES (panel B: 7 years) (Expressed as cumulative weekly spatfall)

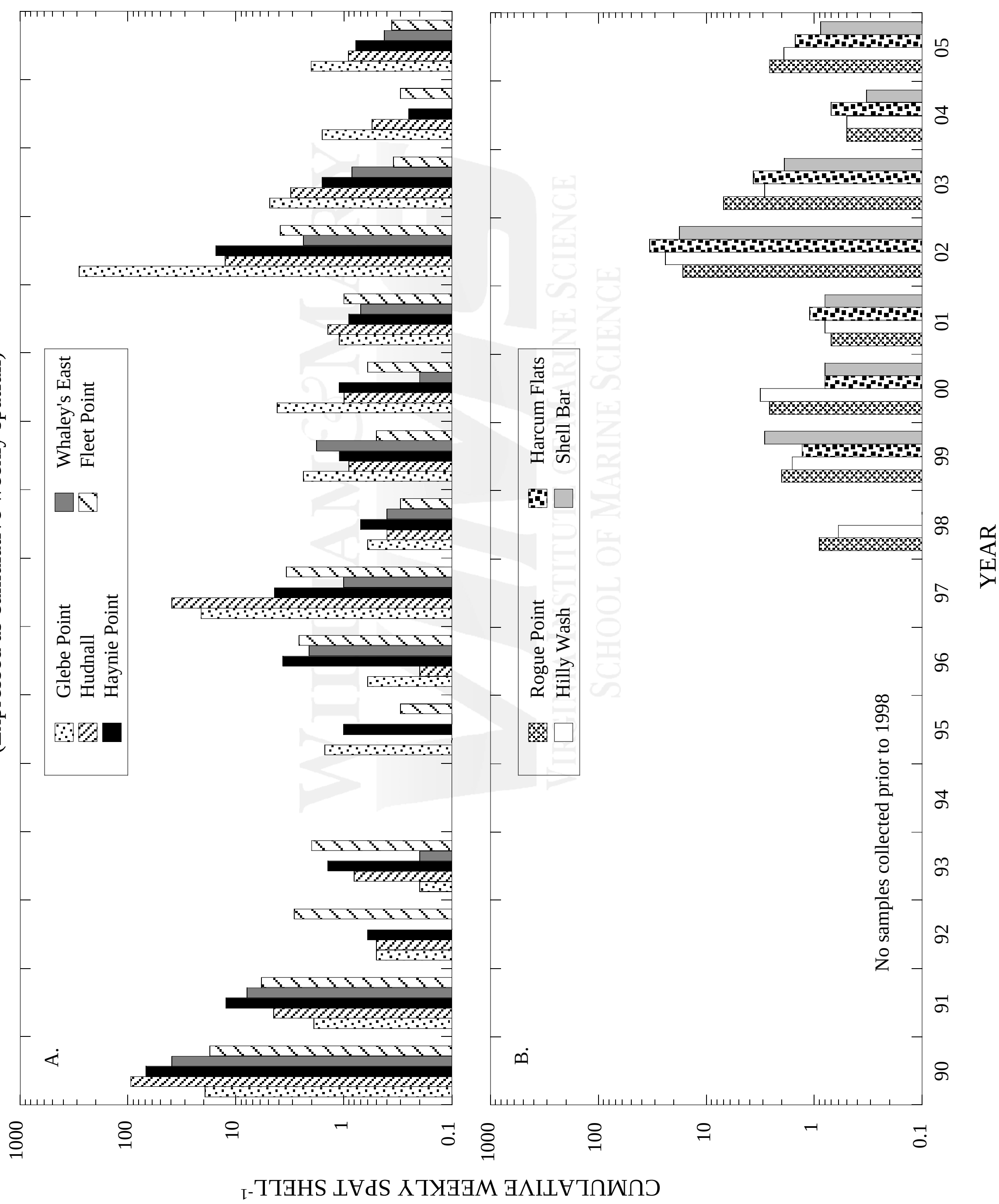
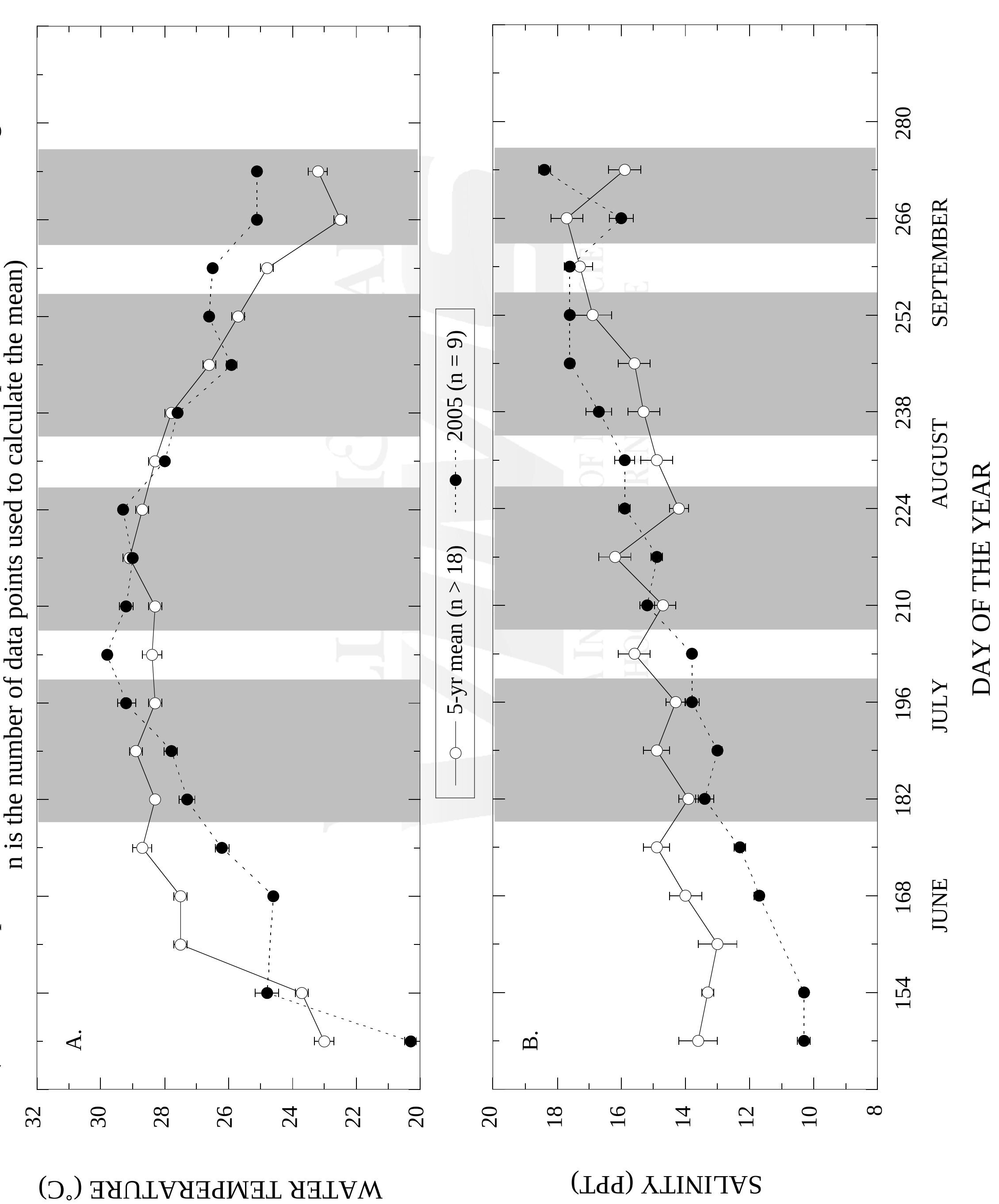


FIGURE S11: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE SETTLEMENT PERIOD: 5 -YEAR MEAN COMPARED WITH 2005
(Error bars represent standard error of the mean; shaded areas represent settlement during 2005; n is the number of data points used to calculate the mean)



Part II. Dredge Survey of Selected Oyster Bars in Virginia During 2005

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 during September and October 2004.

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 October 2005 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 2005) 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, 2005 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).

Beginning in February 2005 and continuing on a weekly or bi-weekly basis for the remainder of the year, broodstock oysters were planted on Shell Bar Reef in the Great Wicomico River (www.vims.edu/mollusc/NORM).

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 54 bu^{-1} at Deep Water Shoal to a high of 877 bu^{-1} at Dry Shoal.

The average number of market oysters in the James River remains low when compared with historical numbers. Point of Shoal had 102 market oysters bu^{-1}, a relatively high number compared to past years. Dry Shoal, Long Shoal, Horsehead, Swash and Wreck Shoal all had a moderate number of market oysters ranging from 31 (Dry Shoal) to 51 (Swash and Wreck Shoal) bu^{-1}. There was a slight increase in the number of market oysters at six out of the ten sites monitored when compared with 2004 (Figure D2). For the third year in a row, the number of market oysters at Deep Water Shoal was the lowest out of all of the stations monitored (Figure D3).

