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The Status of Virginia's Public Oyster Resource 1999

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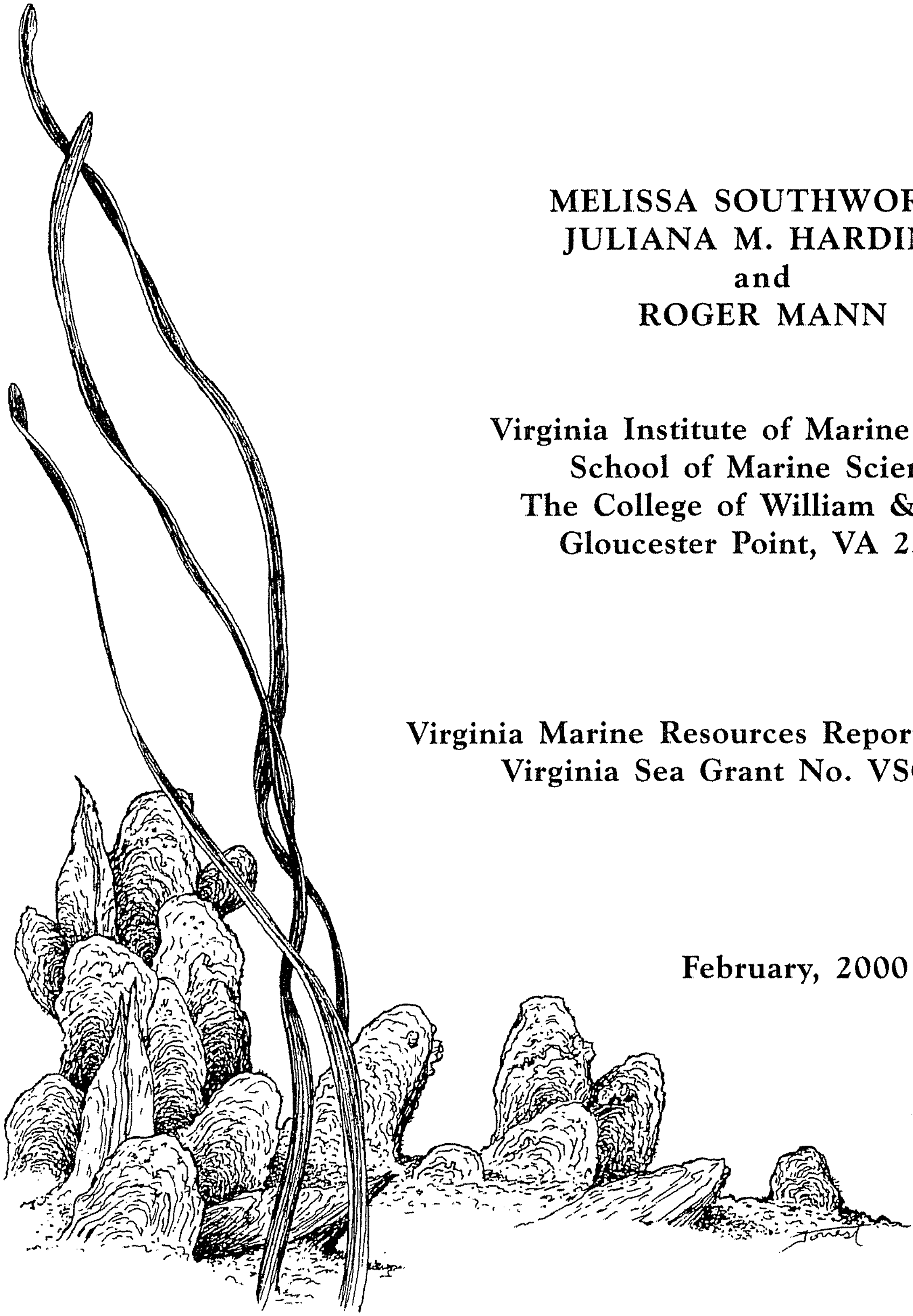


Part I. OYSTER SPATFALL IN VIRGINIA DURING 1999

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 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 in an estuary and successful development and survival of larvae to the settlement stage. 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 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 1999 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 1999 was monitored from the beginning of June through mid-October at all stations. Spatfall stations included 8 historical sites in the James River, 3 historical and 5 new sites in the Piankatank River, 5 historical and 4 new sites in the Great Wicomico River and 4 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 10 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. The change in the number and location of shellstring sites during 1998, was implemented to provide a means of quantitatively monitoring these oyster reefs. In particular, broodstock oysters were planted on a reef in the Great Wicomico River during the Winter, 1996 and on reefs in the Piankatank and Great Wicomico Rivers during Winter, 1997, 1998, and 1999. The increase during 1998 in the number of shellstring sites in the two rivers coincides with the areas of new shell planting in Spring, 1998 and 1999, and provides means of monitoring the reproductive activity of the planted broodstock on the artificial oyster reefs. Continued deployment during 1999 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. Shellstrings were once again deployed at Pungoteague, Virginia during 1999 to continue the monitoring of broodstock oyster production on the artificial oyster reef built in the creek.

Oyster shellstrings were used to monitor oyster spatfall. A shellstring consists of 12 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. Throughout the monitoring period, shellstrings were deployed approximately 0.5 m (18 in) off the bottom at each station. Shellstrings were replaced after a one-week exposure (with some occasional deviations), and the number of spat that attached to the smooth underside of the middle 10 shells were counted with the aid of a dissecting microscope. This number was then divided by 10 to get the mean number of spat $shell^{-1}$ for the corresponding time interval.

Although shellstring collectors at most stations were deployed for 7-day periods, some deviations due to weather did occur such that shellstring deployment periods ranged from 5 to 21 days. These periods did not usually coincide among the different rivers and areas monitored. Spat counts for different deployment dates and periods were, therefore, standardized to correspond to the 7-day standard periods specified in Table 1. Standardized spat per shell (S) was computed using the formula; $S = \sum$ spat $shell^{-1}$ / 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 (°C) 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 1999 is summarized in Table S1 and is discussed below for each river system monitored. A summary of settlement for the past 11 years appears in Table S2. Unless otherwise specified, the information presented below refers to those two tables. When comparing 1999 data with historical data in the James River, all 8 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 1999. 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 previous data reports).

James River

Oyster settlement in the James River was first observed during the week of July 15 at Rock Wharf and Wreck Shoal (Table S1). Settlement began at all other stations during the week of July 22 and continued consistently (at least 0.1 spat shell^{-1} / week) until the week of September 23 at all stations except Horsehead and Point of Shoal. The last settlement seen at these two stations was during the week of September 6. The lack of data for several weeks towards the end of the sampling period was due to stormy weather that prevented collection of the shellstrings.

Cumulative spat shell^{-1} / week for 1999 ranged from a low of 3.1 at Wreck Shoal, to a high of 8.0 at Rock Wharf. Overall, oyster settlement during 1999 was moderate throughout the system, with the highest settlement occurring at the more downriver stations located along the Southern shore.

1999 was the first year in the last four to show a marked improvement in spatfall in the James River. Settlement was higher at all stations compared to settlement during 1998 (Table S2; Figures S2A & B). However, settlement during 1999 was still lower than the 10 yr mean at all stations except Deep Water Shoal and Rock Wharf (Table S2; Figures S2A and B).

Average river water temperatures reached a maxima in late July (29.2°C; Figure S3A). Water temperatures for the 1999 sampling season were average when compared with the mean for the past 6 years (Figure S3A). Salinity, on the other hand, was higher than average when compared with the previous 6 yr mean (Figure SB). Salinity during most of the 1999 shellstring sampling period was approximately 4 to 6 ppt higher than the 6 yr mean until the beginning of September, when Hurricanes Dennis and Floyd occurred within 10 days of each other. On average there was a 4 to 8 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 Bland Point, Cape Toon, Stove Point, and Burton Point (Table S1). As in the James River, the majority of oyster settlement occurred between the end of July and the end of September.

Cumulative spat shell^{-1} / week for the year ranged from a low of 5.9 at Wilton Creek to a high of 44.1 at Bland Point. Prior to the 1999 reproductive season two events that might effect oyster spatfall occurred in the Piankatank River: broodstock oysters were placed on oyster reefs near Bland Point, Iron Point, and Palace Bar, and oyster shells (cultch) were planted at Cape Toon, Bland Point, Palace Bar, Burton Point, Heron Rock, and Ginney Point (Figure S1), to provide clean substrate for larval oysters to set on. Comparing the major spatfall in the 2 areas with broodstock oysters, the larvae appeared to travel and set upriver and adjacent to the broodstock oysters.

Based on data from the 3 historical sites in the system, spatfall during 1999 continued to increase as had been observed during 1998. All of the sites (historical and new) except Heron Rock, showed an increase in spatfall during 1999 when compared with 1998 (Table S2; Figure S4; Southworth et. al, 1999). However, 1999's spatfall was still low when compared to the 10 yr mean for the 3 historical sites. The increase in spatset in the Piankatank was similar to that seen in the Great Wicomico River in 1997, after broodstock were planted on an artificial reef in that river (Morales-Alamo and Mann, 1998; Southworth and Mann, 1998).

The average river water temperature ranged from 19 to 30°C throughout the sampling period, reaching a maximum in the beginning of July. Water temperature did not vary much from the average temperatures previously recorded for the river (Figure S5A).

However, similar to the James River, salinity in the Piankatank was higher than average, until the beginning of September (Figure S5B). There was a 4 to 6 ppt difference between the 1999 salinity and the mean salinities recorded for the past 6 years. During 1999, there was about a 2 to 3 ppt difference recorded on most days between Wilton Creek (the most upriver station) and Burton Point (the most downriver station; Figure S1).

Great Wicomico River

Settlement in the Great Wicomico River was first observed during the week of June 17 (Table S1) at Hilly Wash. No other settlement was observed until mid August. Settlement was consistent from the week of August 26 through September 23 at most stations. Prior to the 1999 reproductive season (Spring, 1999), oyster shell was planted at Fleet Point, Haynie Point, Shell Bar, and Whaley's East (Figure S1). Broodstock oysters were placed on the artificial oyster reef built at Cranes Creek during 1998 (Figure S1).

Cumulative spat shell^{-1} / week for the year ranged from a low of 0.5 at Fleet Point to a high of 2.9 at Shell Bar. As observed in the Piankatank River, settlement at all stations (both historical and new) was higher during 1999 than during 1998. However, comparing 1999 numbers with those recorded over the past few years, overall settlement in the Great Wicomico was low for the second year in a row. The 1999 numbers for the historical stations were also much lower than the 10 yr mean (Table S2; Figure S6).

Average river water temperatures ranged between 18 and 30°C throughout the sampling period (Figure S7A). Water temperature reached a maximum in mid July. Unfortunately, due to lack of historical data, salinity in the Great Wicomico during 1999 cannot be compared with the average. However, comparing the salinities recorded during 1999 with those from 1998 (Figure S7B) the pattern of higher salinity occurring early in the season is evident (similar to that recorded in the James and Piankatank Rivers; Figures S3B and S5B). 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).

Eastern Shore

As observed during 1998, settlement at the Pungoteague reef site was low, with a total of 0.4 cumulative spat shell^{-1} / week. One spat set each week between the weeks of August 19 and September 16. Water temperature at the Pungoteague site reached a maxima of 31°C in the beginning of July and fluctuated between 23 and 30°C for the majority of the sampling season (Figure S9A). Salinity at the site ranged between 18 and 29 ppt (Figure S9B).

Settlement was first recorded at Fisherman Island south, the week of July 1. Spatfall was intermittent at this site from the beginning of July through the second week of October. Spat was first recorded at Fisherman Island north during the week of July 8 and continued consistently from then until the week of September 23. As in the previous 4 years, more spat settled at the northern site when compared to the southern site (Figure S8). Settlement at both sites was slightly higher than that recorded over the past two years. The cumulative spat shell^{-1} / week was 19.5 for Fisherman Island south and 45.5 for Fisherman Island north. Water temperature and salinity were similar for both Fisherman Island sites (Figures S9A and B). Temperature ranged between 19 and 29°C and salinity ranged between 25 and 35 ppt throughout most of the sampling season.

Settlement was first observed at the Wachapreague site during the week of July 15. Spatfall was consistent from mid July through the beginning of October. Settlement at Wachapreague was lower than that recorded during 1998 and lower than the 10 yr mean (Table S2; Figure S8). Prior to 1999, settlement at Wachapreague had been steadily increasing each year since hitting an all time low in 1994. Settlement during 1999 was once again at this low level of spatfall (6.9 spat $shell^{-1}$ during 1999 vs. 7.7 spat $shell^{-1}$ during 1994; Table S2; Figure S8). Water temperature and salinity at the Wachapreague site was similar to the values recorded at the Fisherman Island sites (Figures S9A and S9B).

DISCUSSION

Oyster spatfall during 1999 was low to moderate in all Virginia tributaries of the western shore of 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 during 1999, (Table S1 and S2). Total annual spatfall during 1999 at all stations monitored, with the exception of Deep Water Shoal and Rock Wharf in the James River, was lower than the previous 10 year mean (1989 to 1998). Moderate to heavy spatfall recorded at some stations in 1991 and 1993 may have resulted from advantageous conditions that enhanced production thereby producing higher than normal spawn by oyster stocks in those tributaries.

Overall, oyster settlement during 1999 in the James River was an improvement over the past few years. Historically, spatfall in the James tends to be highest at the more downriver stations (i.e., those with a higher salinity). The 10 year mean spatfall values for Day's Point and Dry Shoal are three times as high as the 10 year mean for Point of Shoal, the next highest station (Table S2). The pattern of settlement observed during 1999 (as during 1998) did not mirror this historical trend of higher settlement at higher salinity sites. Salinity in the James was higher than normal when compared with the mean for the past 6 years. This was most likely due to a lack of precipitation in both winter and spring of 1999. This higher than normal salinity may explain the consistent spatfall that occurred throughout the James River system. While water temperature is thought to play a larger role in timing of the spawn, salinity can also effect both spawning and larval survival in the plankton (Thompson et.al, 1996). The combination of average temperatures and high salinity may have acted together to produce favorable spawning conditions for the broodstock in the system.

Settlement in the Piankatank River during 1999 was the highest observed since 1992. This increase was most likely due to the placement of broodstock oysters on the reefs at Bland Point, Palace Bar, and Iron Point (Figure S1). The highest settlement of oysters occurred on (Bland Point site) and around (slightly upriver and downriver) of these three reefs. This increase in settlement is similar to the increase that was recorded in the Great Wicomico River during 1997, after the addition of broodstock to a reef in that river (Southworth and Mann, 1998). A major difference in the two systems is the amount of time taken to reach the desired results. The increase in spatfall occurred quickly (within one season) in the Great Wicomico, whereas in the Piankatank, there has been a slow increase over the past few years. This may be due to a difference in methods employed in the two rivers. The Great Wicomico received a large plant (approximately 2300 bushels) of broodstock at one time, whereas the Piankatank has been receiving small numbers (between 400 and 800 bushels) of broodstock each year. The method used in the Piankatank may help to reduce the mortality of the broodstock by disease, ensuring that at least a portion of the oysters each year are disease free, thereby increasing the reproductive output of the oysters. Salinity may also have played a role, given that salinity during 1999 in the Piankatank River, like the James, was higher than the average throughout most of the spawning season.

