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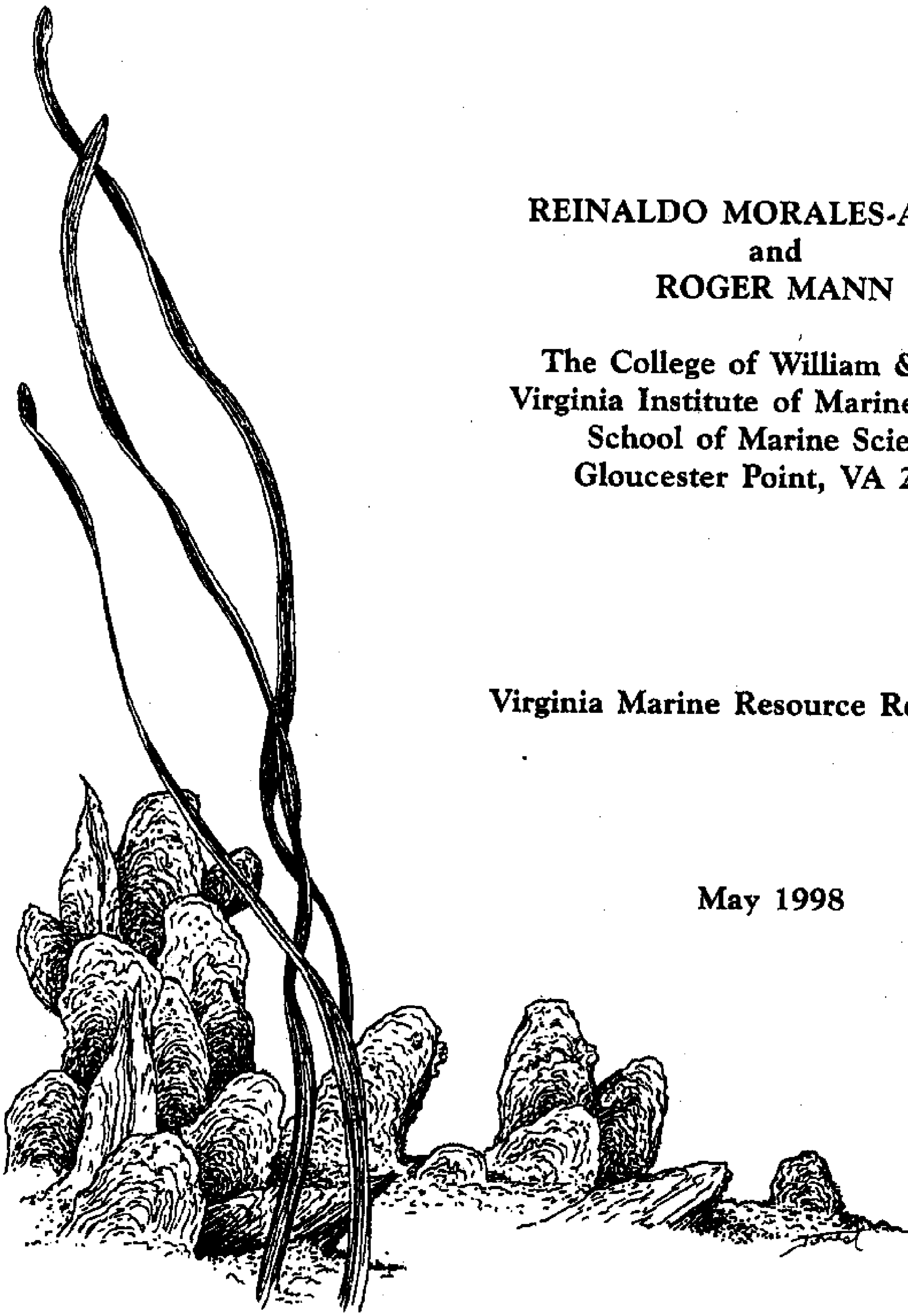
The Status of Virginia's Public Oyster Resource 1997



REINALDO MORALES-ALAMO
and
ROGER MANN

The College of William & Mary
Virginia Institute of Marine Science
School of Marine Science
Gloucester Point, VA 23062

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Status of the Public Oyster Resource of Virginia in 1997

Summary

1. Oyster spatfall in 1997 was low at all Virginia tributaries of the western Chesapeake Bay and the Potomac River, as well as on the seaside of the Eastern Shore. Low spatfall has been prevalent in Virginia since 1991, with the exception of the James River in 1993, when spatfall was moderate. Total annual spatfall in 1997 at all stations monitored was considerably lower than the average for the previous 10 years.

2. Total spatfall for 1997 in the James River marked the third year in a row of poor settlement on the suspended collectors. It appears that low salinity was a major factor affecting spatfall in the James River in the last three years. Spatfall in 1997 was considerably lower at all stations than the 10 year average for 1987-1996 and miniscule when compared to peaks recorded in several years between 1958 and 1993. Most of the spatfall in 1997 was concentrated between July 27 and October 5.

3. Most of the spatfall in the James River in the last 13 years has been recorded at stations downriver of Burwell Bay, on the southwest side, where salinity is usually above 15 ppt, and where most of the accrued recruitment is lost due to the effect of oyster diseases. Larvae setting on shellstring collectors at those bars, however, are most likely produced in lower-salinity bars upriver, particularly at Burwell Bay, where oysters are abundant. Consequently, management of Burwell Bay bars should include steps to maximize oyster settlement in the same area by periodic addition of new shell substrate and by protection of the existing broodstock.

4. A large increase in spatfall in the Great Wicomico River in 1997 above that recorded in the previous six years can be attributed to introduction of large oysters from Tangier Sound in December 1996 onto an artificial reef built upriver of Shell Bar. These oysters were the likely source of larvae that settled in large numbers on shellstring collectors at Hudnall's Dock and Glebe Point and which accounted for most of the spatfall recorded in the river. There was very little difference between the 1996 and 1997 spatfall at the other four stations. Water circulation in the river may have been the factor responsible for the difference in settlement between those two groups of stations.

5. Abundance of market oysters (3 in or larger) was low at all bars sampled by dredging during the bottom surveys of 1997. They made up a small percentage of populations on the bars sampled. At most bars, with a total per bushel (bu) of 100 oysters of all sizes, the percentage of market oysters was under 17%. In recent years, most of the market oysters have been found in the upper limits of oyster distribution of the James and Rappahannock rivers, where lower water salinity pro-

tects oysters from the diseases that kill them elsewhere. The number of market oysters remains low because growth rate of oysters in those area is relatively low. Moderate mortality due to diseases and freshets as well as intermittent removal through harvesting also contribute to a reduction in the number of market oysters in those areas.

6. Small oysters (seed oysters, excluding spat) were found in low numbers at all bars sampled in 1997, with the exception of three bars in the James River; as has been usual in recent years, the highest concentration of small oysters was found in the Burwell Bay area of that river. Increases in the number of small oysters at Bowlers Rock and Morattico Bar in the Rappahannock River in 1997 were primarily the result of transplantation of James River seed by the Virginia Marine Resources Commission.

7. The number of market oysters off Broad Creek in 1997 matches that recorded at Bowlers Rock, even though the area off Broad Creek is usually considered to be within the salinity limits at which the effects of oyster diseases are significant. In 1997, however, there was no evidence of significant mortality off Broad Creek and disease prevalence was low.

8. With the exception of Haynie Point in the Great Wicomico River, the average number of spat per bu was very low (well below 100) at most bars sampled in 1997. Spatfall on bottom substrate has been low since 1991 throughout Virginia tributaries of the western Chesapeake Bay. Low numbers of spat in the James river in 1997 may have been due in good part to low water salinity in June, along with lower than optimal temperatures. The average number of spat per bu in the Great Wicomico River was higher in 1997 than in the previous three years, due primarily to a high number at Haynie Point, which was most likely associated with massive spawning by large Tangier Sound oysters planted on an artifical reef across the river from Haynie Point.

9. Mortality presumed to have occurred within one month of sampling was very low at all but five of the bars sampled in the fall of 1997. Mortality presumed to have occurred within several months before sampling in October 1997, was high only at Thomas Rock, Wreck Shoal and Dry Shoal in the James River and at Parrot Rock in the Rappahannock River.

