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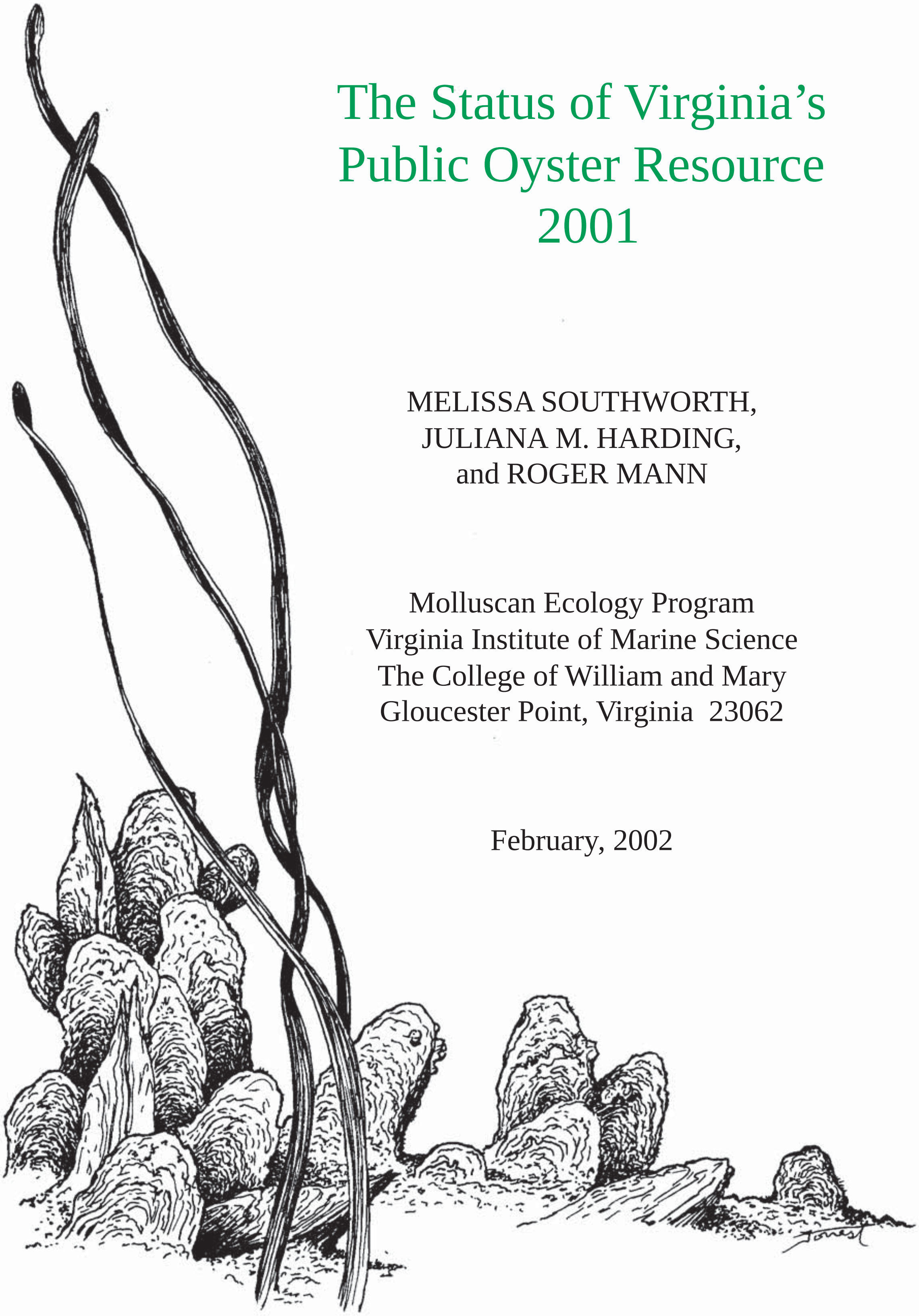

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Part I.

Oyster Spatfall in Virginia During 2001

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) monitors the reproductive activity of the Eastern oyster, *Crassostrea virginica* (Gmelin 1791), annually from June through October, by deploying spatfall (settlement of larval oysters or spat) collectors (shellstrings) at stations throughout Virginia in western Chesapeake Bay tributaries and on the Eastern Shore. 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 define the timing of settlement events. Information obtained from this monitoring effort is added to a database that 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 are reflective of the abundance of ready-to-settle oyster larvae in an area, and thus, provide an index of both oyster population reproduction and successful development and survival of larvae to the settlement stage in an estuary. Environmental factors affecting these physiological activities 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) is affected by many factors, including physical and chemical environmental conditions, the physiological condition of the larvae when they set, 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 bottom cultch is expected to be commensurate.

This report summarizes data collected during the 2001 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2001 was monitored from the last week of May through mid October at all stations. Spatfall stations included eight historical sites in the James River, three historical and five new sites in the Piankatank River, five historical and four new sites in the Great Wicomico River and four sites on the Eastern Shore (Atlantic Ocean side) of Virginia (Figure S1). The new sites in both the Piankatank and Great Wicomico Rivers correspond to those sites that were considered "new" in the 1998 survey. In this report, historical sites refer to those that have been monitored yearly for at least the past ten years whereas "new" sites are stations that were added during 1998 to monitor the effects of replenishment efforts by the Commonwealth of Virginia. Since 1993, the Virginia Marine Resources Commission (VMRC) has built numerous artificial oyster shell reefs in several tributaries of the western Chesapeake Bay as well as inshore of Fisherman's Island and in Pungoteague Creek on the Eastern Shore (Figure S2). The change in the number and location of shellstring sites during 1998 was implemented to provide a means of quantitatively monitoring oyster spatfall around 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, every year since 1997, including 2001. The increase in the number of shellstring sites during 1998 in the two rivers coincide with areas of new shell plantings in spring, 1998 through 2001 and provides means of monitoring the reproductive activity of planted broodstock on the artificial oyster reefs. Continued deployment during 2000 of shellstrings at two Fisherman Island stations, was associated with concurrent ecological studies on artificial (oyster shell, clam shell, and coal ash) reefs at that location. Deployment of a shellstring at Wachapreague, Virginia represents continuation of long-term data collections at that station.

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 S3). 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 get the mean number of spat shell^{-1} for the corresponding time interval, the total number of spat 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, some weather related deviations did occur such that shellstring deployment periods ranged from six to fifteen days in the western tributaries and seven to twenty eight days at the Eastern Shore, Wachapreague station. 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 seven day standard periods specified in Table 1. Standardized spat shell^{-1} (S) was computed using the formula:

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

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).

Water temperature and salinity measurements were taken at all stations. Water was collected each week from approximately 0.5 m off the bottom with a Niskin bottle. Temperature (degrees Celcius) was then measured with an alcohol thermometer and salinity (in ppt, or parts per thousand) was measured with a hand-held refractometer.

RESULTS

Spatfall on shellstring collectors for 2001 is summarized in Table S1 and is discussed below for each river system monitored. A summary of settlement at the historical stations for the past eleven years appears in Table S2. 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 throughout a river system. When comparing 2001 data with historical data in the James River, all eight stations were used. 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 2001. Historical sites in the Piankatank are Burton Point, Ginney Point, and Palace Bar. Historical sites in the Great Wicomico 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 15 at five out of the eight stations monitored (Table S1). Settlement continued from then until the week of September 30 with the peak settlement occurring in late August into early September. The peak in oyster settlement in late August / early September was the only one seen in the James River during the 2001 sampling season (Figure S4).

Cumulative spat shell^{-1} / week for 2001 ranged from a low of 1.6 at Day's Point to a high of 8.5 at Rock Wharf. Settlement was moderate at all stations. In contrast to most previous years, where the pattern of settlement tended to be higher along the southern shore stations, settlement during 2001 was spread throughout the river system.

Similar to the increase in spatfall observed in the James River during 1999, settlement during 2001 showed a slight improvement over the previous year. Settlement during 2001 was higher at all stations except Dry Shoal and Wreck Shoal than during 2000 (Table S2: Figures S5A and S5B). Settlement during 2001 was also slightly higher when compared with the 5-yr. mean at all stations except Dry Shoal and Wreck Shoal. However, settlement continued to be lower at all stations except Rock Wharf when compared with the ten-year mean (Table S2: Figures S5A and S5B). Rock Wharf saw an exceptionally high spat fall, the fourth highest since 1991.

Average river water temperatures reached a maximum in early August (28.0 degrees Celcius: Figure S6A). Water temperatures throughout the 2001 sampling season were normal when compared with the mean for the previous five years (Figure S6A). For the first half of the 2001 sampling season salinity was consistent with the previous 5-yr. mean. However, due to a lack of rain during the latter part of the summer (beginning in early August), the salinity in the James slowly began to increase from the normal. This lead to as much as a 10 ppt difference between 2001 and the previous 5-yr mean. There was anywhere from a 5 to 10 ppt salinity difference between Deep Water Shoal (the most upriver station) and Day's Point (the most downriver station: Figure S1), a slightly higher difference than in previous years.

Piankatank River

Settlement in the Piankatank River was first observed during the week of August 12 at all stations except Palace Bar and Heron Rock (Table

S1). Settlement continued throughout the month of August at most of the stations monitored. The majority of spatfall occurred in mid August, with another small peak in set in mid September at Bland Point, Heron Rock, and Cape Toon (Figure S7). The week of August 12 was the only week in which settlement occurred at Wilton Creek, the most upriver station monitored in the Piankatank River.

Cumulative spat shell^{-1} / week for the year ranged from a low of 0.2 at Wilton Creek and Palace Bar to a high of 1.8 at Cape Toon. As in previous years, prior to the 2001 reproductive season (spring, 2001) three events that might affect oyster spatfall occurred in the Piankatank River. Broodstock oysters were placed on oyster reefs near Bland Point, Burton Point, and Palace Bar (Figure S2), seed (small oysters) were removed from Heron Rock, and clean shells (cultch) were planted on Heron Rock, Bland Point, Palace Bar, and Ginney Point (Figure S1) to provide clean substrate for larval oysters to set on. Comparing the major spatfall in the two areas with broodstock oysters, the larvae appeared to travel and set upriver and adjacent to the broodstock oysters.

Spatfall during 2001 showed a decrease from 2000 at all three of the historical stations (Table S2: Figure S8). Cape Toon was the only station (historical and new) that showed an increase when compared with 2000. Spatfall during 2001 was lower at all three historical stations when compared with both the five and ten-year means. Settlement at these three stations was the lowest observed since 1997 (during which Burton Point was the only station monitored that recorded settlement).

The average Piankatank River water temperature ranged from 19 to 28 degrees Celcius throughout the sampling period, reaching a maximum in early to mid August. Water temperature did not vary much from the average temperatures previously recorded in the river (Figure S9A). Salinity ranged from 14.5 to 19 ppt throughout the sampling period. Similar to the James River, as the season progressed there was a deviation from the normal (previous five-year mean) salinity observed in 2001 (Figure S9B). During the latter part of the 2001 sampling season the salinity was 3 to 4 ppt higher than the previous five-year mean. The difference recorded between Wilton Creek (the most upriver station) and Burton Point (the most downriver station: Figure S1) during 2001 was anywhere from 1 to 3 ppt.

Great Wicomico River

There were two major peaks in settlement in the Great Wicomico River during 2001. The first occurred only at stations upriver of Sandy Point, with the exception of Haynie Point, (Figure S1) between June 24 and July 8 (Table S1: Figure S10). After that, no further settlement was seen until the week of August 8. The second peak lasted longer than the first continuing into mid September throughout the river system. Prior to the 2001 reproductive season (spring, 2001), oyster shell was planted at Rogue Point, Harcum Flats, and Sandy Point (Figure S1). Broodstock oysters were placed on the artificial oyster reef located at Shell Bar (Figure S2)

Cumulative spat shell-1 / week for the year ranged from a low of 0.7 at Whaley's East and Rogue Point to a high of 1.4 at Hudnall. As has been observed over the past few years, settlement at the stations downriver of Sandy Point (Whaley's East and Fleet Point) has continued to increase. Upriver of Sandy Point only one historic (Hudnall) and one new (Harcum Flats) station showed an increase in settlement when compared with 2000. Settlement at the historical stations during 2001 was much lower than both the five and ten-year means (Table S2: Figure S11).

Average river water temperatures ranged between 21 and 30 degrees Celcius throughout the sampling season (Figure S12A). Water temperature reached a maximum in late June and again in early August. Given the lack of historical data for the Great Wicomico, temperature and salinity during 2001 could only be compared with the previous three-year mean instead of the five-year mean as it was in the James and Piankatank Rivers. Temperature in the Great Wicomico during 2001 did not vary much from the previous three-year mean (Figure S12A). Similar to what was observed in the James and Piankatank Rivers however, salinity was slightly higher than normal (2 to 3 ppt) during the latter part of the sampling season and for a short time in mid June. 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 a majority of the sampling season.

Eastern Shore of Virginia

Due to a lack of data during the second half of the sampling season it is difficult to draw conclusions about settlement success at the Wachapreague station. Settlement was first observed at the Wachapreague site during the week of August 5 and probably continued the end of September (Table 1). Cumulative spat shell-1 / week for the year was 3.5. However given that the shellstrings during the time in which settlement was occurring were deployed for extended periods of time (up to 28 days), most likely the overall settlement was higher than that observed.

DISCUSSION

Oyster spatfall during 2001 was low to moderate in all Virginia tributaries of the western shore of the Chesapeake Bay. Low spatfall has been prevalent in Virginia since 1991, with the exception of parts of the James River in 1993, and to some extent the Great Wicomico River in 1997 and the Piankatank River in 1999. Spatfall at all sites, except Rock Wharf in the James River, during 2001 was lower than the previous ten-year mean (1991-2000). Oyster settlement was also lower than the previous five-year mean (1996-2000), with the exception of six sites in the James River.

Overall oyster settlement in the James River during 2001 was higher than during 2000 and higher than the previous five-year mean. Settlement at Rock Wharf, which historically has received good strikes, was even slightly higher than the previous 10-yr mean. In general however, settlement was still low throughout the system when compared with observed settlement over the past ten years. Historically, spatfall in the James tends to be highest at the more downriver stations (i.e., those with a higher salinity) and along the southern shore of the river: Day's Point, Rock Wharf, and Dry Shoal. However, over the past few years, including 2001, settlement has been more evenly spread throughout the river system. While Rock Wharf had a relatively good set during 2001, the other two downriver, southern shore sites had two of the lowest sets in the river. The good set observed at the more upriver, less saline sites may have been due to the lack of rain throughout the end of the spawning season, which caused a higher than normal salinity at those sites. Oyster larvae have been shown to respond to tidal stages, swimming up on the flood tide and down on the ebb tide (Wood and Hargis, 1971). Haskin (1964) also demonstrated that larval swimming activity increased with an increase in salinity. Perhaps the higher than normal salinities during the latter half of the 2001 spawning season, when larvae would have been present in the water column, induced the larvae to play a more active role and hence increased dispersal in the upper reaches of the river system.

Settlement in the Piankatank River during 2001 was relatively low. Prior to the 2001 settlement period, the Piankatank had experienced several years of good spatfall, beginning in 1998. This year (1998) marked the first year of oyster broodstock enhancement on the artificial oyster reefs in the system. This pattern observed in the Piankatank is similar to what was observed in the Great Wicomico River after subsequent years of broodstock enhancement on Shell Bar Reef (Southworth et al., 2001). While settlement success fluctuates from year to year, the general pattern is an overall increase in settlement post broodstock enhancement (when compared with pre broodstock enhancement numbers). As has been observed in the past, the highest settlement of oysters in the Piankatank River occurred around and upriver of the broodstock enhanced reefs. The location of settlement of spat during the past few years supports the suggestion that the Piankatank River is a trap-type estuary (Andrews, 1983).

Oyster settlement in the Great Wicomico River was light to moderate. Four of the nine stations showed a marked improvement over 2000, which was also a relatively good settlement year for the river. The Great Wicomico River had experienced relatively low settlement during 1999, most likely due to high disease prevalence and a large number of small and market size oysters dying early in the spawning season (Calvo and Burreson, 2000). Added to that factor was the lack of broodstock on Shell Bar Reef (Figure S2), which has been shown to be an important area in terms of circulation and larval retention in the system (Southworth and Mann, 1998). Given these two factors the increase in spatfall in the system over the past two years is most likely a combination of recovery from death of a large number of oysters and a positive feedback from broodstock enhancement on Shell Bar Reef.

Settlement at the Wachapreague, Eastern Shore station, while higher than that observed in 2000, was still relatively low when compared with settlement throughout much of the 1990’s. This low settlement may have been caused by longer than normal exposure times of the shellstrings. Due to unseen constraints, shellstrings were left exposed for as many as 28 days at a time. This longer exposure time increases natural mortality of the newly settled oysters as well as predation, so while a lot of spat may have set on the string, by the time the strings were collected, many of the spat may have died thus were not included in the numbers reported. Caution must therefore be taken when drawing conclusions from the data collected at the Wachapreague, Eastern Shore site.

Overall, settlement during 2001 was good in the James and Great Wicomico Rivers and poor in the Piankatank River. Spawning success has been related to many things such as water temperature, adequate food supply, and substrate availability (Thompson et al., 1996). Given that water temperature was similar throughout all of the rivers, and shell was planted in both the Piankatank and Great Wicomico Rivers to provide clean substrate for settlement, the most likely cause for the lower settlement seen in the Piankatank River was related to food supply.