Oyster settlement in the Great Wicomico River was once again light, especially when compared with the 1997 spatfall numbers. As previously mentioned, 1997 was a unique case due to the addition of a large number of broodstock oysters to Shell Bar Reef. No additional broodstock have been added since to Shell Bar Reef as they have been to the reefs in the Piankatank River. In addition to a lack of annual broodstock enhancement on the reef, there was a large die-off of small and market sized oysters recorded throughout the river early in the spawning season. The primary cause of this die-off was MSX infections carried over from the previous summer brought on by the higher than normal salinities and higher than normal winter temperatures (Calvo and Burreson, in press). Mortality in June and early July accounted for as much as 40% of the total oyster population throughout the river. This greatly reduced the spawning stock in the river, thereby decreasing the larval/spat supply to the bottom. In addition to high MSX infections causing mortality early in the spawning season, the prevalence of *Perkinsus* infections was also high in the surviving spawning stock. This could have further affected the spawning by reducing the fecundity of the already depleted spawning stock. Choi et.al (1994) found no measurable impact of *Perkinsus* in the spring, when most infections were light, but observed a clear negative association between reproductive development and parasitism in the late-summer/fall when infections were heavier as was found in the Great Wicomico River oysters during 1999 (Calvo and Burreson, in press).

Overall settlement on shellstrings during 1999 on the Eastern Shore of Virginia was low to moderate depending on the location. As was seen during 1998, settlement on shellstrings at the Pungotegue site was essentially non-existent (4 spat throughout the entire season), a surprising observation given the proximity of the shellstring site to the reef area, an area that received a relatively high set of oysters in 1999 (Wesson, personal communication). It is not very clear why settlement on the shellstrings remains low, when settlement on the reef is on the rise. While temperature and salinity appear to be similar to that found in the Western tributaries and therefore probably not much of a limiting factor in spawning, little is known regarding the water circulation patterns around the site. One possible explanation for the lack of settlement could be the circulation patterns in the area. Often times, there are large discrepancies between what settles on the bottom (or just off the bottom in the case of shellstrings) and what settles on reefs. This may be due to small changes in circulation patterns around the shellstring site, flushing the larvae away from the area. The location of the shellstring site, may need to be changed to get a more accurate reading of how many oysters are setting in the area.

The remaining Eastern shore sites had low to moderate settlement. Settlement during 1999 at both of the Fisherman Island sites was similar to that recorded over the past few years. Since the spatset numbers observed during 1999 have been similar for the past 3 years (Morales-Alamo and Mann, 1998), one can infer that the reefs (built in 1995 and 1996) continue to have a positive effect on increasing and sustaining spatset in the area.

Settlement in all 3 of the western Chesapeake Bay tributaries monitored was higher during 1999 than during 1998. The first spatfall occurred early in the season and continued consistently for most of the sampling period. This is in contrast to most years, when settlement is more pulse-like with several pulses occurring throughout the spawning season. This may have been due to the favorable salinity conditions experienced throughout the spawning season. Salinity was 3 to 6 ppt higher than the average 6 yr mean for most of the season until the occurrence of Hurricanes Dennis and Floyd when a sudden decline in salinity occurred. This increased salinity was probably due to low run-off rates caused by the combination of a dry winter and spring season and a dryer than normal summer.

TABLE S1

AVERAGE NUMBER OF SPAT SHELL[-1] FOR STANDARDIZED WEEK STARTING 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	10/14 287	10/21 294	YEAR TOTAL
JAMES RIVER																							
Deep Water Shoal	D	0	0	0	0	0	0	0	0.2	1.9	0.6	0.9	0.9	-	1.1	-	-	0.1	0	0			5.7
Horsehead	D	0	0	0	0	0	0	0	0.6	1.9	0.3	0.2	0.2	-	0.6	-	-	0	0	0			3.8
Point of Shoal	D	0	0	0	0	0	0	0	0.4	1.1	0.2	0.4	1.2	-	0.2	-	-	0	0	0			3.5
Swash	D	0	0	0	0	0	0	0	0.8	3.7	0.2	0.4	0.9	-	0.6	-	-	0.2	0	0			6.8
Dry Shoal	D	0	0	0	0	0	0	0	2.8	1.4	0.6	1.0	N	-	0.2	-	-	N	0.1	0			6.1
Rock Wharf	D	0	0	0	0	0	0	0.1	3.0	1.5	0.6	1.1	1.1	-	0.4	-	-	0.2	0	0			8.0
Wreck Shoal	D	0	0	0	0	0	0	0.2	0.7	1.0	0.1	0.2	0.3	-	0.4	-	-	0.1	0.1	0			3.1
Day's Point	D	0	0	0	0	0	0	0	1.4	2.7	0.4	1.2	1.1	-	0.4	-	-	0.1	0	0			7.3
PIANKATANK RIVER																							
Wilton Creek		D	0	0	0	0	0	0	0	0	0	0	2.3	0.9	-	1.8	0.9	0	-	0	0		5.9
Ginney Point		D	0	0	0	0	0	0	0	0	0	0.5	3.3	1.2	-	0.7	0.4	0.3	-	0	0		6.4
Palace Bar		D	0	0	0	0	0	0	0	0	0.5	1.2	2.7	4.6	-	0.9	0.1	0.1	-	0	0		10.1
Bland Point		D	0	0	0	0	0	0	0	1.3	2.1	4.0	21.2	9.5	-	2.0	3.4	0.6	-	0	0		44.1
Heron Rock		D	0	0	0	0	0	0	0	0	1.1	1.3	5.7	0.6	-	0.4	0.2	0	-	0	0		9.3
Cape Toon		D	0	0	0	0	0	0	0	0.6	0.4	3.3	3.9	2.7	-	0.3	0.7	0.4	-	0	0		12.3
Stove Point		D	0	0	0	0	0	0	0	0.1	0.9	2.2	2.4	1.0	-	0.4	0	0	-	0.1	0		7.1
Burton Point		D	0	0	0	0	0	0	0	0.5	2.5	2.9	6.6	1.2	-	0.2	0.8	0.1	-	0.1	0		14.9
GREAT WICOMICO																							
Glebe Point		D	0	0	0	0	0	0	0	0	0	0	0	0.2	-	0.8	0.6	0.8	-	0	0		2.4
Rogue Point		D	0	0	0	0	0	0	0	0	0	0	0.1	0.8	-	0.7	0.2	0.2	-	0	0		2.0
Hilly Wash		D	0	0.1	0	0	0	0	0	0	0	0	0.1	0.9	-	0.4	0	0.1	-	0	0		1.6
Harcum Flats		D	0	0	0	0	0	0	0	0	0	0	0.1	0.4	-	0.5	0.1	0.2	-	0	0		1.3
Hudnall		D	0	0	0	0	0	0	0	0	0	0	0	0.5	-	0.4	0	0	-	0	0		0.9
Shell Bar		D	0	0	0	0	0	0	0	0	0	0	0	1.6	-	0.7	0.4	0.2	-	0	0		2.9
Haynie Point		D	0	0	0	0	0	0	0	0	0	0	0	0.7	-	0.2	0.1	0.1	-	0	0		1.1
Whaley's East		D	0	0	0	0	0	0	0	0	0	0	0	0.6	-	0.3	0.7	0.2	-	0	0		1.8
Fleet Point		D	0	0	0	0	0	0	0	0	0	0	0	0.1	-	0.1	0.1	0.2	-	0	0		0.5
EASTERN SHORE																							
Fisherman Island N	D	0	-	0	0	0	0.1	1.3	1.1	0.2	35.5	3.9	1.5	-	0.7	0.1	0.1	1.0	-	0	-	0	45.5
Fisherman Island S	D	0	-	0	0	0.1	0	0.3	0	0	15.7	0.4	1.4	-	0.4	0	0	1.0	-	0.2	-		19.5
Pungoteague	D	0	-	0	0	0	0	0	-	0	0	0	0.1	0	0.1	0.1	0.1	0	-	0	-	0	0.4
Wachapreague	D	0	-	0	0	0	0	0.3	0.7	0.4	1.4	1.0	2.2	0	-	0.6	0.1	0.1	-	0.1	0		6.9

D: Date deployed
N: String was lost (no data).
"-": String not collected during that week.

TABLE S2

SPATFALL TOTALS FOR THE YEARS 1989 through 1999 AND THE MEAN FOR 1989-1998

Presented as cumulative sum of weekly spat shell $^{-1}$ values for each year

STATION	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	Mean 89-98	1999	Ref. 1998	Ref. Mean
JAMES RIVER														
Deep Water Shoal	2.0	2.6	10.6	0.7	15.7	0.6	1.7	0.5	1.3	1.2	3.7	5.7	+	+
Horsehead	1.5	0.9	24.7	3.6	43.7	3.2	0.3	3.6	2.4	1.1	8.5	3.8	+	-
Point of Shoal	3.7	14.3	21.4	5.4	73.7	15.0	4.8	2.3	2.3	1.5	14.4	3.5	+	-
Swash	3.8	3.3	68.7		46.2	4.8	1.8	2.2	1.7	1.6	14.9	6.8	+	-
Dry Shoal	10.0	30.9	217.1	14.2	119.0	25.8	2.8	11.0	1.1	1.1	43.3	6.1	+	-
Rock Wharf	2.1	1.8		11.4	34.3	10.7	0.2	2.4	5.6	2.1	7.8	8.0	+	+
Wreck Shoal	10.2	4.0	35.3	3.3	15.5	2.2	2.6	10.0	0.7	0.7	8.4	3.1	+	-
Day's Point	26.1	22.4	145.6	14.2	131.5	42.2	3.0	4.6	5.6	0.4	39.6	7.3	+	-
PIANKATANK RIVER														
Ginney Point	29.9	62.6	25.4	11.4	1.7	0.0	0.5	1.3	0.0	2.2	13.5	6.4	+	-
Palace Bar	42.4	119.2	38.9	24.9	5.0	0.8	1.0	1.6	0.0	5.5	23.9	10.1	+	-
Burton Point	31.6	87.4	16.4	11.7	6.5	0.1	1.0	1.0	0.7	1.3	15.8	14.9	+	-
GREAT WICOMICO														
Glebe Point	8.2	19.5	1.9	0.5	0.2	0.0	1.5	0.6	21.2	0.6	5.4	2.4	+	-
Hudnall	26.4	94.8	4.5	0.5	0.8	0.0	0.1	0.2	39.1	0.5	16.7	0.9	+	-
Haynie Point	17.0	68.2	12.4	0.6	1.4	0.0	1.0	3.7	4.4	0.7	10.9	1.1	+	-
Whaley's East	8.4	39.1	7.9	0.1	0.2	0.0	0.3	2.1	1.0	0.4	5.9	1.8	+	-
Fleet Point	7.9	17.4	5.8	2.9	2.0	0.0	0.3	2.6	3.4	0.3	4.3	0.5	+	-
EASTERN SHORE														
Wachapreague	144.1	210.7	286.9	61.8	99.6	7.7	16.1	19.5	32.0	52.0	93.0	6.9	-	-

"+" and "-" indicate direction of change during 1999 in reference to 1998 and to the 10 yr mean.

Figure S1: Map showing the 1999 shellstring sites including those sites in the 3 western tributaries and on the Eastern Shore

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, 10) Ginney Point, 11) Palace Bar, 12) Bland Point, 13) Heron Rock, 14) Cape Toon, 15) Stove Point, 16) Burton Point.
Great Wicomico:	17) Glebe Point, 18) Rogue Point, 19) Hilly Wash, 20) Harcum Flats, 21) Hudnall, 22) Shell Bar, 23) Haynie Point, 24) Whaley's East, 25) Fleet Point.
Eastern Shore:	26) Pungoteague, 27) Wachapreague, 28) Fisherman Island.

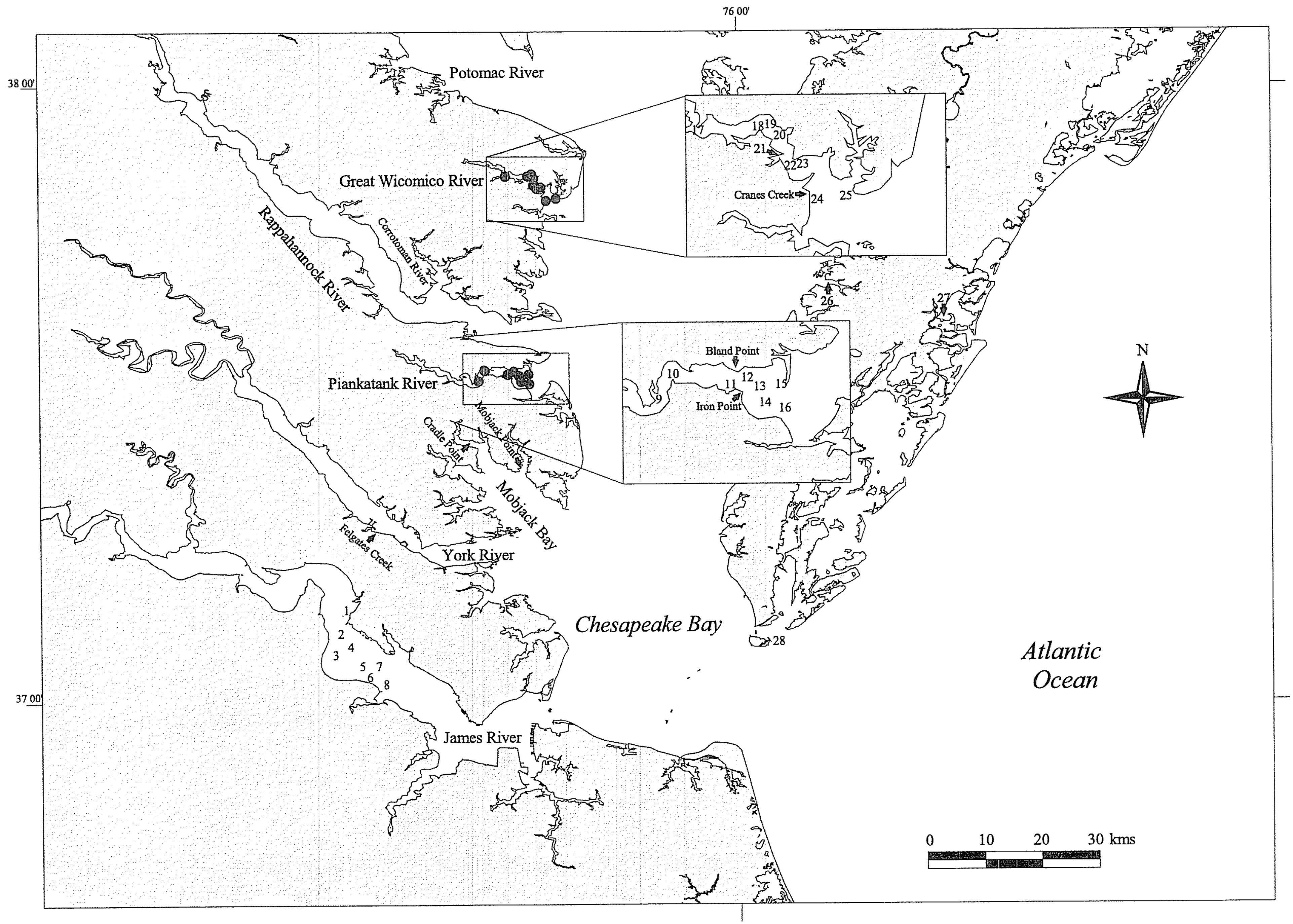

76 00'
38 00'
37 00'
Potomac River
Great Wicomico River
Rappahannock River
Corrotoman River
Piankatank River
Mobjack Point
Cradle Point
Mobjack Bay
York River
Felgates Creek
James River
Chesapeake Bay
Atlantic
Ocean
N
0 10 20 30 kms
Cranes Creek
Bland Point
Iron Point
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28