Part I. Oyster Spatfall in Virginia in 1997

Introduction

The Virginia Institute of Marine Science (VIMS) monitors the reproductive activity of the eastern oyster, *Crassostrea virginica* (Gmelin 1791), during the summer season by deploying spatfall collectors (shellstrings) at stations throughout Virginia on western Chesapeake Bay tributaries and on the Eastern Shore. The survey provides an estimate of the *potential* of a particular area for receiving a "strike" or set of oysters on the bottom and helps define the timing of setting events. Information obtained from this monitoring effort is added to a data base that provides an overview of long-term trends in spatfall in the lower Chesapeake Bay and contributes to assessment of the current condition of the oyster resource and the general health of the Bay system. The data are also valuable to parties interested in potential timing and location of shell plantings.

Results from the spatfall monitoring program are reflective of the abundance of ready-to-set oyster larvae in an area, and thus, are an index of reproduction by oyster populations in an estuary and of succesful development and survival of the larvae to the settlement stage. Environmental factors affecting those physiological activities cause seasonal and annual fluctuations in spatfall which are evident in the data collected.

Data from spatfall monitoring are also an indicator of the *potential* for recruitment into oyster populations in a particular estuary. However, 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 those factors. Abundance and condition of the bottom cultch also affects settlement and survival of spat on the bottom. Thus, settlement on shellstrings may not correspond directly with recruitment on bottom cultch at all times or places. Under most circumstances, however, the relationship between the two is expected to be commensurate.

This report summarizes data collected during the 1997 setting season.

Methods

Spatfall in 1997 was monitored from June through September at most of the stations and through the middle of October at some of them. The stations monitored included 32 in the Virginia tributaries of the western Chesapeake Bay, 12 in the Potomac River, and three in the seaside (Atlantic Ocean side) of the Eastern Shore of Virginia (Figure 1). The absence of data for some weekly periods was due to logistical difficulties in deployment or retrieval of collectors. Reduction to three in the number of stations monitored on the Eastern Shore was due to termination of the exploratory program conducted there in 1995 and 1996. Continued deployment in 1997 of shellstrings at two stations by Fisherman Island was associated with concurrent ecological studies on an artificial oyster shell reef at that location; deployment of a shellstring at Wachapreague represented continuation of long-term data collections at that station.

The collectors used oystershell strings to monitor spatfall. A shellstring consisted of 12 oyster shells of similar size (about 7.6 cm, or 3 in) drilled through the center and strung (inside of shell down) 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 surface (underside) of the central 10 shells was counted with the aid of a dissection microscope. This number was then divided by 10 to get the number of spat-per-shell for the corresponding time interval.

Although shellstring collectors at most stations were deployed for 7-day periods, some were frequently deployed for periods that ranged between 5 and 22 days and the deployment periods did not usually coincide among the different rivers and areas monitored. Spat counts for different deployment dates and periods were, therefore, standardized through computation to correspond to the 7-day standard periods specified in Table 1; those periods coincide with the calendar sequence that begins on June 1. Standardized weekly periods allow comparison of spatfall trends over the course of the summer between the various locations, as well as between data for different years.

Total annual spatfall for each station was computed by adding the weekly values of spat-per-shell for the entire season. This is a non-dimensional value (it no longer represents spat/shell) and is used as an index for comparative purposes. The same is also true for the sum of weekly or annual spatfall for all stations in any one river.

A change in computation of spat averages for standard weekly periods was introduced for the 1996 data. Those computations and the change made in 1996 are explained in Appendix A.

Spat-per-shell-per-week values were categorized for comparison purposes as follows: less than 0.10, *very light*; 0.10-1.00, *light*; 1.01-10.00, *moderate*; and 10.01 or more, *heavy*.

Water temperature and salinity measurements were made only at stations in the James and Piankatank Rivers and the Eastern Shore. Temperature (in degrees C) was measured with a stem thermometer, and salinity (in ppt, or parts per thousand) was measured with a hand-held refractometer.

When reference is made in the text to the Burwell Bay area of the James River, it is liberally defined as the area south-southwest of the navigation channel, above Dry Shoal, and which includes Long Rock, Point of Shoals and Horsehead.

Unqualified references to *diseases* in this text imply diseases caused by *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (*Perkinsus*, or Dermo).

Results

Spatfall on shellstring collectors for 1997 is summarized in Table 1 and is discussed below for each river system. A summary of settlement for the last 11 years appears in Table 2. Table 3 summarizes temperature and salinity data for stations where they were measured. The information presented below refers to those tables.

❖ *James River*

Settlement of oysters on shellstring collectors in the James River was very low in 1997. It was considerably lower at all the stations than the 10 year average for 1987-1996 and miniscule when compared to peaks recorded in several years between 1958 and 1993 (Table 2; Figs. 2 and 3). Total spatfall for the year marked the third year in a row of poor settlement on the suspended collectors.

Settlement on shellstrings was recorded two to three weeks earlier at Deep Water Shoal (on week of July 6) and at Nansemond Ridge (on week of July 13) than at any other station in the James River (Table 1). That is an interesting fact because Deep Water Shoal is the station farthest upriver and Nansemond Ridge is the station farthest downriver; those stations are, respectively, 8 and 24 nautical miles from the river mouth. No spatfall was recorded at any of the other stations before July 27. Total spatfall for the year, however, was much lower at Deep Water Shoal and Nansemond Ridge than at Naseway Shoal, Days Point, and Rock Wharf. Settlement at five other stations was similar to that at Deep Water Shoal.

Most of the spatfall in the James River was concentrated between July 27 and October 5 in 1997 and was recorded continuously during that period at seven of the twelve stations monitored. Spatfall was recorded after October 5 at only three stations: Nansemond Ridge, Dog Shoal and Days Point. The highest single weekly value of spat per shell (2.3) was recorded at Naseway Shoal on the week of August 3. Weekly settlement reached values between 1 and 2 spat/shell in only seven instances (at four stations).

Distribution of weekly oyster settlement on shellstrings in terms of percent frequency over time during the 1997 season was almost identical to that observed in 1996 (Fig. 4). Maximum total weekly settlement for all stations occurred between July 27 and August 31 in 1997 and between July 27 and August 24 in 1996. Distribution of weekly settlement in other years was much different than that in 1996 and 1997 and very variable among years. Settlement can occur as early as mid-June and as late as early October, but it is usually concentrated in July and August.

Water temperature at all stations ranged from 21.0 to to 28.5°C in June and between 24.8 and 30.4°C from July to September; it ranged from 20.8 to 14.2 in October (Table 3). Water salinity was lowest at all stations in June and highest in September and October. At Deep Water Shoal, Horsehead and Point of Shoals, it ranged from 3 to 6 ppt in June, from 6 to 12 ppt in July and August and from 11 to 14 ppt in September and October. Salinity was slightly higher at Swash than at the three aforementioned stations (June range: 4-6 ppt; July-August range: 10-15ppt; September-October range: 15-17ppt). At the seven stations further downriver (not including Nansemond Ridge), salinity ranged from 7 to 17 ppt in June, from 11 to 21 ppt between July and September, and from 16 to 20 ppt in October. At Nansemond Ridge, salinity ranged from 14 to 19 ppt in June and July, and from 18 to 21 ppt in September and October.

◆ *York River*

The only shellstring in the York River was located at the VIMS oyster pier. Spatfall was recorded on only two weekly periods: those starting on July 13 and July 20. Total annual spatfall was very low, adding up to only 0.6.

◆ *Mobjack Bay*

Spatfall in Mobjack Bay was very low in 1997 (total for the year was 0.7) and considerably lower than the average for the past 10 years. It extended intermittently from July 29 to October 4 at the five stations monitored. Spatfall was recorded between August 3 and September 7, but only off Pepper Creek was spatfall recored on each of the six weekly periods included. At the other three stations, spatfall was recorded on only two, three and four of those weeks, respectively. Settlement was very light on all weeks.

◆ *Piankatank River*

For the fourth year in a row, spatfall was extremely low in the Piankatank River. No spatfall was recorded at three of the four stations in that river until August 17 and then for only two weeks (assuming that, as at Burton Point, settlement would have been observed at Palace Bar and Ginney Point on August 17 and 24, periods during which the collectors at the latter two stations were lost). At Burton Point, spatfall was recorded on the three successive weeks that started on July 27. No spatfall was recorded after August 31 at any station. All weekly averages were light and the annual total for all stations was 1.4 .

Water salinity was similar at all stations in the Piankatank River throughout the summer and ranged from 14 to 18 ppt in June and July, from 15 to 20 ppt in August and September, and from 17 to 19 ppt in October. There was little variation in water temperature between stations on any month (temperature ranged from 19 and 28°C between June and September and between 19 and 21°C in October).