For the second year in a row, the number of small oysters at Dry Shoal and Wreck Shoal showed a substantial increase, while those at Deep Water Shoal, Mulberry Point, Horsehead and Point of Shoal showed a small decrease (Figure D2 and D3). Overall, the number of small oysters at Nansemond Ridge, Thomas Rock and Wreck Shoal has been on the rise for the past several years and are numbers are similar to those observed in the early 1990s after several years of very low numbers throughout the mid 1990s (Figure D3). Numbers of small oysters bu^{-1} ranged from a low of 30 at Deep Water Shoal to a high of 786 at Dry Shoal.

The average number of spat varied depending on location in the river, but was low throughout the system ranging from a low of 7 bu^{-1} at Point of Shoal to a high 65 bu^{-1} at Nansemond Ridge. This translated into a decrease in the number of spat at the six most down river sites when compared with 2004 (Figure D2), however it should be noted that spatfall during 2004 was among the highest observed during the past 15 years. 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 2005, but given the low spatfall throughout the system seven out of the ten sites had greater than 73% small oysters. While Deep Water Shoal had approximately a 60/40 split between small oysters and spat, once again for the third year in a row the overall number of live oysters at Deep Water Shoal was extremely low.

The average number of boxes bu^{-1} ranged from a low of 6 (Deep Water Shoal) to a high of 102 (Wreck Shoal). During 2005, boxes at Wreck Shoal, Thomas Rock and Nansemond Ridge accounted for a much higher percentage of the total oysters (live and dead) than during 2004 (greater than 15% versus less than 5%). Boxes at the other seven sites monitored accounted for less than 10% of the total (live and dead) oysters. There was a slightly higher percentage of new boxes observed throughout the river than has been observed in the past few years. The boxes observed at Deep Water Shoal were split 50/50 between small oysters and spat, but overall the number of boxes at that site was extremely low.

Water temperature during the sampling period ranged from 15.5 to 18.3 degrees C (Table D2). Salinity was variable depending on location in the river, increasing in a downriver direction, from 9.9 ppt at Deep Water Shoal to 18.5 ppt at Thomas Rock and 18.8 ppt at Nansemond Ridge.

York River

The average total number of live oysters bu^{-1} in the York River was 37 at Aberdeen Rock and 256 at Bell Rock. The live oysters at Aberdeen Rock and Bell Rock were predominately small; 68 and 92% of the total, respectively. There was a notable increase in the number of market oysters at Bell Rock for the second year in a row (Figure D4 and D5). Compared with 2004 numbers, the number of spat at Bell Rock during 2005 was remarkably low (Figure D4 and D5). While the total number of boxes (new and old) $bushel^{-1}$ was low at Aberdeen Rock (17 bu^{-1}) and moderate at Bell Rock (65 bu^{-1}), boxes accounted for 32 and 20% of the total oysters (live and dead) respectively. Of these greater than 25% were new boxes at both stations. Water temperature on the day of sampling was 21.9 degrees C at Bell Rock and 23.0 degrees C at Aberdeen Rock. There was a 4.5 ppt difference in salinity observed: 16.5 ppt at Bell Rock and 21.0 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters at Pultz Bar was low (2.5 bu^{-1}). There was a decrease in all size classes of oysters and 2005 marked the seventh year in a row with exceptionally low numbers of oysters at Pultz Bar (Figure D4 and D6). At Pultz Bar, there was a 50/50 split of live oysters and boxes and 60% of the boxes were spat boxes. Two out of the three total spat boxes observed had drill holes, indicating predation by oyster drills. At Tow Stake there were an average of 50.5 live oysters bu^{-1} and 97% of these were small oysters. There was a notable decrease in both market oysters and spat at Tow Stake when compared with 2004 numbers (Figure D4 and D6). The decrease in market oysters observed marked the fourth year in a row at that site (Figure D6). The total number of boxes was low (3.5 bu^{-1}) accounting for 6% of the total oysters (live and dead) observed. Of these boxes 71% were old boxes. Both spat boxes observed at Tow Stake appeared to be caused by oyster drills (as indicated by the presence of a drill hole). Water temperature was approximately 22 degrees C and salinity was approximately 21 ppt at both stations (Table D2) on the day of sampling.

Piankatank River

The average total number of live oysters bu^{-1} in the Piankatank River was low at all three stations ranging from 4.5 at Ginney Point to 23.5 at Palace Bar. The number of market oysters throughout the system had been on a steady, but slow increase since the mid 1990s, but 2005 marked the second year in a row with no market oysters at Ginney Point and the first year in the last five with a notable decrease at Burton Point (Figure D7 and D8). Ginney Point continues to have low numbers of oysters with little recruitment to replace the dead oysters. There was a substantial decrease in the number of small oysters at all three sites when compared with 2004 numbers (Figure D7). For the third year in a row, there was a relatively low number of spat throughout the system, the lowest observed over the past 15 years at all three stations monitored (Figure D8). The number of small oysters was also the lowest observed over the past 15 years of sampling

(Figure D8). The low number of live oysters throughout the system was coupled with a high number of boxes. The average total number of boxes bu^{-1} was greater at all three stations than the average total number of live oysters bu^{-1} accounting for 63 (Palace Bar), 72 (Burton Point) and 77% (Ginney Point) of the total oysters (live and dead). Water temperature on the day of sampling was approximately 22 degrees C at all three sites. Salinity ranged between 17.1 (Ginney Point) and 18.6 ppt (Burton Point; Table D2).

Rappahannock River

The average total number of live oysters bu^{-1} in the Rappahannock River was low at all ten stations sampled ranging from 4 (Middle Ground) to 95 (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 seen in the James River. Six out of the ten stations sampled had some spatfall, with an average of 3.3 spat bu^{-1} while the other four stations sampled had no spat.

The average number of market oysters bu^{-1} ranged from 0.5 (Middle Ground) to 41.5 (Broad Creek). The number of market oysters at Ross Rock has been slowly increasing since about 1998, and 2005 was the first year that showed a notable decrease in market oysters at that station (Figures D9 and D10). The number of market oysters at Broad Creek has remained relatively steady since about 1994 with a slight increase observed during 2005 (Figure D10). There was a notable decrease in the number of market oysters at Middle Ground when compared with 2004 (Figure D9). For the fourth year in a row, Drumming Ground near the mouth of the Corrotoman River had the highest number of small oysters bu^{-1} with 56.5, but this was a notable decrease from that observed during 2004 (Figure D9 and D10). When compared with 2004 numbers, there was a notable decrease in small oysters at the seven most downriver stations (Figure D9). While there was a small increase in spat at Drumming Ground, recruitment throughout the Rappahannock River remains at a very low level. Settlement at the five most upriver stations, while low or absent during 2005, was typical for those sites (historically characterized by low spatfall), whereas settlement at the five most downriver stations (which were historically higher) was among the lowest observed during the past 15 years of monitoring (Figure D10).

The average total number of boxes bu^{-1} ranged from 0.5 (Long Rock) to 74.5 (Middle Ground). Boxes accounted for greater than 32% of the total (live and dead) at four of the five most downriver stations. The large number of boxes observed at Middle Ground accounted for 95% of the total (live and dead) oysters counted. The only spat box observed was at Drumming Ground which also had the highest number of live spat.

Water temperature during the sampling period ranged from 19.7 to 22.0 degrees C. Salinity increased moving from the most upriver station (Ross Rock: 10.0 ppt) toward the mouth (Broad Creek: 19 ppt).

Great Wicomico River

The average total number of live oysters bu^{-1} in the Great Wicomico River was very low averaging 5.0 (Whaley's East), 12 (Fleet Point) and 39 (Haynie Point). The live oysters found were predominately small oysters and spat at all three stations sampled. Compared with 2004, there was a notable decrease in the number of small oysters at all three stations monitored and a notable decrease in market oysters at Whaley's East and Fleet Point (Figures D11 and D12). Settlement in the Great Wicomico River during 2005 was once again extremely low and while there was a notable increase in spat at Haynie Point when compared with 2004, settlement throughout the river was still among the lowest observed during the past 15 years of monitoring (Figure D12). As in the Piankatank River there were a large number of boxes accounting for 47 (Haynie Point), 56 (Whaley's East) and 86% (Whaley's East) of the total number of oysters (live and dead). There were more boxes than live oysters observed at both Whaley's East and

Fleet Point. There were no spat boxes observed in any of the samples collected in the Great Wicomico River. Water temperature was approximately 19 degrees C and salinity was around 18.5 ppt at all three stations 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). In recent years 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 (mean of 20 market oysters bu^{-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 three to four years however this trend has been less apparent. During 2005 only the oyster populations in the James and York Rivers were composed primarily of small oysters. In the Piankatank and Great Wicomico Rivers, both of which had record low oyster populations, the live oysters were composed of either a 50/50 split between small oysters and spat or a 60/30 split of small oysters and spat with the remaining 10% being composed of market oysters. In the Rappahannock River market oysters dominated at six of the ten sites and small oysters dominated at the other four with no clear pattern based on location in the system.

Some caution must be used when interpreting the settlement data from the fall dredge survey. During years in which settlement occurs earlier, the spat are larger and thus easier to see, but have a higher mortality than in years when settlement occurs late in the season (Southworth et al. 2003). Most of the settlement in the James and Piankatank Rivers occurred late in September (Part I of this report), so at the time of sampling it is possible that some of the spat were too small to adequately see with the naked eye.