FIGURE S2: SPATFALL TRENDS IN THE JAMES RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE WEEKLY SPATFALL

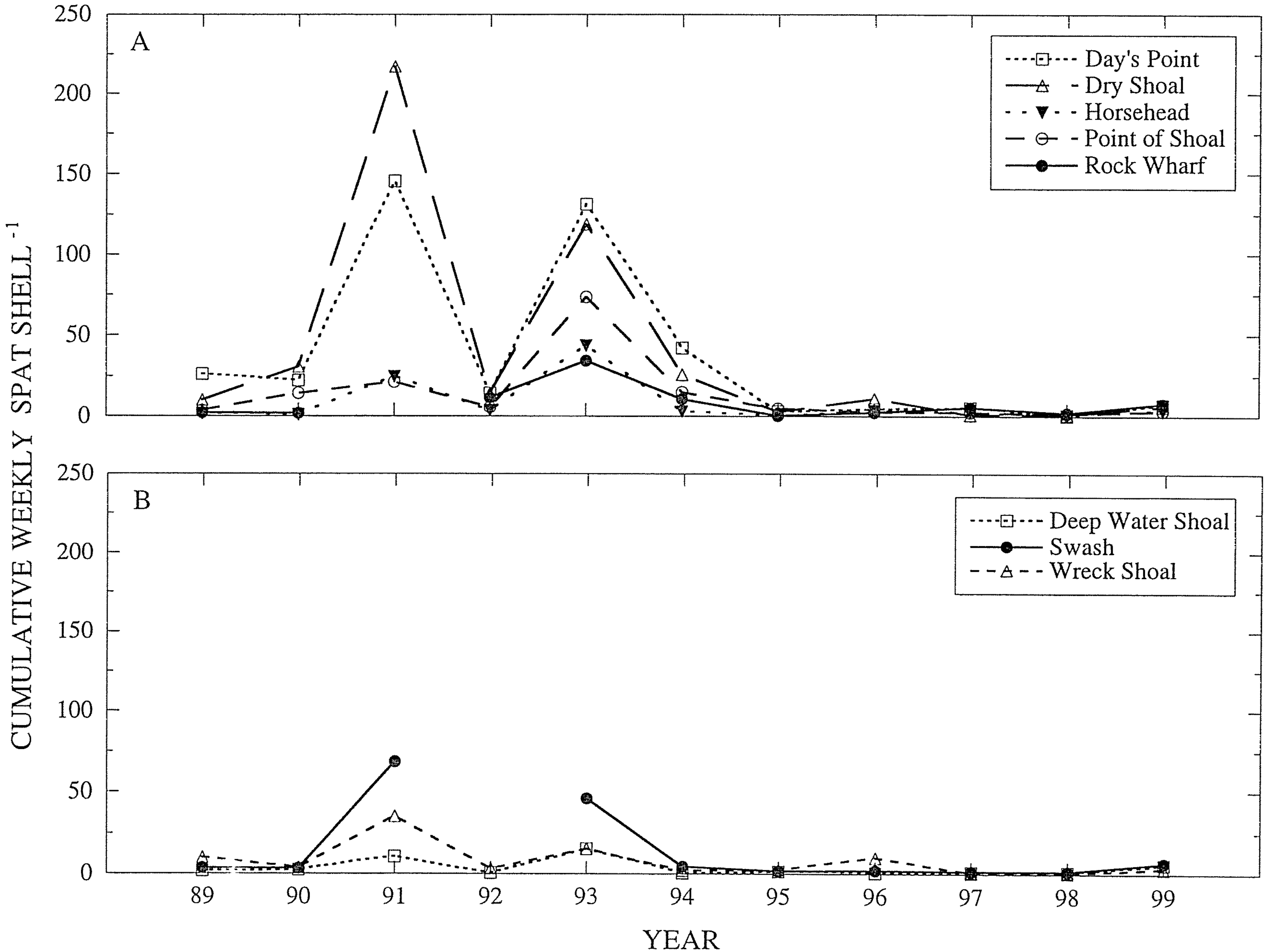


FIGURE S3: TEMPERATURE AND SALINITY TRENDS IN THE JAMES RIVER OVER THE PAST 6 YEARS COMPARED WITH 1999

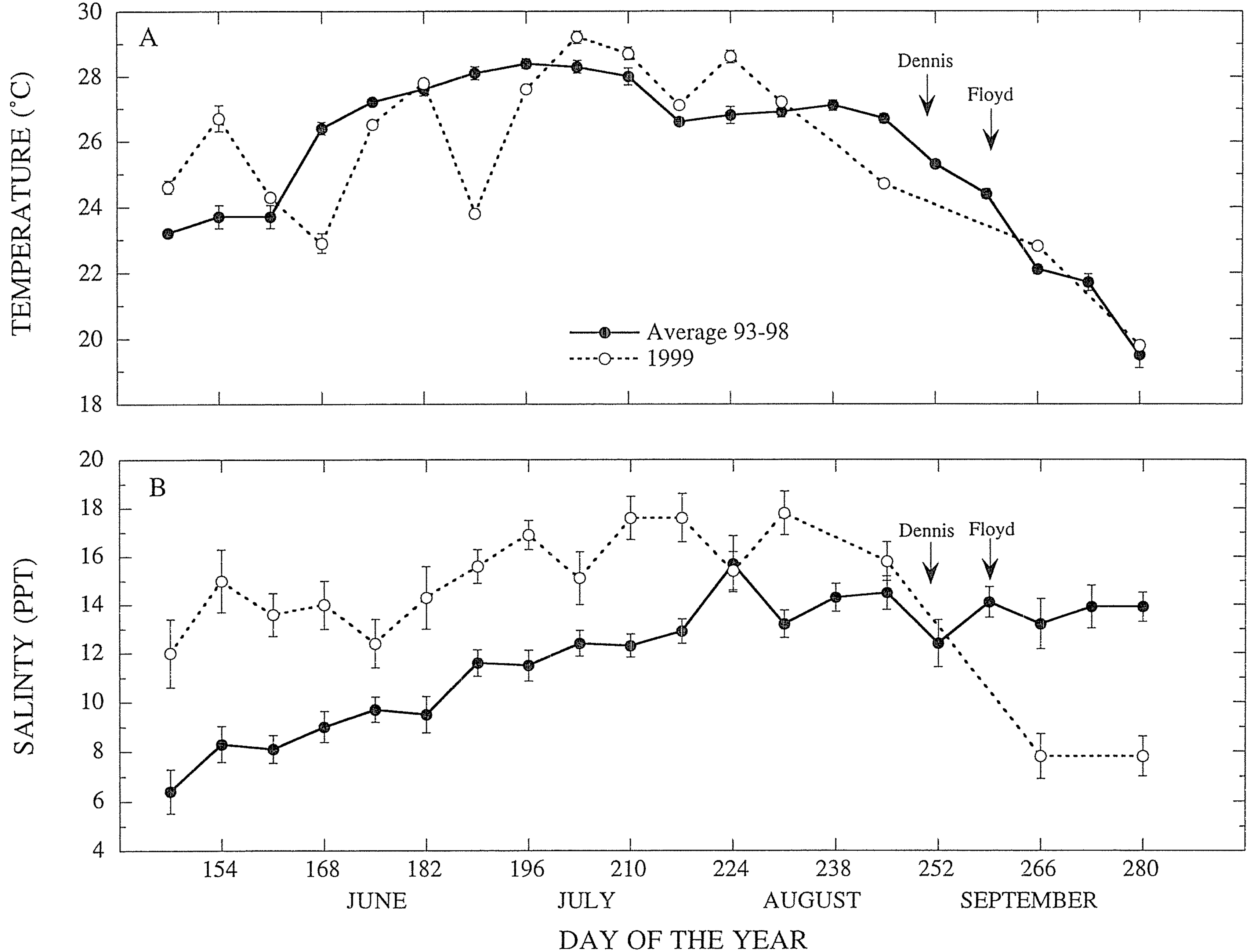


FIGURE S4: SPATFALL TRENDS IN THE PIANKATANK RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE SPATFALL

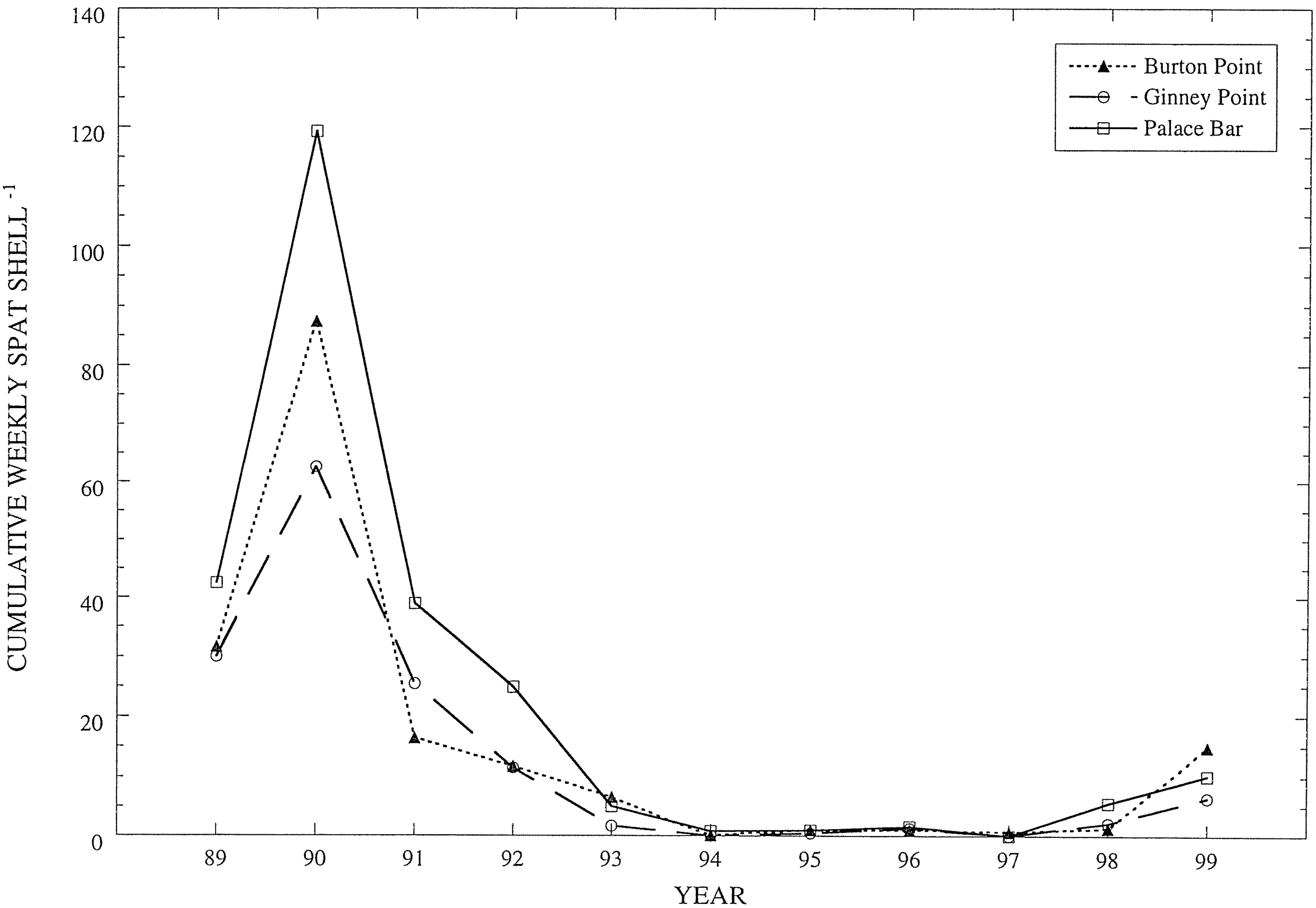


FIGURE S5: TEMPERATURE AND SALINITY TRENDS IN THE PIANKATANK RIVER OVER THE PAST 6 YEARS COMPARED WITH 1999

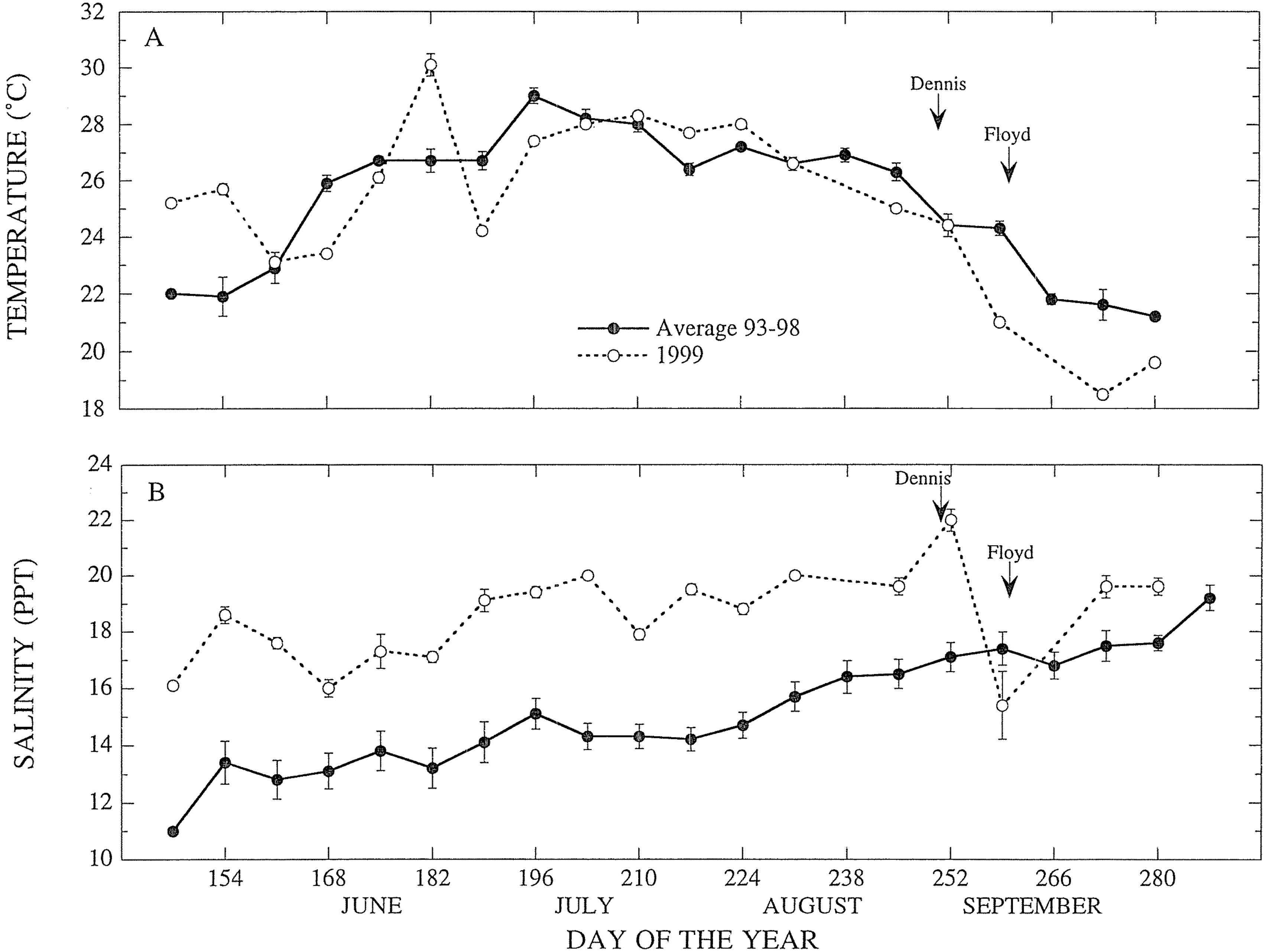


FIGURE S6: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE WEEKLY SPATFALL