TABLE S1

AVERAGE NUMBER OF SPAT PER SHELL IN 2001 FOR STANDARDIZED WEEK BEGINNING ON THE DATE SHOWN

STATION	5/27 147	6/3 154	6/10 161	6/17 168	6/24 175	7/1 182	7/8 189	7/15 196	7/22 203	7/29 210	8/5 217	8/12 224	8/19 231	8/26 238	9/2 245	9/9 252	9/16 259	9/23 266	9/30 273	10/7 280	YEAR TOTAL
JAMES RIVER																					
Deep Water Shoal	D	0	0	0	0	0	0	0	-	0.1	0	0	0	1.0	0.3	-	0.5	0	0.1		2.0
Horsehead	D	0	0	0	0	0	0	0	-	0	0	0.1	0.2	1.5	1.1	-	1.1	0	0		4.0
Point of Shoal	D	0	0	0	0	0	0	0.1	-	0.1	0.1	0	0.4	0.6	1.7	-	0.6	0.4	0		4.0
Swash	D	0	0	0	0	0	0	0.1	-	0	0	0.2	0.7	0.4	1.4	-	0.7	0	0		3.5
Dry Shoal	D	0	0	0	0	0	0	0	-	0	0	0	0.4	0.4	0.2	-	0.6	0.5	0		2.1
Rock Wharf	D	0	0	0	0	0	0	0.1	-	0.1	0	0.5	1.1	2.9	0.5	-	0.7	2.5	0.1		8.5
Wreck Shoal	D	0	0	0	0	0	0	0.1	-	0	0.3	1.1	0.4	0.2	0.4	-	0.6	0.1	0		3.2
Day's Point	D	0	0	0	0	0	0	0.3	-	0	0	0	0	0.5	0.3	-	0.2	0.3	0		1.6
PIANKATANK RIVER																					
Wilton Creek	D	0	0	0	0	0	0	0	-	0	0	0.2	0	0	0	0	0	0	0		0.2
Ginney Point	D	0	0	0	0	0	0	0	-	0	0	0.4	0.2	0.4	0.2	0	0	0	0		1.2
Palace Bar	D	0	0	0	0	0	0	0	-	0	0	0	0.1	0	0.1	0	0	0	0		0.2
Bland Point	D	0	0	0	0	0	0	0	-	0	0	0.5	0.5	0.2	0	0	0.1	0	0		1.3
Heron Rock	D	0	0	0	0	0	0	0	-	0	0	0	0.2	0.1	0.1	0	0.2	0	0		0.6
Cape Toon	D	0	0	0	0	0	0	0	-	0	0	0.7	1.0	0	0	0	0.1	0	N		1.8
Stove Point	D	0	0	0	0	0	0	0	-	0	0	0.9	0.6	0	0.1	0	0	0	0		1.6
Burton Point	D	0	0	0	0	0	0	0	-	0	0	0.1	0.3	0.4	0	0	0	0	0		0.8
GREAT WICOMICO																					
Glebe Point	D	0	0	0	0.3	0.2	0	0	-	0	0.1	0.5	0	0	0	0	0	0	0		1.1
Rogue Point	D	0	0	0	0	0.1	0	0	-	0	0	0.1	0.1	0	0.3	0	0.1	0	0		0.7
Hilly Wash	D	0	0	0	0	0.3	0.1	0	-	0	0	0	0.1	0.2	0	0	0	0.1	0		0.8
Harcum Flats	D	0	0	0	0.1	0	0.1	0	-	0	0	0	0	0.2	0.4	0.2	0.1	0	0		1.1
Hudnall	D	0	0	0	0.2	0	0	0	-	0	0	0.1	0.2	0.7	0.1	0.1	0	0	0		1.4
Shell Bar	D	0	0	0	0.1	0	0	0	-	0	0	0.1	0.1	0.3	0	0.1	0.1	0	0		0.8
Haynie Point	D	0	0	0	0	0	0	0	-	0	0	0	0.3	0.1	0	0.1	0.4	0	0		0.9
Whaley's East	D	0	0	0	0	0	0	0	-	0	0	0.1	0.3	0.2	0	0.1	-	0	0		0.7
Fleet Point	D	0	0	0	0	0	0	0	-	0	0	0.3	0.2	0.5	0	0	0	0	0		1.0
EASTERN SHORE																					
Wachapreague	D	0	0	0	0	-	0	0	0	-	0.1	-	-	-	3.0	-	-	-	0.4		3.5

D: Date deployed

N: String was lost (no data).

"-": String not collected during that week.

TABLE S2

SPATFALL TOTALS AT THE HISTORICAL SITES FOR THE YEARS 1991 - 2001 AND THE MEANS FOR 1991-2000 AND 1996-2000

Presented as the cumulative sum of weekly spat per shell values for each year

STATION	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Mean 96-00	Mean 91-00	2001	Ref. 2000	Ref. 5 yr	Ref. 10 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	1.9	3.9	2.0	+	+	-
Horsehead	24.7	3.6	43.7	3.2	0.3	3.6	2.4	1.1	3.8	2.3	2.6	8.9	4.0	+	+	-
Point of Shoal	21.4	5.4	73.7	15.0	4.8	2.3	2.3	1.5	3.5	0.7	2.1	13.1	4.0	+	+	-
Swash	68.7	N/A	46.2	4.8	1.8	2.2	1.7	1.6	6.8	2.6	3.0	15.2	3.5	+	+	-
Dry Shoal	217.1	14.2	119.0	25.8	2.8	11.0	1.1	1.1	6.1	3.7	4.6	40.2	2.1	-	-	-
Rock Wharf	N/A	11.4	34.3	10.7	0.2	2.4	5.6	2.1	8.0	1.0	3.8	8.4	8.5	+	+	+
Wreck Shoal	35.3	3.3	15.5	2.2	2.6	10.0	0.7	0.7	3.1	0.9	3.1	7.4	3.2	+	+	-
Day's Point	145.6	14.2	131.5	42.2	3.0	4.6	5.6	0.4	7.3	4.3	4.4	35.9	1.6	-	-	-
PIANKATANK RIVER																
Ginney Point	25.4	11.4	1.7	0.0	0.5	1.3	0.0	2.2	6.4	6.8	3.3	5.6	1.2	-	-	-
Palace Bar	38.9	24.9	5.0	0.8	1.0	1.6	0.0	5.5	10.1	3.9	4.2	9.2	0.2	-	-	-
Burton Point	16.4	11.7	6.5	0.1	1.0	1.0	0.7	1.3	14.9	2.7	4.1	5.6	0.8	-	-	-
GREAT WICOMICO																
Glebe Point	1.9	0.5	0.2	0.0	1.5	0.6	21.2	0.6	2.4	4.2	5.8	3.3	1.1	-	-	-
Hudnall	4.5	0.5	0.8	0.0	0.1	0.2	39.1	0.5	0.9	1.0	8.3	4.8	1.4	+	-	-
Haynie Point	12.4	0.6	1.4	0.0	1.0	3.7	4.4	0.7	1.1	1.1	2.2	2.6	0.9	-	-	-
Whaley's East	7.9	0.1	0.2	0.0	0.3	2.1	1.0	0.4	1.8	0.2	1.1	1.4	0.7	+	-	-
Fleet Point	5.8	2.9	2.0	0.0	0.3	2.6	3.4	0.3	0.5	0.6	1.5	1.8	1.0	+	-	-
EASTERN SHORE																
Wachapreague	286.9	61.8	99.6	7.7	16.1	19.5	32.0	52.0	6.9	1.9	22.5	58.4	3.5	+	-	-

"+" and "-" indicate direction of change in 2000 in reference to 1999 and to the 5 and 10-yr means

N/A; data was not available for that year.

Figure S1: Map showing the location of the 2001 shellstring sites including those sites in the 3 western tributaries and on the Eastern Shore. Numbers in the blown up maps of the Piankatank and Great Wicomico Rivers are represented by the closed black circles on the big map. 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.

Eastern Shore: 26) Wachapreague

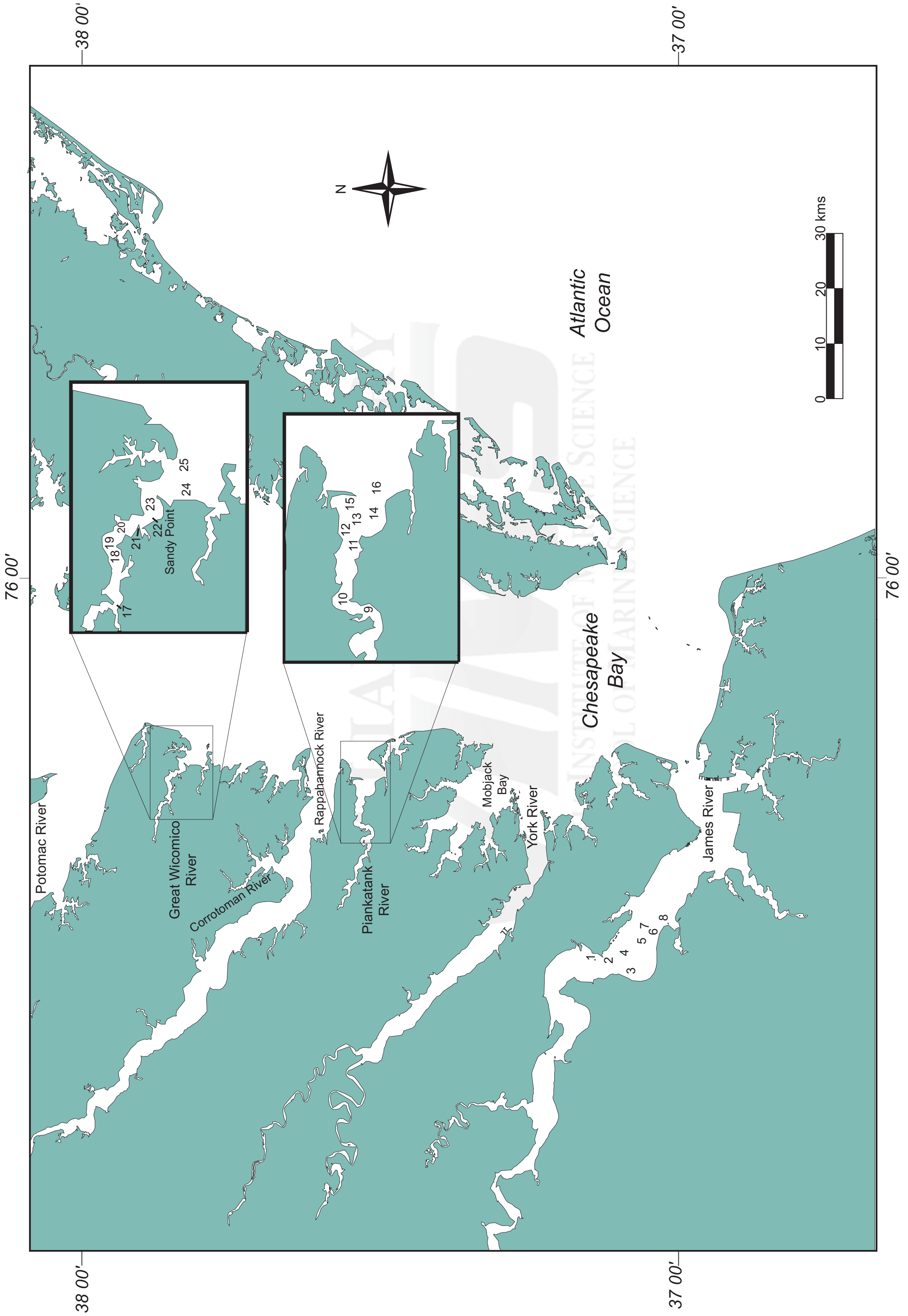
38 00'
37 00'
76 00'
N
Atlantic Ocean
Chesapeake Bay
0 10 20 30 kms
Potomac River
Great Wicomico River
Corrotoman River
Rappahannock River
Piankatank River
Mobjack Bay
York River
James River
Sandy Point
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 16
17 18 19 20 21 22 23 24 25

Figure S2: Map showing the location of the artificial oyster reefs in the Virginia portion of the Chesapeake Bay.

Lynnhaven River: 1) Lynnhaven River Reef.

Lafayette River: 2) Hampton Boulevard Bridge Reef, 3) Tanner's Point Reef.

Elizabeth River: 4) Western Branch Reef, 5) Craney Island Reef.

York River: 6) Felgate's Creek Reef, 7) Amoco Reef.

Mobjack Bay: 8) Ware River Reef, 9) North River Reef, 10) East River Reef.

Piankatank River: 11) Palace Bar Reef, 12) Bland Point Reef, 13) Iron Point Reef, 14) Burton Point Reef.

Rappahannock River: 15) Ferry Bar Reef, 16) Drumming Ground Reef, 17) Temple Bay Reef, 18) Parrot's Rock Reef, 19) Mill Creek Reef, 20) Sturgeon Bar Reef, 21) Broad Creek Reef, 22) Butler's Hole Reef.

Great Wicomico River: 23) Shell Bar Reef, 24) Cranes Creek Reef.

Potomac River: 25) Yeocomico River Reef, 26) Coan River Reef.

Eastern Shore: 27) Pungoteague Creek Reef, 28) Fishermen's Island Reefs.

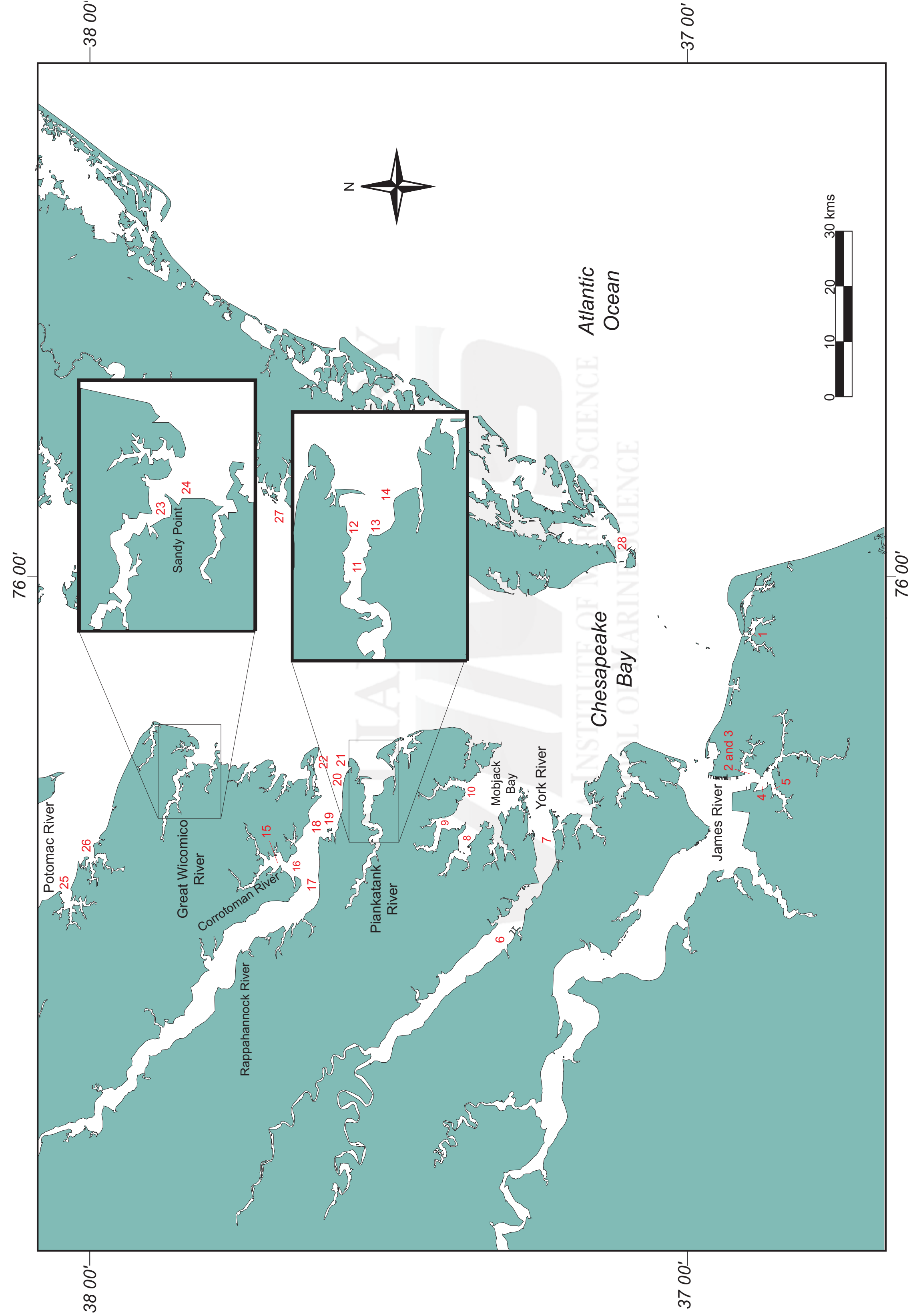

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Figure S3: Diagram of shellstring setup on buoys.

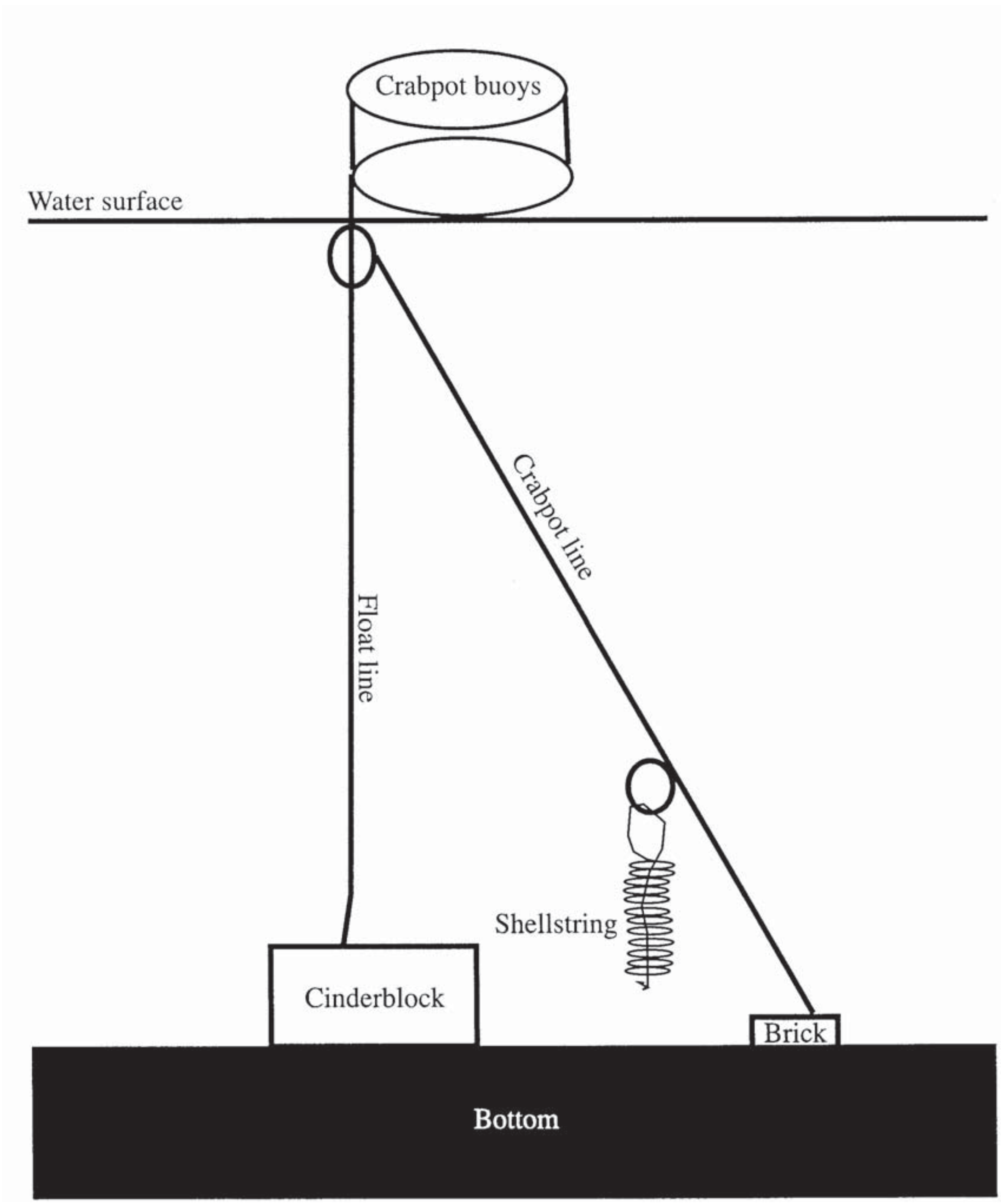


FIGURE S4: JAMES RIVER (2001) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}