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 average) salinity and an increase in the populations of the adults located in the more downriver seed area (Figure D13). Despite populations in the lower part of the system remaining at a relatively high level, when compared with the mid 1990s, 2005 was still a low settlement year for the entire James River. Disease may have played a role in that both MSX and Perkinsus have been shown to have a detrimental effect in the development of the gonad (Choi et al. 1994, Ford & Figuereas 1988). In 2005, 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). This is also most likely the reason for the increase in boxes seen at the three most downriver stations during 2005.

Spatfall during 2005 was once again low

throughout the Piankatank, Rappahannock and Great Wicomico Rivers with an average of 3.5 spat bu^{-1}. In the Piankatank and Great Wicomico river systems, spatfall was among the lowest observed during the past 15 years of monitoring. As previously mentioned oyster recruitment in the upper Rappahannock has been extremely low for the past 15 years, while recruitment in the lower Rappahannock has been steadily decreasing to the levels observed in the upper part of the estuary. For the second year in a row, there was almost total recruitment failure in both the Piankatank and Great Wicomico Rivers during 2005. This fact coupled with the continual decreasing populations in the two systems is very alarming. The number of boxes observed in the two systems has been on the rise over the past few years with no apparent recruitment to compensate for the loss. Population levels, especially in the Piankatank may have reached such low levels that recovery may not be possible without increased restoration efforts in the system.

Oyster populations in Mobjack Bay, remain at low levels, this is especially apparent at Pultz Bar. The number of small oysters at Tow Stake have remained relatively stable over the past few years, this is promising if Tow Stake continues to get occasional good settlement like that seen during 2004. This is also true of Bell Rock in the York River, which has had a steady increase in small oysters, and a relatively stable population of market oysters during the past eight years. Bell Rock had a notable increase in the number of market oysters during 2005 when compared with 2004, despite some harvesting on the bar by the owner (Dr. Jim Wesson, VMRC, personal communication).

The average total number of boxes observed during 2005 was high in all systems except the James, accounting for greater than 30% of the total (live and dead) at twelve out of the twenty stations monitored in Mobjack Bay, the York, Rappahannock, Piankatank and Great Wicomico Rivers. Thomas Rock was the only station in the James River that had greater than 25% of the total oysters composed of boxes. There were a large number of boxes observed in both the Piankatank and Great Wicomico Rivers, greater than 50% at five out of the six stations in those two rivers. Some of the boxes in the Piankatank River could have been old boxes left over from the 2004 die-off (Southworth et al. 2005), but given the large decrease in live oysters throughout both of these systems many of the boxes were probably "new" at some point during 2005. The large numbers of boxes observed at Middle Ground in the Rappahannock River (95% of the total live plus dead) were a combination of all sizes classes. The die-off at this site may have been caused by low oxygen conditions during the summer months due to the oyster bar's proximity to the channel in the Corrotoman River. Low oxygen was prevalent throughout the lower stem of the Chesapeake Bay for a large portion of the summer and monitoring showed the largest-ever area of anoxia reported in the Bay (http://www.bayjournal.com/). This included areas in the Rappahannock, Piankatank, Great Wicomico and York Rivers.

There were a relatively low number of spat boxes observed at all of the sites monitored, which one would expect given the overall low number of spat. The majority of the spat boxes at both stations in the Mobjack Bay had drill holes. 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 drill eggmasses 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 52	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 05	76 44 58
	Aberdeen Rock	37 20 00	76 36 06
Mobjack Bay			
	Tow Stake	37 20 18	76 23 28
	Pultz Bar	37 20 22	76 23 16
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 35	76 44 08
	Long Rock	37 48 59	76 42 50
	Morattico Bar	37 46 55	76 39 33
	Smokey Point	37 43 07	76 34 48
	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 2005. York River station numbers (*) are based on two 1 bushel samples. 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	10/26	16.0	9.9	4	30.0	19.5	53.5	0.0	2.5	3.0	5.5
Mulberry Point	10/26	15.5	11.3	18.5	301.0	8.0	327.5	4.5	9.0	0	13.5
Horsehead	10/26	16.2	12.0	45.5	414.0	16.5	476.0	9.0	10.5	0	19.5
Point of Shoal	10/26	16.1	12.2	102.5	296.0	7.0	405.5	4.0	8.0	0	12.0
Swash	10/26	16.1	12.3	50.5	329.5	33.0	413.0	11.0	12.0	0	23.0
Long Shoal	10/26	16.1	12.6	35.5	560.0	37.0	632.5	9.0	18.5	0	27.5
Dry Shoal	10/26	16.0	14.0	30.5	7860	60.0	876.5	26.0	18.0	1.5	45.5
Wreck Shoal	10/24	18.2	17.0	50.0	466.0	58.0	574.5	33.0	64.0	5.0	102.0
Thomas Rock	10/24	18.3	18.5	21.0	47.0	33.0	101.0	11.5	27.5	1.5	40.5
Nansemond Ridge	10/24	18.3	18.8	14.5	34.5	65.0	114.0	1.0	18.5	1.5	21.0
York River*											
Bell Rock **	10/11	21.9	16.5	16.5	234.5	5.0	256.0	16.0	49.0	0	65.0
Aberdeen Rock	10/11	23.0	21.0	9.5	25.0	2.5	37.0	5.5	10.0	1.5	17.0
Mobjack Bay											
Tow Stake	10/10	22.8	21.6	1.0	50.0	0.5	51.5	0	2.5	1.0	3.5
Pultz Bar	10/10	22.3	21.3	0.5	1.5	0.5	2.5	0.5	0.5	1.5	2.5
Piankatank River											
Ginney Point	10/12	21.9	17.1	0	2.0	2.5	4.5	2.0	13.5	0	15.5
Palace Bar	10/12	22.0	17.7	2.5	12.5	8.5	23.5	1.0	39.5	0	40.5
Burton Point	10/12	21.6	18.6	5.0	7.5	4.0	16.5	0.5	42.0	0	42.5
Rappahannock River											
Ross Rock	10/14	19.7	10.0	12.0	38.5	0	50.5	0	2.5	0	2.5
Bowler's Rock	10/14	20.2	13.2	30.5	5.0	0	35.5	0	1.5	0	1.5
Long Rock	10/14	20.5	14.7	20.0	5.5	0	25.5	0	0.5	0	0.5
Morattico Bar	10/14	21.0	16.9	14.5	17.0	0.5	32.0	1.0	3.0	0	4.0
Smokey Point	10/14	20.6	15.9	16.5	3.0	0.5	20.0	0.5	2.5	0	3.0
Hog House	10/14	20.3	15.9	4.0	1.5	0	5.5	0	3.5	0	3.5
Middle Ground #	10/14	20.9	17.8	0.5	3.0	0.5	4.0	0	74.5	0	74.5
Drumming Ground	10/14	21.1	18.2	26.5	56.5	12.0	95.0	4.5	42.0	0.5	47.0
Parrot Rock	10/12	21.9	17.8	22.5	14.0	1.0	37.5	2.0	5.0	0	7.0
Broad Creek	10/12	22.0	19.0	41.5	20.5	5.0	67.0	2.0	30.5	0	32.5
Great Wicomico River											
Haynie Point	10/17	18.9	18.4	2.0	19.5	17.5	39.0	1.0	33.0	0	34.0
Whaley's East	10/17	19.1	18.7	0.5	3.0	1.5	5.0	1.5	30.0	0	31.5
Fleet Point	10/17	19.1	18.7	2.0	7.0	3.0	12.0	0	15.5	0	15.5

Figure D1: Map showing the location of the oyster bars sampled during the 2005 dredge survey.

James River: 1) Deep Water Shoal, 2) Mulberry Point, 3) Horsehead, 4) Point of Shoal, 5) Swash, 6) Long Shoal, 7) Dry Shoal, 8) Wreck Shoal, 9) Thomas Rock, 10) Nansemond Ridge.

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

Mobjack Bay: 13) Tow Stake, 14) Pultz Bar.

Piankatank River: 15) Ginney Point, 16) Palace Bar, 17) Burton Point.

Rappahannock River: 18) Ross Rock, 19) Bowler's Rock, 20) Long Rock, 21) Morattico Bar, 22) Smokey Point, 23) Hog House, 24) Middle Ground, 25) Drumming Ground, 26) Parrot Rock, 27) Broad Creek.

Great Wicomico River: 28) Haynie Point, 29) Whaley's East, 30) Fleet Point.