◆ *Rappahannock River*

Spatfall in the Rappahannock River was very low in 1997, which continued the trend of single-digit annual spatfall observed in the previous five years. The last time that spatfall was recorded in double digits in the Rappahannock River was in 1990 and 1991. Spatfall in 1997 was also one order of magnitude lower than the average for the previous 10 years. Spatfall was recorded for only two (non-coinciding) weekly periods at two of the three stations monitored, on July 13 and 20 at Windmill Point and on July 27 and August 3 off Locklies Creek. At the third station, Sturgeon Bar, spatfall was recorded for five successive weeks, between August 3 and September 14. Total spatfall for the year, all stations combined, was only 1.2.

◆ *Great Wicomico River*

Spatfall in the Great Wicomico River in 1997 occurred under special circumstances which affect the manner in which the data are interpreted. In December 1996, 2500 bu of large oysters from Tangier Sound were planted on a man-made oyster-shell reef, upriver from Shell Bar and off the mouth of Shell Creek. The reef is located approximately 0.8 km (900 yd) downriver from the shellstring station at Hudnall's Dock, on the same side of the river, and approximately 0.6 km (700 yd) across the river from the shellstring station at Haynie Point (Fig. 5). The exceptional increase in spatfall in the river during the 1997 season, when compared to what had been observed in the previous six years, is attributed by inference to the introduction of the Tangier Sound oysters and not to a substantial change in the natural oyster populations, because no such changes were apparent in our bottom survey of October 1996.

Combined spatfall for all stations in the Great Wicomico in 1997 was much higher than in the previous six years and was of the same magnitude as the mean for the previous 10 years. Increases of two orders of magnitude in spatfall at Hudnall's Dock and Glebe Point over what was recorded in 1996 accounted for 85% of the total spatfall in 1997. The sum for those two stations alone equaled the mean for the previous 10 years, and spatfall at the other four stations had a minimal impact on the overall increase in 1997.

Spatfall was concentrated primarily between June 29 and August 3, with some significant differences among the six stations. First settlement was recorded at Hudnall's Dock on June 22 but not until June 29 at four of the other five stations. At Dameron Marsh, at the mouth of the river, first spatfall was not recorded until July 13. Spatfall extended for a much longer period at Dameron Marsh and Glebe Point, through September 14, than at the other stations even though Glebe Point and Dameron Marsh are located on opposite ends of the river area covered by our monitoring program (at Glebe Point there was a three-week break between August 3 and August 24 and spat/shell values there were lower than at Dameron Marsh in August and September). Spatfall ended at three of the stations on August 3, and on August 10 at Hudnall's Dock and Haynie Point.

The highest total spatfall for the year was recorded at Hudnalls' Dock; it was almost twice as high as what was recorded at Glebe Point, and approximately ten or more times as high as at the remaining four stations. The highest weekly spatfall at each station was recorded concurrently on the weeks of July 13 and July 27, with similar spat/shell values in those two weekly periods. There was very little difference in total annual spatfall between 1996 and 1997 at the four stations other than Hudnall's Dock and Glebe Point.

Spatfall on additional shellstrings suspended at each end of the artificial reef (upriver and downriver) was similar in intensity to that observed at Hudnall's Dock on the weeks of July 13 and July 20. Spatfall on the reef shellstrings extended through September 7 and September 14, respectively, at the downriver and upriver ends, which was longer than at any of the stations monitored every year, but settlement on the reef shellstrings was very light in August and September.

❖ *Little Wicomico River*

Spatfall in the Little Wicomico was very low in 1997, as it has been since 1992, and was lower than the average for the previous 10 years. It was limited to three weeks between August 3 and August 24.

❖ *Potomac River*

Spatfall was also very low in the Potomac River in 1997. It was limited to a few scattered weeks at seven of the 12 stations monitored. Light to very light settlement was recorded on three successive weeks between July 20 and August 10 at Coan River and in two successive weekly periods between July 20 and August 3 at Great Neck and Jones Shore. The only other settlement (light to very light) was recorded in two successive weeks at four other stations: Currioman Bay (Aug 17 to Aug 31), Lynch Point and Cornfield (August 24 to September 7), and Lower Machodoc (September 21 to October 5). No set was recorded at Hog Island, Nomini Bay, Ragged Point, Monroe Bay and Upper Machodoc.

Spatfall in 1997 continues a 5 year succession of extremely low annual spatfall in the Potomac River. Total spatfall was much lower than the average for the previous 10 years at stations monitored for that long.

❖ *Eastern Shore*

Spatfall at the Fisherman Island North station was higher than at the Fisherman Island South station in 1997, as was also the case in the previous two years of monitoring. At the North station, spatfall extended from June 29 to October 19, but most of the settlement occurred between the last week in August and the last week in September. Settlement peaked on week of August 24. First settlement at the South station was recorded four weeks later than at the North station in 1997, and most of the settlement at the South station also occurred between the last week of August and the last week of September. Total annual spatfall at the Wachapreague station was similar to that recorded at the Fisherman Island South station. Settlement at Wachapreague was evenly spread from July 13 on through October 5 with very low spatfall on the first week, July 6, and on the next-to-last week, October 5 (no spatfall was recorded on the last week, October 12). Total settlement at Wachapreague in 1997 was about half of the average for the previous ten years.

Discussion

Oyster spatfall in 1997 was low at all Virginia tributaries of the western Chesapeake Bay and the Potomac River. Low spatfall has been prevalent in Virginia since 1991, with the exception of the James River in 1993, when spatfall was moderate (Table 2). Total annual spatfall in 1997 at all stations monitored was considerably lower than the average for the previous 10 years. Moderate to heavy spatfall recorded at some stations in 1991 and 1993 probably resulted from advantageous conditions which at that time may have enhanced production of significant spawn by oyster stocks on those tributaries.

Most of the spatfall in the James River in the last 13 years has been recorded at stations downriver of Burwell Bay, on the southwest side, where salinity is usually above 15 ppt: Nansemond Ridge, Naseway Shoal, Dog Shoal, Days Point, Rock Wharf, and Dry Shoal (Fig. 6). From 1985 to 1997, spatfall at those six stations constituted between 63 and 91% of the total annual spatfall at all stations monitored in the James River. However, oysters are very scarce on those bars. It would appear, therefore, that the larvae setting on shellstring collectors below Burwell Bay are most likely produced in bars where oysters are abundant (such as in Burwell Bay, across from Burwell Bay on the northeast side of the channel, and possibly Deep Water Shoal). Thus, a high percentage of larval production in the James River may be lost because the areas where they are most likely to settle lack suitable substrate as a result of depletion by MSX and *Perkinsus*. It would, therefore, be advisable that management of the oyster bars in the Burwell Bay area include steps to maximize retention within that area of a higher percentage of the larvae produced. That may be accomplished by annual addition of suitable shell substrate and protection of the existing broodstock.

Scarcity of good-quality substrate in the higher salinity areas downriver from Burwell Bay, where most of the spatfall occurs on shellstring collectors may have a significant negative impact on eventual recovery of oyster populations in those areas. Long-term succession of large numbers of recruits, as would be expected on the downriver bars if substantial quantities of suitable substrate were present, would allow continuous exposure of some oysters to the disease pathogens, and potentially result in development over an extended period of time of a resistant strain through genetic modification.

At the lower-salinity locations where oysters are abundant, oysters are susceptible to the harmful effects of frequent increases in freshwater runoff and are, therefore, subject to the effect of unpredictable changes in salinity that may seriously impair oyster spawning and/or larval survival and would have a negative impact on spatfall. The great variability in weekly distribution of spatfall in the James River since 1985, as shown in Fig. 4, could be associated with differences between years in water salinity (combined with differences in water temperature and other factors) during the reproductive season.

Ninety percent of the total spatfall at all stations in the James River occurred before August 17 in the years in which the highest spatfall values since 1985 were recorded (1985, 1987, 1991 and 1993); the earliest date was July 20 in 1985 (Figs. 2, 3 and 4; Table 2). In the years when the lowest total spatfall was recorded (1992, 1995, 1996 and 1997), the earliest week on which 90% of the spatfall had occurred was August 24 in 1992 and 1996 and the latest week was September 7 and 21, respectively, in 1995 and 1997. Comparison of those observations with weekly records of temperature and salinity at the shellstring stations, suggested a possible relationship between intensity and timing of spatfall and water temperature and salinity in June.

Average temperature and salinity in June at Point of Shoals were selected for comparison with spatfall because they were similar to those recorded at Horsehead and may be considered representative of the conditions over the still-productive oyster bars in Burwell Bay. Regression analysis of data for 1985 to 1997 indicated that the relationship was weak for temperature (r sq= 0.217) and for an index obtained by adding temperature and salinity (r sq= 0.298) (Figs. 7A and 7B). Obviously, the relationship under consideration is not a simple one and other factors may be involved.