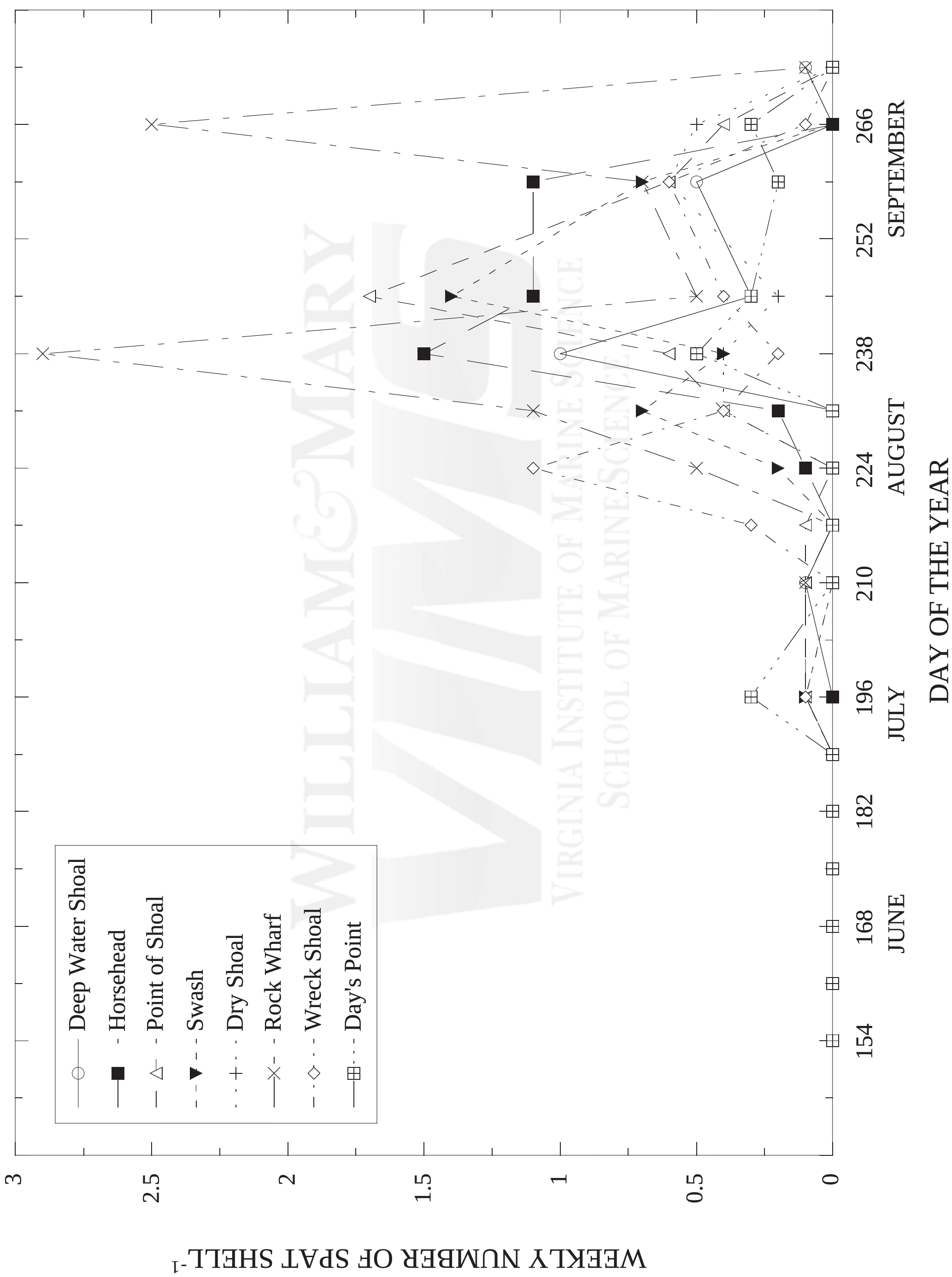


FIGURE S5: SPATFALL TRENDS IN THE JAMES RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE WEEKLY SPATFALL

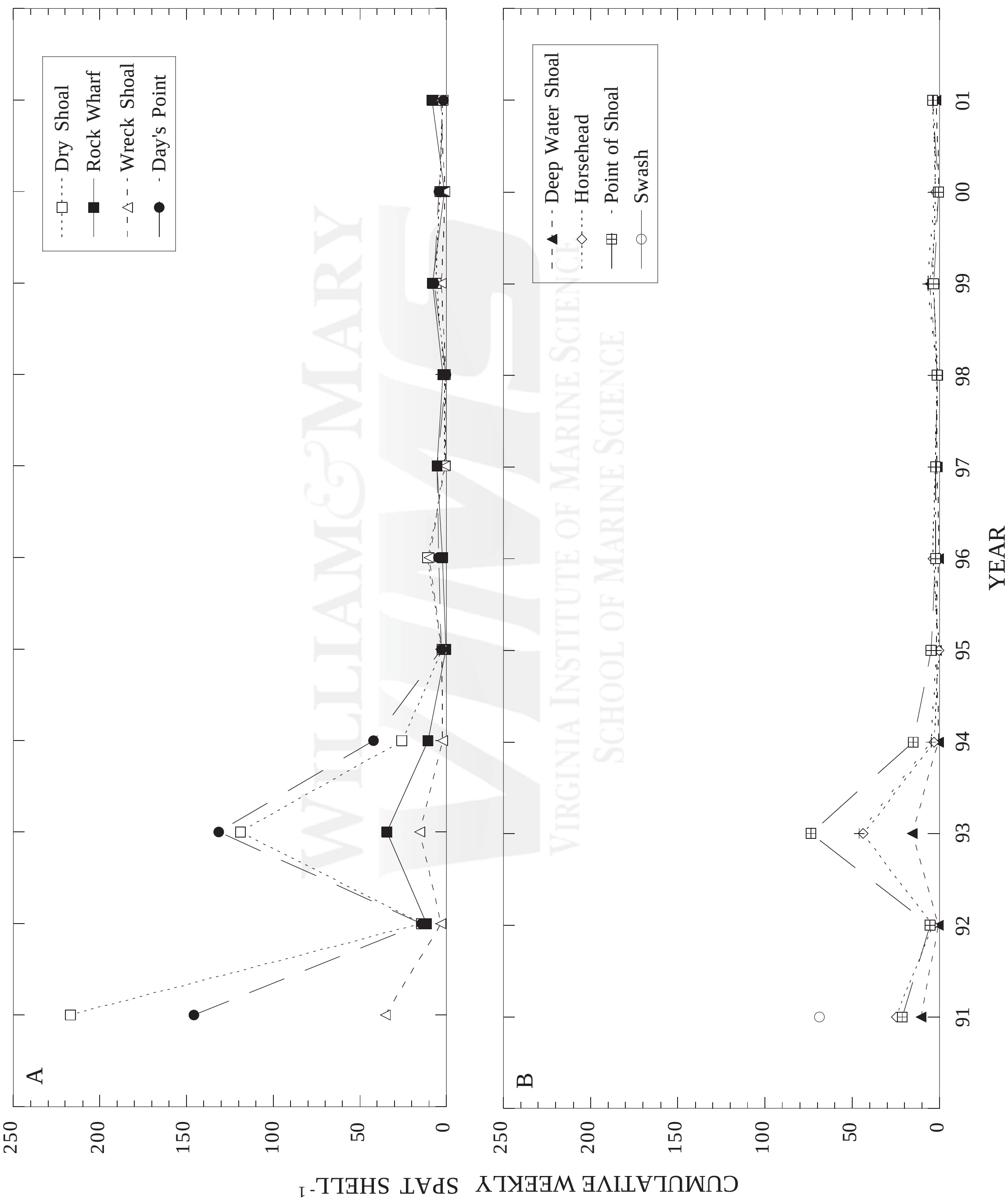


FIGURE S6: TEMPERATURE AND SALINITY TRENDS IN THE JAMES RIVER OVER THE PAST 5 YEARS COMPARED WITH 2001
(error bars represent standard error of the mean)

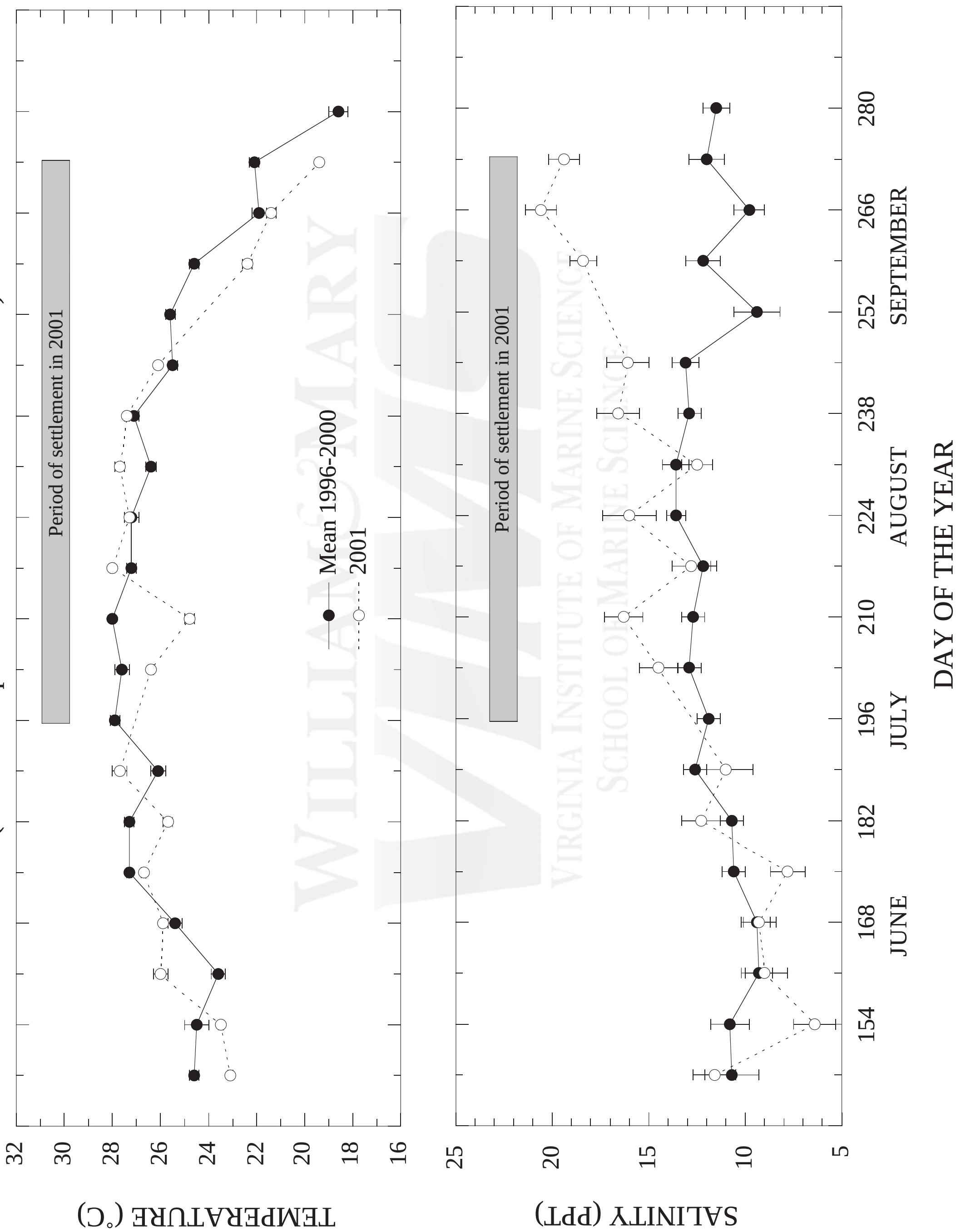
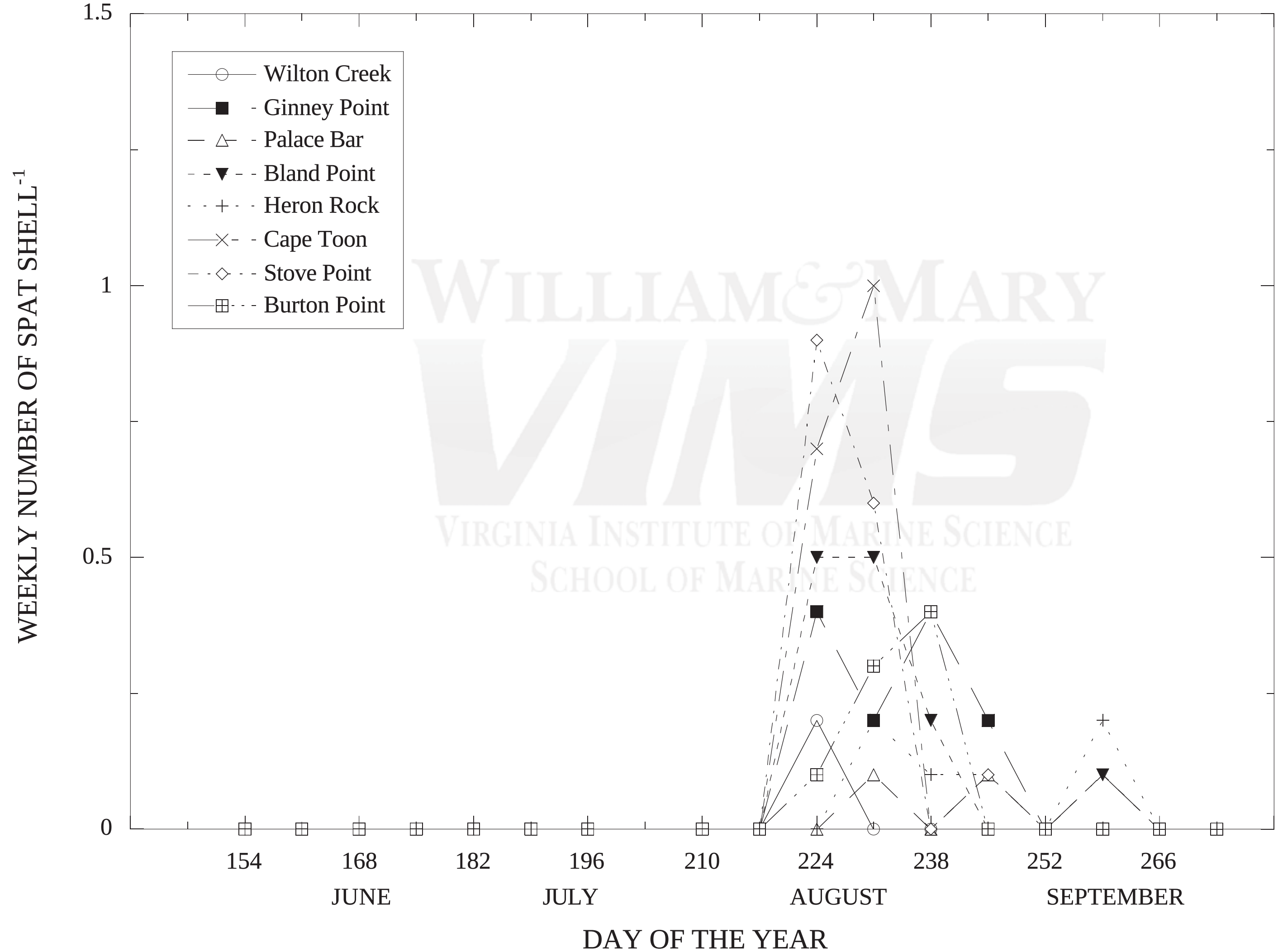


FIGURE S7: PIANKATANK RIVER (2001) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}