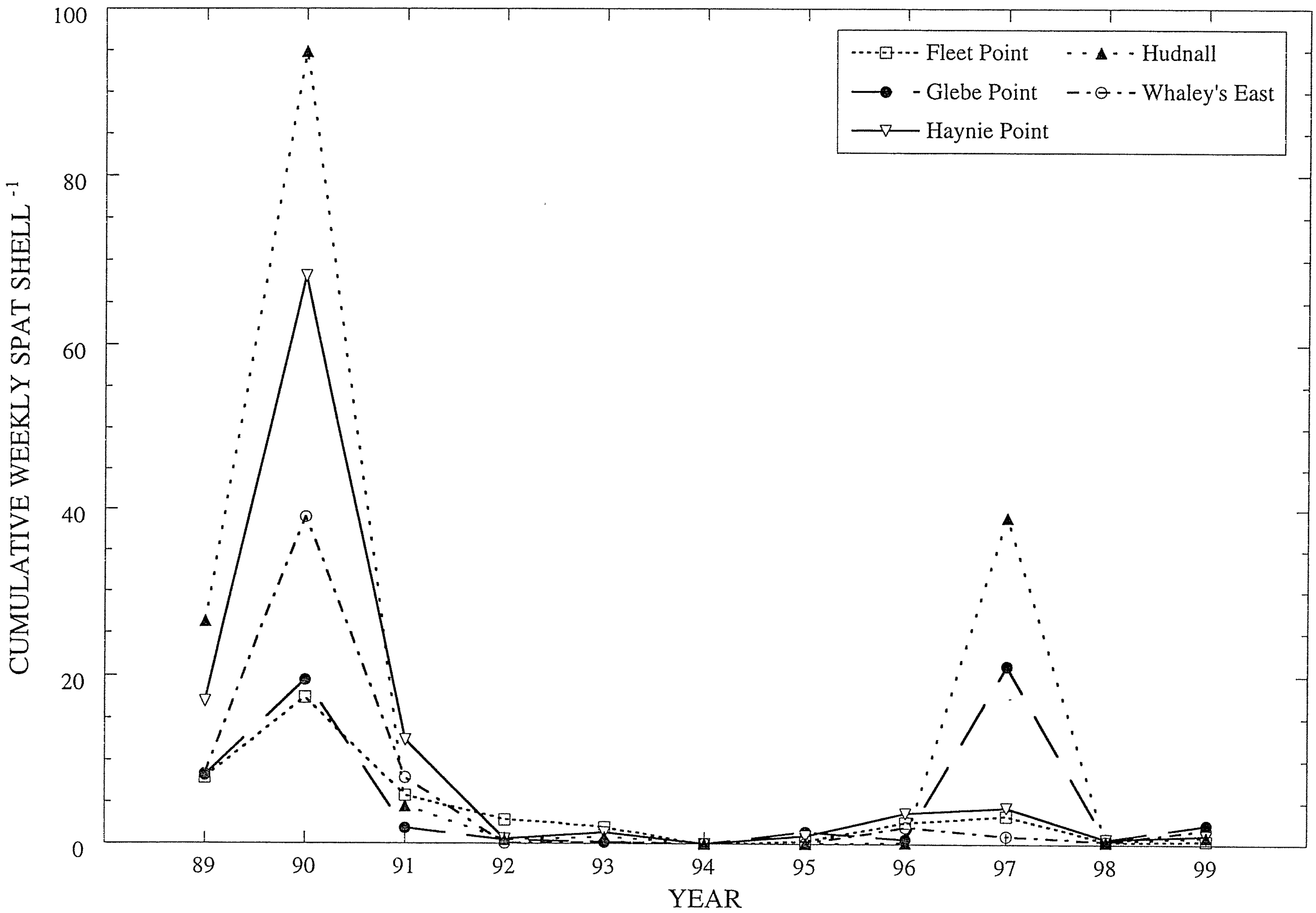


FIGURE S7: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER DURING THE PAST 2 YEARS (1998-99)

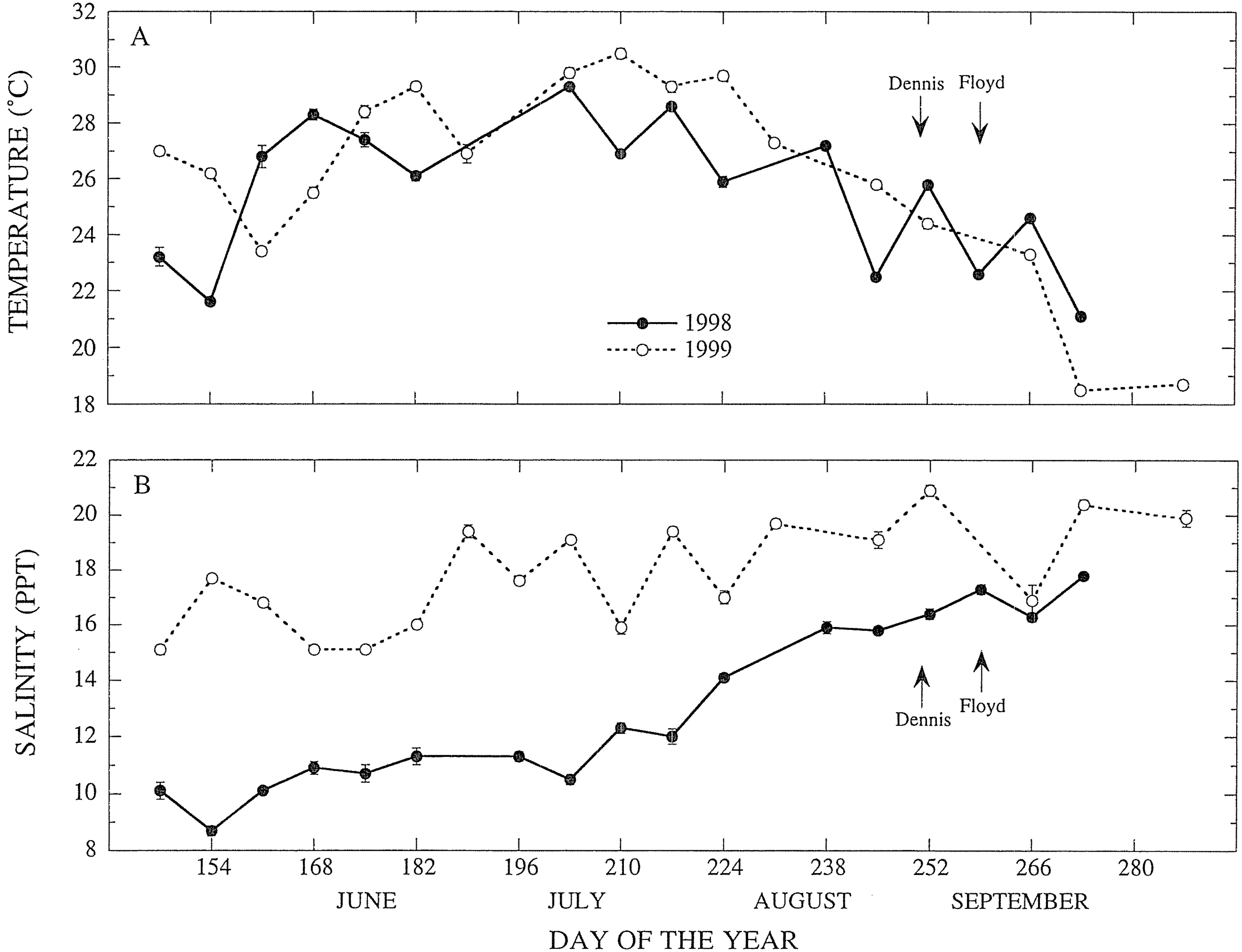


FIGURE S8: SPATFALL TRENDS AT THE EASTERN SHORE STATIONS OVER THE PAST 5 (FISHERMAN ISLAND) TO 10 (WACHAPREAGUE) YEARS

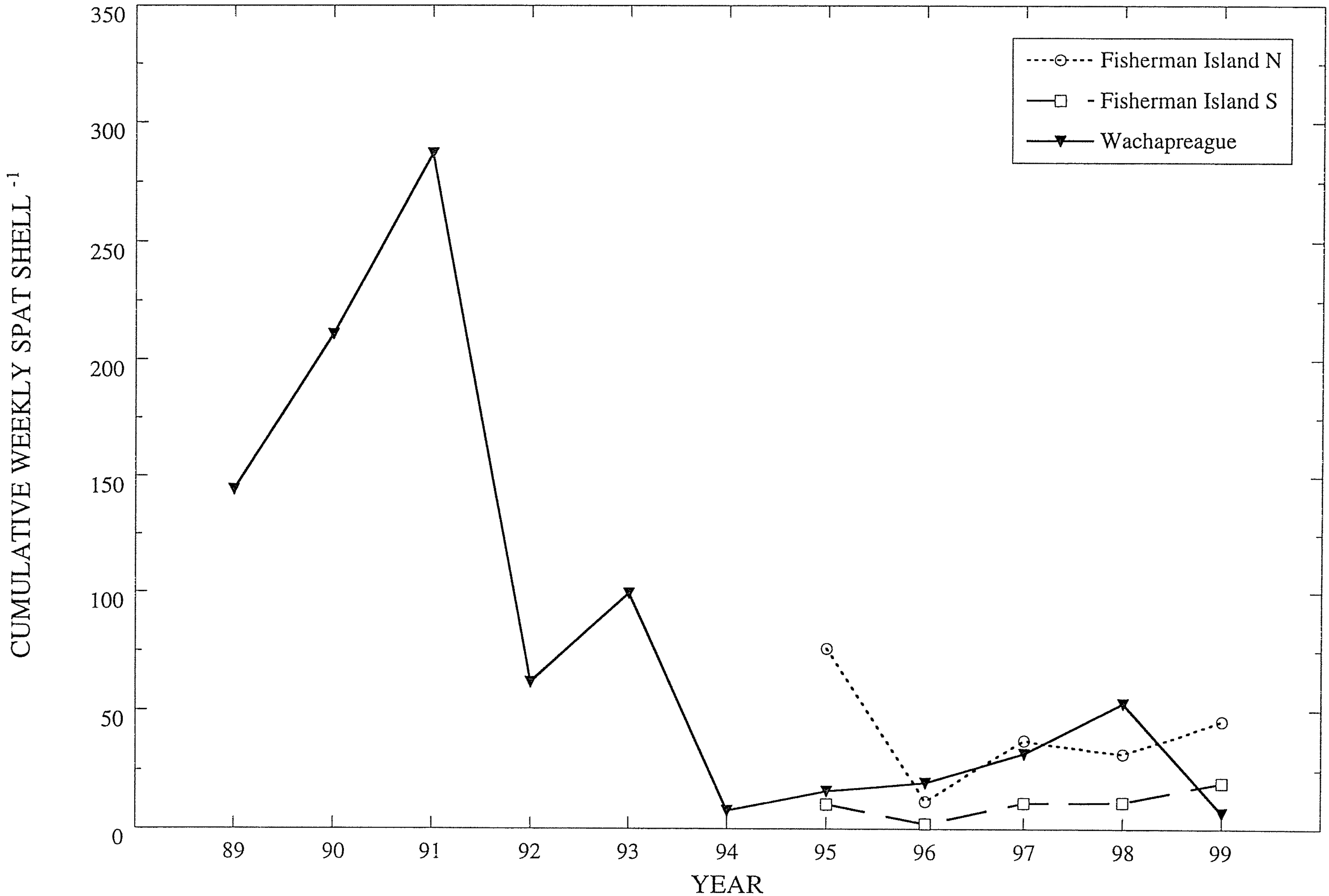
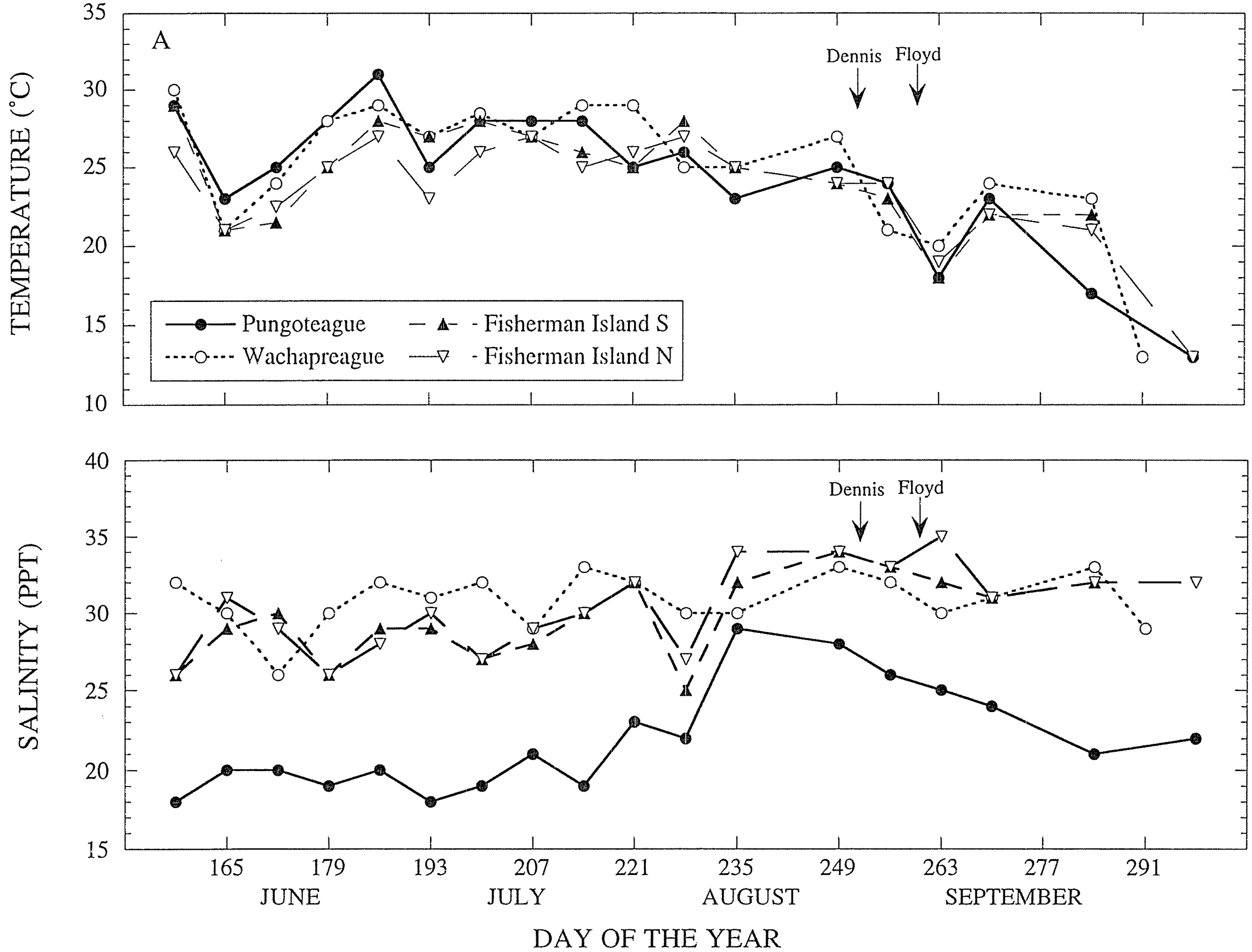


FIGURE S9: TEMPERATURE AND SALINITY AT THE EASTERN SHORE STATIONS DURING THE 1999 SPAWNING SEASON



Part II. DREDGE SURVEY OF SELECTED OYSTER BARS IN VIRGINIA DURING 1999

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, 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 the bar surveys conducted in October, 1999.