Figure 7, however, shows that the sum of June temperature and salinity was lowest in three of the years with lowest spatfall (1992, 1996 and 1997) and among the highest in three of the years with highest spatfall (1985, 1987, and 1991). Thus, the suggestion that temperature and salinity in June in the upper reaches of oyster distribution in the James River may be major factors in larval settlement in the river appears plausible. An average salinity of 10 ppt or higher combined with an average temperature of 26°C or higher in June would enhance gonad development and spawning of oysters early in the season and possibly result in high spatfall, as was the case in 1985, 1987 and 1991. An average June temperature substantially lower than that, as in 1992 (23.8°C), and an average June salinity of 5-6 ppt (as in 1992, 1996 and 1997) would delay gonad development with an apparent drastic reduction in spatfall for the year. However, inconsistencies in other years indicate that well-planned studies are required to establish the relative significance on spatfall of those two factors and to identify other relevant factors.

Spatfall in 1997 at other Virginia tributaries of the Chesapeake Bay and the Potomac River, with the exception of the Great Wicomico River, continued to be extremely low and does not forebode well for oyster populations in public grounds in those areas.

The large increase in spatfall in the Great Wicomico River in 1997 over what was recorded in the previous six years can be attributed to introduction in December 1996 of large oysters from Tangier Sound onto the artificial reef built upriver of Shell Bar. These oysters were the likely source of larvae that settled in large numbers on the shellstring collectors at Hudnall's Dock and Glebe Point and which accounted for most of the spatfall recorded at the six stations in the river.

The effect of spawning by the Tangier Sound oysters apparently affected only settlement at Hudnall's Dock and Glebe Point because there was very little difference between the 1996 and 1997 spatfall at the other four stations. Water circulation in the river may have been the factor responsible for the occurrence of high spatfall at Hudnall's Dock and Glebe Point and much lower settlement at the other four stations (M. Southworth, personal communication).

The increase in spatfall in the Great Wicomico River in 1997, although highly significant when compared with most recent years, did not historically represent an unusual magnitude for the river. It was about half of what was recorded in 1987, 1988 and 1990, and about seven times lower than spatfall in 1986. Review of the shellstring data for Hudnall's Dock since 1968 shows that the 1997 spatfall matched or exceeded most of the annual spatfall values recorded since 1970, even though it was short of the record for several years, especially 1970, when total spatfall was almost seven times greater (Fig. 8)

The increase in spatfall attributed to the Tangier Sound oysters transplanted to the artificial reef in the Great Wicomico River reinforces the view of scientists and resource managers that older and larger oysters produce much larger quantities of larvae than smaller and younger ones and that it is advisable to allow oysters to remain and grow in their beds to increase their reproductive output. Restoration of oyster populations in the Chesapeake Bay may depend on such a strategy because it also increases the potential for establishment of natural populations resistant to the diseases that are killing them now. It is understood, however, that such a development would require a long period of time, probably measured in decades.

Tidal circulation in estuaries affects the final place of settlement of larvae produced by oysters in estuarine bars as described by Ruzecki and Hargis (1989), Mann and Evans (in press) and M. Southworth, (personal communication). That appears to be the case in the observed spatial distribution of spatfall in the James River for the last 13 years and in the Great Wicomico in 1997. In the Great Wicomico, larvae produced by the introduced oysters near Shell Bar set mostly on shellstrings suspended around the artificial reef itself or at shellstring stations upriver from it, but apparently few set at stations across the river or downriver from the reef. In the James River, it appears that most of the spatfall occurs at stations on bars below Burwell Bay, even though it is assumed that most of the larvae are produced on Burwell Bay bars. Numbers retained in the Burwell Bay area, however, are still considered important for maintenance of oyster populations there.

Spatfall in the Eastern Shore in 1997 was light to very light.

The record for Fisherman Island is too short to evaluate properly. However, the record at Wachapreague is longer and shows that the 1997 spatfall was significantly lower than that for four of the previous ten years but greater or similar to the other six years in that period. That would indicate that settlement at Wachapreague falls within the variability observed through the past ten years and does not warrant special concern.

The complex combination of factors that affect abundance and settlement of oyster larvae makes it very difficult to explain annual variations in spatfall, especially when many of the factors are not monitored. The same difficulty is encountered in trying to forecast, from shellstring data, the extent of final recruitment of seed or adult oysters in bottom populations; location of the shellstring on or in the vicinity of an oyster bar and its distance from deep channels are factors that affect such comparisons. Nevertheless, the magnitude of standing stocks of large market-size oysters and others close to market size is considered a major factor in spatfall because large oysters are the most prolific source of reproductive material in the population, as apparently demonstrated by the large oysters introduced into the Great Wicomico River. Oyster bars above Wreck Shoal in the James River, and especially those in the Burwell Bay area, remain as the only bars in the Virginia tributaries of western Chesapeake Bay with the reproductive potential to produce a substantial recruitment of new oysters; the potential of other bars is handicapped by mortality due to diseases. Spatfall on bars in Burwell Bay is, therefore, critical to sustenance of the only healthy oyster populations left in Virginia's portion of Chesapeake Bay. Consequently, management of those bars should include steps to protect the existing broodstock and promotion of increased oyster settlement by periodic addition of new substrate.

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TABLE 1

AVERAGE NUMBER OF SPAT PER SHELL FOR STANDARDIZED WEEK STARTING ON DATE SHOWN *

Blank space indicates that spat count was zero on that week. Hyphen (–) indicates that no data were collected.

1997 SEASON

	STA	JUN					JUL				AUG					SEP				OCT				YEAR
	ID.	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	TOTAL
JAMES RIVER																								
Nansemond Ridge	S131	–						0.04	0.06	0.11	0.09	0.04	0.14	0.15	0.05	0.02	0.03	0.04	0.04	0.04	–	0.02	–	0.85
Naseway Shoal	S098	–								0.34	2.26	1.59	0.15	0.23	0.30	0.24	0.14	0.09	0.06		–		–	5.40
Dog Shoal	S194	–								0.80	0.60	0.04	0.26	0.36	0.10	0.04	0.05	0.09	0.07	0.04	–	0.02	–	2.45
Miles Watch House**	S089	–											0.04	0.06			0.03	0.04	0.03		–		–	0.20
Days Point	S040	–								0.51	1.01	0.47	0.68	1.36	0.60	0.31	0.24	0.35	0.27	0.07	–	0.04	–	5.89
Rock Wharf	S199	–								0.74	0.56	0.62	1.62	1.32	0.10	0.04	0.10	0.18	0.13		–		–	5.40
Wreck Shoal	S174	–								0.11	0.09	0.13	0.21	0.12	0.11	0.03					–		–	0.80
Dry Shoal	S195	–								0.17	0.13	0.31	0.43	0.06			0.08	0.13	0.09		–		–	1.40
Point of Shoals	S123	–								0.11	0.31	0.62	0.64	0.29	0.30	0.30	0.18	0.09	0.06		–		–	2.90
Swash	S096	–								0.11	0.09	0.49	0.73	0.18			0.10	0.18	0.13		–		–	2.00
Horsehead	S073	–								0.23	0.29	0.84	1.06	0.18			0.05	0.09	0.06		–		–	2.80
Deep Water Shoal	S042	–					0.05	0.05		0.06	0.33	0.39	0.22	0.12	0.22	0.06	0.03	0.04	0.03		–		–	1.60
																			JAMES RIVER	Year Total All Stations				31.68
YORK RIVER																								
VIMS Oyster Pier	S106	–						0.26	0.34												–	–	–	0.60
																			YORK RIVER (VIMS)	Year Total All Stations				0.60
MOBJACK BAY																								
Brown's Bay	S017	–																		–	–	–	–	0.00
Tow Stake	S151	–									0.06	0.07	0.07	0.01						–	–	–	–	0.20
Wilson Creek	S171	–												0.08	0.03					–	–	–	–	0.10
Pultz Bar	S210	–									0.03	0.03	0.03							–	–	–	–	0.10
Pepper Creek	S113	–									0.03	0.03	0.03	0.08	0.11	0.02				–	–	–	–	0.30
																			MOBJACK BAY	Year Total All Stations				0.70
PIANKATANK RIVER																								
Three Branches	S150												0.30	0.40										0.70
Burton Point	S020									0.19	0.37	0.11	–	–										0.67
Palace Bar	S110												–	–								–	–	0.00
Ginney Point	S050												–	–								–	–	0.00
																			PIANKATANK RIVER	Year Total All Stations				1.37
RAPPAHANNOCK RIVER																								
Sturgeon Bar	S200	–									0.10	0.20	0.35	0.18	0.06	0.01			–	–	–	–	–	0.90
Locklies Creek	S208	–								0.07	0.03								–	–	–	–	–	0.10
Windmill Point	S217	–						0.11	0.09										–	–	–	–	–	0.20
																			RAPPAHANNOCK RIVER	Year Total All Stations				1.20