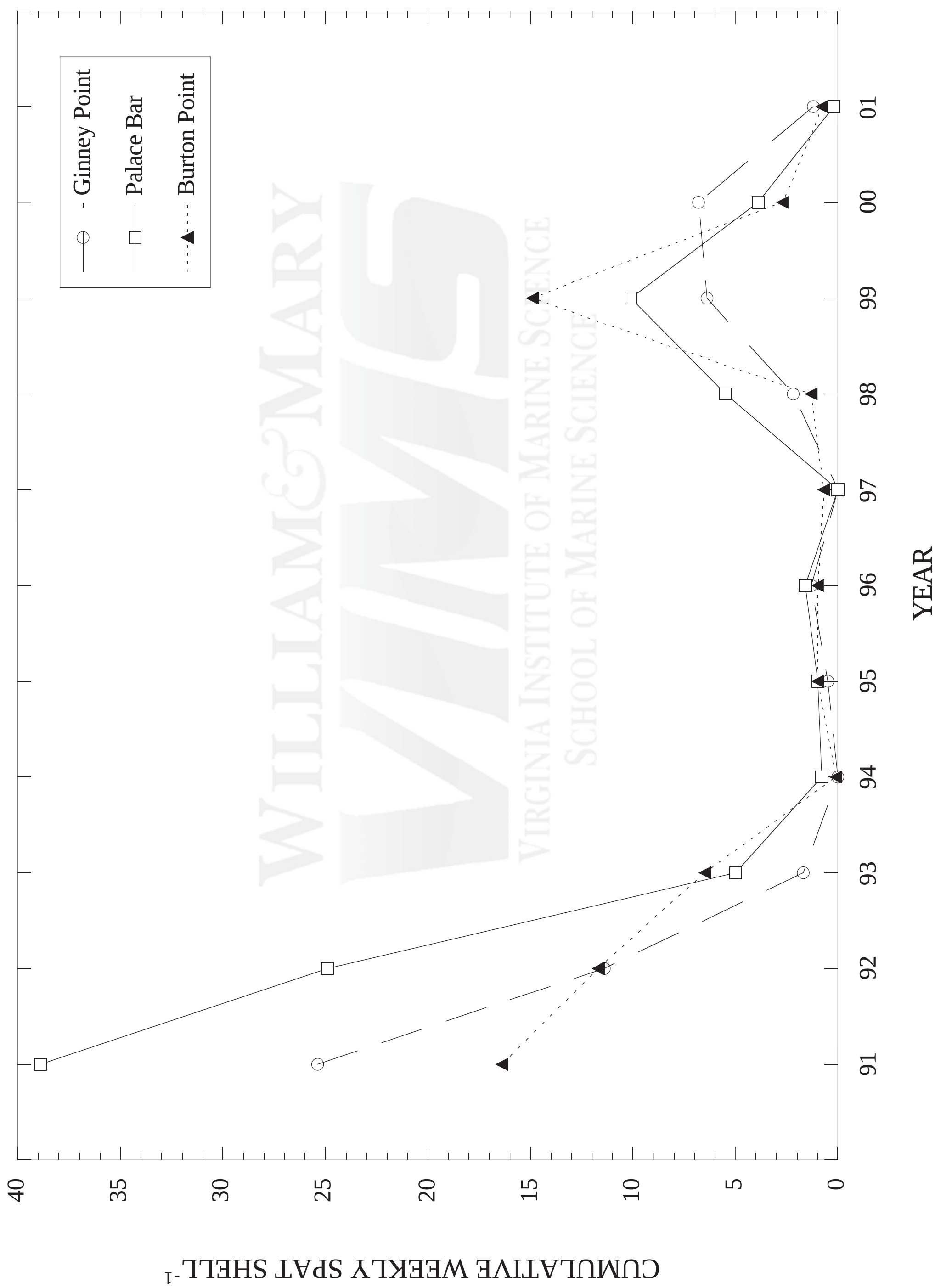


FIGURE S8: SPATFALL TRENDS IN THE PIANKATANK RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE WEEKLY SPATFALL

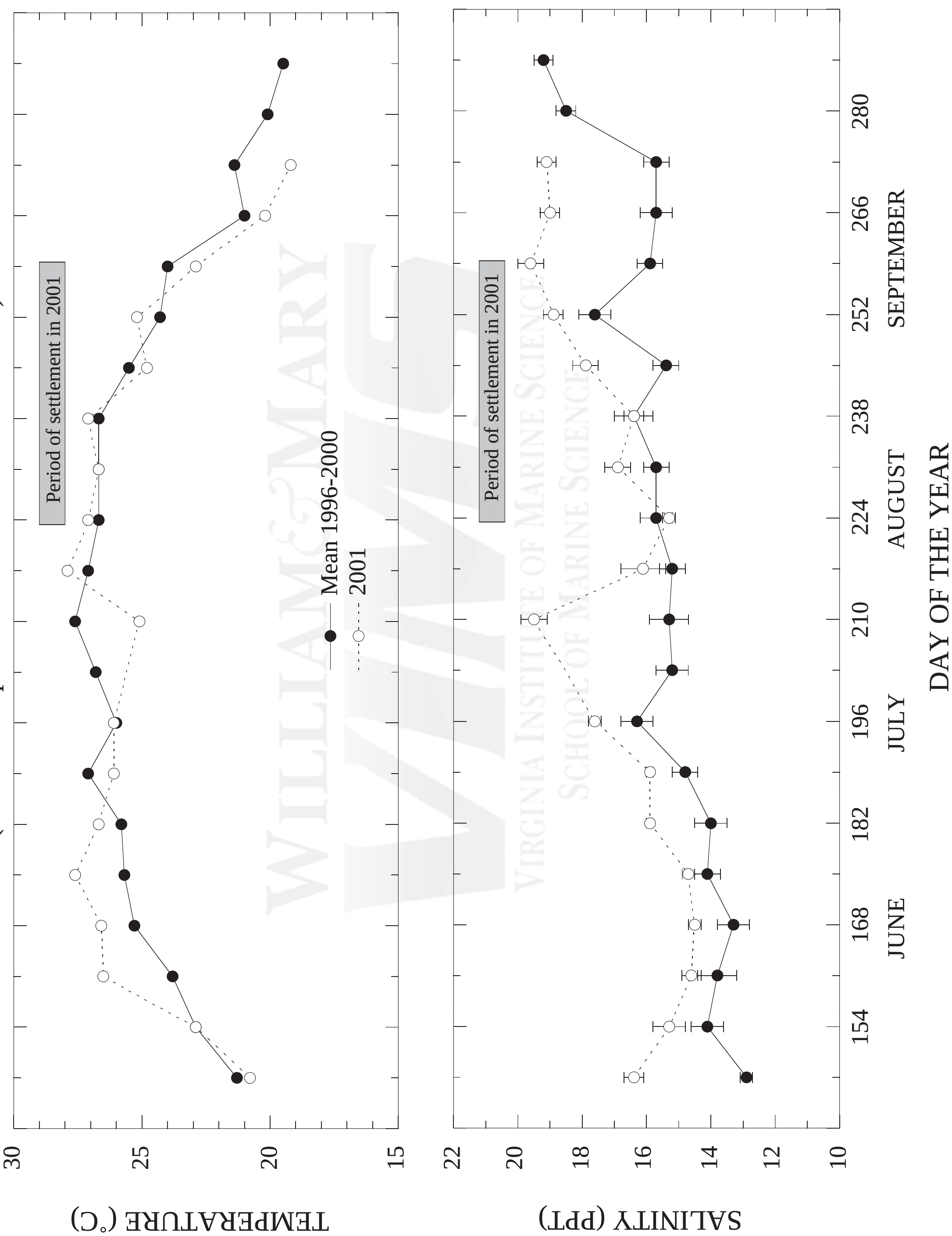


FIGURE S9: TEMPERATURE AND SALINITY TRENDS IN THE PIANKATANK RIVER OVER THE PAST 5 YEARS COMPARED WITH 2001 (error bars represent standard error of the mean)

FIGURE S10: GREAT WICOMICO RIVER (2001) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL^{-1}

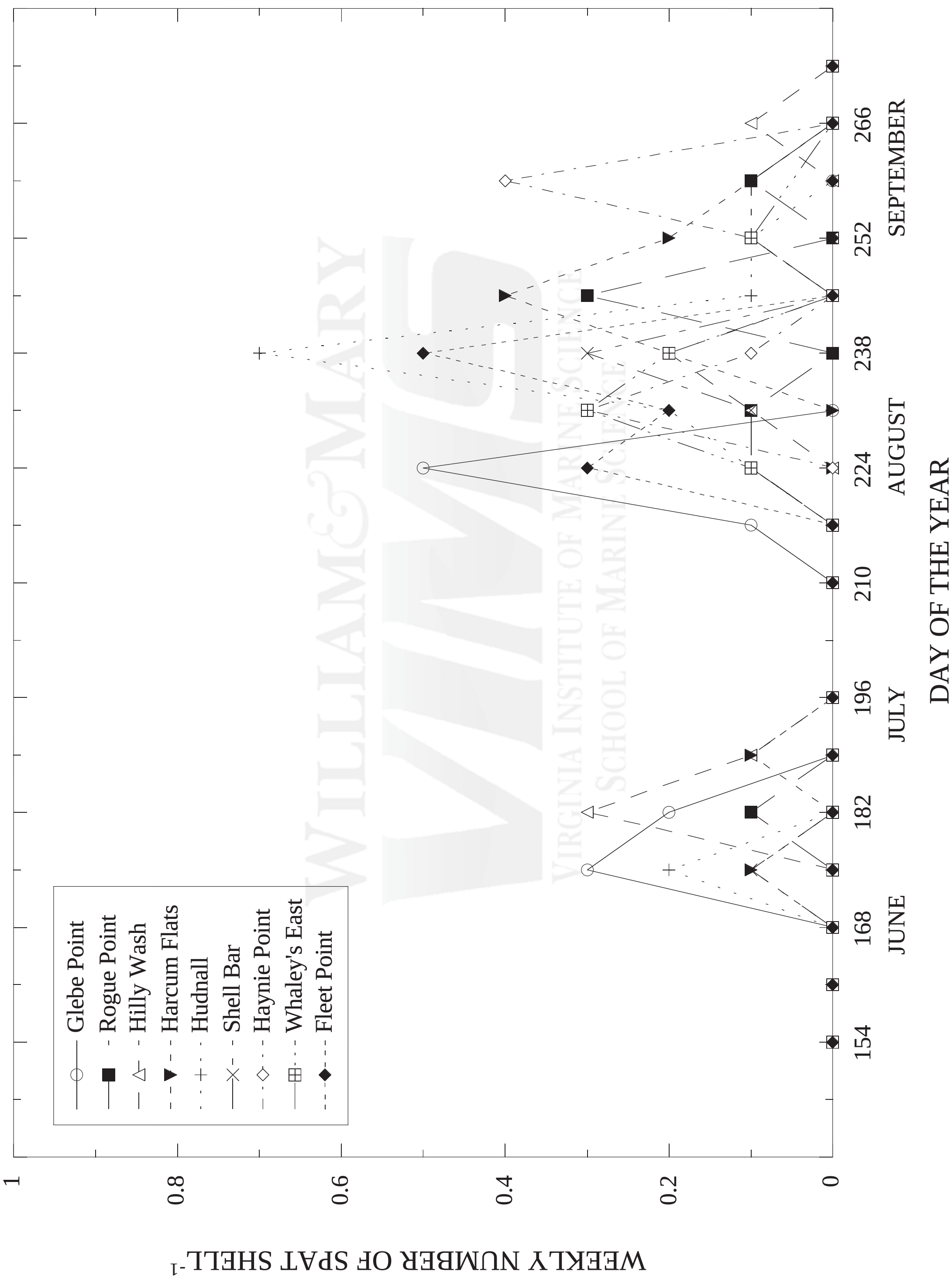


FIGURE S11: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE WEEKLY SPATFALL

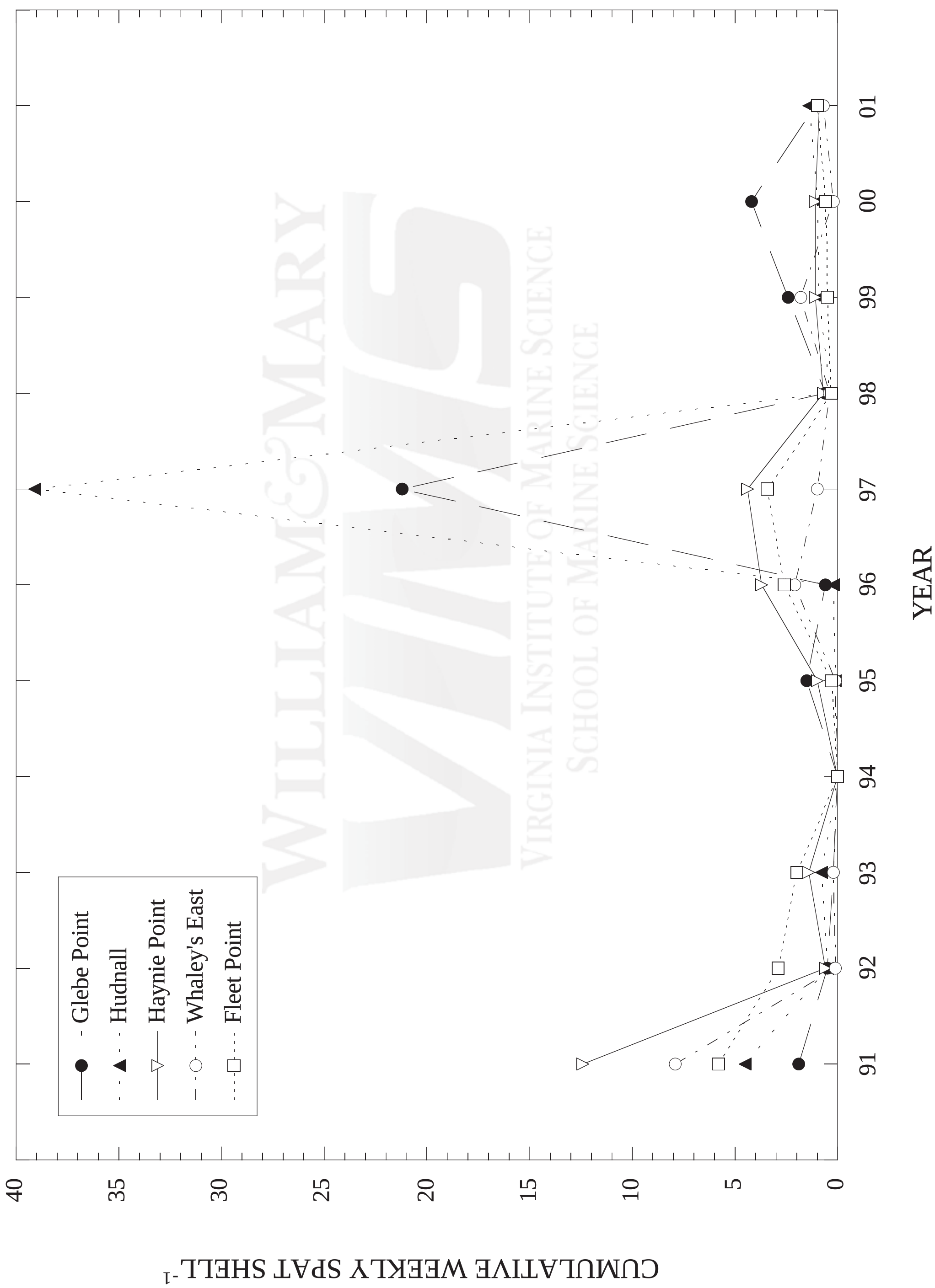
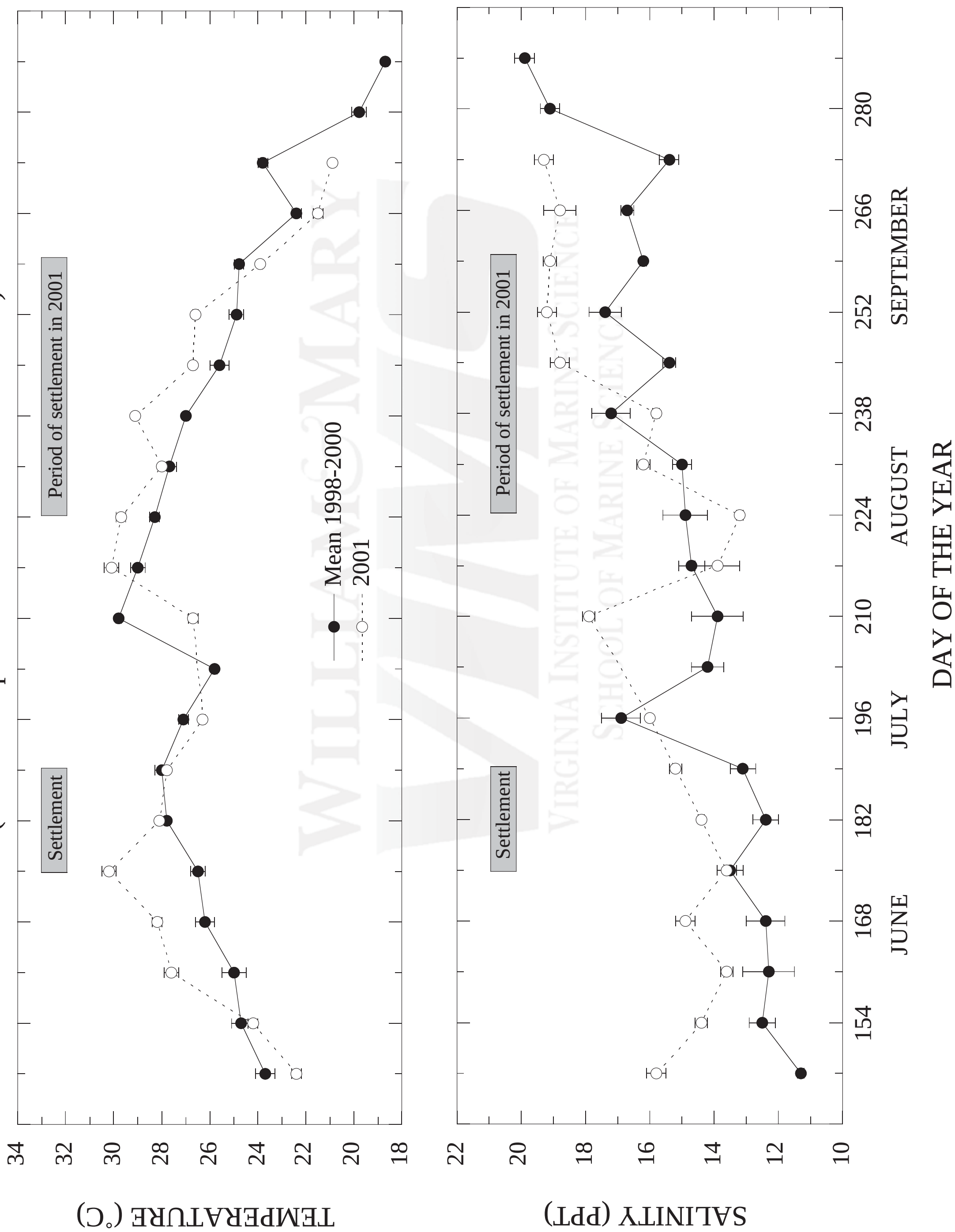


FIGURE S12: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER OVER THE PAST 3 YEARS COMPARED WITH 2001
(error bars represent standard error of the mean)



Part II.

Dredge Survey of Selected Oyster Bars in Virginia During 2001

INTRODUCTION

The Eastern oyster, *Crassostrea virginica* (Gmelin 1791), has been harvested from Virginia waters as long as humans have inhabited the area. 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. 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; they are presently under management by the Virginia Marine Resources Commission (VMRC).

Every year the Virginia Institute of Marine Science (VIMS) conducts a dredge survey of selected public oyster bars in Virginia tributaries of the western Chesapeake Bay to assess the status of the existing oyster resource. These surveys provide information about spatfall and recruitment, mortality, and changes in abundance of seed and market-size oysters from one year to the next. This section summarizes data collected during bar surveys conducted during October 2001.

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, Virginia) during 1998. 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

Location of the oyster bars sampled by VIMS during October 2001 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 preceding 1995, sampling was effected using a 2-ft wide dredge with 4-in teeth towed from a 21-ft boat; volume collected in the dredge bag was 1.5 bushels. 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 three bushels. In all surveys a half-bushel (25 quarts) subsample was taken from each tow for examination. Data presented give the average of the four samples collected at each station for live oyster 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 (3-in), excluding spat), spat (recently settled (2000 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 two categories of boxes is a qualitative description based on visual observations. Temperature (in degrees Celcius) and salinity (in ppt, parts per thousand) were recorded at each of the dredge stations at the time of sampling using an alcohol thermometer and a hand-held refractometer.

During spring and early summer 2001, the following changes that may have had some effect on settlement and oyster abundance were made (Figure D1 and D2 for locations). Seed was removed from Heron Rock and moved to a bar in the Rappahannock River. Clean shells (cultch) were planted on Heron Rock, Bland Point, Palace Bar, and Ginney Point in the Piankatank River and on Harcum Flats, Rogue Point, and Sandy Point in the Great Wicomico River to provide clean substrate for oyster larvae to settle on. Two new artificial oyster reefs were built in the Rappahannock River at Butler's Hole and Broad Creek. Seed oysters were moved from various bars around the Rappahannock River (Broad Creek, Temple Bay, Drumming Ground and Butler's Hole) to other areas in the river (Broad Creek, Sturgeon Bar, Drumming Ground, Temple Bay, Butler's Hole, and Bowler's Rock). In cases where the areas removed of seed are the same as those receiving seed, the seed was simply moved from one part of the bar to another. In addition, broodstock oysters were planted on the artificial reefs at Palace Bar, Burton Point, and Bland Point in the Piankatank River and on Shell Bar Reef in the Great Wicomico River. In mid 1999 an artificial oyster reef was built in the York River in Felgates Creek and 2 reefs were built in Mobjack Bay: one in the North River (Cradle Point) and one in the East River (Mobjack Point). A third reef was built in the Ware River during 2000.

RESULTS

Thirty oyster bars were sampled between October 15 and 24, 2001, 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 total number of oysters at Deep Water Shoal and Long Shoal was moderate with 461 and 520 oysters bushel^{-1} respectively. This is in contrast to most previous years when Horsehead had the highest abundance of oysters in the system. The number of oysters at Point of Shoal, Mulberry Point, Nansemond Ridge, Swash, and Horsehead was low to moderate ranging from 331 to 397 oysters bushel $^{-1}$. Total number of oysters at the other three bars was relatively low averaging less than 300 bushel $^{-1}$, with a range of 102 (Thomas Rock) to 297 (Dry Shoal) total oysters bushel $^{-1}$.

While the overall number of market oysters in the James River continues to be low when compared with historical numbers, compared with the past few years there was an overall increase observed in 2001. As in most previous years the majority of market oysters were found at the more upriver sites. The number of market oysters at the six most upriver sites (Figure D1) ranged between 37 (Mulberry Point) and 86 bushel $^{-1}$ (Deep Water Shoal) whereas the 4 down river sites had considerably fewer market oysters ranging between 0 (Nansemond Ridge) and 3 (Thomas Rock) bushel $^{-1}$. Comparing the number of market oysters between the 2000 and 2001 surveys, there was a noticeable increase at all of the upriver sites (Figure D3, D4A, and D4B). The increase in market oysters at Long Shoal was the first seen in four years, which prior to 2001 had been showing a steady decline. Three out of the four downriver sites also showed an increase in market oysters compared with 2000, but given the low numbers in both years, it is difficult to conclude whether or not this increase is significant.