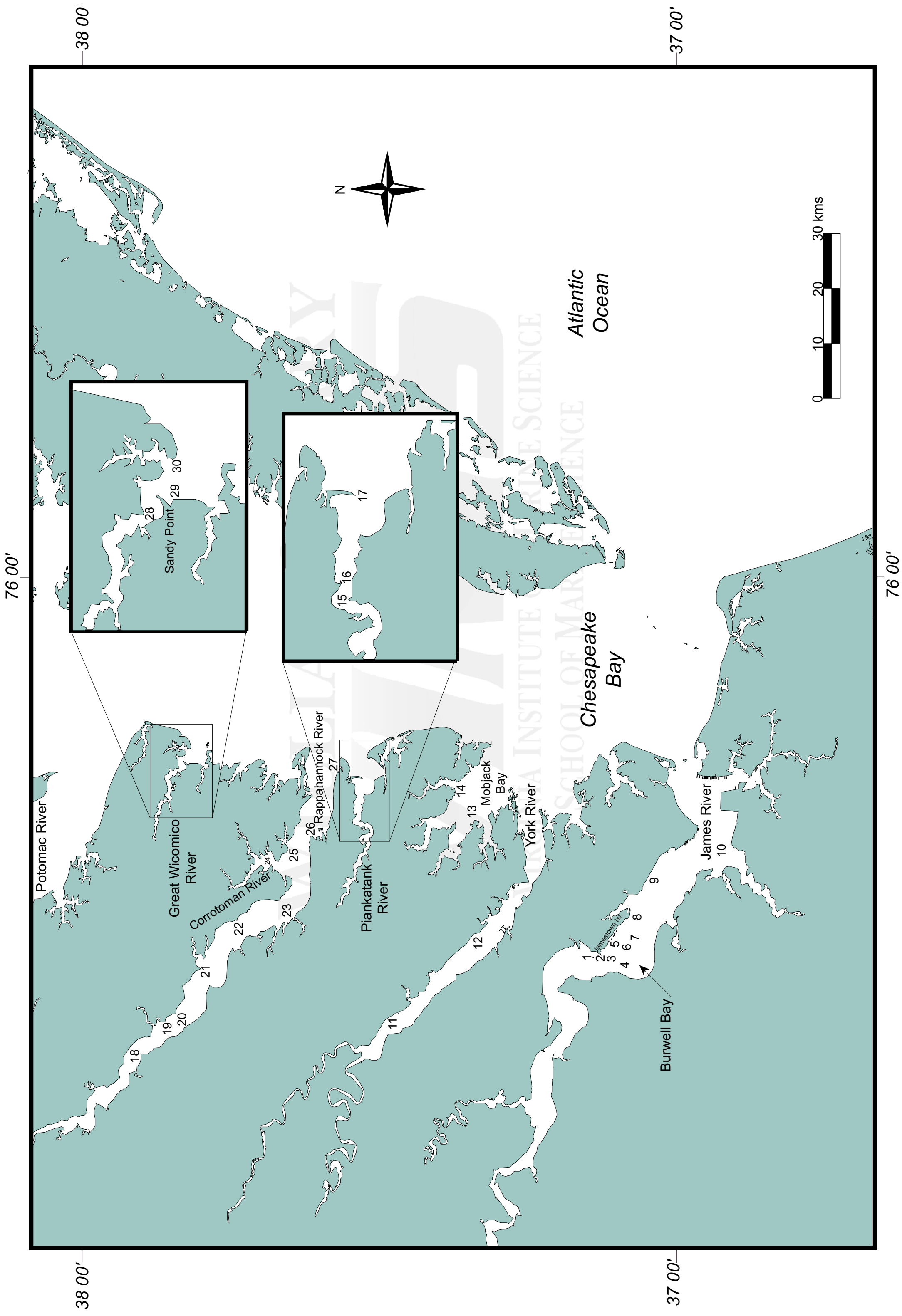

38 00'
37 00'
76 00'
N
Atlantic Ocean
Chesapeake Bay
0 10 20 30 kms
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Burwell Bay
Sandy Point
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 25 26 27 28 29 30

FIGURE D2: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY
IN THE JAMES RIVER (2004-2005)
(Error bars represent standard error of the mean)