TABLE 1 (Continued)

1997 SEASON

	STA	JUN					JUL				AUG					SEP				OCT				YEAR
	ID.	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	TOTAL
GREAT WICOMICO RIVER																								
Dameron Marsh	S087	–						0.96	1.35	0.39		0.14	0.20	0.16	0.15	0.04						–	–	3.40
Fleet Point	S048	–				0.04	0.05	2.44	3.40	0.97												–	–	6.90
Cranes Creek	S037	–				0.08	0.09	0.67	0.90	0.26												–	–	2.00
Hudnall's Dock	S074	–			0.42	7.84	9.05	23.52	29.30	8.45	0.02											–	–	78.60
Haynie Point	S064	–				0.48	0.56	2.80	3.70	1.14	0.02											–	–	8.70
Glebe Point	S051	–				1.72	2.01	14.25	19.15	5.47				0.04	0.05	0.01						–	–	42.70
																GREAT WICOMICO RIVER				Year Total All Stations				**142.30**
Reef, SE (downriver)***	S258	–	–	–	–	–	–	19.20	22.40	3.33	0.15	0.02		0.04	0.05	0.01		–	–	–	–	–	–	45.20
Reef, NW (upriver)***	S259	–	–	–	–	–	–	21.43	25.00	3.61	0.05	0.01		0.04	0.05	0.05	0.05	–	–	–	–	–	–	50.29
LITTLE WICOMICO RIVER																								
P.G. No. 42	S207	–									0.34	0.14	0.01							–	–	–	–	0.50
																LITTLE WICOMICO RIVER (PG 42				Year Total All Stations				**0.50**
POTOMAC RIVER (LOWER)																								
Lynch Point	S247	–												0.15	0.05							–	–	0.20
Hog Island	S066	–																				–	–	0.00
Coan River	S030	–							0.51	0.26	0.03											–	–	0.80
Great Neck	S053	–							0.09	0.01												–	–	0.10
Jones Shore	S080	–							0.17	0.03												–	–	0.20
Cornfield	S035	–												0.23	0.08							–	–	0.30
																POTOMAC RIVER (LOWER)				Year Total All Stations				**1.60**
POTOMAC RIVER (MIDDLE)																								
Curioman Bay	S224												0.03	0.08							–	–	–	0.10
Nomini Bay	S101																				–	–	–	0.00
Lower Machodoc	S225																	0.11	0.09		–	–	–	0.20
Ragged Point	S130																				–	–	–	0.00
																POTOMAC RIVER (MIDDLE)				Year Total All Stations				**0.30**
POTOMAC RIVER (UPPER)																								
Monroe Bay	S249	–															–	–	–	–	–	–	–	0.00
Upper Machodoc	S248	–															–	–	–	–	–	–	–	0.00
																POTOMAC RIVER (UPPER)				Year Total All Stations				**0.00**

TABLE 1 (Continued)

1997 SEASON

	STA	JUN					JUL				AUG					SEP				OCT				YEAR
	ID.	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12			TOTAL
EASTERN SHORE Seaside																								
Fisherman Island N (FI2)	S250	–				0.43	0.54	0.17	0.13		0.05	0.16	0.16	13.30	8.80	5.93	4.38	4.29	1.79	0.53	0.31	–	–	40.97
Fisherman Island S (FI3)	S251	–								0.18	0.22		0.17	3.10	2.21	2.66	2.01	0.97	0.66	0.11		–	–	12.30
Wachapreague (W3)	S156	–					0.25	3.62	2.78	1.08	3.64	7.91	4.64	1.49	2.43	2.98	3.23	3.56	2.09	0.43		–	–	40.10

EASTERN SHORE SEASIDE Year Total All Stations 93.37

Slight discrepancies between sum of individual values and Year Total for each station are due to rounding.

* See text for description of standardized weeks.

** Miles Watch House station is on Thomas Rock.

*** Additional stations at each end of artificial reef in Great Wicomico River with Tangier oysters on it. Limited monitoring interval.

TABLE 2

SPATFALL TOTALS FOR YEARS 1987-1997 AND MEAN FOR 1987-1996

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

(+ and - indicate direction of change in 1997 in reference to 1996 and to 10-Yr Mean; nc = no change)

Parentheses around value for a given year and station indicate significant gaps in weekly data; no comparisons made.

Location	STA ID.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Mean 87-96	1997	Change Ref. 1996	Change Ref. Mean
JAMES RIVER															
Nansemond Ridge	S131	18.4	8.9	26.0	40.6	56.5	7.0	13.7	3.1	4.5	10.3	*18.9*	**0.9**	-	-
Naseway Shoal	S098	296.6	18.5	59.4	20.6	179.0	1.9	11.3	3.4	4.1	12.7	*60.8*	**5.4**	-	-
Dog Shoal	S194	356.9	27.5	73.0	34.4	274.8	11.6	58.6	30.4	2.0	14.7	*88.4*	**2.6**	-	-
Miles Watch House*	S089	33.7	3.2	4.2	2.4	18.7	3.5	5.2	2.2	0.2	7.8	*8.1*	**0.2**	-	-
Days Point	S040	481.6	17.3	25.9	28.6	146.6	15.7	131.6	49.2	3.4	5.2	*90.5*	**5.9**	+	-
Rock Wharf	S199	285.7	40.9	3.5	17.1	–	11.7	34.4	12.0	2.6	2.8	*41.1*	**5.4**	+	-
Wreck Shoal (Middle)*	S174	35.1	10.0	10.5	5.9	35.4	3.2	15.5	2.2	0.2	11.0	*12.9*	**0.8**	-	-
Dry Shoal	S195	241.5	13.2	10.1	45.8	217.2	14.2	119.0	41.3	1.8	11.8	*71.6*	**1.4**	-	-
Point of Shoals	S123	75.4	9.9	2.1	2.9	21.4	5.4	73.5	17.2	5.5	2.6	*21.6*	**2.9**	+	-
Swash	S096	79.5	7.6	3.8	3.9	68.6	–	46.2	5.5	0.3	2.4	*21.8*	**2.0**	-	-
Horsehead	S073	100.0	3.7	1.5	1.0	24.6	3.6	43.7	3.8	2.8	3.6	*18.8*	**2.8**	-	-
Deepwater Shoal	S043	30.6	4.3	2.1	3.8	10.8	0.7	15.6	0.8	1.7	0.5	*7.1*	**1.6**	+	-
Total all stations**		2035	165	222	207	1054	79	568	171	29	85	*462*	**32**		
YORK RIVER															
VIMS Oyster Pier	S106	25.0	7.1	5.4	14.4	18.7	2.2	1.1	0.2	6.1	4.4	*8.5*	**0.6**	-	-
Total all stations**		25	7	5	14	19	2	1	0	6	4	*8*	**1**		
MOBJACK BAY															
Off Brown's Bay	S017	8.0	2.2	29.9	44.7	40.2	6.3	2.7	0.2	0.0	1.4	*13.6*	**0.0**	-	-
Tow Stake	S151	1.9	5.3	28.8	64.7	16.1	7.7	1.5	1.7	0.6	1.0	*12.9*	**0.2**	-	-
Off Wilson Creek	S171	2.6	4.8	42.8	101.9	12.1	29.7	5.1	1.2	0.4	0.9	*20.2*	**0.1**	-	-
Pultz Bar	S210	8.9	13.1	37.8	64.0	32.0	7.2	3.3	1.2	0.3	3.8	*17.2*	**0.1**	-	-
Off Pepper Creek	S113	40.7	4.7	18.0	74.2	70.1	4.0	3.3	2.1	2.6	5.4	*22.5*	**0.3**	-	-
Total all stations**		62	30	157	350	171	55	16	6	4	13	*86*	**1**		

TABLE 2 (Continued)