The number of small oysters bushel $^{-1}$ ranged from a low of 8 (Thomas Rock) to a high of 377 (Long Shoal). The composition of the oyster populations at five of the six upriver stations was made up of greater than 50% small oysters. There was a noticeable increase in small oysters at Deep Water Shoal and Dry Shoal and a decrease at Horsehead and Point of Shoal between 2000 and 2001 (Figures D3 & D4A). Long Shoal and Thomas Rock also showed a decrease in small oysters when compared to 2000 numbers, but the change was relatively small. The other four sites showed very little change in the number of small oysters.

The number of spat bushel $^{-1}$ ranged from a low of 68 (Point of Shoal) to a high of 325 (Nansemond Ridge). This represented a noticeable increase during 2001 when compared with 2000 at all ten stations sampled (Figure D3: Figure D4A and B). As has been observed in the James River in the past, there is a relationship between location in the river and the composition of live oysters in terms of the size distribution of live oysters. 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. At the three most downriver sites, spat made up 86 to 93% of the total oysters bushel $^{-1}$.

The average number of boxes bushel $^{-1}$ ranged from a low of 8 (Thomas Rock) to a high of 128 (Long Shoal). At all of the stations monitored boxes accounted for less than 20% of the total oysters found (live and dead). In general there were more boxes found at the more upriver sites and these accounted for a higher percentage of the total oysters found (live and dead). Greater than 75% of the boxes counted were old at all of the stations except Nansemond Ridge and Thomas Rock.

Water temperature during the sampling period remained fairly constant ranging from 18.4 to 19.2 degrees Celcius (Table D2). Salinity was more variable depending on location in the river, increasing in a downriver direction, from 12 ppt at Deep Water Shoal to 22 ppt at Nansemond Ridge.

York River

The average total number of live oysters bushel $^{-1}$ in the York River were similar for both bars sampled (39 at Aberdeen Rock, 35 at Bell Rock). The oysters found at Aberdeen were predominately small oysters (74% of total), while the oysters at Bell Rock were about a 50/50 split of small and spat, with a slightly higher percentage of spat. There was a noticeable decrease in oysters in all size classes at Bell Rock and a decrease in small oysters at Aberdeen Rock (Figure D5 & D6). Market oysters were scarce at both bars, accounting for 3 and 11% of the total live oysters at Aberdeen Rock and Bell Rock respectively. The total number of boxes (new and old) bushel -1 was low at Bell Rock (8%), but relatively high at Aberdeen Rock (40%). Water temperature on the day of sampling was 18.0 degrees Celcius at Aberdeen Rock and 18.5 degrees Celcius at Bell Rock. There was a 4 ppt difference in salinity, 18 ppt at Bell Rock and 22 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters bushel $^{-1}$ in Mobjack Bay was 14 at Pultz Bar and 120 at Tow Stake. Pultz Bar oysters consisted of approximately 50% small, with the other 50% being an equal mix of spat and market size oysters. There was a noticeable decrease in the number of spat at Pultz Bar compared with 2000 (Figure D5 and D6). Overall the total number of oysters found at Pultz Bar continues to be low. The composition of live oysters at Tow Stake consisted of about 65% small with the other 35% equally split between spat and market oysters. Similar to Pultz Bar there was a noticeable decrease in the number of spat at Tow Stake when compared with 2000. The number of market oysters at Tow Stake has been on a steady increase since about 1996. While the increase in 2001 was not as great as in some of the previous years, there was a small increase observed and a continuation of the trend. The total number of boxes was moderate at both bars accounting for 32 (Tow Stake) and 35% (Pultz Bar) of the total oysters (live and dead) found. In contrast to the 1999 dredge survey (Southworth et al., 2000), there were no boxes attributed to oyster drills in Mobjack Bay during fall 2001 sampling. Water temperature at both stations was 18 degrees Celcius on the day of sampling and salinity was 20 ppt (Table D2).

Piankatank River

The average total number of live oysters bushel $^{-1}$ in the Piankatank River was low to moderate at Palace Bar (297) and low at Burton Point (180) and Ginney Point (183). The number of market size oysters at all three stations was relatively low. There was approximately a 50/50 mixture of spat and small oysters on all three bars, with a slightly higher percentage of small, 56 to 59% versus 38 to 42% spat. When compared with 2000, there was a noticeable decrease in small oysters and spat at Ginney Point and a decrease in market oysters and spat at Palace Bar (Figure D7 and D8). There was no difference observed in any size class between 2000 and 2001 at Burton Point. There was a moderate number of boxes bushel $^{-1}$ at all three sites ranging from 52 (Burton Point) to 69 (Ginney Point). This accounted for 18 to 27% of the total oysters (live and dead) sampled. Four out of the nine spat boxes observed at Burton Point had drill holes, indicative of predation by oyster drills. On the day of sampling, water temperature was 18 degrees Celcius at Burton Point and 18.7 degrees Celcius at Palace Bar and Ginney Point. Salinity was 18 ppt at all three stations (Table D2).

Rappahannock River

The average total number of live oysters in the Rappahannock River was low at all ten stations sampled ranging from 8 (Hog House) to 260 (Broad Creek) bushel $^{-1}$. There appears to be no relation 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. However, four out of the five stations with greater than 100 total oysters bushel $^{-1}$ were downriver of the Corrotoman River (Table D2 and Figure D1). At all of the sites upriver of the Corrotoman, except Hog House, samples were comprised primarily of small oysters ranging from 70 (Middle Ground) to 92% (Ross Rock) of the total oysters. Drumming Ground, Parrot Rock, and Broad Creek, the more downriver sites, on the other hand had a higher percentage of spat, accounting for 56 (Drumming Ground) to 79% (Broad Creek) of the total.

The number of market oysters ranged from 4 (Hog House) to 17 (Bowler's Rock and Smokey Point) bushel $^{-1}$. Middle Ground in the Corrotoman River had the largest number of small oysters bushel $^{-1}$ with 108. The largest number of spat were found at the Parrot Rock, Drumming Ground, and Broad Creek with 70, 115, and 207 spat bushel $^{-1}$ respectively. There was a noticeable decrease in market oysters at Smokey Point and Broad Creek and a decrease in small oysters at Smokey Point, Middle Ground, Parrot Rock, and Broad Creek when compared with 2000 (Figures D9, D10A, and D10B). On the other hand there was a noticeable increase in market oysters at Ross Rock, and Hog House and an increase in small oysters at Ross Rock and Long Rock. There was also a noticeable increase in spat at all sites except Hog House when compared with 2000. The number of market oysters at Broad Creek appears to be in a steady, but slow decline since about 1999. Prior to 1999 Broad Creek enjoyed a steady six-year increase in the number of market oysters (Figure D10A). There has been a steady decrease in market oysters at Bowlers Rock over the past few years, which despite seeding at this site (see Methods above), does not appear to be making a recovery.

The total number of boxes bushel $^{-1}$ ranged from 0 (Ross Rock) to 91 (Middle Ground). A moderate percentage of oysters (live and dead) at all of the stations sampled except Ross Rock were boxes (12 to 37%). There were only a few spat boxes observed in the samples and these were all in and downriver of the Corrotoman River. There was no evidence of oyster drill predation in any of the spat boxes sampled.

Water temperature on the day of sampling ranged from 17.2 to 19.7 degrees Celcius. Salinity increased moving from the most upriver station (Ross Rock: 11 ppt) toward the mouth (Broad Creek: 20 ppt).

Great Wicomico River

The average total number of live oysters at all three stations sampled in the Great Wicomico River was low ranging from 84 bushel $^{-1}$ (Whaley's East) to 153 bushel $^{-1}$ (Haynie Point). The live oysters found were predominately small at Whaley's East (81% of total) and spat at Haynie Point and Fleet Point (74 and 61% of total). There was a noticeable decrease in the number of small oysters at Haynie Point and Fleet Point when compared with 2000 (Figures D11 and D12). There was no difference in the number of market oysters at any of the sites between 2000 and 2001. As was observed in the James and Rappahannock Rivers, there was a noticeable increase in spat at all of the stations sampled when compared with 2000. Boxes made up 11 (Haynie Point) to 24% (Whaley's East) of the total (live and dead) oysters counted. This was a decrease from 2000, when boxes made up almost 50% of the total (live and dead) composition. One out of the two spat boxes observed in the

Haynie Point samples had a drill hole, indicative of oyster drill predation. Water temperature was between 17.7 and 18.1degrees Celcius and salinity was between 18 and 19 ppt on the day of sampling.

DISCUSSION

As is well known, the abundance of market oysters throughout the Chesapeake Bay region has been in serious decline since the turn of the century. 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 Rappahannock River. Presently, the abundance of market oysters in the Virginia tributaries of the Chesapeake remains low. However, there was a noticeable increase in market oysters at six of the ten bars sampled in the James River when compared with 2000. The highest number of market oysters observed during 2000 was 36 bushel -1 whereas it was double that in 2001 with 86 bushel -1 (both occurred at Deep Water Shoal in the James River). While this looks promising for the James River, no other rivers sampled showed a significant increase in market oysters.

As in recent years, the bulk of the oyster population during 2001 consisted primarily of small oysters. Twenty-one out of the thirty stations sampled had a higher percentage of small oysters than spat or market. Of the other nine stations, eight had a higher proportion of spat, those being: the four most downriver stations in the James River, Bell Rock in the York River, the 3 most downriver stations in the Rappahannock River, and Fleet Point and Haynie Point in the Great Wicomico River. The final station, Hog House, had an equal percentage of small and market, but the numbers were so low, it's difficult to make compelling conclusions.

Similar to historical patterns of oyster abundance in the James River, as one moves toward the mouth, the number of spat increases while the number of small oysters decreases. Circulation in the system is such that oyster larvae from the upper limits of oyster abundance (lower salinity areas) are flushed further down river to set at the higher salinity sites (Haven and Fritz, 1985). One would expect that over time this would translate into an increase in small and market oysters at the higher salinity sites. The most likely explanation for why this does not appear to be the case is disease. Both Perkinsus marinus and Haplosporidium nelsoni increase in intensity and prevalence as salinity increases (Calvo and Burreson, 2000).

The 2001 dredge survey in the James River showed an increase in spat from the previous year. This was the first observed increase in spat since 1998. As discussed in the 1998 dredge report (Southworth et al., 1999), one must look at the timing of set when interpreting the data. In years when spatfall occurs earlier (as in 1999 and 2000), the natural mortality that occurs post-settlement occurs over a longer time frame (in terms of time from set to sampling). For example, say overall 1000 spat bushel -1 set during both years. However during 1999 the spat did not set until the end of September, whereas during 2000, the spat were all set by the end of August, creating a difference of one-month post-settlement mortality time. Assuming a mortality rate of 50% each month, by sampling time during 2000 there would be 500 spat bushel -1, whereas during 1999 there would only be 250 spat bushel -1. During 2001, the majority of the spatfall occurred later in the season (September), allowing for less time for post-settlement mortality to occur prior to sampling. The situation in the James must be monitored to see if there is an increase in small oysters during 2002. If there is not, the apparent increase in spat during 2001 was most likely not a true increase, but rather a discrepancy due to a change in temporal scale.

Overall, there was an increase in oyster settlement on all of the bars sampled in the James, Rappahannock, and Great Wicomico Rivers during 2001 when compared with 2000. There was at least a two-fold increase at all of the stations with several bars showing as high as a four to five times increase in spat bushel -1. The lower Rappahannock River in particular had a high spatfall when compared with previous years. Settlement in the lower reaches of the Rappahannock was among the highest seen over the past ten years. This increase in settlement is most likely due to a combination of things. Similar to the Piankatank and Great Wicomico Rivers, there were several reefs built in the lower reaches of the Rappahannock in 2000 and 2001 (Figure D2). While these reefs were not supplemented with broodstock, just the building of three-dimensional reefs has been shown to increase oyster survival (Mann et al., 1996). If oysters survive on the reefs better than on the bottom cultch, then one would expect a higher spatfall around and adjacent to the reefs as the years progress. The decrease in spatfall in the Piankatank River during 2001 is hopefully a reflection of poor setting conditions (i.e. harmful phytoplankton populations, low oxygen content, etc.) and not an indication that the artificial reefs are only capable of sustaining viable oyster populations for a few years. The historical implications of the success of oyster reefs throughout the Chesapeake Bay region suggest that spawning/setting conditions in the Piankatank during 2001 were simply poor.

There was very little change in the number of small oysters at most of the bars sampled. About half of the bars monitored did show either an increase or decrease in small oysters when compared with 2000, but there was no relation to location in the river or the number of boxes. On three bars in the James River (Horsehead, Point of Shoal, and Long Shoal), a decrease in small oysters was coupled with an increase in market oysters. For most of the bars showing a change however, the expected change in market oysters and/or boxes was not observed. On several bars a decrease in small oysters was not coupled with an increase in market oysters or boxes.

On the positive side, there was a relatively low number of boxes bushel $^{-1}$ at most of the bars sampled during 2001 when compared with 2000. Twenty out of the thirty stations sampled had fewer boxes bushel $^{-1}$ than during 2000. Aberdeen Rock in the York River however had double the number of boxes when compared with 2000, making up 40% of the total number of oysters (live and dead). This may have been caused by an increase in disease due to a higher than normal salinity. Salinity during 2000 was 19 ppt compared with 22 ppt during 2001. Disease prevalence tends to increase as salinity increases (Calvo and Burreson, 2000).

The overall number of spat boxes recorded during 2001 was similar to that recorded during 2000, except at the bars in the Piankatank River, where they were considerably lower. This is to be expected when considering the low spatfall numbers observed in the Piankatank River during 2001. There were once again no spat boxes found with gastropod bore holes in them at Tow Stake. At Burton Point, in the Piankatank River, the percentage of the total spat boxes found to have small holes in them remained relatively high similar to 1999 and 2000. There was also one spat box found at Haynie Point in the Great Wicomico River with a drill hole in it. These holes were most likely caused by the oyster drills Urosalpinx cinera and Eupleura caudata which are common 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 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 (Carriker, 1955; 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, including some in the 1999, 2000, and 2001 dredge samples. The drill box found at Haynie Point in the Great Wicomico River is the first one that has been recorded in that system since Hurricane Agnes (1972).

TABLE D1
STATION LOCATIONS FOR FALL DREDGE SURVEY

STATION	LATITUDE	LONGITUDE
JAMES R.		
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 08 32	76 29 33
Nansemond Ridge	36 55 20	76 27 10
YORK R.		
Bell Rock	37 28 42	76 44 48
Aberdeen Rock	37 20 00	76 36 06
MOBJACK BAY		
Tow Stake	37 20 18	76 23 28
Pultz Bar	37 21 06	76 21 06
PIANKATANK R.		
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 R.		
Ross Rock	37 54 00	76 47 30
Bowlers 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 26	76 33 03
Middle Ground	37 41 00	76 28 24
Drumming Ground	37 38 41	76 28 10
Parrot Rock	37 36 24	76 25 12
Broad Creek	37 34 31	76 18 18
GREAT WICOMICO R.		
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 2001

Station	Date	Temp	Sal	Average number of oysters per bushel				Boxes per bushel			
		(° C)	(ppt)	Market	Small	Spat	Total	New	Old	Spat	Total
JAMES											
Deep Water Shoal	10/24	18.7	12.0	86.0	206.0	169.0	461.0	3.5	30.0	0.5	34.0
Mulberry Point	10/24	18.7	15.0	37.0	220.0	90.5	347.5	4.5	31.0	1.0	36.5
Horsehead	10/24	18.6	14.0	69.0	245.0	83.0	397.0	10.5	47.5	1.5	59.5
Point of Shoal	10/24	18.7	14.0	78.0	185.0	68.0	331.0	13.0	46.0	2.5	61.5
Swash	10/24	18.4	16.0	43.0	238.5	84.0	365.5	12.0	44.5	0.0	56.5
Long Shoal	10/24	18.8	15.0	67.5	377.0	75.0	519.5	21.0	105.5	1.5	128.0
Dry Shoal	10/23	18.9	16.0	2.0	106.5	188.0	296.5	7.5	51.5	2.0	61.0
Wreck Shoal	10/23	19.2	18.0	2.0	23.0	153.0	178.0	0.5	10.0	0.5	11.0
Thomas Rock	10/23	19.1	19.0	3.0	7.5	91.0	101.5	0.5	4.5	2.5	7.5
Nansemond Ridge	10/23	18.9	22.0	0.0	23.5	324.5	348.0	1.0	6.0	5.0	12.0
YORK											
Bell Rock *	10/18	18.5	18.0	4.0	14.0	17.0	35.0	0.0	3.0	0.0	3.0
Aberdeen Rock	10/18	18.0	22.0	1.0	29.0	9.0	39.0	6.0	20.0	0.0	26.0
MOBJACK BAY											
Tow Stake **	10/16	18.0	20.0	25.0	79.0	16.0	120.0	10.0	45.0	1.0	56.0
Pultz Bar	10/16	18.0	20.0	4.5	6.5	3.0	14.0	0.0	7.5	0.0	7.5
PIANKATANK											
Ginney Point	10/15	18.7	18.0	6.0	107.5	69.5	183.0	10.5	58.0	0.5	69.0
Palace Bar	10/15	18.7	18.0	3.0	175.0	119.5	297.5	20.5	46.5	0.0	67.0
Burton Point	10/15	18.0	18.0	3.5	100.5	75.0	179.0	13.0	34.5	4.5	52.0
RAPPAHANNOCK											
Ross Rock	10/22	17.8	11.0	5.5	69.0	0.5	75.0	0.0	0.0	0.0	0.0
Bowler's Rock	10/22	17.5	12.0	16.5	63.0	1.5	81.0	0.5	10.5	0.0	11.0
Long Rock	10/22	17.4	13.0	6.0	39.5	2.5	48.0	0.5	6.0	0.0	6.5
Morattico Bar	10/22	17.5	15.0	14.0	73.5	5.0	92.5	3.0	16.5	0.0	19.5
Smokey Point	10/22	17.4	17.0	16.5	77.0	11.0	104.5	5.5	27.5	0.0	33.0
Hog House	10/22	17.3	19.0	3.5	3.5	1.0	8.0	0.5	1.0	0.0	1.5
Middle Ground #	10/22	19.7	14.0	8.5	108.0	38.5	155.0	8.0	82.0	0.5	90.5
Drumming Ground	10/22	19.0	18.0	10.0	78.5	114.5	203.0	4.0	32.0	0.5	36.5
Parrot Rock	10/22	17.2	20.0	9.0	43.5	70.0	122.5	2.5	44.0	1.0	47.5
Broad Creek	10/15	18.2	20.0	16.0	37.5	206.5	260.0	7.5	26.0	1.0	34.5
GREAT WICOMICO											
Haynie Point	10/17	18.1	18.0	2.0	38.0	112.5	152.5	3.0	15.0	1.5	19.5
Whaley's East	10/17	18.0	19.0	4.5	67.5	11.5	83.5	4.0	22.0	0.0	26.0
Fleet Point	10/17	17.7	19.0	5.5	43.0	76.0	124.5	3.5	19.5	0.5	23.5

* Private Bar (number based on one 1/2 bushel sample) ** Numbers based on two 1/2 bushel samples.
# Located in the Corrotoman River (part of the Rappahannock River system).

Figure D1: Map showing the location of the oyster bars sampled during the 2000 dredge survey. Numbers in the blown up maps of the Piankatank and Great Wicomico Rivers represent the closed black circles on the big map.

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.