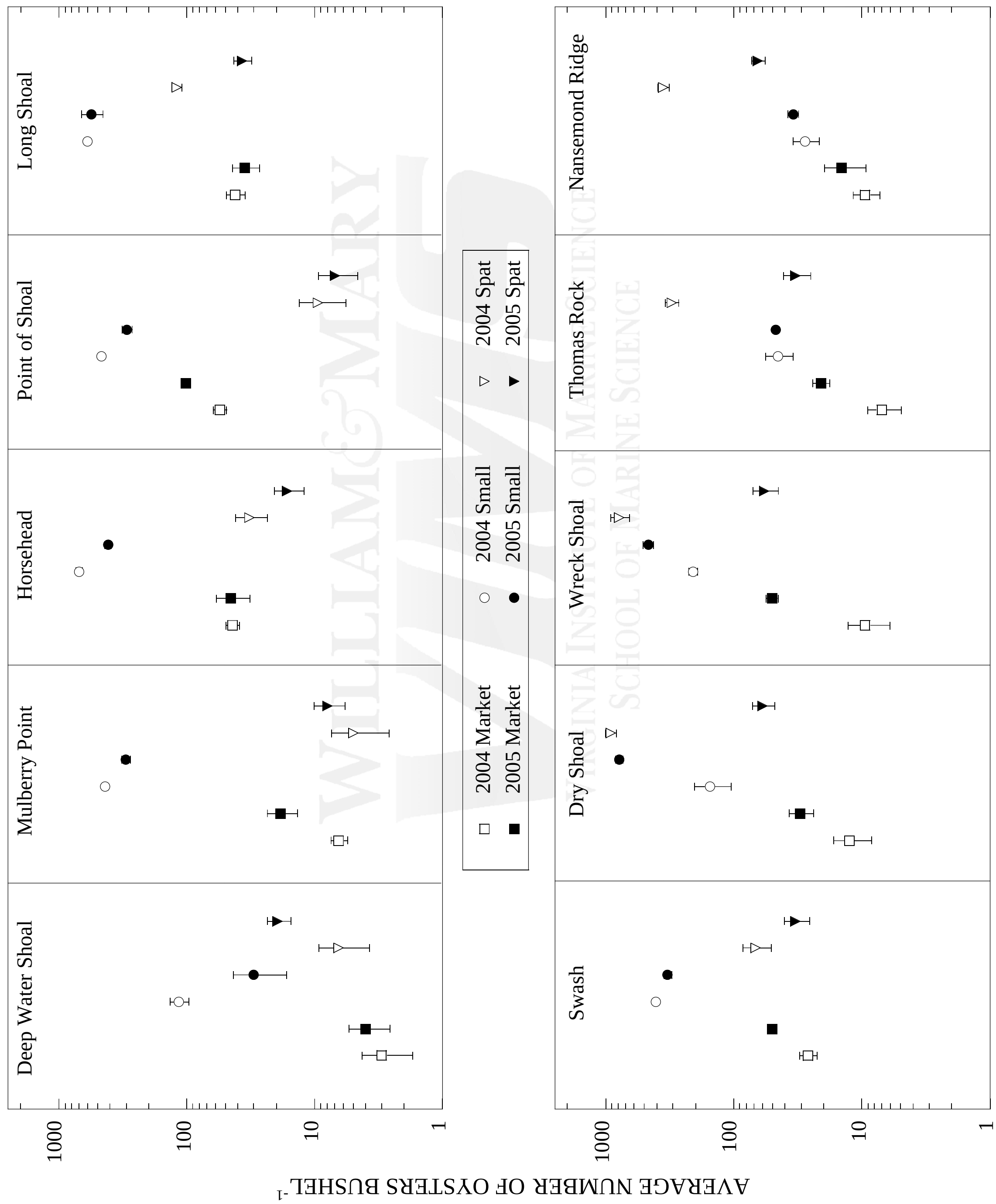


FIGURE D3: JAMES RIVER OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

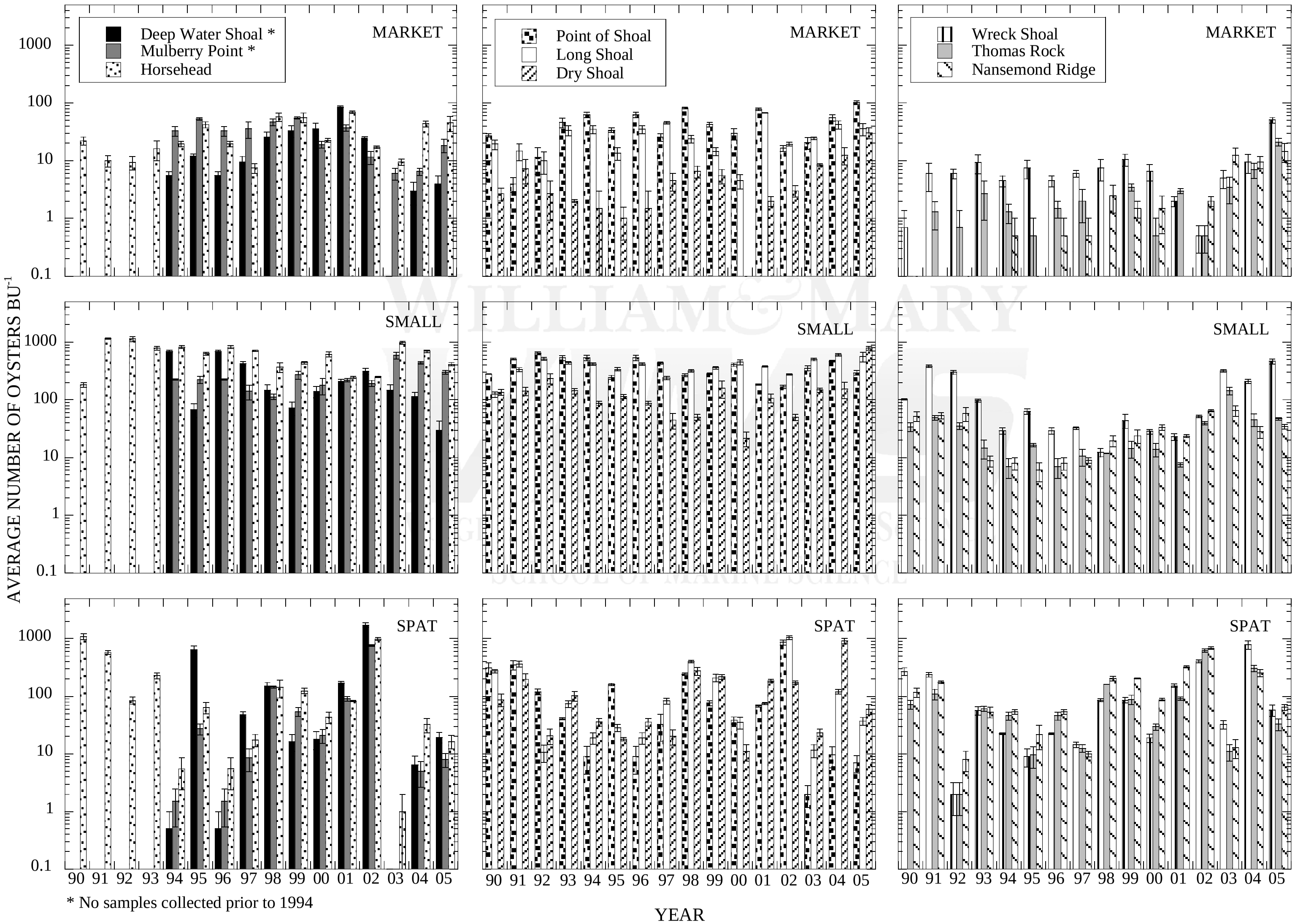
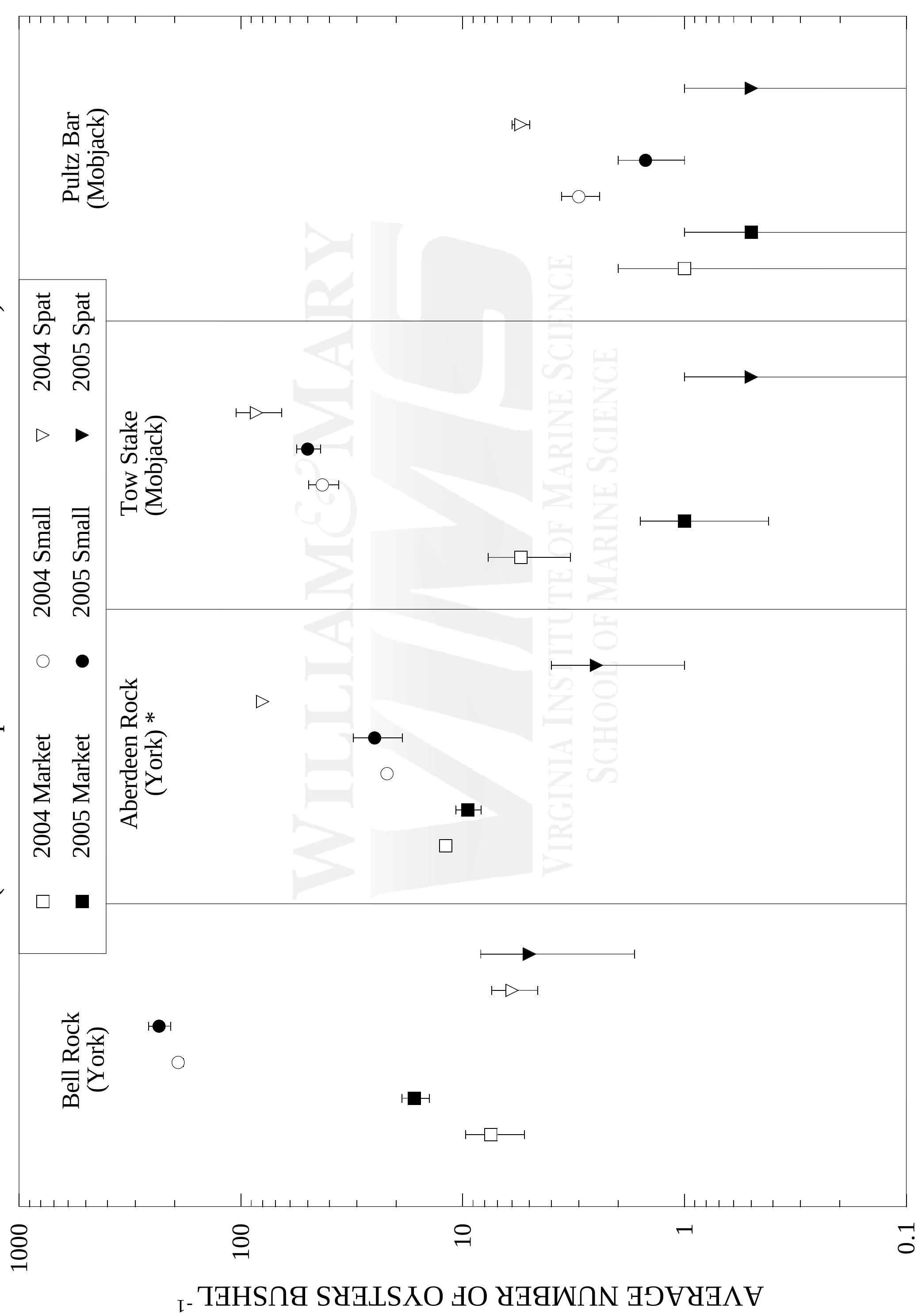


FIGURE D4: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE YORK RIVER AND MOBJACK BAY (2004-2005)
(Error bars represent standard error of the mean)



* No error bars at Aberdeen Rock for 2004 (numbers based on one 0.5 bu sample)