Location	STA ID.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Mean 87-96	1997	Change Ref. 1996	Change Ref. Mean
PIANKATANK RIVER															
Three Branches	S150	64.9	1.7	22.5	55.7	19.7	4.6	1.5	0.1	0.5	0.4	*17.2*	**0.7**	+	-
Burton Point	S020	43.9	4.7	31.6	102.1	16.3	4.3	6.5	0.1	1.0	1.0	*21.2*	**0.7**	-	-
Palace Bar	S110	243.9	9.1	42.3	139.9	39.1	24.9	5.9	0.9	1.0	1.6	*50.9*	**0.0**	-	-
Ginney Point	S050	133.3	5.6	30.0	85.6	25.2	11.9	1.7	0.0	0.5	1.3	*29.5*	**0.0**	-	-
Total all stations**		421	19	104	328	81	41	14	1	3	4	*102*	**1**		
RAPPAHANNOCK RIVER															
Sturgeon Creek	S200	1.1	1.7	1.7	--	12.7	0.4	0.6	(0.0)	1.2	1.0	*1.9*	**0.9**	-	-
Locklies Creek	S208	2.8	3.3	2.4	4.6	25.5	0.3	0.5	(0.0)	0.8	0.7	*4.0*	**0.1**	-	-
Windmill Point	S217	45.9	1.4	1.0	98.5	23.4	0.4	0.0	(0.0)	2.3	4.1	*17.5*	**0.2**	-	-
Total all stations**		50	6	5	103	62	1	1	(0)	4	6	*23*	1		
GREAT WICOMICO RIVER															
Dameron Marsh	S039	29.1	59.3	6.1	29.2	11.0	0.7	1.2	(0.0)	0.1	3.9	*14.1*	**3.4**	-	-
Fleet Point	S048	157.9	10.1	9.0	18.1	10.1	7.4	2.4	0.0	2.8	4.2	*22.2*	**6.9**	+	-
Cranes Creek	S037	30.5	17.4	11.7	39.1	10.7	0.3	0.2	0.0	0.6	3.5	*11.4*	**2.0**	-	-
Hudnall's Dock	S074	50.8	61.8	28.4	119.6	7.0	1.2	0.9	0.0	0.3	0.4	*27.0*	**78.6**	+	+
Haynie Point	S064	10.5	57.4	20.1	67.9	13.6	1.5	1.6	0.0	0.3	5.4	*17.8*	**8.7**	+	-
Glebe Point	S051	23.6	27.1	9.1	19.8	3.8	0.9	0.2	0.0	2.1	0.6	*8.7*	**42.7**	+	+
Total all stations**		302	233	84	294	56	12	7	0	6	18	*101*	**142**		
LITTLE WICOMICO RIVER															
P.G. No. 42	S207	--	--	0.2	5.2	4.8	0.0	0.3	0.0	1.5	0.1	*1.8*	**0.5**	+	-

TABLE 2 (Continued)

Location	STA ID.	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	Mean 87-96	1997	Change Ref. 1996	Change Ref. Mean
POTOMAC RIVER															
Monroe Bay	S249	–	–	–	–	–	–	–	–	0.0	(0.0)	***	0.0		
Upper Machodoc	S248	–	–	–	–	–	–	–	–	0.0	(0.0)	***	0.0		
Currioman Bay	S224	–	–	–	–	–	0.0	0.0	0.0	0.0	0.2	0.0	0.1	-	+
Nomini Bay	S101	–	–	–	–	–	0.0	0.0	0.0	0.0	0.3	0.0	0.0	-	-
Lower Machodoc	S225	–	–	–	–	–	0.0	0.0	0.0	0.0	0.0	0.0	0.2	+	+
Ragged Point	S130	–	–	–	–	–	0.0	0.0	0.0	0.0	0.2	0.0	0.0	-	-
Lynch Point	S247	–	–	–	–	–	–	–	–	0.0	0.0	***	0.2		
Hog Island	S066	1.8	0.0	0.1	0.2	0.4	0.1	0.1	0.0	0.0	0.0	0.3	0.0	nc	-
Coan River	S030	0.0	0.4	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.8	+	-
Great Neck	S053	1.9	1.4	0.0	0.2	1.1	0.1	0.0	0.1	0.1	0.0	0.5	0.1	+	-
Jones Shore	S080	27.2	3.8	0.1	0.4	8.2	0.3	0.0	0.0	1.5	0.2	4.2	0.2	nc	-
Cornfield	S035	49.6	6.7	1.8	8.9	50.5	0.3	0.2	0.1	1.0	0.1	11.9	0.3	+	-
Total all stations**		81	12	2	10	61	1	0	0	3	1	17	2		
EASTERN SHORE SEASIDE															
Fisherman Island N	S250	–	–	–	–	–	–	–	–	83.2	(11.1)	***	41.0		
Fisherman Island S	S251	–	–	–	–	–	–	–	–	10.2	(2.0)	***	12.3		
Wachapreague	S156	29.7	47.1	144.1	211.4	287.4	61.1	105.7	7.7	16.3	(17.0)	91.1	40.1	+	-
Total all stations**										110	(30)		97		

* Miles Watch House station is on Thomas Rock; Wreck Shoal station between Wreck Shoal Inshore and Wreck Shoal Offshore since 1982.

** Rounded off to the nearest whole number.

*** Mean not computed for data fewer than five years.

TABLE 3

RANGE OF WEEKLY BOTTOM TEMPERATURE AND SALINITY BY MONTH AT SPATFALL STATIONS IN 1997

	STA.	JUNE 11-25 (2)		JULY 2-30 (5)		AUG 6-27 (4)		SEPT 9-17 (2)		OCT 3-23 (2)	
	ID.	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)
JAMES RIVER											
Nansemond Ridge	S131	21.0-27.0	14-15	25.0-28.2	17-19	25.5-27.3	18-20	24.6-25.0	21-21	14.3-20.3	20-21
Naseway Shoal	S098	21.5-26.0	9-17	25.7-28.7	15-18	25.9-27.1	16-19	24.6-25.0	20-21	15.1-20.8	19-20
Dog Shoal	S194	22.2-27.0	9-15	25.4-29.0	15-19	25.7-27.3	15-19	24.6-25.0	20-20	15.1-19.9	19-20
Miles Watch House**	S089	21.5-27.0	9-14	25.5-28.8	14-18	24.8-27.9	16-18	24.5-25.0	19-20	15.2-19.6	20-20
Days Point	S040	21.5-27.0	9-14	25.9-28.2	13-16	25.3-27.3	12-17	24.9-25.0	17-18	14.3-20.0	16-17
Rock Wharf.	S199	21.9-27.5	7-14	25.9-28.5	11-15	26.2-28.2	13-16	25.0*	17*	14.2-19.9	16-17
Wreck Shoal Middle	S174	21.2-28.5	7-14	26.5-29.4	12-16	26.7-29.5	13-18	24.5-26.5	18.20	16.6-20.8	17-19
Dry Shoal	S195	20.5-27.2	11-11	26.2-29.1	13-16	26.5-28.0	13-17	24.9-25.0	16-18	15.2-20.9	16-18
Point of Shoals	S123	22.0-28.0	4-6	26.8-29.2	8-11	26.0-28.3	10-12	25.1-27.0	14-14	15.6-20.0	14-14
Swash	S096	21.5-28.0	5-8	26.9-30.0	10-12	26.5-28.2	10-15	24.6-26.0	16-17	16.5-20.3	15-16
Horsehead	S073	21.7-28.0	4-6	27.0-29.9	7-11	26.7-28.0	10-11	24.8-27.0	12-14	15.8-20.8	14-14
Deep Water Shoal	S043	22.3-28.5	3-4	27.2-30.4	6-8	27.0-29.5	7-9	24.7-27.0	11-12	16.2-21.1	12-13

	STA.	JUNE 5-26 (4)		JULY 2-31 (5)		AUG 8-29 (4)		SEPT 3-25 (4)		OCT 2-16 (3)	
	ID.	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)
PIANKATANK RIVER											
Three Branches	S150	19-27	14-17	26-27.4	15-18	26-27*	16-18*	20.5-27	17-19*	19-21*	19-19*
Burton Point	S020	19-27	14-18	26-28	15-17	26.4-27.5*	16-16*	20.5-27	17-20*	20-21*	18-19*
Palace Bar	S110	20-26	14-17	25-28*	14-16	26.8-27*	15-16*	21-27.5	16-18	19-21	18-18
Ginney Point	S050	20-26	14-17	24-28	14-15	26.5-28.0*	15-16*	21-27	16-18	19.5-21.0	17-18

	STA.	JUNE 13-25 (2)		JULY 3-31 (5)		AUG 8-25 (3)		SEPT 2-30 (5)		OCT 7-16 (2)	
	ID.	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)	TEMP (C)	SAL (ppt)
EASTERN SHORE SEASIDE											
Fisherman Island N (FI 2)	S250	20-25	23-27	24-29	25-37	24-27	32-33*	22-28	28-32	20-25	32-34
Fisherman Island S (FI 3)	S251	23-26	20-29	24-31	23-34	24-28	25-33	22-27	30-32	20-24	31-32
Wachapreague	S156	21.9-28	30-33	17.5-28	32-34	24-27	32-32	18-26*	33-34	16-22	32-32

Number of weekly measurements included in each monthly period given in parentheses. These are the only stations where hydrographic data were collected.