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 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 could be the result of sampling variation rather than actual short-term changes in abundance. If the changes observed 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, 1999 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 24 in wide dredge with 4 in teeth towed from a 21-ft boat; volume collected in the dredge bag was 1.5 bu. 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 was 3 bu. 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 (1999 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 different categories of boxes is a qualitative description based on visual observations.

During spring and early summer 1999, the following changes that may have had some effect on settlement and oyster abundance were made (Figure D1 for locations): Clean shells (cultch) were planted on Point of Shoal in the James River, on Palace Bar, Burton Point, Bland Point, Cape Toon, and Ginney Point in the Piankatank River, and on Shell Bar, Whaley's East, Fleet Point, and Haynie Bar in the Great Wicomico River to provide substrate for larvae to settle on. An artificial oyster reef was built in the York River in Felgates Creek. Two artificial oyster reefs were built in Mobjack Bay, one in the North River (Cradle Point) and one in the East River (Mobjack Point). In addition, broodstock were planted on the artificial reefs at Iron Point, Palace Bar, and Bland Point in the Piankatank River and on Cranes Creek Reef in the Great Wicomico River. Seed (small oysters) were planted on Bowlers Rock and Smokey Point in the Rappahannock River.

Temperature (in °C) and salinity (in ppt, parts per thousand) were recorded at each of the dredge stations during the time of sampling, using an alcohol thermometer and a hand-held refractometer.

RESULTS

Thirty oyster bars were sampled between October 19 and 29, 1999, 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 river. The highest average number of oysters bu^{-1} of all sizes was found at Horsehead (621), as has been the case for the past several years excluding 1998. The number of oysters at Long Shoal was moderate to heavy with 583 oysters bu^{-1}. Total number of oysters at Mulberry Point, Point of Shoal, Swash, and Dry Shoal was moderate ranging from 310 to 403 oysters bu^{-1}. Total number of oysters at all other bars was low averaging less than 250 bu^{-1}, with a range of 107 (Thomas Rock) to 231 (Nansemond Ridge) total oysters bu^{-1}.

The number of market oysters recorded for the James River was low as has been the case for the past several years. There appears to be a separation in numbers based on location. The 5 upriver sites (Figure D1) had the most market oysters ranging between 32 bu^{-1} (Swash) and 56 bu^{-1} (Horsehead). The 5 down river stations had considerably fewer market oysters ranging between 2 (Nansemond Ridge) and 15 (Long Shoal) bu^{-1}. There was a noticeable decrease in the number of market oysters at Point of Shoals compared with 1998 (Figures D2 and D3B).

The number of small oysters bu^{-1} ranged from a low of 14 (Thomas Rock) to a high of 440 (Horsehead). Mulberry Point, Horsehead, and Point of Shoal had the highest percentage of small oysters at approximately 71% (of the total). There was a noticeable increase in small oysters at Deep Water Shoal and Wreck Shoal compared with 1998 (Figures D2 & D3A). This was the first increase seen at Wreck Shoal in over 6 years.

The number of spat bu^{-1} ranged from a low of 17 (Deep Water Shoal) to a high of 219 (Dry Shoal). There was a noticeable decrease in spat at Deep Water Shoal, Long Shoal, and Point of Shoal when compared to 1998 (Figure D2). Observing the composition of live oysters in terms of percentages found in each size class, for the 10 stations sampled in the James River, a pattern emerges based on location in the river. 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.

The average number of boxes bu^{-1} ranged from a low of 17 (Deep Water Shoal) to a high of 213 (Long Shoal). At Point of Shoal, Swash, Long Shoal, Dry Shoal, and Wreck Shoal, this accounted for over 20% of the total oysters found (live and dead). At the remaining 5 stations between 12 and 19% of the total number of oysters were boxes.

Water temperature during the sampling period remained fairly constant ranging from 16.5 to 18°C (Table 2). Salinity was more variable depending on location in the river, increasing in a downriver direction, from 3 ppt at Deep Water Shoal to 16 ppt at Thomas Rock and Nansemond Ridge.

York River

The average total number of live oysters bu^{-1} in the York River were similar for both bars sampled (114 at Aberdeen Rock, 144 at Bell Rock). The oysters found at Aberdeen were predominately spat (71% of total), while the oysters at Bell Rock were predominately small sized oysters (69% of total). There was a noticeable increase in the number of small oysters and a decrease in the number of spat compared with 1998 (Figure D4). Market oysters were scarce at both bars, accounting for 1 and 12% of the total live oysters at Aberdeen Rock and Bell Rock respectively. The total number of boxes (new and old) bu^{-1} was low at both bars sampled in the river. Water temperature at both stations was 19°C on the day of sampling. There was a 3 ppt difference in salinity, 15 ppt at Bell Rock and 18 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters bu^{-1} in Mobjack Bay was 63 at Pultz Bar and 150 at Tow Stake. Pultz Bar oysters consisted of a 50/50 mix of small and market sized oysters with very few spat. There was a noticeable decrease in the number of spat at Pultz Bar compared with 1998 (Figure D4). The composition of live oysters at Tow Stake consisted of a 50/50 mixture of small oysters and spat, with very few market sized oysters. There was a noticeable increase in the number of small oysters at this bar when compared to 1998 (Figure D4). The total number of boxes was relatively high, making up 18 and 23% of the total number of oysters found (live and dead) at Tow Stake and Pultz Bar respectively. While the majority of the boxes found at both stations were old, there were a considerable amount of spat boxes found at Tow Stake. Based on the absence or presence of a round hole in the shell, over 50% of these boxes were attributed to oyster drill (*Urosalpinx cinerea*, the Atlantic oyster drill, or *Eupleura caudata*, the thick-lipped oyster drill) activity (unpublished data). Water temperature was 16°C and salinity was 21 ppt at both stations on the day of sampling.

Piankatank River

The average total number of live oysters in the Piankatank River was high, ranging from 720 (Ginney Point) to 1057 bu^{-1} (Palace Bar). The number of small and market sized oysters at all stations was relatively low. The average number of spat was high, ranging from 652 bu^{-1} at Ginney Point to 959 bu^{-1} at Palace Bar. Spat made up 90-91% of the live oysters found at all three stations. This high number of spat accounted for a large noticeable increase in spat compared with 1998 at all three bars (Figures D5 and D6). There was no noticeable change in any other size category when compared with 1998 numbers. The number of market oysters found at all three bars, though small, continues to increase slowly as it has for the past 3 years (Figure D6). The number of boxes bu^{-1} (old and new) at all three bars accounted for less than 7% of the total oysters (live and dead) sampled. Water temperature on the day of sampling ranged from 18 to 19°C and salinity ranged from 15 to 18 ppt (Table D2).

Rappahannock River

The average total number of live oysters in the Rappahannock River was moderate at 2 of the stations sampled and low at the other 8 stations sampled. The 2 bars with the highest average (Table D2) were Broad Creek (264 bu^{-1}) and Middle Ground (309 bu^{-1}). The remaining 8 bars had a range of 32 (Long Rock) to 164 oysters bu^{-1} (Drumming Ground). This split in live oyster abundance does not appear to be related to location (i.e. upriver vs. downriver; Figure D1), temperature, or salinity (Table D2).

As has been found for the past few years, Broad Creek and Bowlers Rock had the most market oysters bu^{-1} with 32 and 29 respectively. None of the bars sampled had an overly abundant amount of small oysters (ranged from 11 (Long Rock) to 79 (Ross Rock) bu^{-1}). Broad Creek and Middle Ground had the most spat with 169 and 261 bu^{-1} respectively. Long Rock, while having the lowest total number of live oysters, had the highest percentage of market sized oysters (55%).

There was a noticeable increase in all size classes seen at Ross Rock when compared with 1998 (Figures D7 and D8B). Morattico Bar showed a noticeable increase in the number of market oysters compared to 1998, while Broad Creek showed a decrease (Figure D7) . This was the first time in about 6 years that the number of market oysters at Broad Creek decreased (Figure D8A). There was a noticeable decrease in small oysters at Smokey Point and Middle Ground and an increase in spat at all stations except Drumming Ground (Figures D7, D8A and D8B).

The number of boxes bu^{-1} (new and old) ranged from 2.5 (Ross Rock) to 116 (Middle Ground). A high percentage of oysters (live and dead) at all of the stations except Ross Rock were boxes (14 to 46%). Middle Ground, the station with the highest number of live oysters also had the highest number of boxes (115 bu^{-1}).

Water temperature was not recorded on the day of sampling due to a broken thermometer. Salinity increased moving from the most upriver station (Ross Rock: 7 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 94 bu^{-1} (Whaleys East) to 132 bu^{-1} (Haynie Point). The live oysters found were predominately spat, accounting for 63% (Whaleys East), 77% (Fleet Point), and 84% (Haynie Point) of the total. This predominance was coupled with a noticeable increase in spat at all three stations when compared with 1998 (Figures D9 and D10). There was a noticeable decrease in both market and small sized oysters at all three stations sampled (Figures D9 and D 10). This decrease in market and small oysters was reflected in the number of boxes recorded. As many as 59% (Whaley's East) of the oysters found (live and dead combined) were boxes. Greater than 90% of these boxes were old. Water temperature was between 19 and 19.5°C and salinity was between 17 and 18 ppt on the day of sampling.

DISCUSSION

The greatest concentration of market oysters on the public grounds of the western shore of the Chesapeake Bay in Virginia has been found in recent years at the upper limits of oyster distribution (lower salinity areas) in the James River and the Rappahannock River, with the exclusion of Broad Creek in the Rappahannock. 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. Presently, the abundance of market oysters in the tributaries of the

Chesapeake is low. Of the bars that were sampled during 1999, market oysters made up a small percentage of the populations; at most bars with a total greater than 100 oysters bu^{-1}, the percentage of market oysters was under 15% with the exception of Deep Water Shoal in the James River.

In most recent years, the bulk of the population of live oysters has primarily consisted of small oysters. During 1999, the majority of the oyster populations sampled at the various sites were made up primarily of either small oysters or spat, with very few exhibiting a 50/50 mixture (Tow Stake in Mobjack Bay and Smokey Point in the Rappahannock River). The James River populations of live oysters exhibited a pattern of decreasing numbers of small oysters coupled with an increase in the number of spat as one moves from the more upriver stations toward the mouth of the river. The 1998 dredge survey in the James showed an increase in spat from the previous year. This increase was not observed again during 1999, nor was it reflected in the number of small oysters observed (only Wreck Shoal and Dry Shoal showed any noticeable change in small oysters). This further supports the idea discussed in the 1998 dredge report (Southworth et. al, 1999) regarding the effects of a late set and the possible interpretations of the results. Most likely, the increase in spat observed during 1998 was not a true increase, but rather an artifact of the relatively late set (September). In years when spatfall occurs earlier, the natural mortality that occurs post-settlement occurs over a longer time frame (in terms of the time from set until sampling). Therefore, given the lack of an increase in small oysters in the 1999 samples, the apparent increase in spatfall recorded in the 1998 dredge samples was most likely not a true increase in spat, but rather a discrepancy due to a change in temporal scale.

The Piankatank River had an increase in settlement during 1998 and 1999. This was most likely due to the broodstock oysters that were planted on the artificial reefs at Bland Point, Palace Bar, and Iron Point as previously mentioned (Figure D1). Spawning by this broodstock could account for the increase in spat observed in the river and is supported by the location of the major spatfall in the river. Spatfall was higher at Palace Bar, located directly adjacent to one of the broodstock enhanced reefs, than at either of the other two bars sampled. There has been a steady increase in the number of market-size oysters bu^{-1} in the river for the past 5 years. This may be due to the building of three-dimensional reefs (starting with one at Palace Bar in 1993) in the system. Presently there are 4 oyster reefs at various locations in the river. Studies of Palace Bar Reef showed that three-dimensional reefs enhance oyster survival (Mann et. al, 1996). Further support of the importance of broodstock addition can be inferred from the results recorded for the newly built Mobjack Bay reefs and the reefs in the Great Wicomico River. Neither of the Mobjack Bay reefs received broodstock oysters during 1999 and neither of the sampling areas in Mobjack showed an improvement in settlement. In the Great Wicomico on the other hand, the reef near Cranes Creek did have some broodstock replenishment and was coupled with a noticeable increase in the number of spat bu^{-1} found in that river.

There was a high number of boxes bu^{-1} found in most of the rivers sampled during 1999. This was especially apparent in the Great Wicomico River, where boxes accounted for 49 to 59% of the total number of oysters (live and dead) bu^{-1}. Disease during 1999 was found to be especially high in the Great Wicomico, with mortality due to MSX occurring early in the season (June) and increased prevalence of *Perkinsus* infection occurring later in the season (Calvo and Burreson, in press). The number of spat boxes was fairly high in the Piankatank and Rappahannock Rivers. At Tow Stake in the Mobjack Bay a little over 50% of the spat boxes were found to have round holes in them. These were most likely caused by one of two oyster drill species *Urosalpinx* *cinerea* and *Eupleura caudata* 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 the mainstem Bay (Carriker, 1955; Haven, 1974). However, 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 dredge samples (Southworth et. al, in prep).

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TABLE D1
STATION LOCATION FOR FALL DREDGE SURVEY

STATION	LATITUDE	LONGITUDE
JAMES R.		
Deep Water Shoal	37 08.9	76 38.1
Mulberry Point	37 07.2	76 37.9
Horsehead	37 06.4	76 38.0
Point of Shoal	37 04.6	76 38.6
Swash	37 05.9	76 36.7
Long Shoal	37 04.6	76 37.0
Dry Shoal	37 03.7	76 36.2
Wreck Shoal	37 03.6	76 34.3
Thomas Rock	37 01.5	76 29.6
Nansemond Ridge	36 55.3	76 27.2
YORK R.		
Bell Rock	37 20.0	76 36.1
Aberdeen Rock	37 28.7	76 44.8
MOBJACK BAY		
Tow Stake	37 20.2	76 23.7
Pultz Bar	37 21.1	76 21.1
PIANKATANK R.		
Ginney Point	37 32.0	76 24.2
Palace Bar	37 31.6	76 22.2
Burton Point	37 30.9	76 19.7
RAPPAHANNOCK R.		
Ross Rock	37 54.0	76 47.5
Bowlers Rock	37 49.6	76 44.1
Long Rock	37 49.0	76 42.8
Morattico Bar	37 46.9	76 39.6
Smokey Point	37 43.1	76 34.8
Hog House	37 38.4	76 33.2
Middle Ground	37 41.0	76 28.4
Drumming Ground	37 38.9	76 27.6
Parrot Rock	37 36.4	76 25.2
Broad Creek	37 34.5	76 18.3
GREAT WICOMICO R.		
Haynie Point	37 49.8	76 18.6
Whaley's East	37 48.5	76 18.0
Fleet Point	37 48.6	76 17.3