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

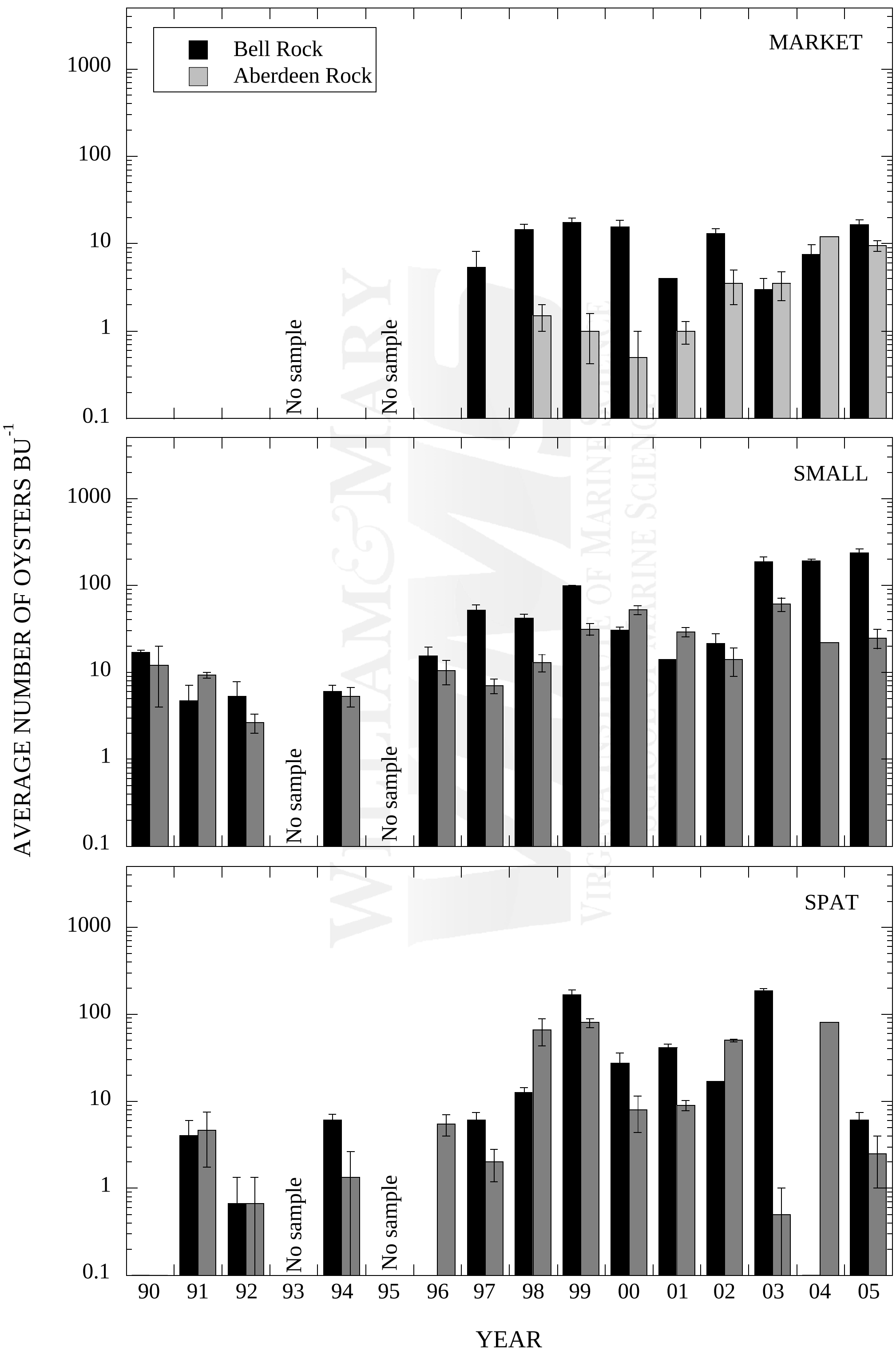


FIGURE D6: MOBJACK BAY OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

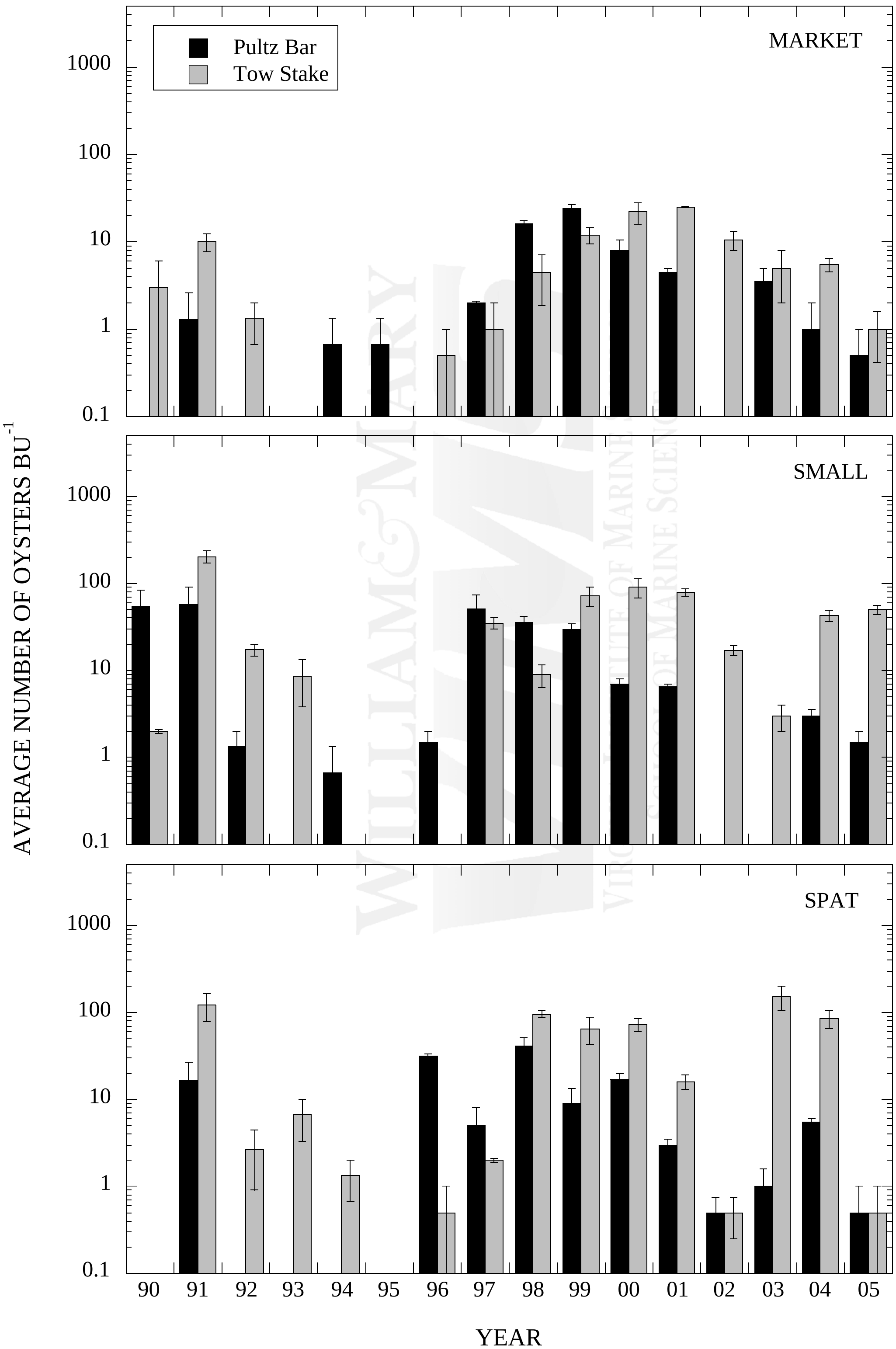


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE PIANKATANK RIVER (2004-2005)
(Error bars represent standard error of the mean)