No trend is implied by listing order of temperature and salinity range in any one month.

* One week's measurement missing.

** Miles Watch House station is on Thomas Rock.

SHELLSTRING SURVEY STATIONS

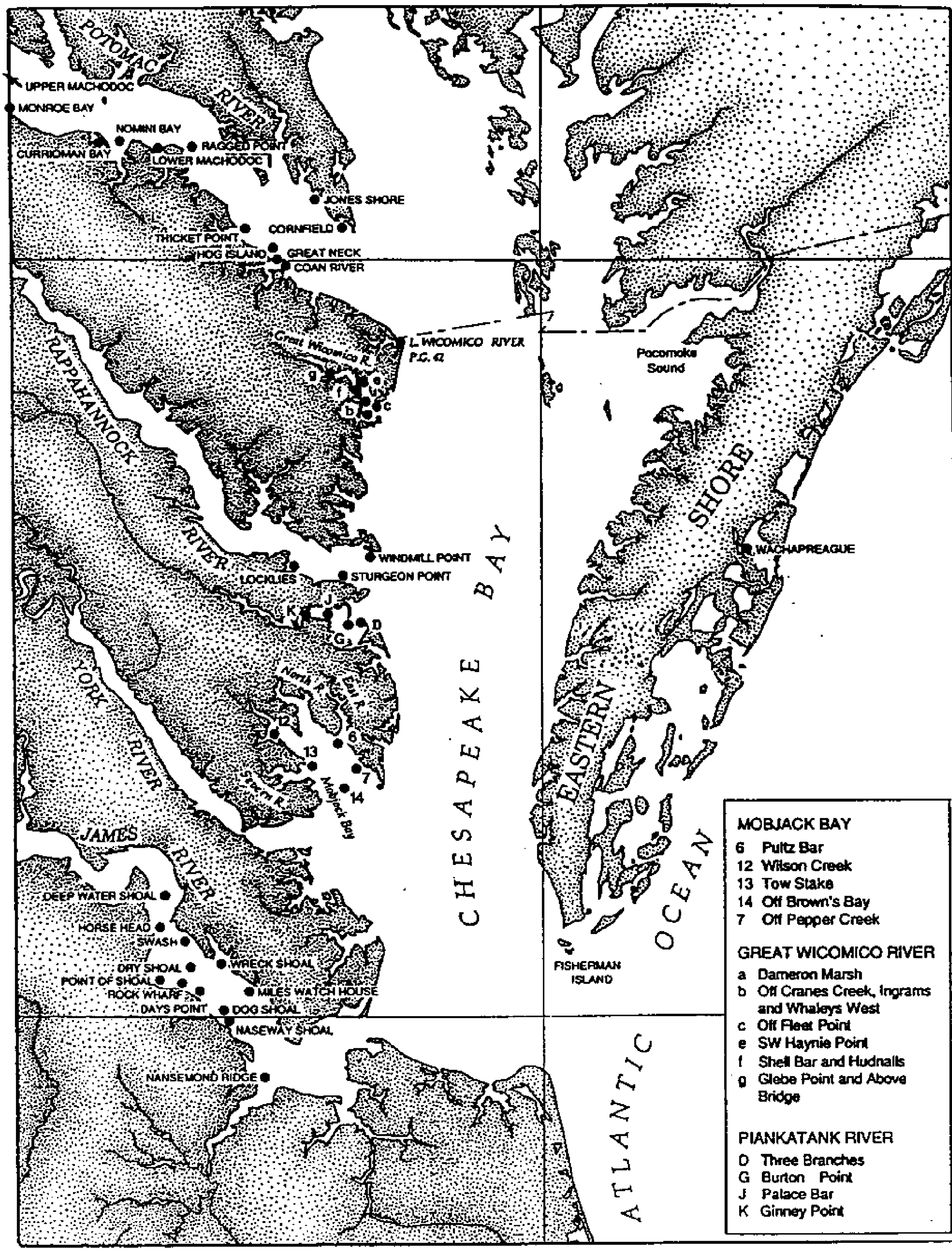

Figure 1. Location of shellstring stations.

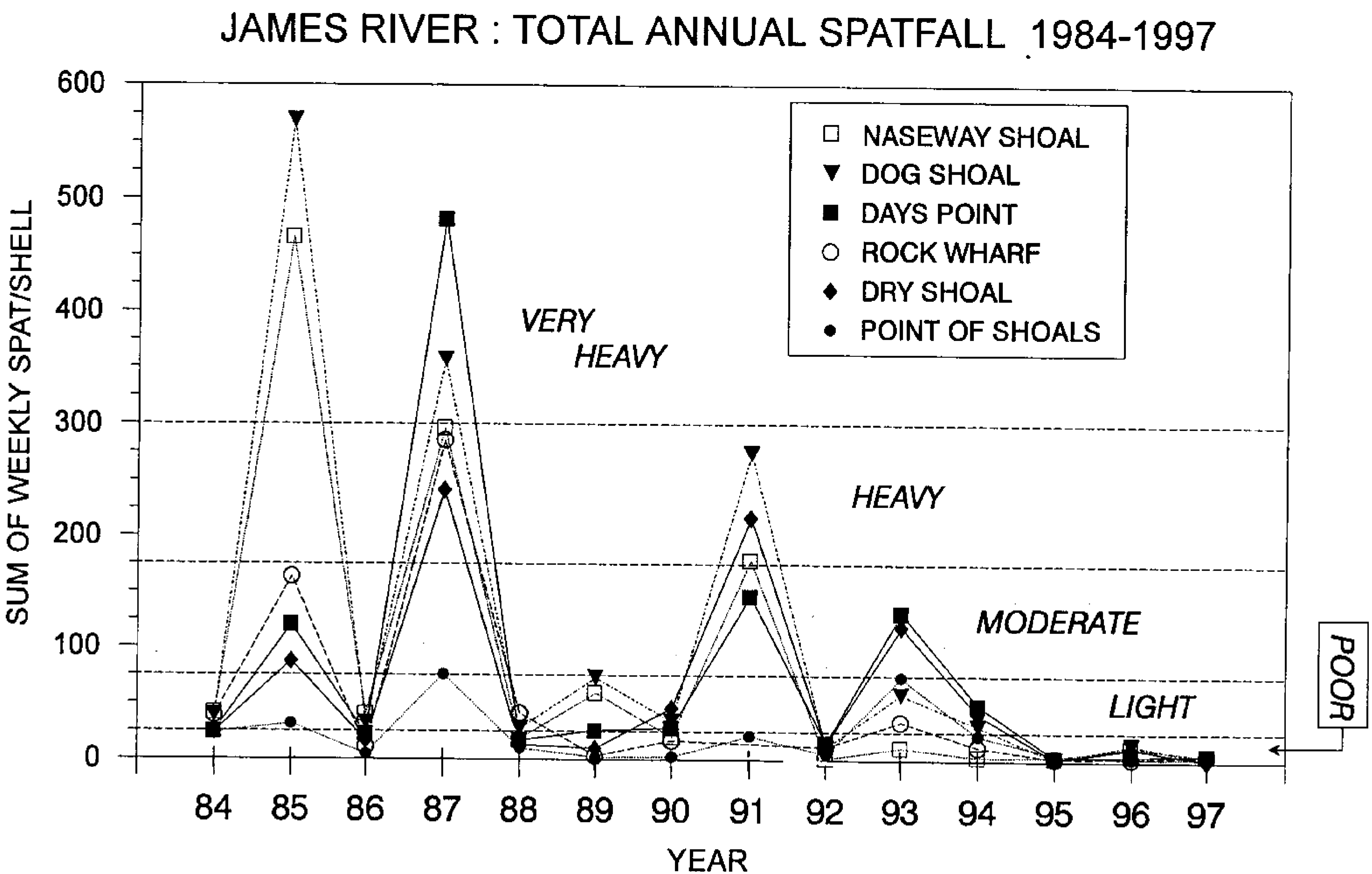

Figure 2. Total annual spatfall (expressed as the sum of weekly spat/shell values) at six shellstring stations with the highest values in any single year during the past 14 years, all on the southwest side of the James River. Of those six, Naseway Shoal is furthest downriver, just below the James River bridge; Dog Shoal is just above the bridge. See Fig. 1 for station locations. Spatfall intensity categories created for comparative purposes. No data collected for Rock Wharf in 1991.