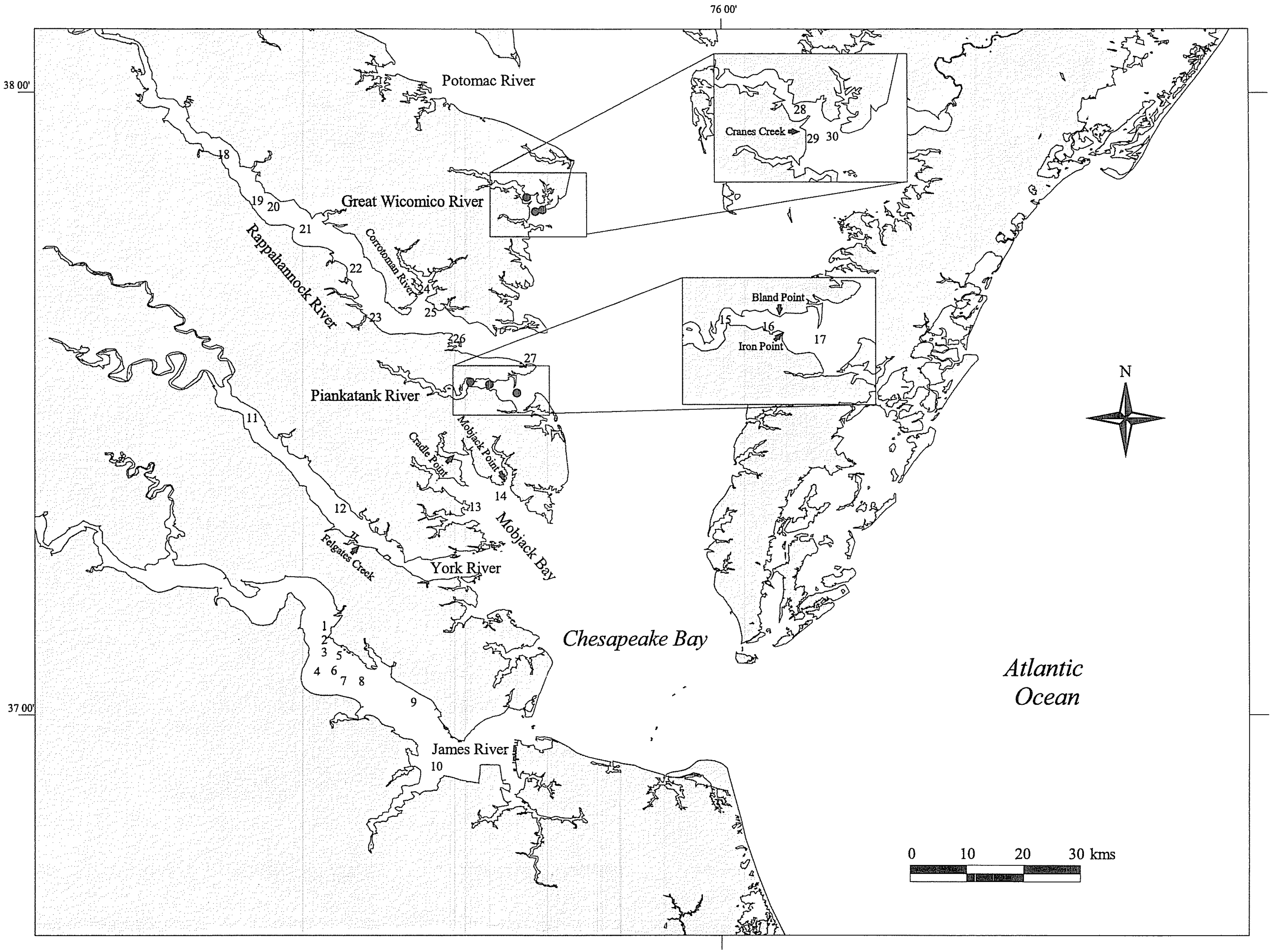
TABLE D2
RESULTS OF THE VIRGINIA PUBLIC OYSTER GROUNDS SURVEY
FALL 1999

Station	Date	Temp. (° C)	Sal. (ppt)	Average number of oysters per bushel				Boxes per bus hel			
				Market	Small	Spat	Total	New	Old	Spat	Total
JAMES R.											
Deep Water Shoal	10/29	17.5	3.0	33.0	72.5	16.5	122.0	3.0	13.0	1.0	17.0
Mulberry Point	10/29	17.0	6.0	55.0	271.0	54.0	380.0	22.5	29.5	2.0	54.0
Horsehead	10/29	17.5	5.0	56.0	440.5	124.5	621.0	56.0	81.0	6.5	143.5
Point of Shoal	10/29	17.0	8.0	42.5	284.5	76.5	403.5	49.5	75.5	2.5	127.5
Swash	10/29	17.0	7.0	32.0	208.0	70.0	310.0	51.0	73.5	4.0	128.5
Long Shoal	10/29	18.0	9.0	14.5	358.5	209.5	582.5	68.0	133.5	11.0	212.5
Dry Shoal	10/28	17.0	11.0	5.5	159.5	219.0	384.0	25.5	102.5	4.0	132.0
Wreck Shoal	10/28	17.0	15.0	10.5	44.0	86.0	140.5	9.0	61.5	1.5	72.0
Thomas Rock	10/28	17.0	16.0	3.5	14.5	88.5	106.5	5.0	14.0	0.0	19.0
Nansemond Ridge	10/28	16.5	16.0	1.5	24.0	205.5	231.0	4.5	21.0	5.0	30.5
YORK R.											
Bell Rock *	10/22	19.0	15.0	17.5	98.5	27.5	143.5	2.5	9.5	0.0	12.0
Aberdeen Rock	10/22	19.0	18.0	1.0	31.5	80.0	112.5	2.5	9.0	1.0	12.5
MOBJACK BAY											
Tow Stake	10/25	16.0	21.0	12.0	72.5	65.0	149.5	4.0	24.0	4.5	32.5
Pultz Bar	10/25	16.0	21.0	24.0	29.5	9.0	62.5	3.0	15.0	0.5	18.5
PIANKATANK R.											
Ginney Point	10/21	19.0	15.0	9.0	59.0	652.0	720.0	2.5	28.5	3.5	34.5
Palace Bar	10/21	19.0	16.0	15.5	82.5	959.0	1057.0	8.5	63.5	7.5	79.5
Burton Point	10/21	18.0	18.0	13.5	68.5	723.0	805.0	4.0	26.0	18.0	48.0
RAPPAHANNOCK R.											
Ross Rock	10/19	N/A	7.0	8.0	78.5	7.0	93.5	0.0	2.5	0.0	2.5
Bowlers Rock	10/19	N/A	10.0	29.0	56.0	4.0	89.0	4.5	41.0	0.0	45.5
Long Rock	10/19	N/A	10.0	17.5	10.5	4.0	32.0	2.5	13.0	0.0	15.5
Morattico Bar	10/19	N/A	12.0	20.5	11.5	19.5	51.5	4.0	32.5	0.0	36.5
Smokey Point	10/19	N/A	14.0	9.0	48.5	44.5	102.0	4.0	83.0	0.0	87.0
Hog House	10/19	N/A	15.0	3.5	14.5	51.0	69.0	2.0	8.5	1.0	11.5
Middle Ground **	10/19	N/A	17.0	5.0	43.0	261.0	309.0	6.5	105.5	3.5	115.5
Drumming Ground	10/19	N/A	17.0	15.0	36.5	112.0	163.5	6.0	45.5	1.0	52.5
Parrot Rock	10/19	N/A	16.0	10.5	34.0	54.5	99.0	4.0	26.0	0.0	30.0
Broad Creek	10/19	N/A	20.0	32.0	63.5	169.0	264.5	7.5	61.5	0.0	69.0
GREAT WICOMICO R.											
Haynie Point	10/20	19.0	18.0	3.0	18.0	110.5	131.5	6.5	119.5	0.0	126.0
Whaley's East	10/20	19.0	17.0	5.5	29.0	59.0	93.5	7.0	126.0	0.5	133.5
Fleet Point	10/20	19.5	18.0	6.0	19.0	84.0	109.0	8.0	96.5	0.5	105.0

* Private Bar
** Located in the Corrotoman River (part of the Rappahannock River system)
N/A - Equipment not available to collect data

Figure D1: Map showing the oyster bars sampled in the 1999 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:	18) Ross Rock, 19) Bowlers 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:	28) Haynie Point, 29) Whaley's East, 30) Fleet Point.



76 00'
38 00'
37 00'
Potomac River
Great Wicomico River
Rappahannock River
Corrotoman River
Piankatank River
Cradle Point
Mobjack Point
Mobjack Bay
York River
Felgates Creek
James River
Chesapeake Bay
Atlantic
Ocean
Cranes Creek
Bland Point
Iron Point
N
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FIGURE D2: COMPARISON OF OYSTER ABUNDANCE IN THE JAMES RIVER (1998-99)