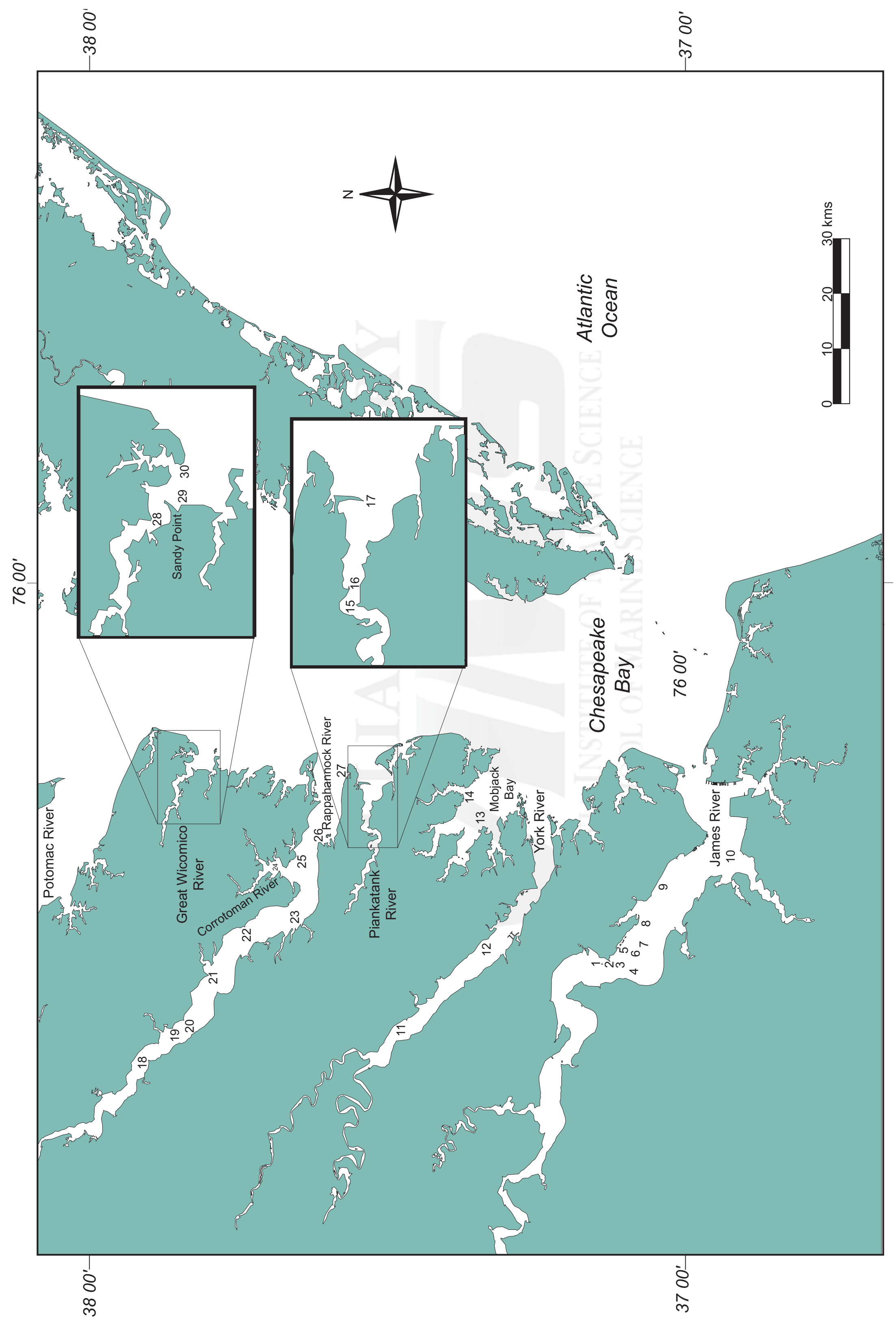
York River: 11) Bell Rock, 12) Aberdeen Rock.

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
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 26 27 28 29 30

Figure D2: Map showing the location of the artificial oyster reefs in the Virginia portion of the Chesapeake Bay.

Lynnhaven River: 1) Lynnhaven River Reef.

Lafayette River: 2) Hampton Boulevard Bridge Reef, 3) Tanner's Point Reef.

Elizabeth River: 4) Western Branch Reef, 5) Craney Island Reef.

York River: 6) Felgate's Creek Reef, 7) Amoco Reef.

Mobjack Bay: 8) Ware River Reef, 9) North River Reef, 10) East River Reef.

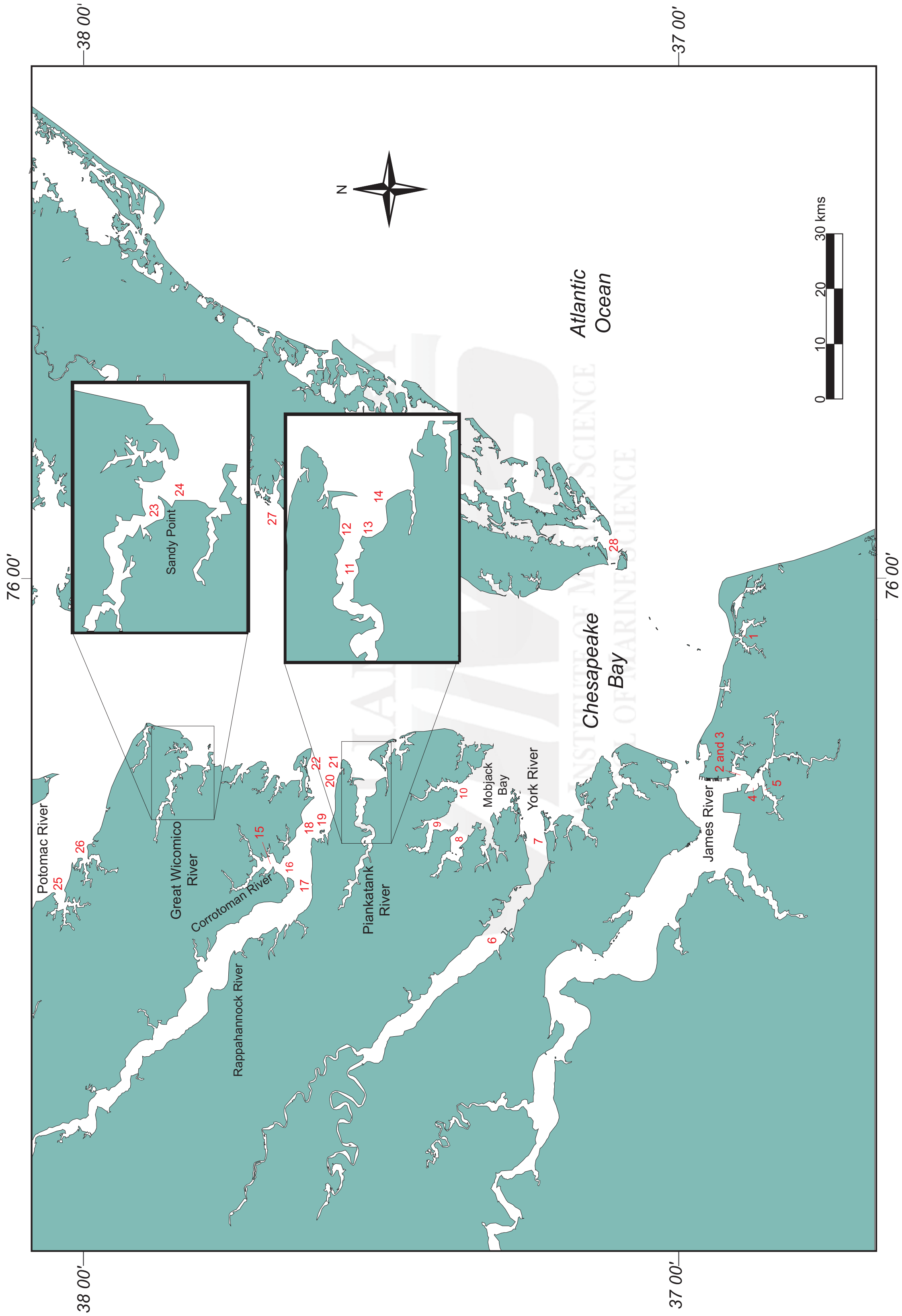
Piankatank River: 11) Palace Bar Reef, 12) Bland Point Reef, 13) Iron Point Reef, 14) Burton Point Reef.

Rappahannock River: 15) Ferry Bar Reef, 16) Drumming Ground Reef, 17) Temple Bay Reef, 18) Parrot's Rock Reef, 19) Mill Creek Reef, 20) Sturgeon Bar Reef, 21) Broad Creek Reef, 22) Butler's Hole Reef.

Great Wicomico River: 23) Shell Bar Reef, 24) Cranes Creek Reef.

Potomac River: 25) Yeocomico River Reef, 26) Coan River Reef.

Eastern Shore: 27) Pungoteague Creek Reef, 28) Fishermen Island Reefs.


38 00'
37 00'
76 00'
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Bay
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30 kms
Potomac River
Great Wicomico
River
Corrotoman River
Rappahannock River
Piankatank
River
Mobjack
Bay
York River
James River
Sandy Point
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FIGURE D3: COMPARISON OF OYSTER ABUNDANCE IN THE JAMES RIVER (2000-2001)
(error bars represent standard error of the mean)

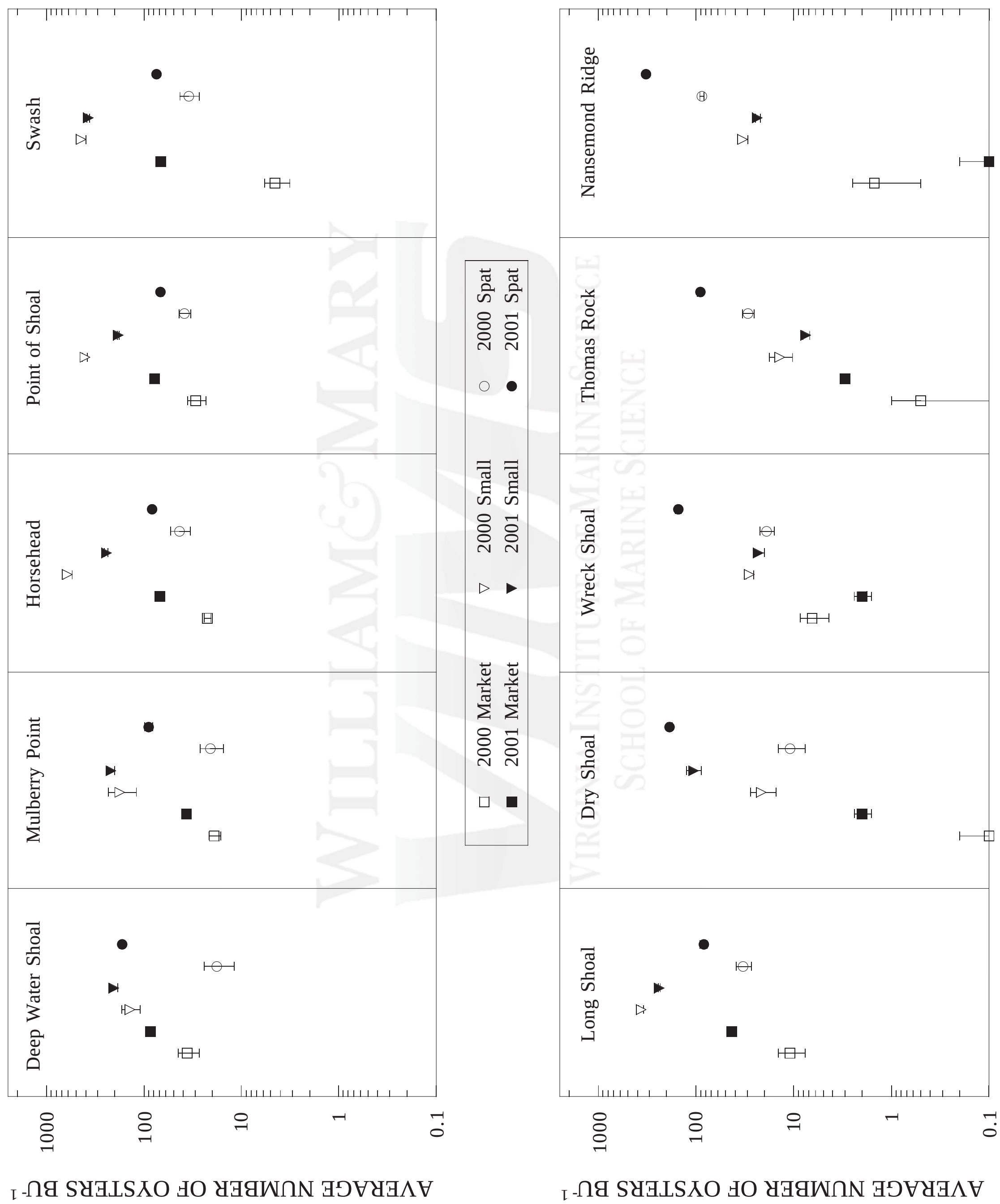


FIGURE D4A: JAMES RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

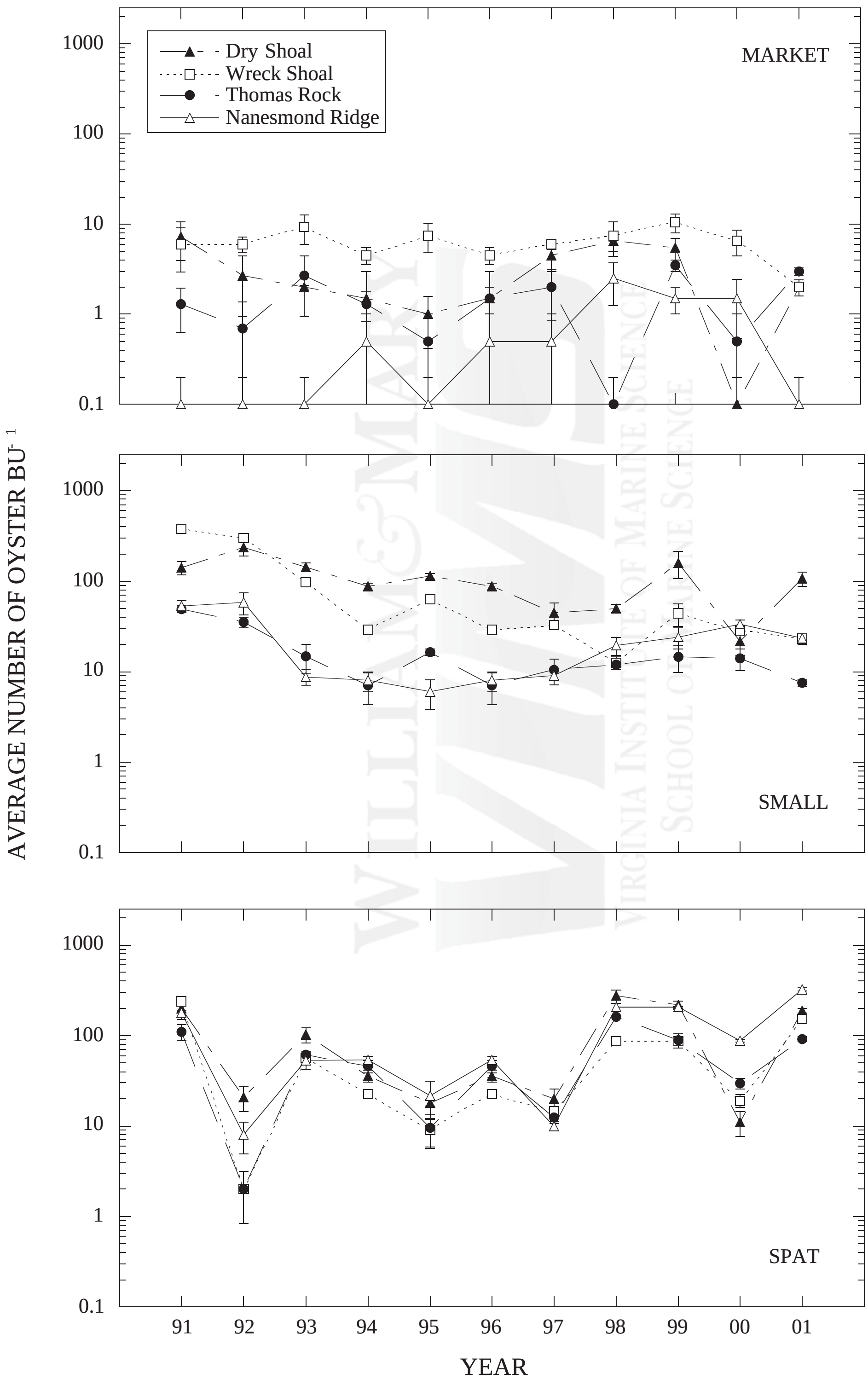


FIGURE D4B: JAMES RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

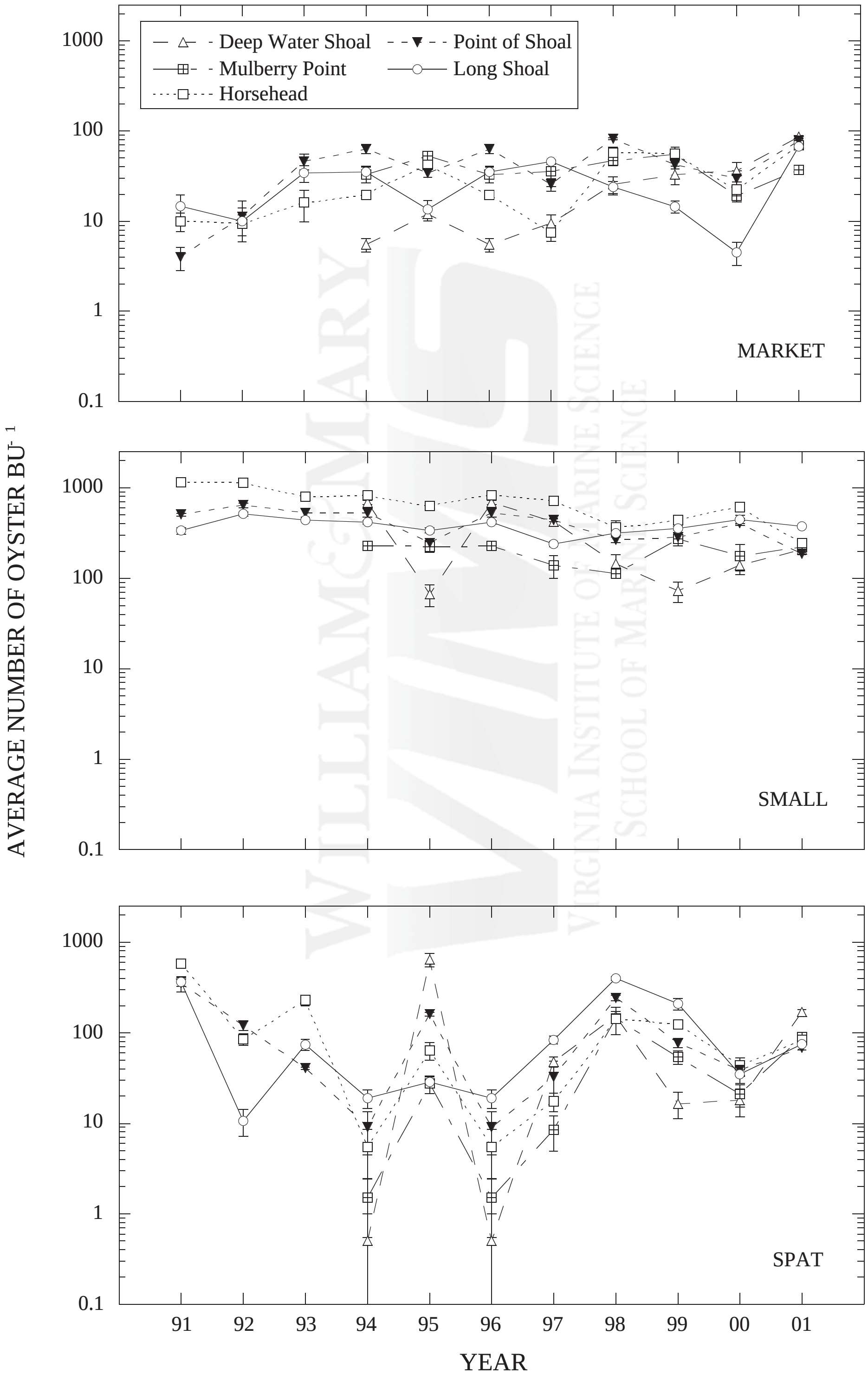


FIGURE D5: COMPARISON OF OYSTER ABUNDANCE IN THE YORK RIVER AND MOBJACK BAY (2000-2001)
(error bars represent standard error of the mean)