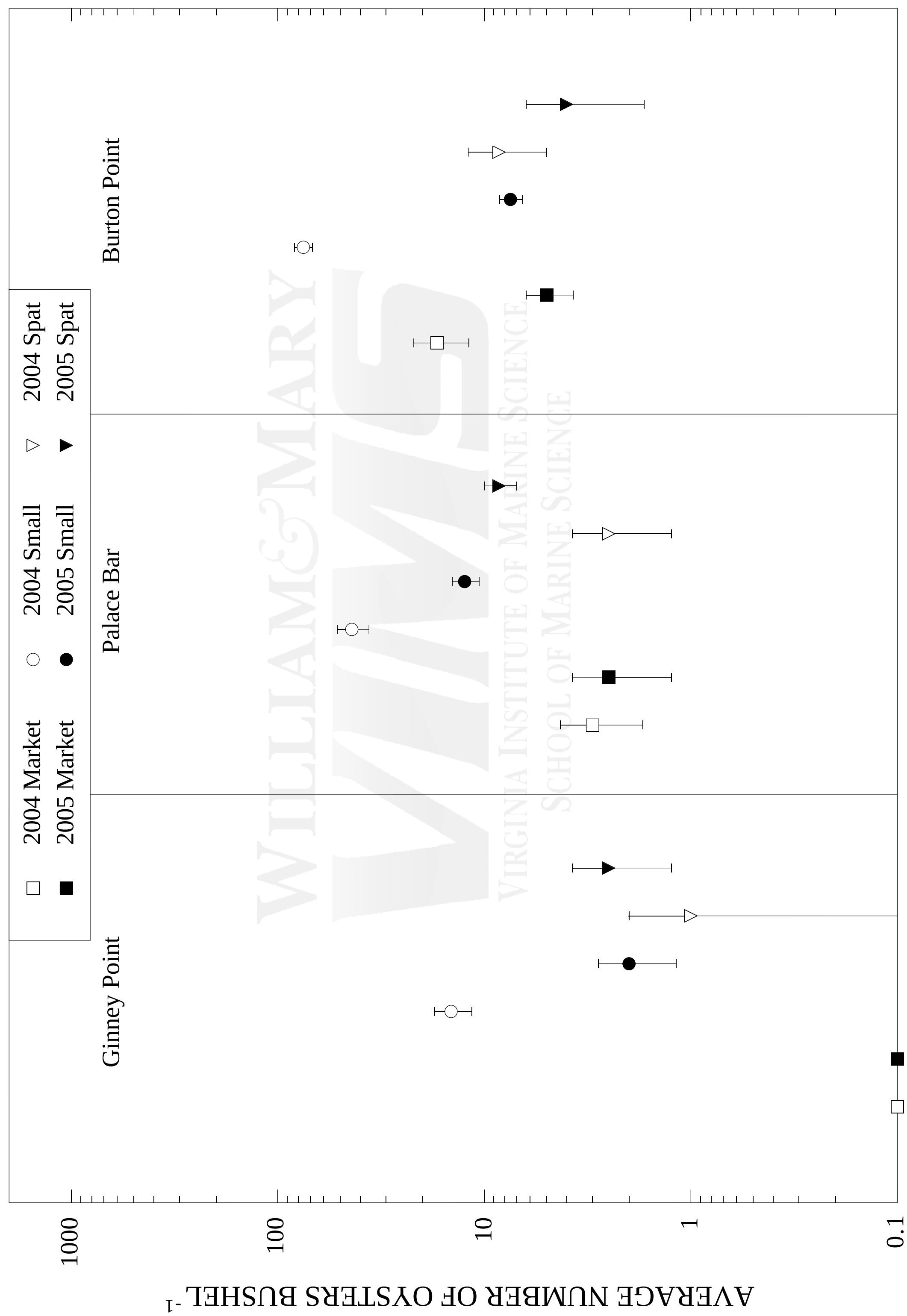


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

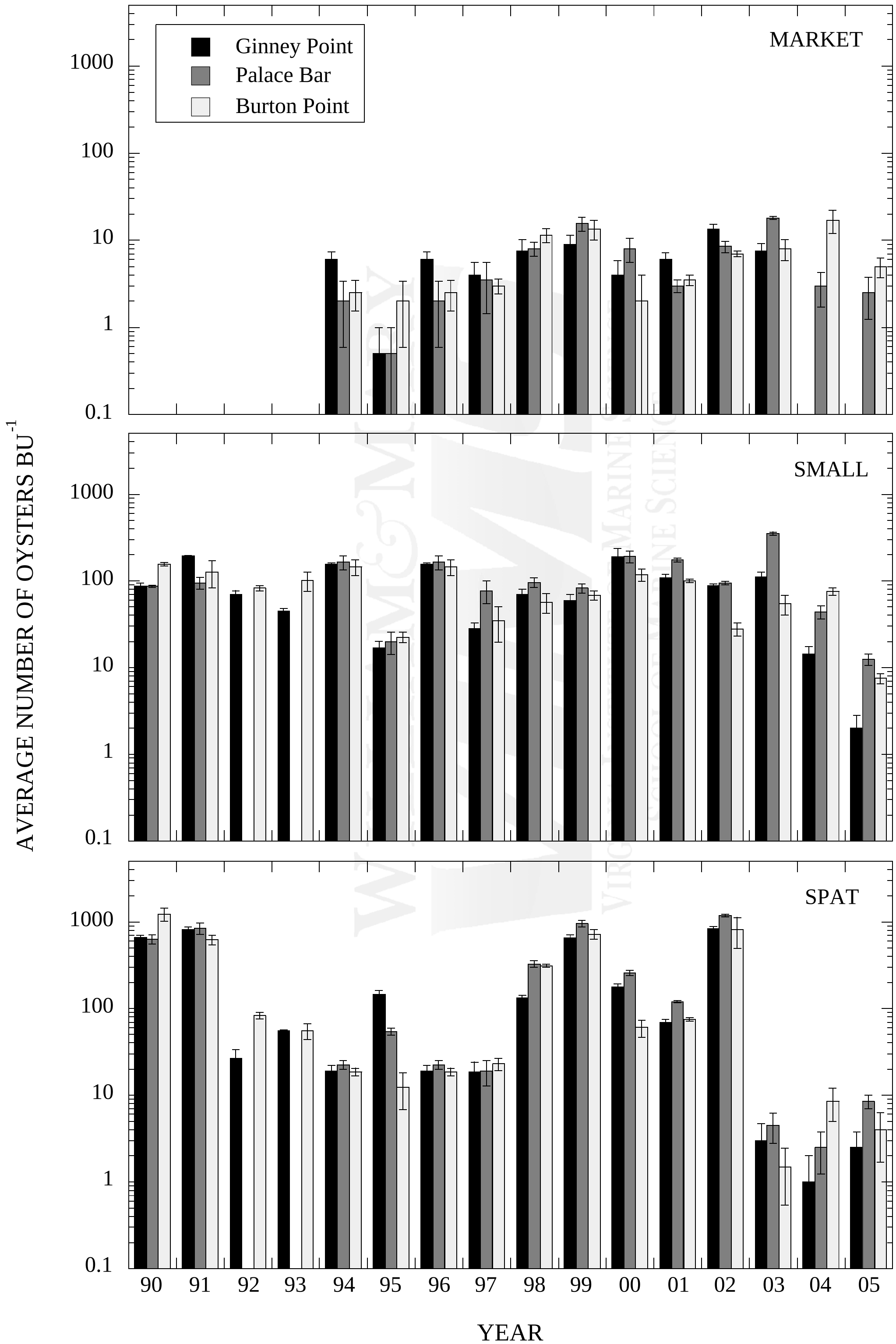


FIGURE D9: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE RAPPAHANNOCK RIVER (2004-2005)
(Error bars represent standard error of the mean)

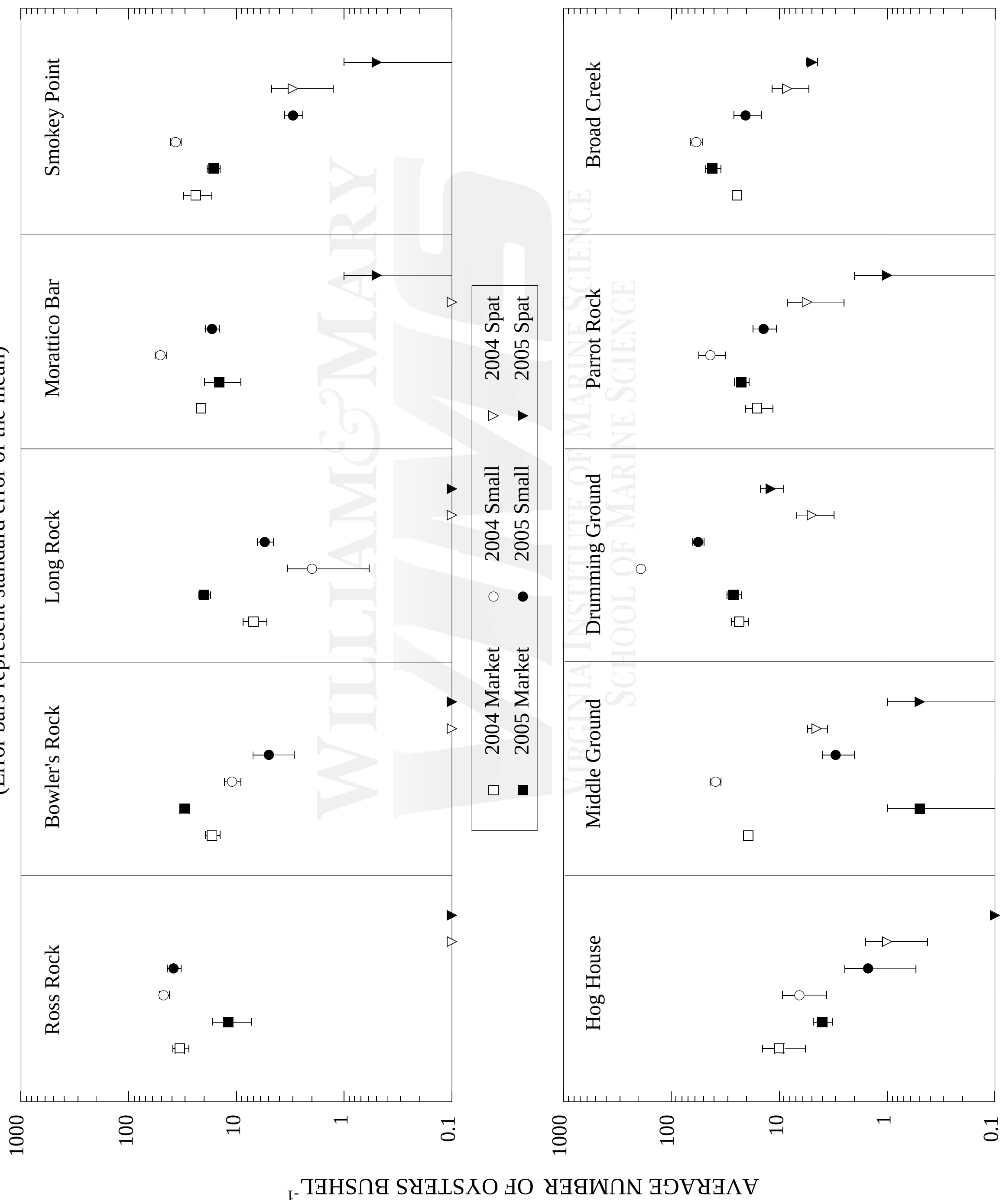


FIGURE D10: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)