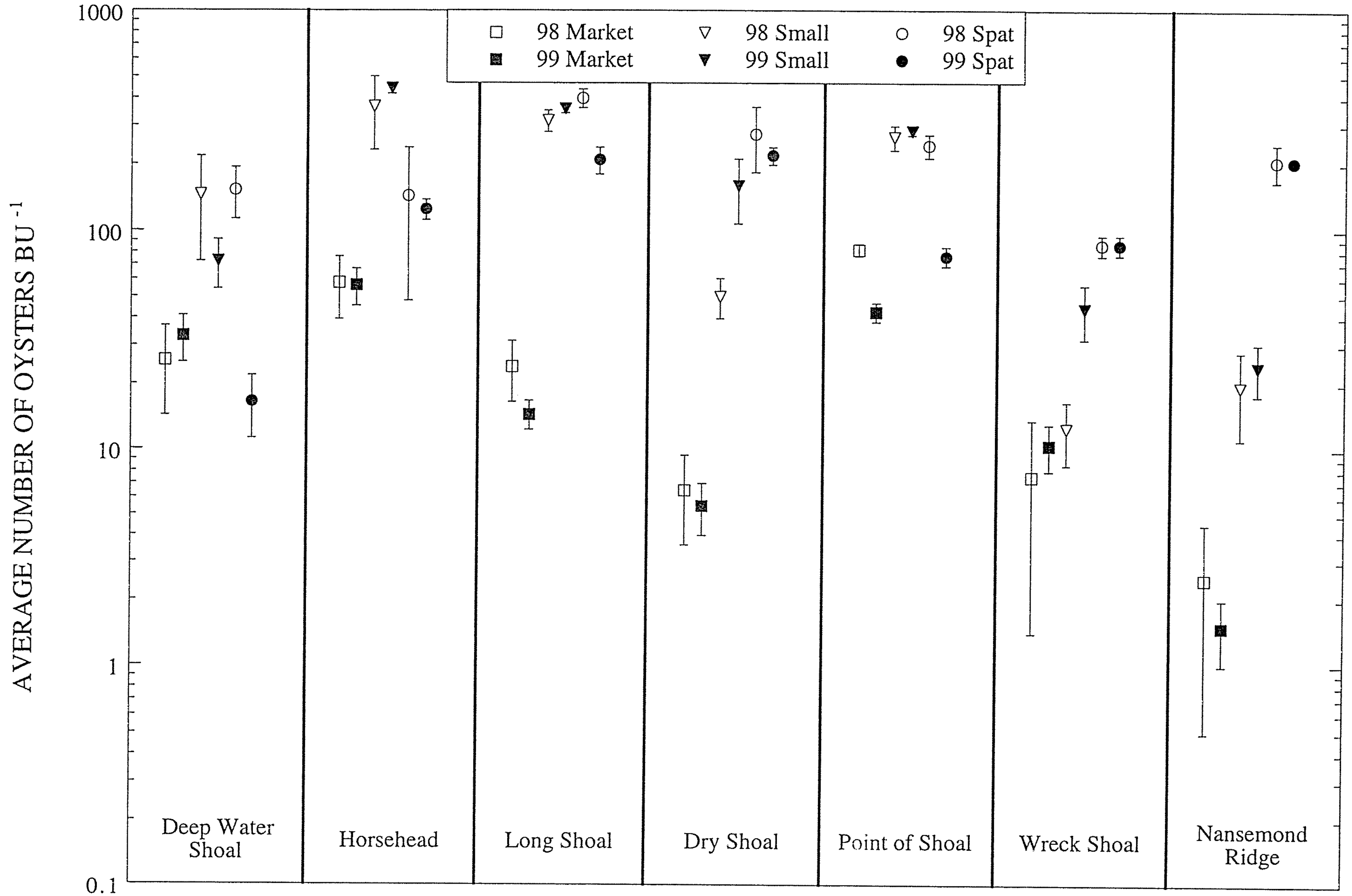

FIGURE D3A: JAMES RIVER OYSTER TRENDS OVER THE PAST 10 YEARS

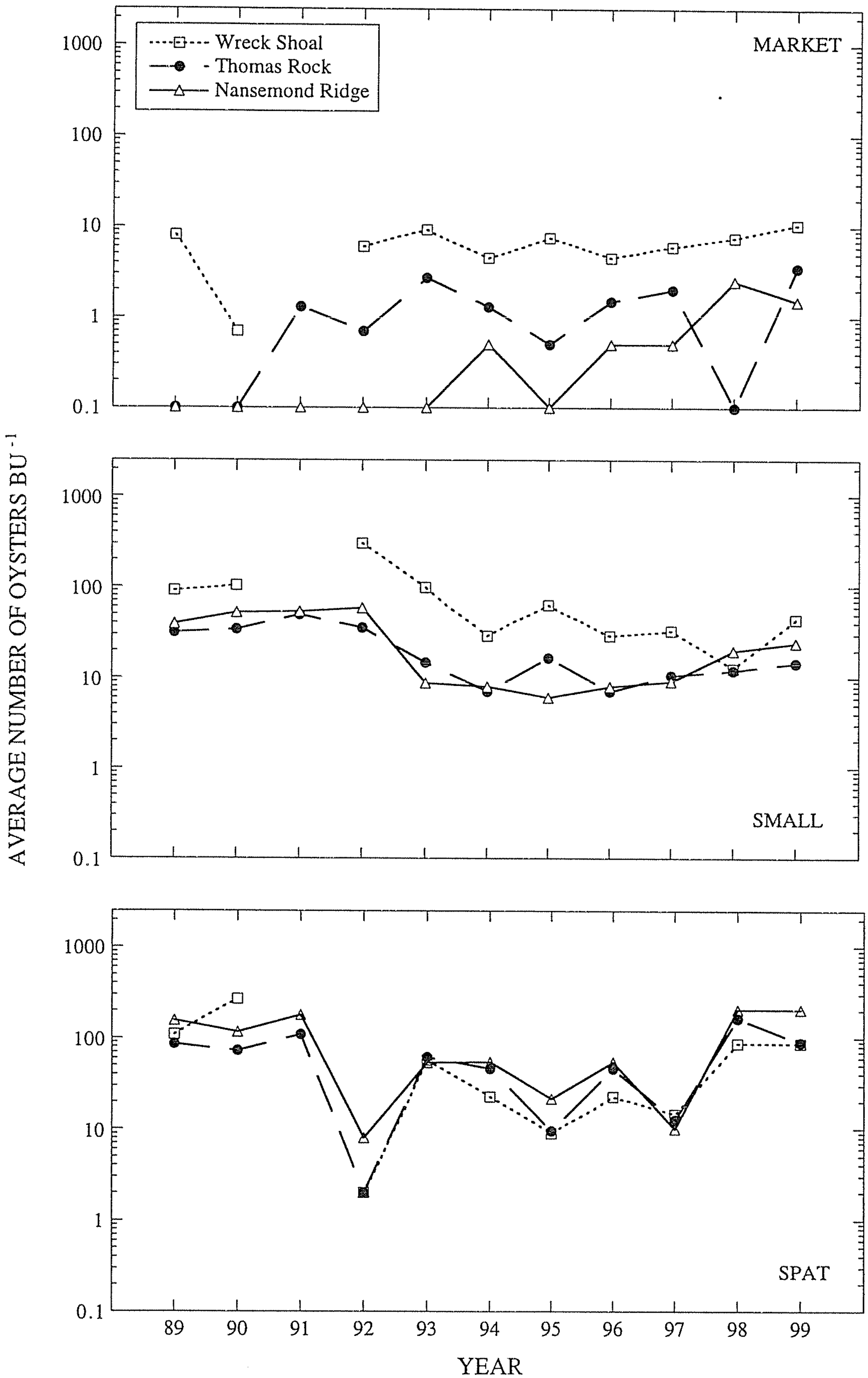

FIGURE D3B: JAMES RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS

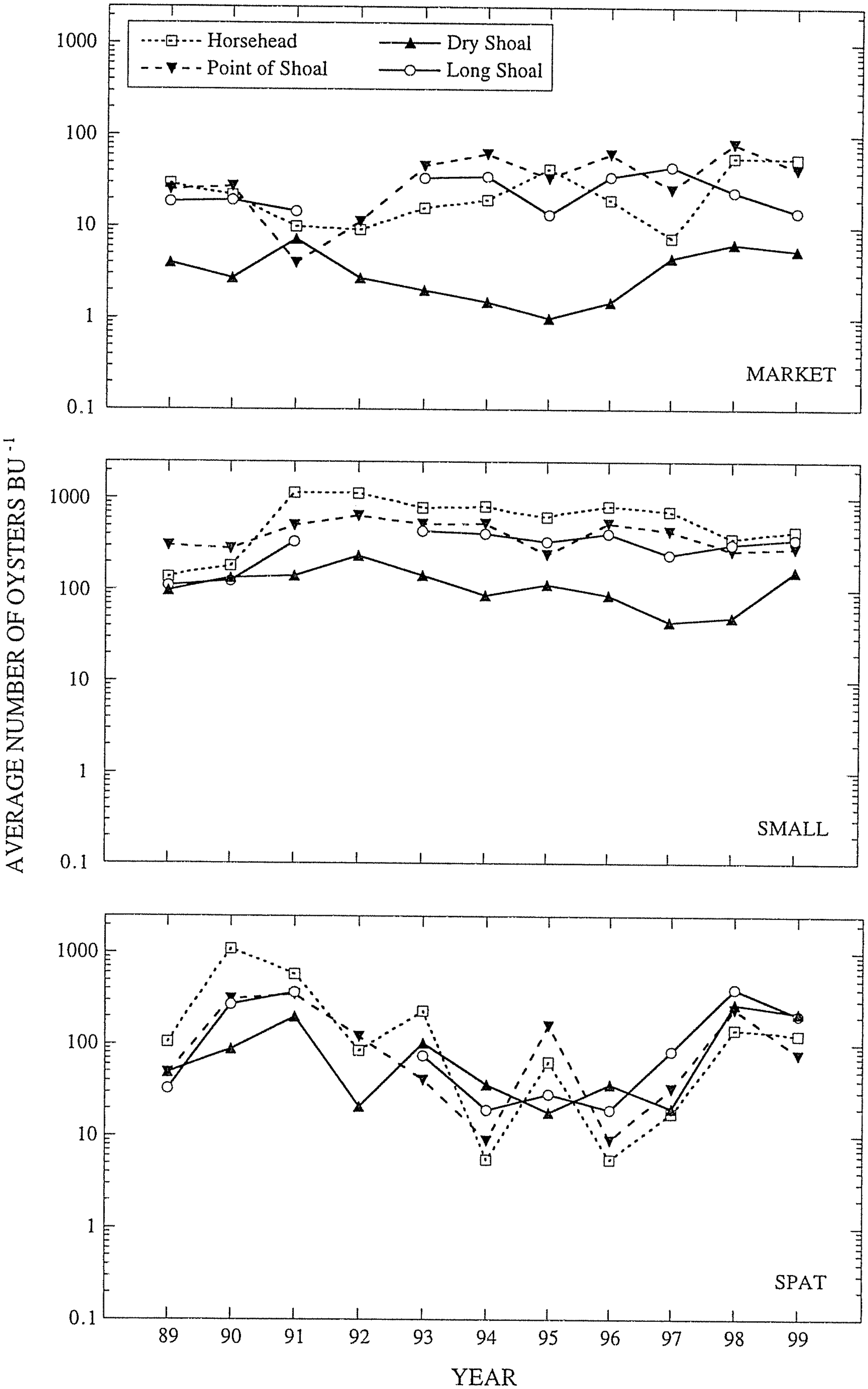

FIGURE D4: COMPARISON OF OYSTER ABUNDANCE IN THE YORK RIVER AND MOBJACK BAY (1998-99)

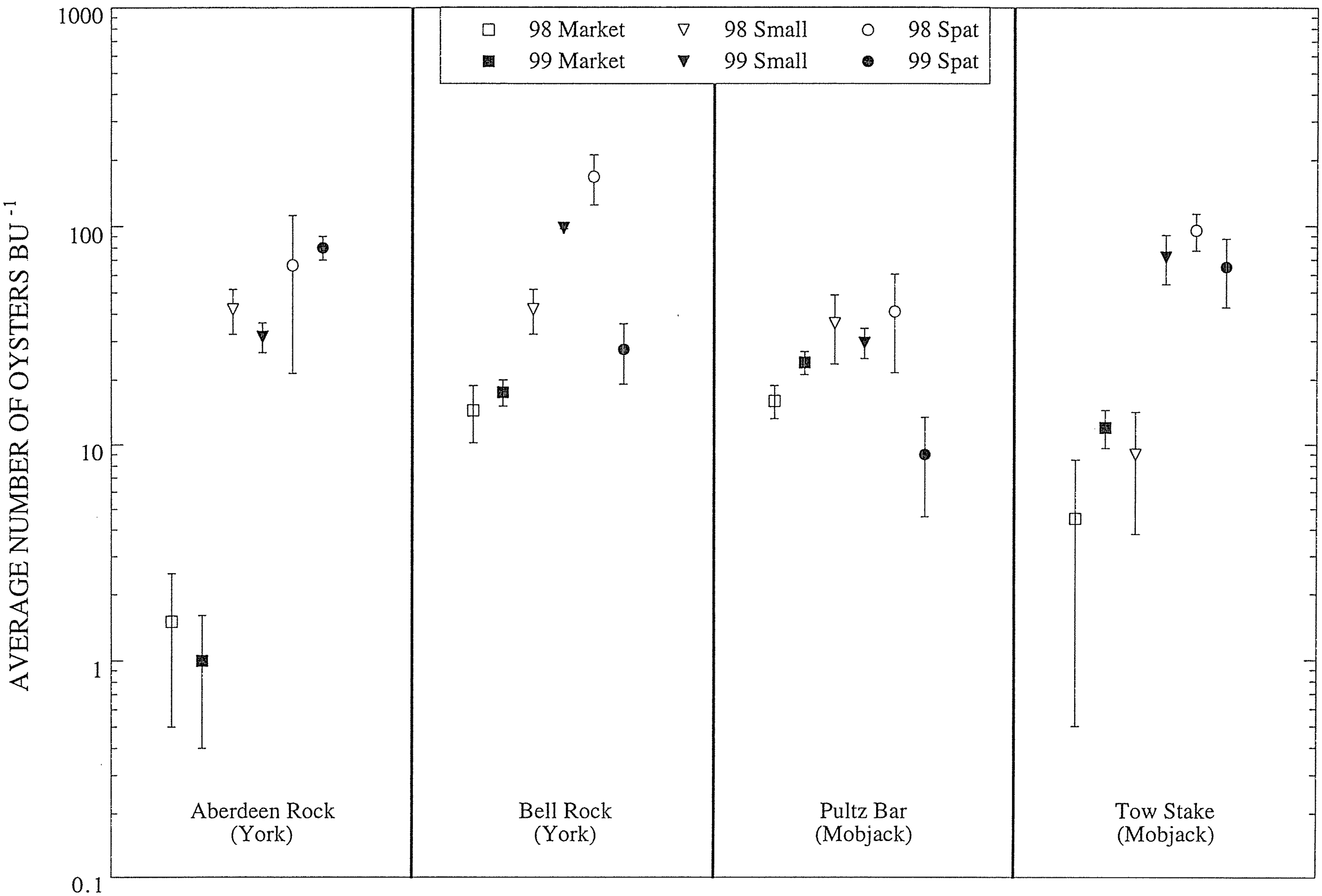

FIGURE D5: COMPARISON OF OYSTER ABUNDANCE IN THE PIANKATANK RIVER (1998-99)

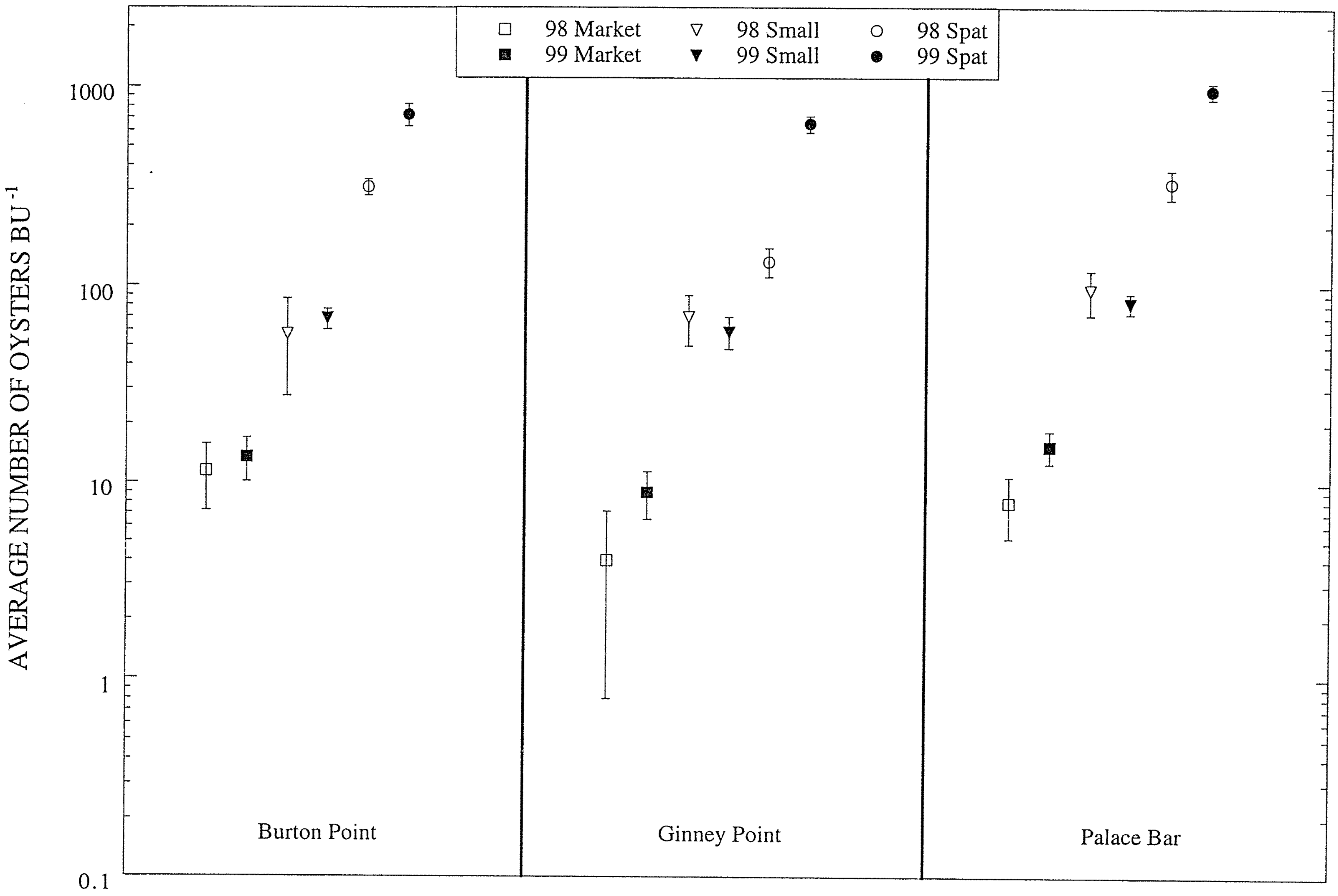

FIGURE D6: PIANKATANK RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS

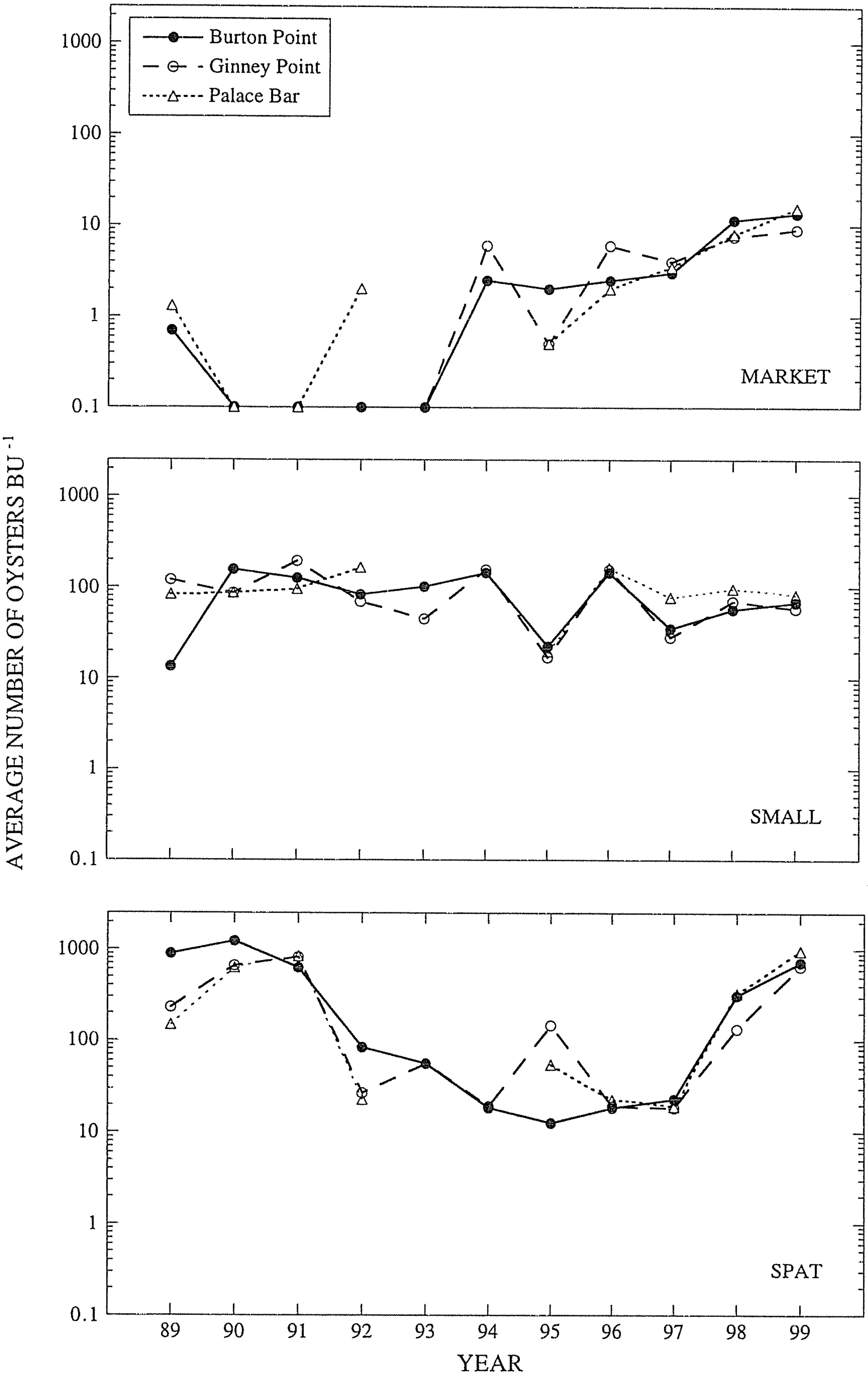

FIGURE D7: COMPARISON OF OYSTER ABUNDANCE IN THE RAPPAHANNOCK RIVER (1998-99)