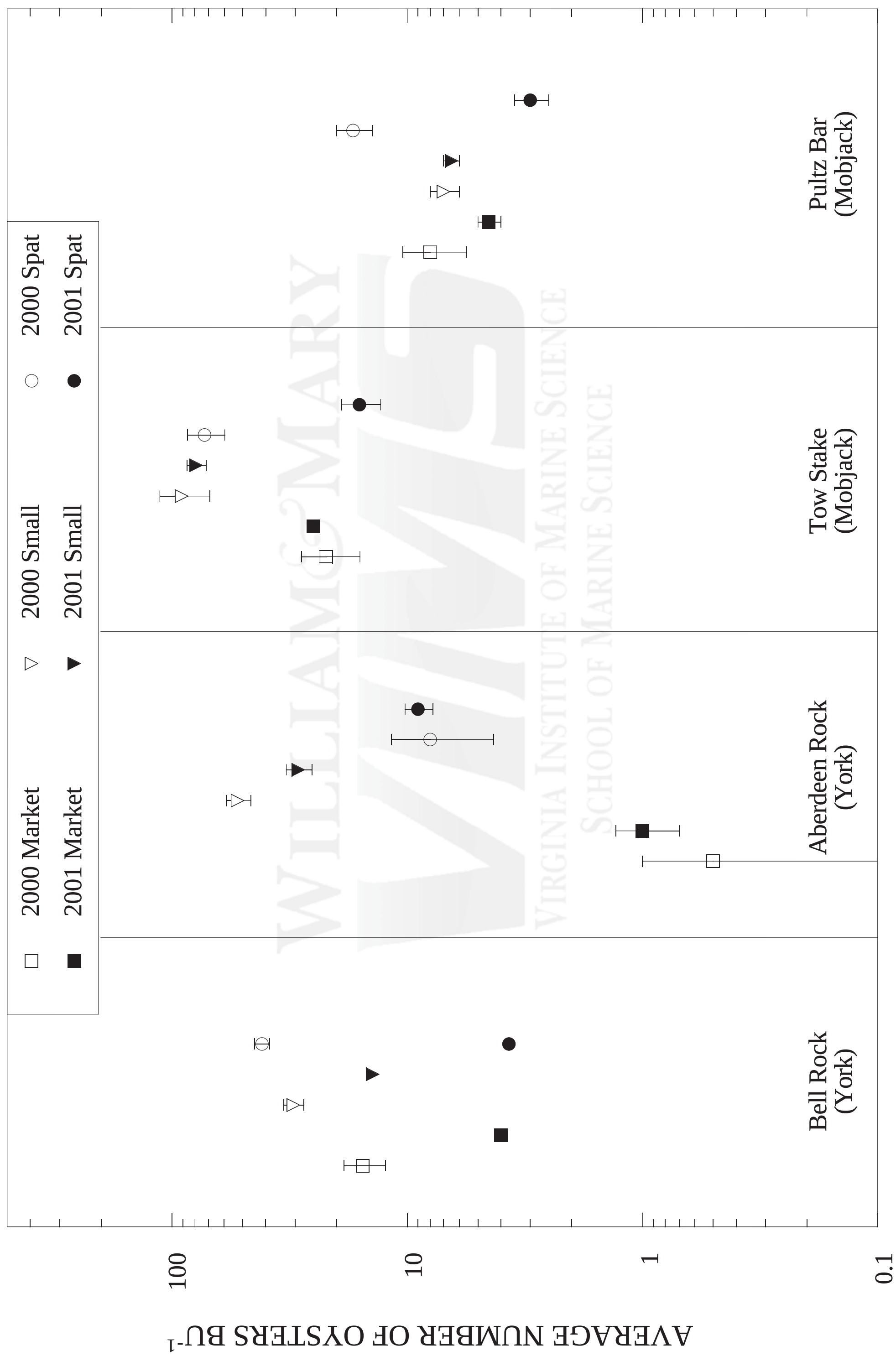


FIGURE D6: YORK RIVER AND MOBJACK BAY OYSTER TRENDS OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

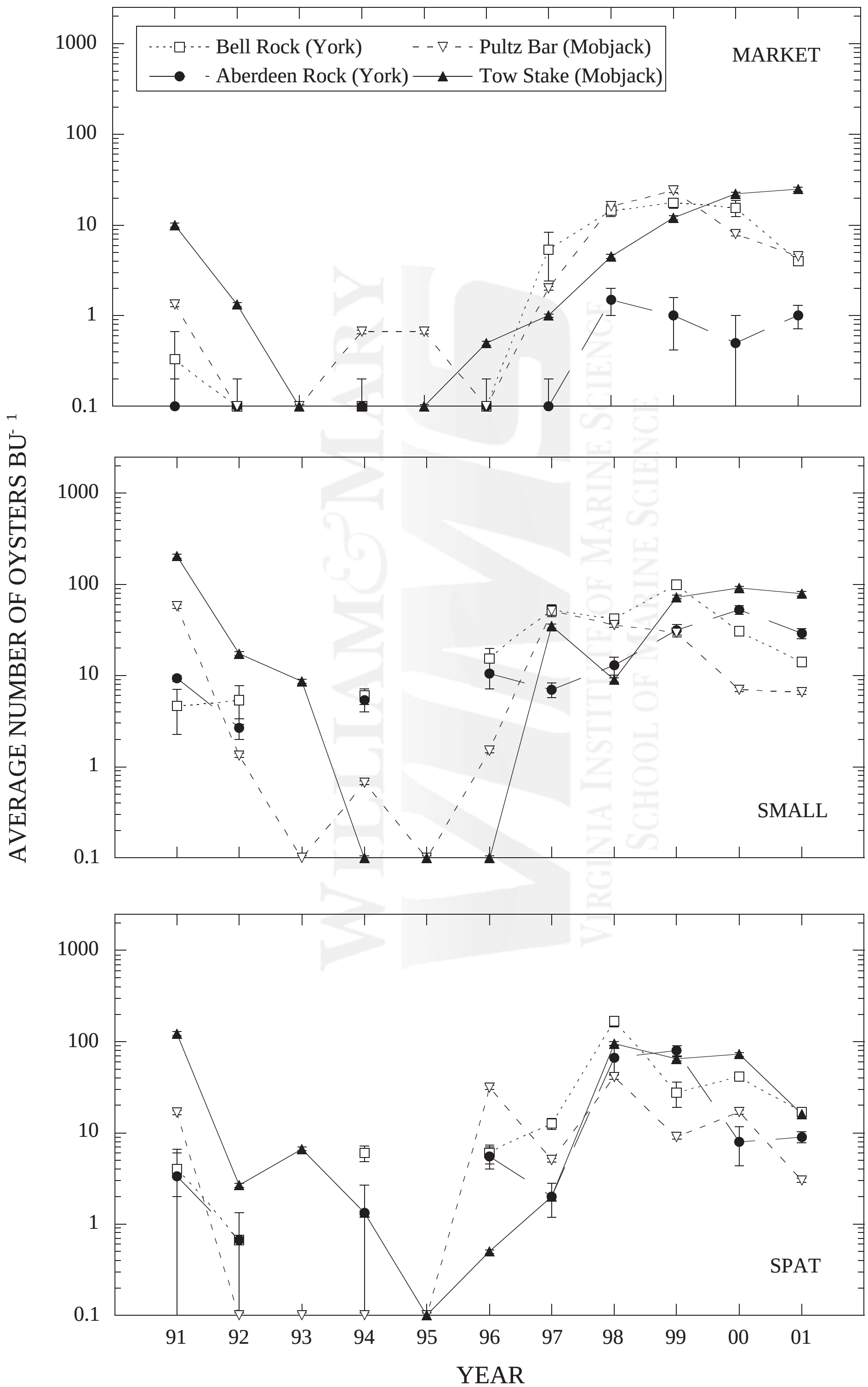


FIGURE D7: COMPARISON OF OYSTER ABUNDANCE IN THE PIANKATANK RIVER (2000-2001)
(error bars represent standard error of the mean)

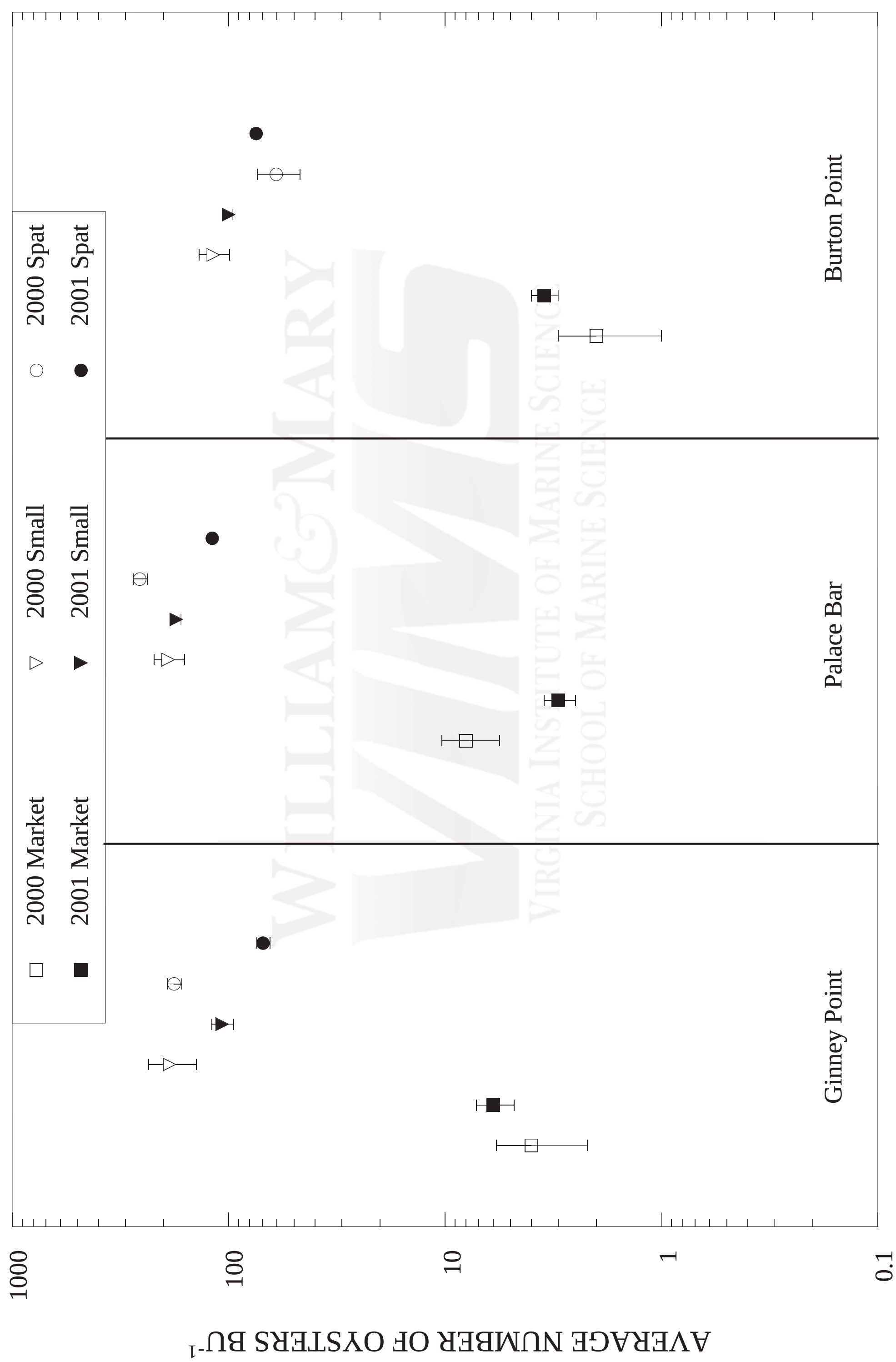


FIGURE D8: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

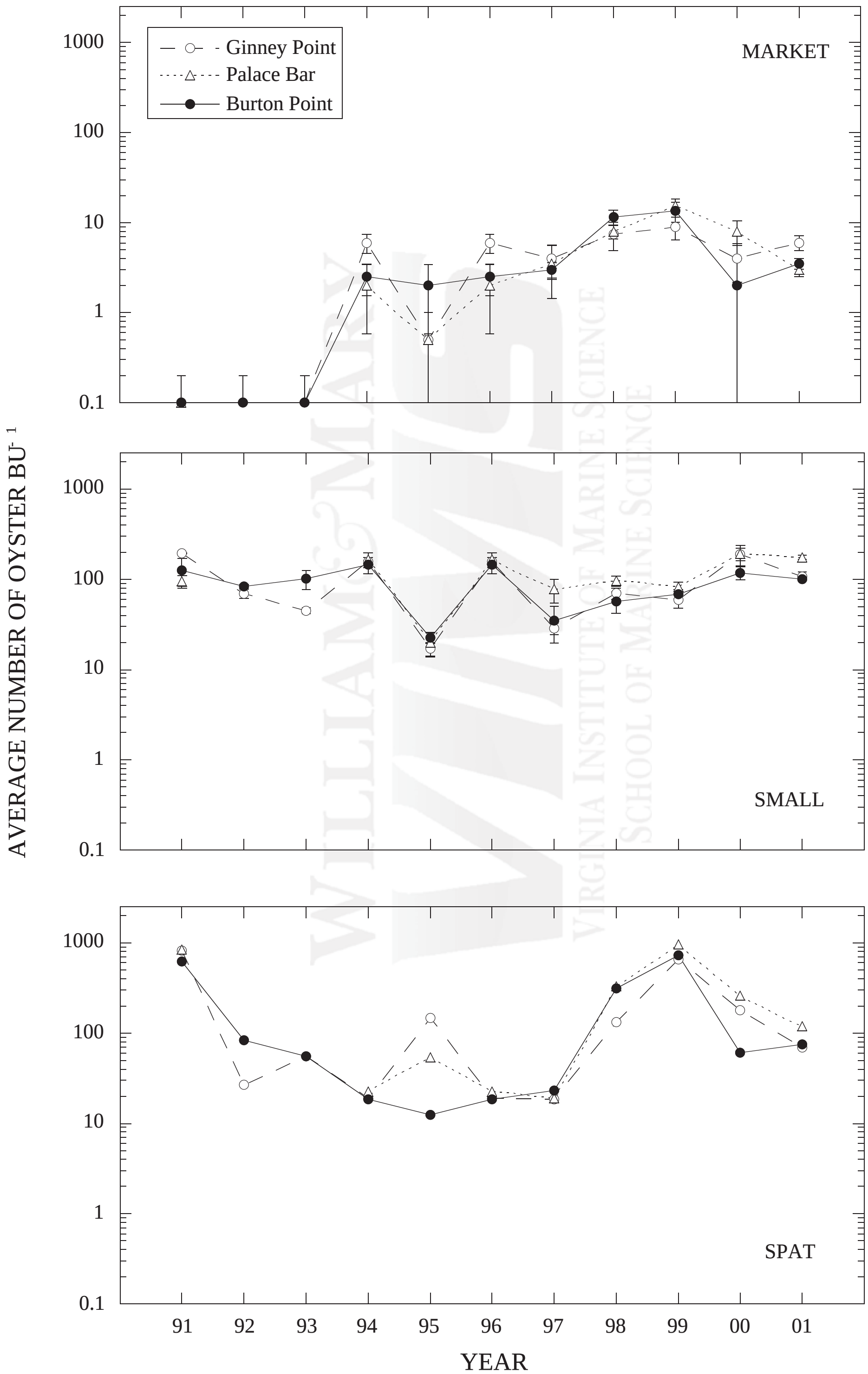


FIGURE D9: COMPARISON OF OYSTER ABUNDANCE IN THE RAPPAHANNOCK RIVER (2000-2001)
(error bars represent standard error of the mean)