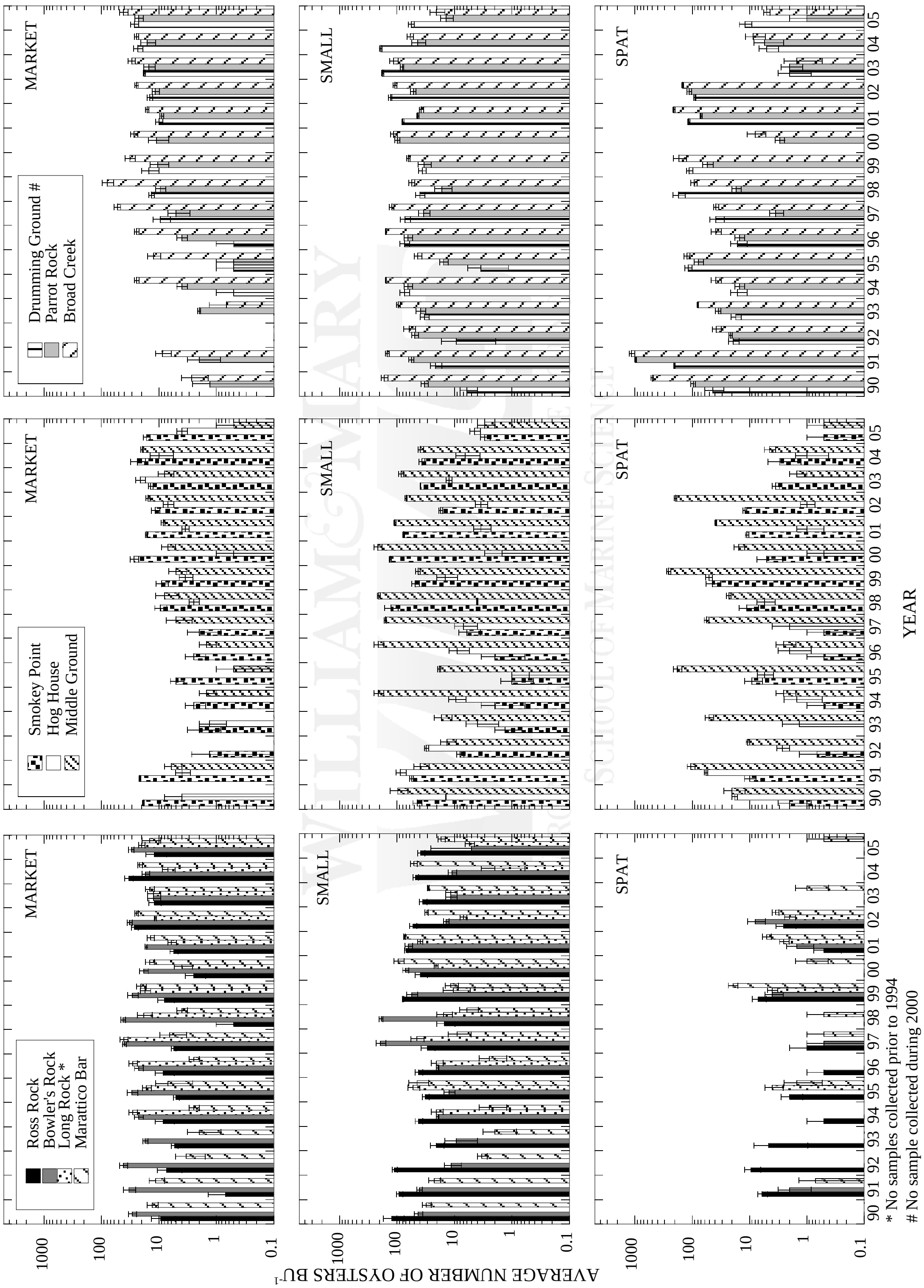


FIGURE D11: COMPARISON OF OYSTER ABUNDANCE BY SIZE CATEGORY IN THE GREAT WICOMICO RIVER (2004-2005)
(Error bars represent standard error of the mean)

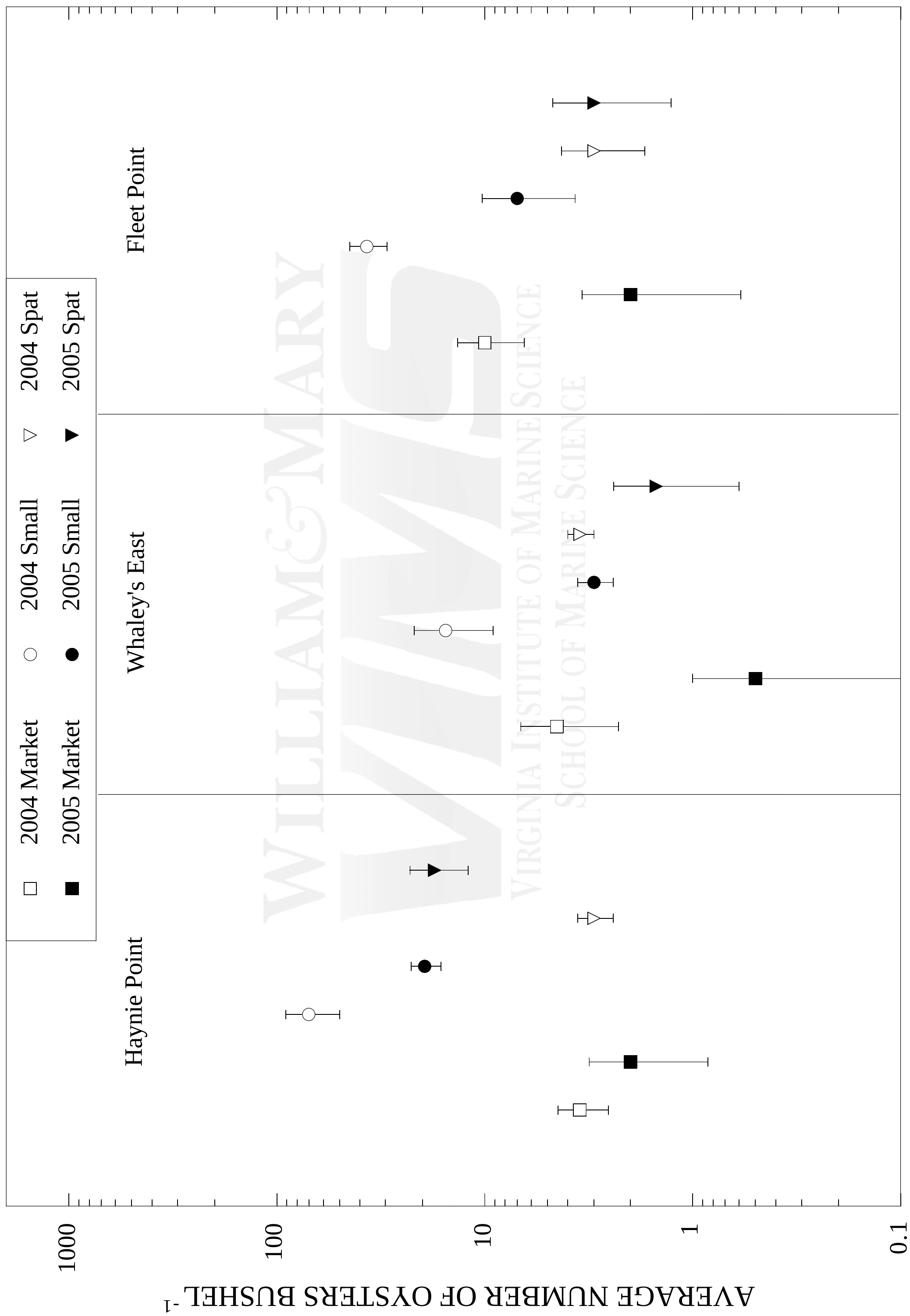
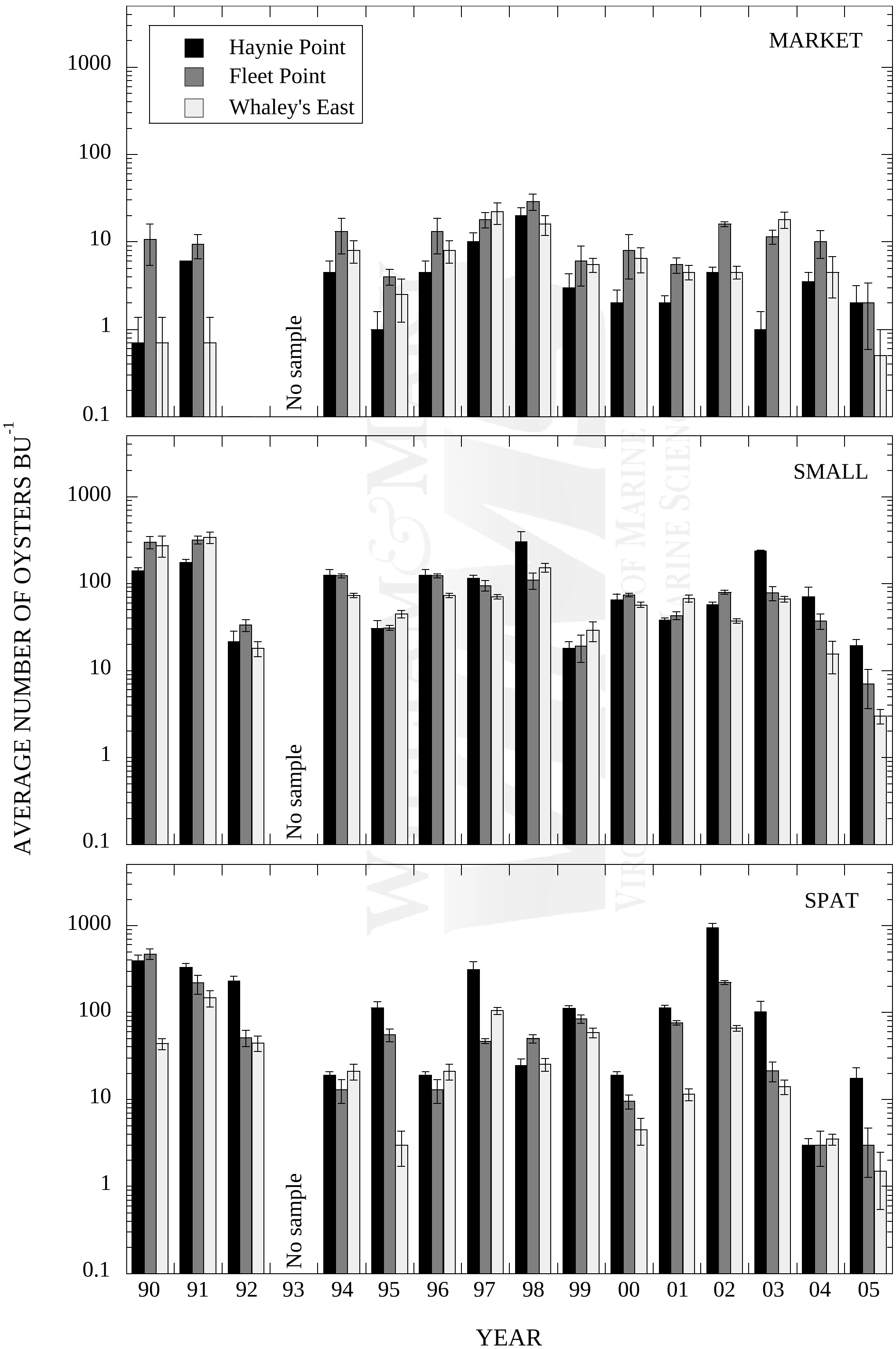


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 15 YEARS
(Error bars represent standard error of the mean)



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