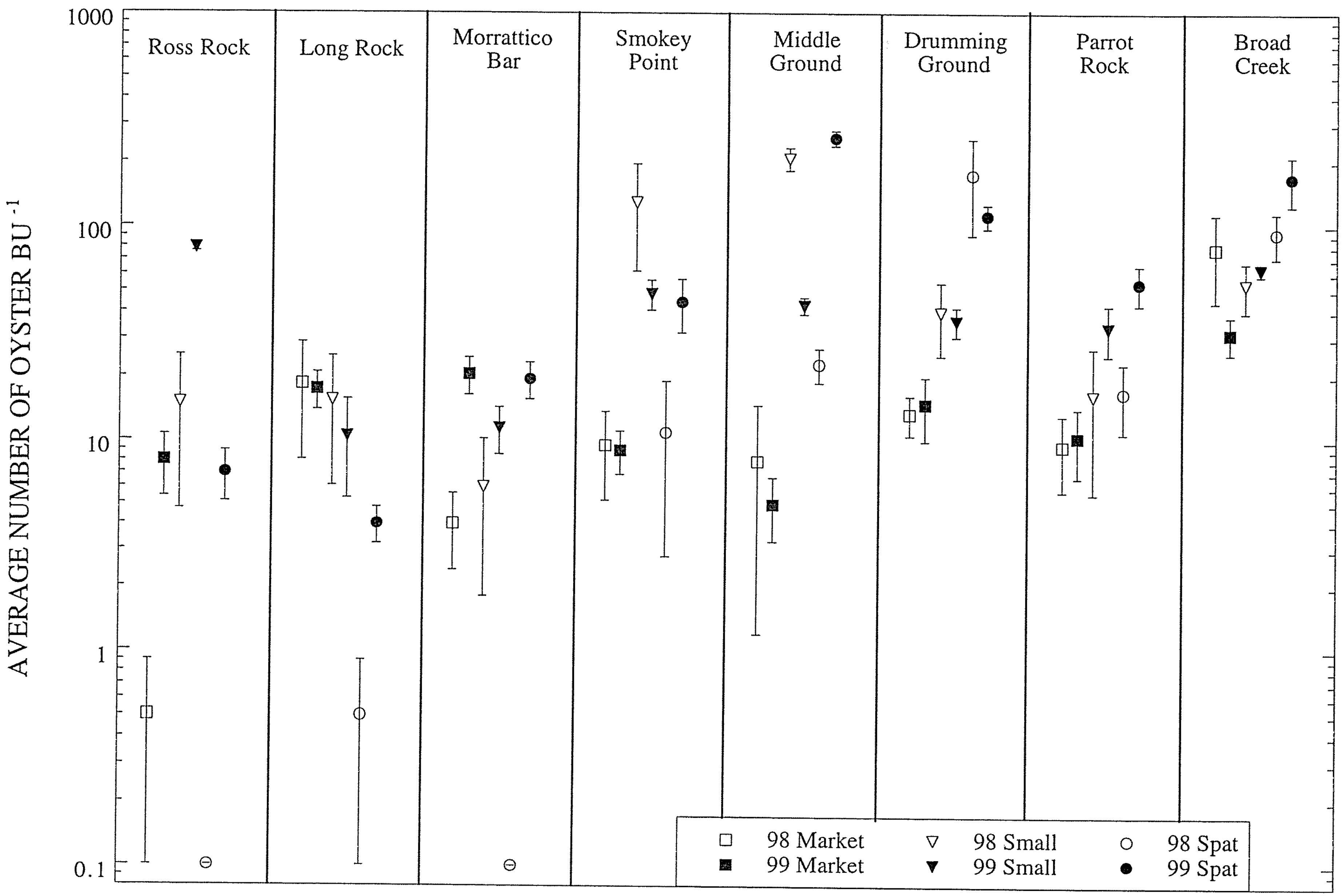

FIGURE D8A: RAPPAHANNOCK RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS

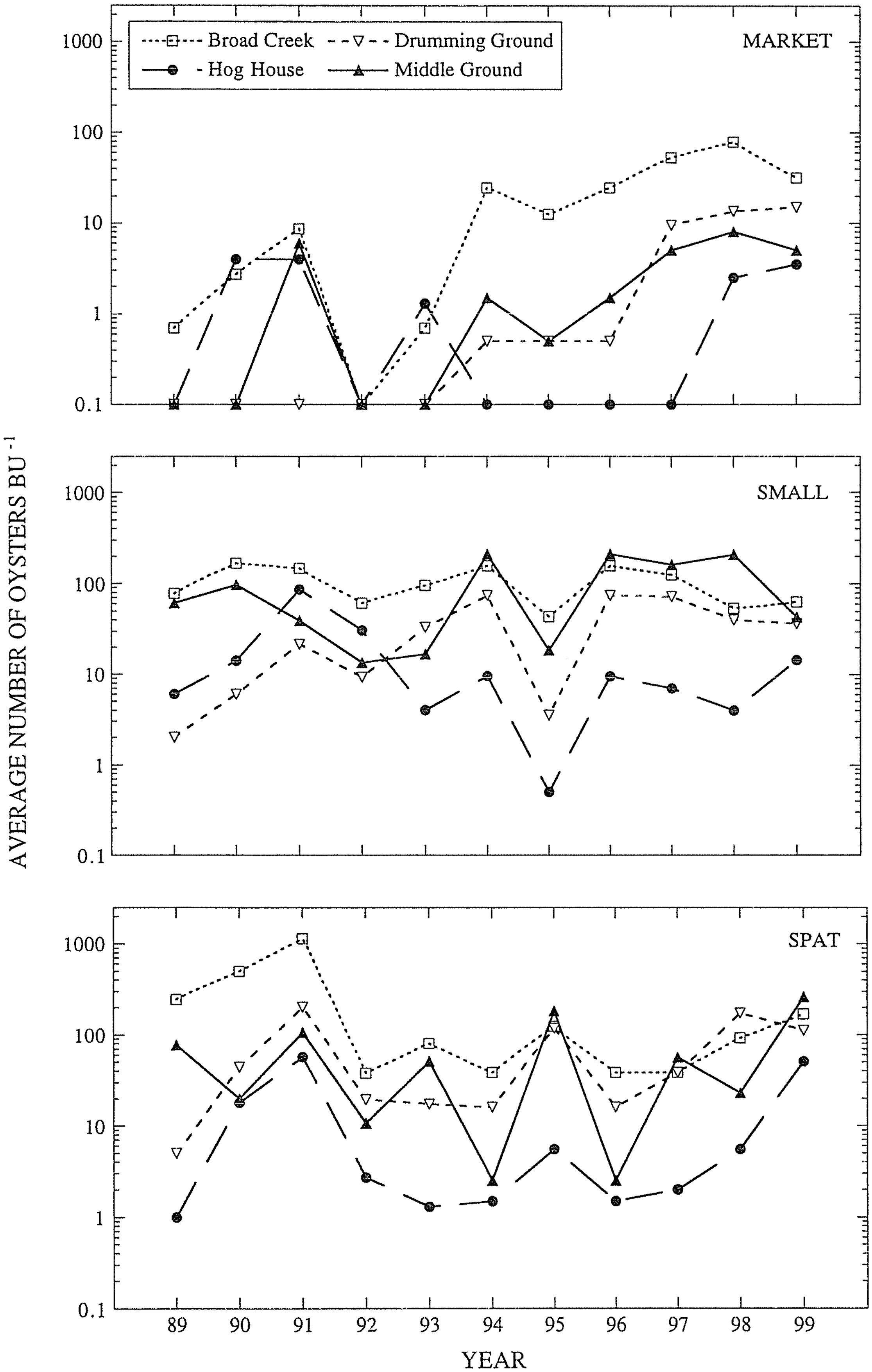

FIGURE D8B: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 10 YEARS

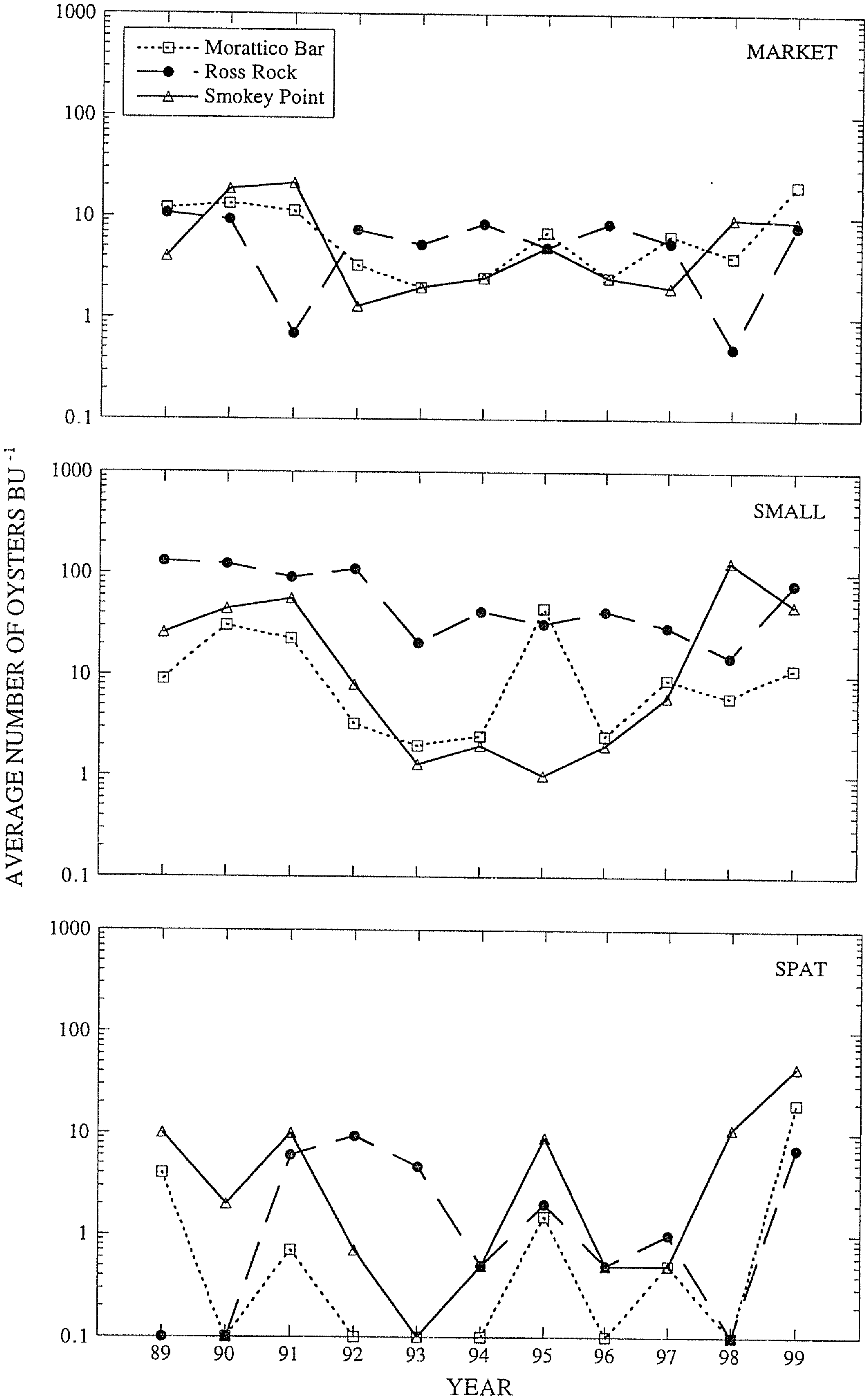

FIGURE D9: COMPARISON OF OYSTER ABUNDANCE IN THE GREAT WICOMICO RIVER (1998-99)

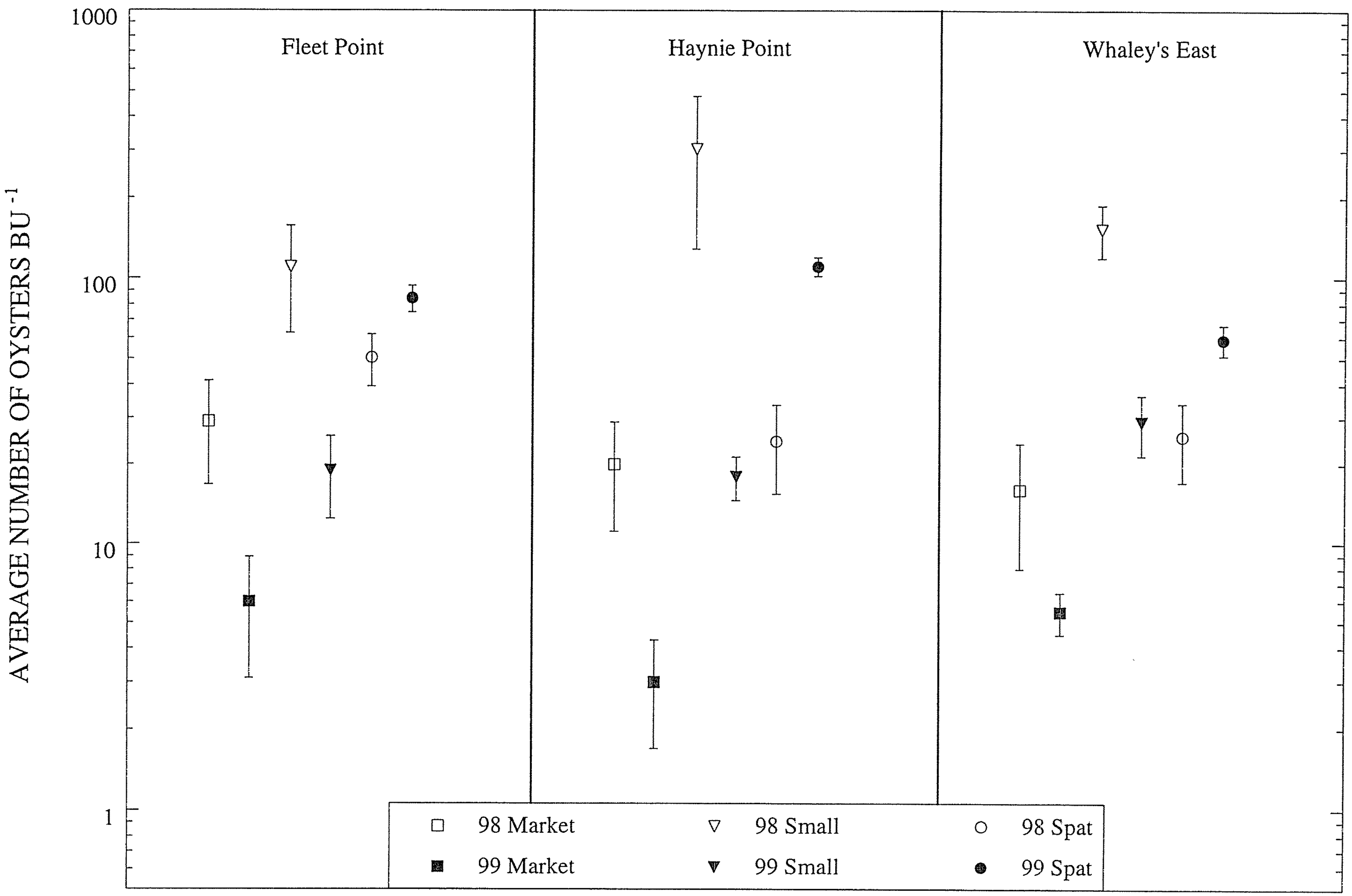

FIGURE D10: GREAT WICOMICO RIVER OYSTER TRENDS
OVER THE PAST 10 YEARS