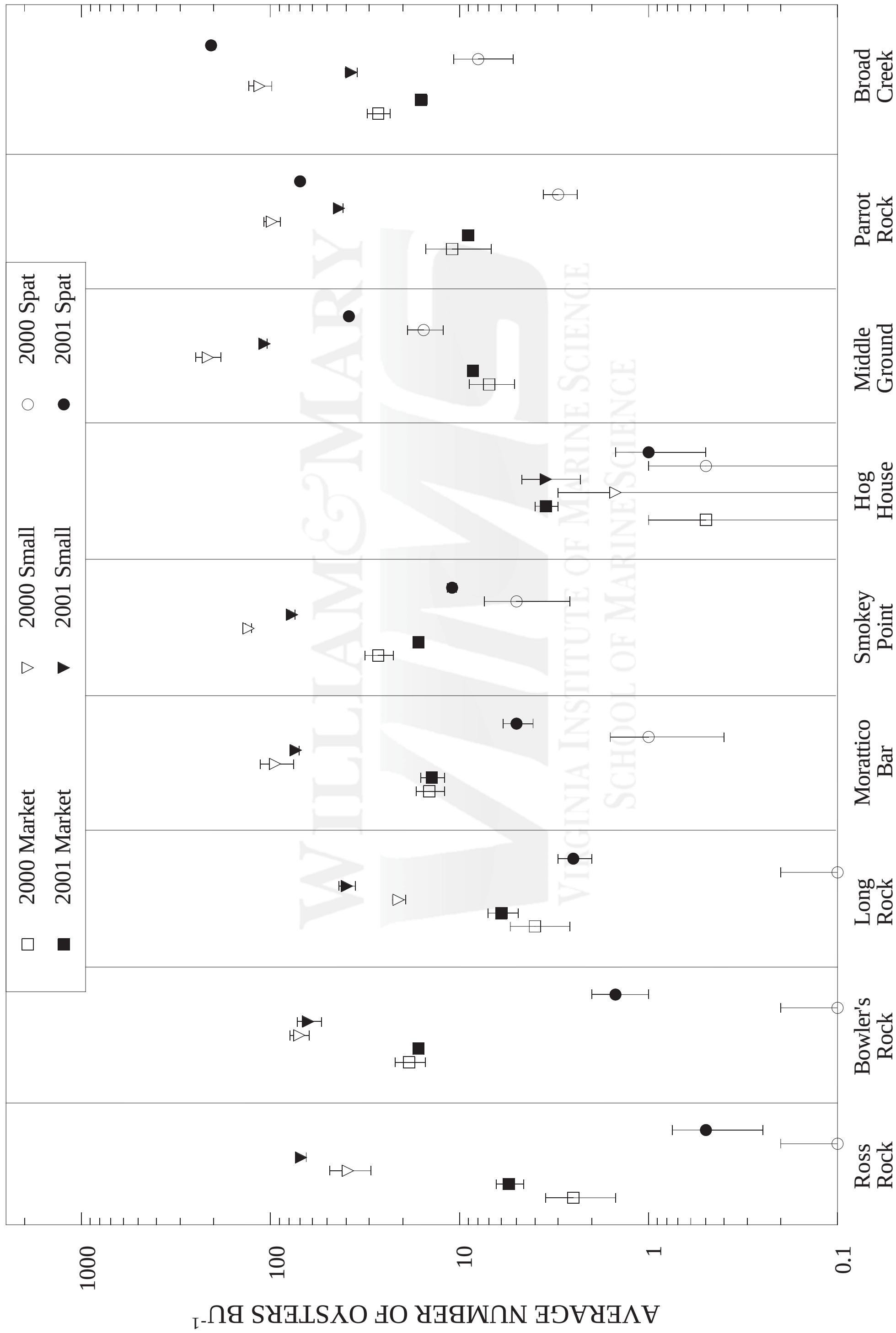


FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

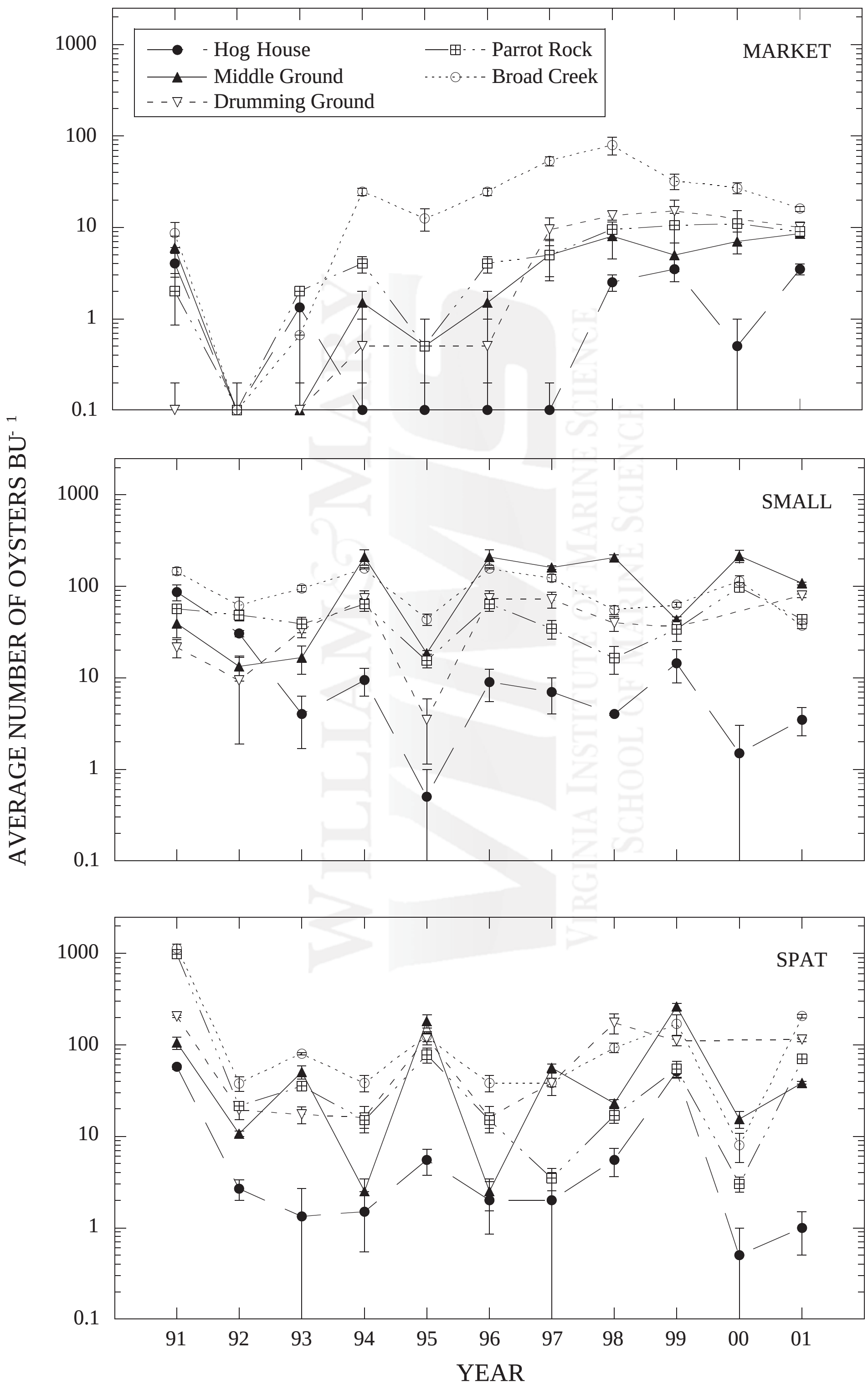


FIGURE D10B: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

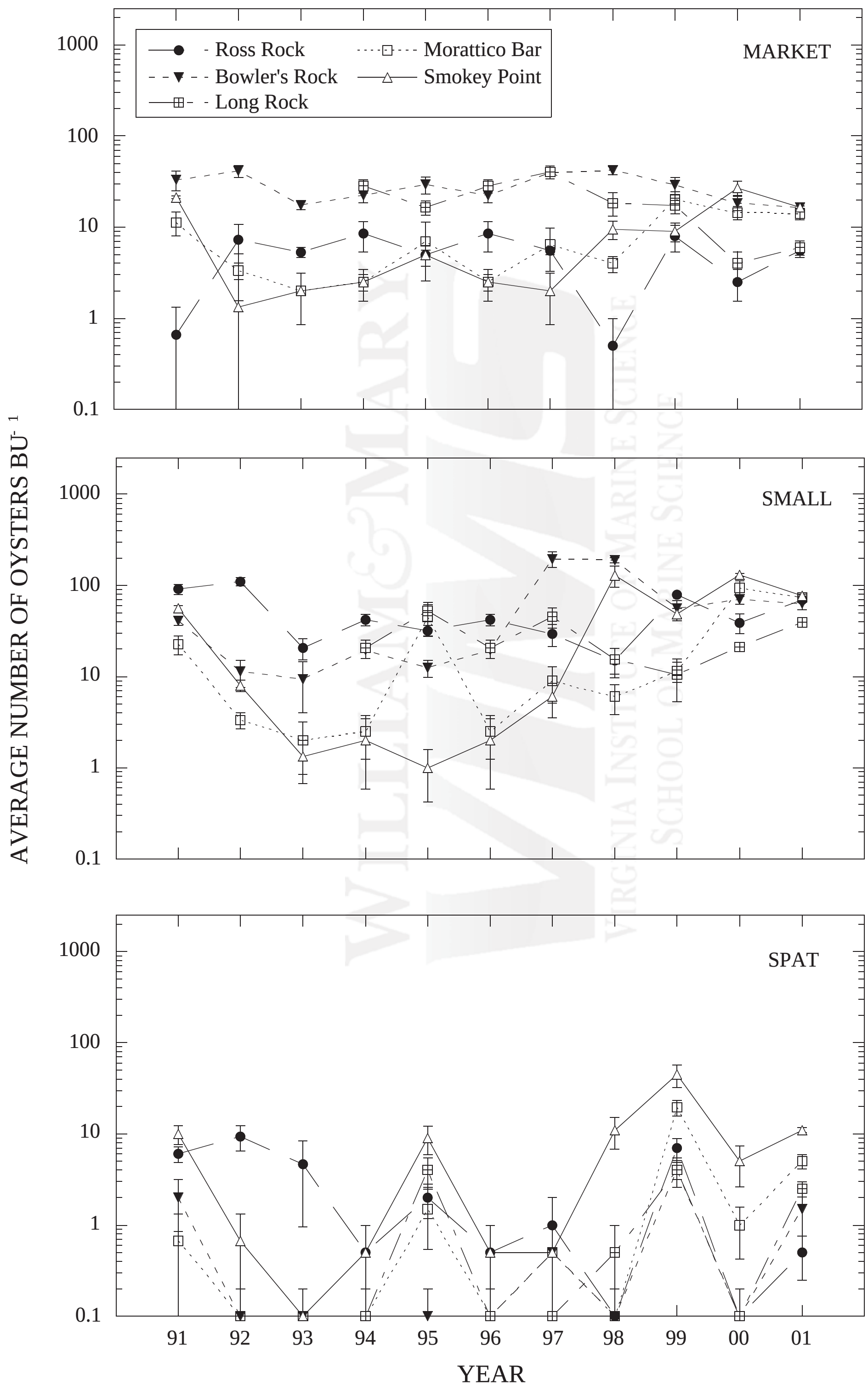


FIGURE D11: COMPARISON OF OYSTER ABUNDANCE IN THE GREAT WICOMICO RIVER (2000-2001)
(error bars represent standard error of the mean)

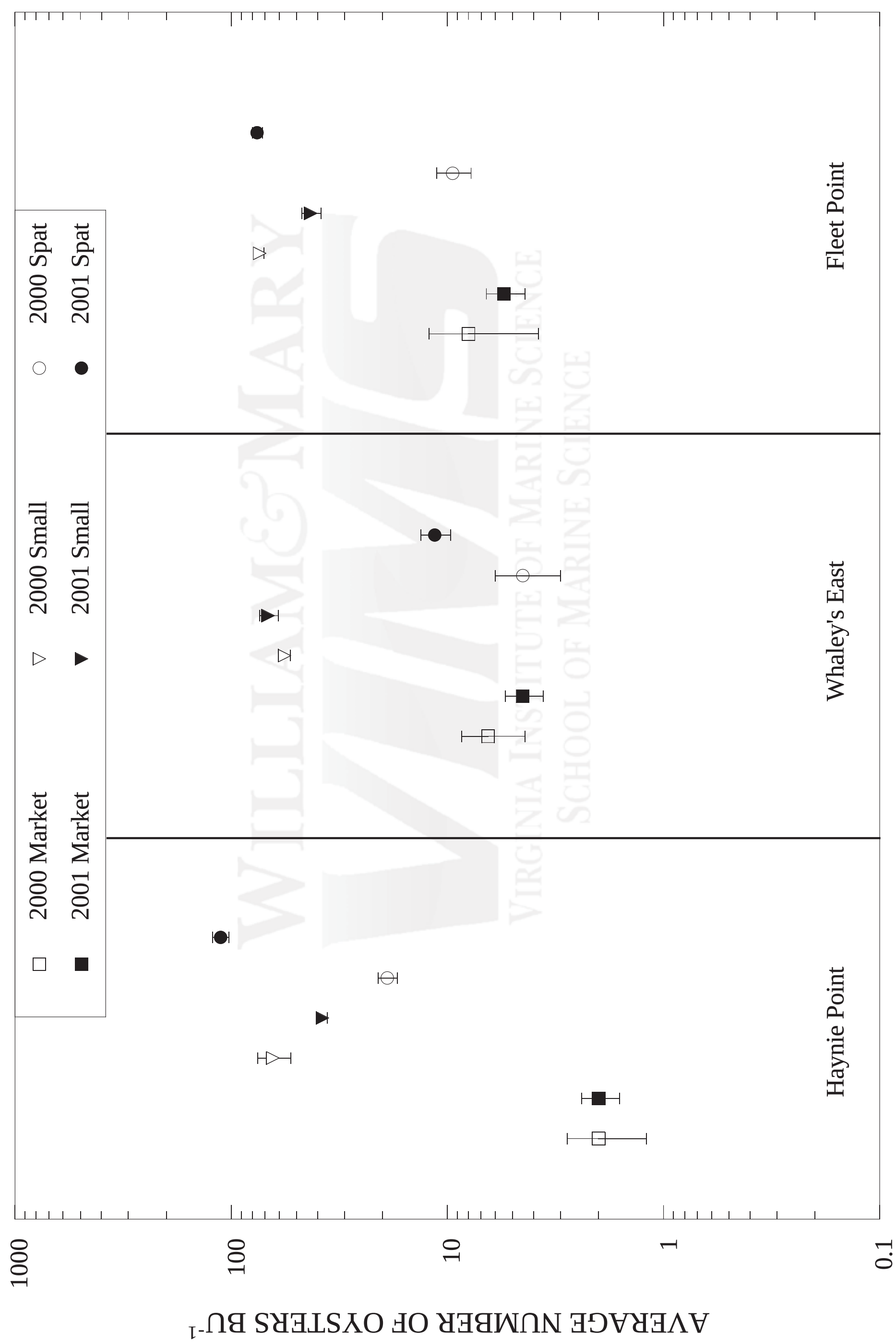
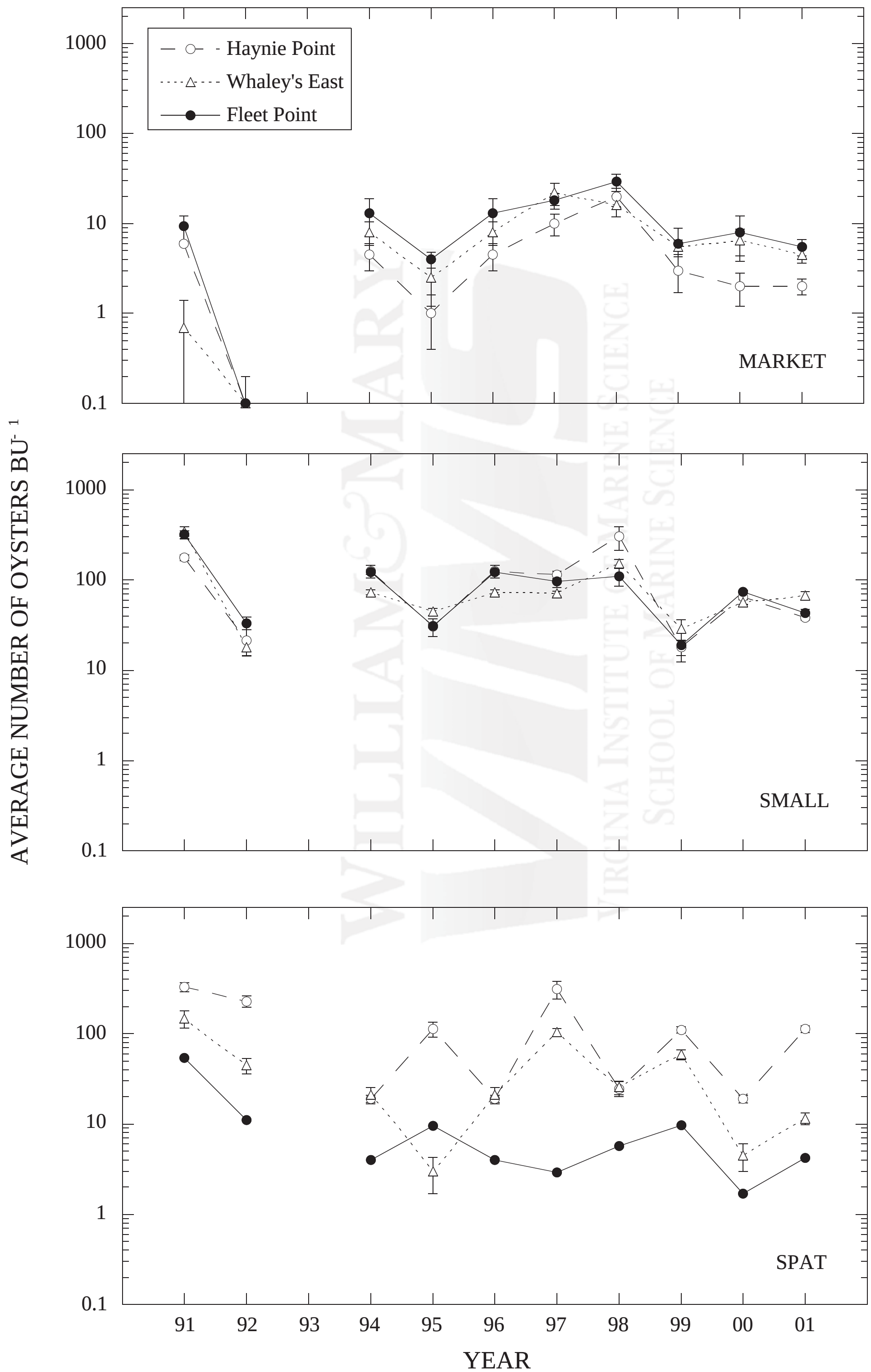


FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)



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REFERENCES

Andrews, J.D. 1983. Transport of bivalve larvae in James River, Virginia. J. Shellfish Res. 3(1): 29-40.

Calvo, L.M. and E.M. Burreson, 2000. Status of the major oyster diseases in Virginia 1999: A summary of the annual monitoring program. Virginia Marine Resource Report No. 00-2. 23 pp.

Carriker, M.R. 1955. Critical review of biology and control of oyster drills *Urosalpinx* and *Eupleura*. Special Scientific Report: Fisheries No. 148. 150 pp.

Haskin, H.H. 1964. The distribution of oyster larvae. Proc. Symp. Exp. Mar. Ecol., Kingston, Rhode Island, Occas. Publ. 2:76-80.

Haven, D.S. 1974. Effect of Tropical Storm Agnes on oysters, hard clams, and oyster drills. In: The effects of Tropical Storm Agnes on the Chesapeake Bay estuarine system. Chesapeake Research Consortium Publication No. 27. 28 pp.

Haven, D.S. and L.W. Fritz, 1985. Setting of the American oyster *Crassostrea virginica* in the James River, Virginia, USA: temporal and spatial distribution. Mar. Biol. 86: 271-282.

Mann, R., F.O. Perkins, J. Wesson, and I.K. Bartol. 1996. Intertidal oyster reefs as a tool for estuarine rehabilitation and rejuvenation of the Virginia oyster fishery. Unpublished final report submitted to the Department of Environmental Quality/Virginia Coastal Resource Management Program, Richmond, VA.

Southworth, M and R. Mann. 1998. Oyster reef broodstock enhancement in the Great Wicomico River, Virginia. J. Shellfish Res. 17(4): 1101-1114.

Southworth, M., J.M. Harding, and R. Mann. 1999. The status of Virginia's public oyster resource 1998. Virginia Marine Resources Report No. 99-6. 37 pp.

Southworth, M., J.M. Harding, and R. Mann. 2001. The status of Virginia's public oyster resource 2000. Molluscan Ecology Program, Virginia Institute of Marine Science, Gloucester Point, Virginia. 56pp.

Thompson, R.J., R.I.E. Newell, V.S. Kennedy, and R. Mann. 1996. Reproductive processes and early development. In: The Eastern Oyster: *Crassostrea virginica*. V.S. Kennedy, R.I.E. Newell and A.F. Eble, (eds.). Maryland Sea Grant Publications, Maryland 722 pp.

Wood, L. and W.J. Hargis, Jr. 1971. Transport of bivalve larvae in a tidal estuary. Pages 29-44 in D.J. Crisp (ed.). Fourth European Marine Biology Symposium. Cambridge University Press, New York.