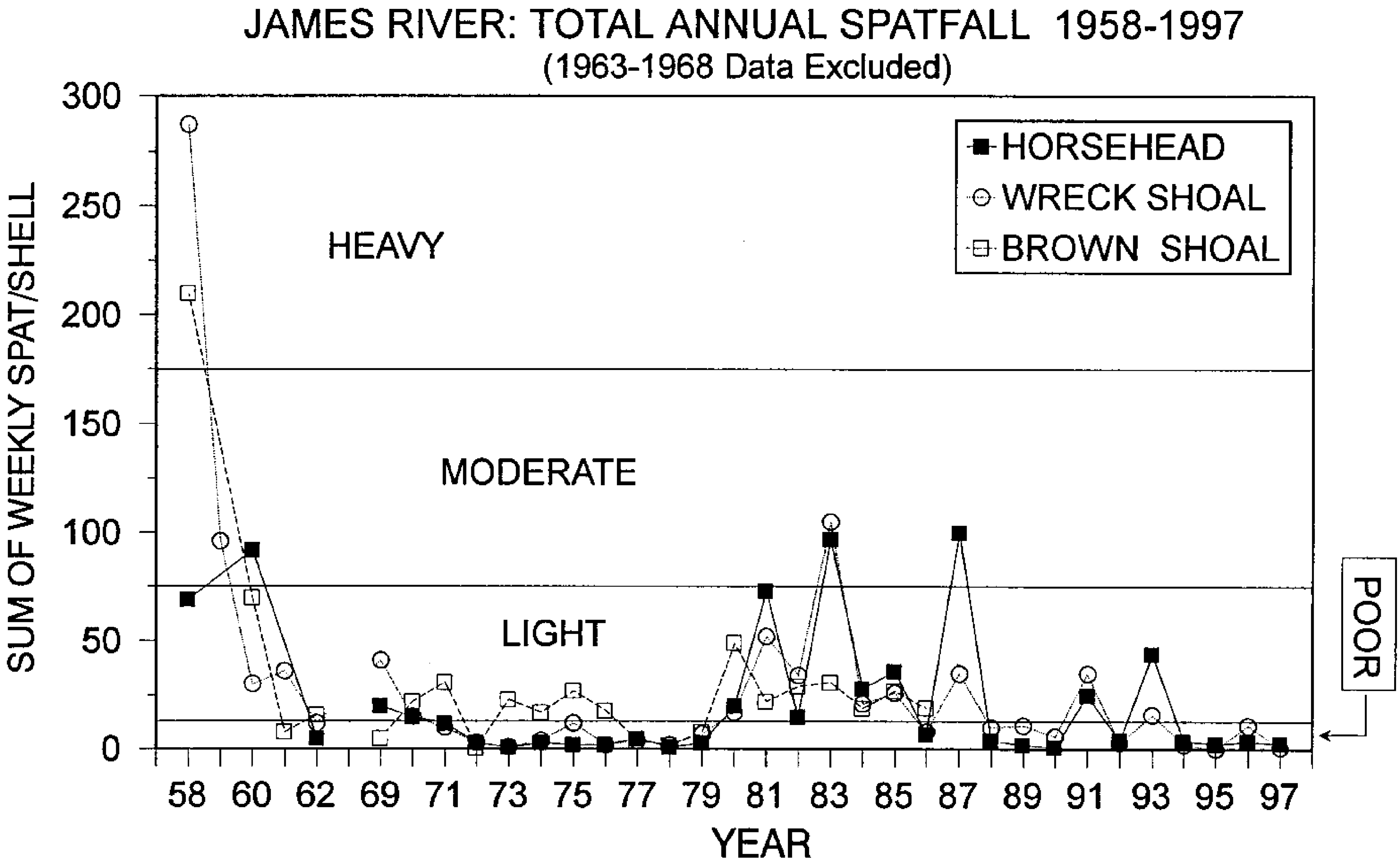

Figure 3. Total annual spatfall (expressed as the sum of weekly spat/shell values) at three shellstring stations in the James River, 1958-1997. Stations selected for the length of their data records. Spatfall intensity categories created for comparative purposes. Values for 1963-1968 omitted; may be obtained from 1993 report.

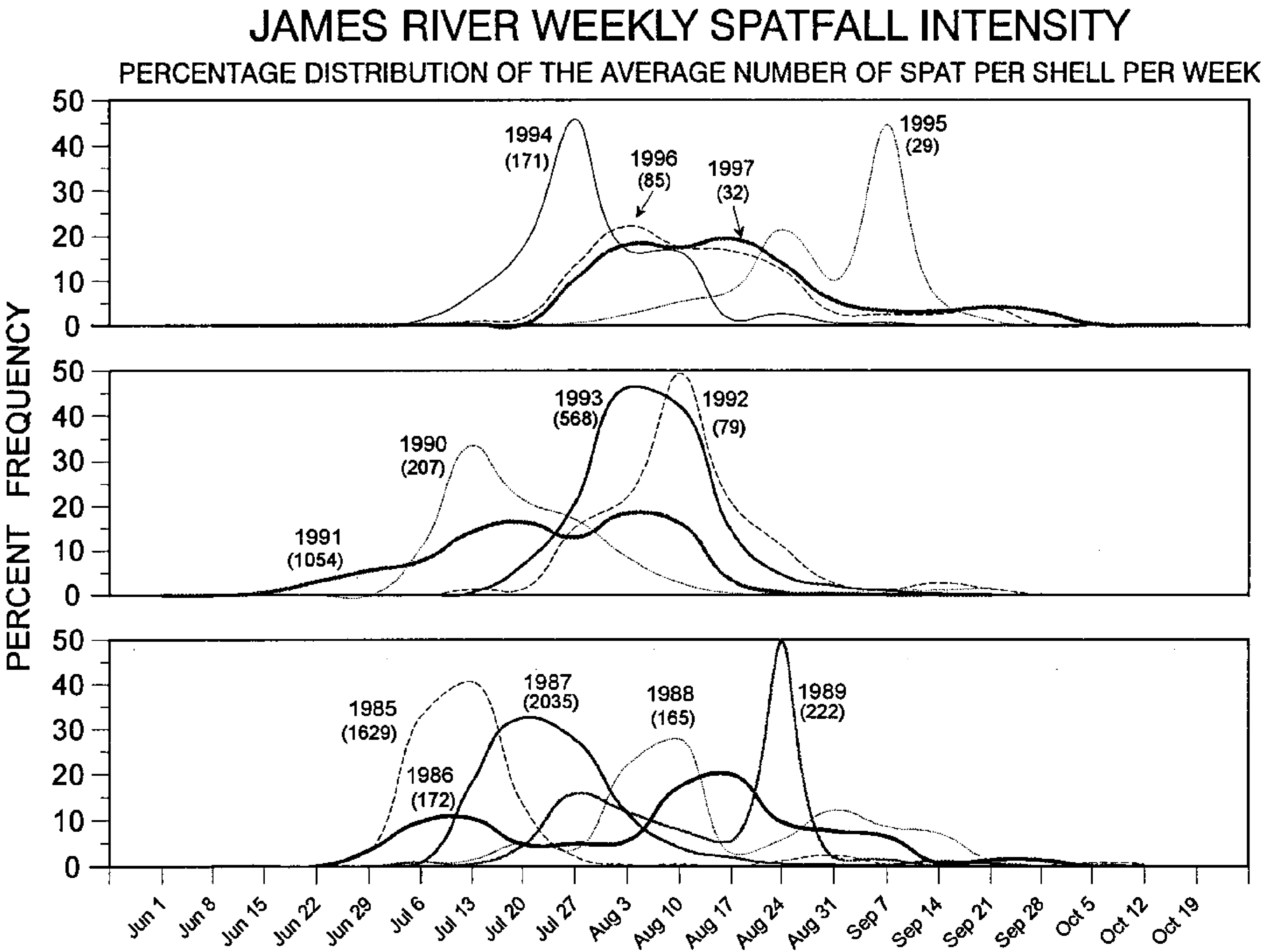

Figure 4. Relative spatfall intensity (given as percent frequency) on standard weekly shellstring exposure periods in the James River from 1985 to 1997. Based on weekly average settlement on shellstring collectors at 12 stations. Weekly periods start on dates given along the base line. Numbers in parentheses are sum of total spatfall values for all stations in the year.

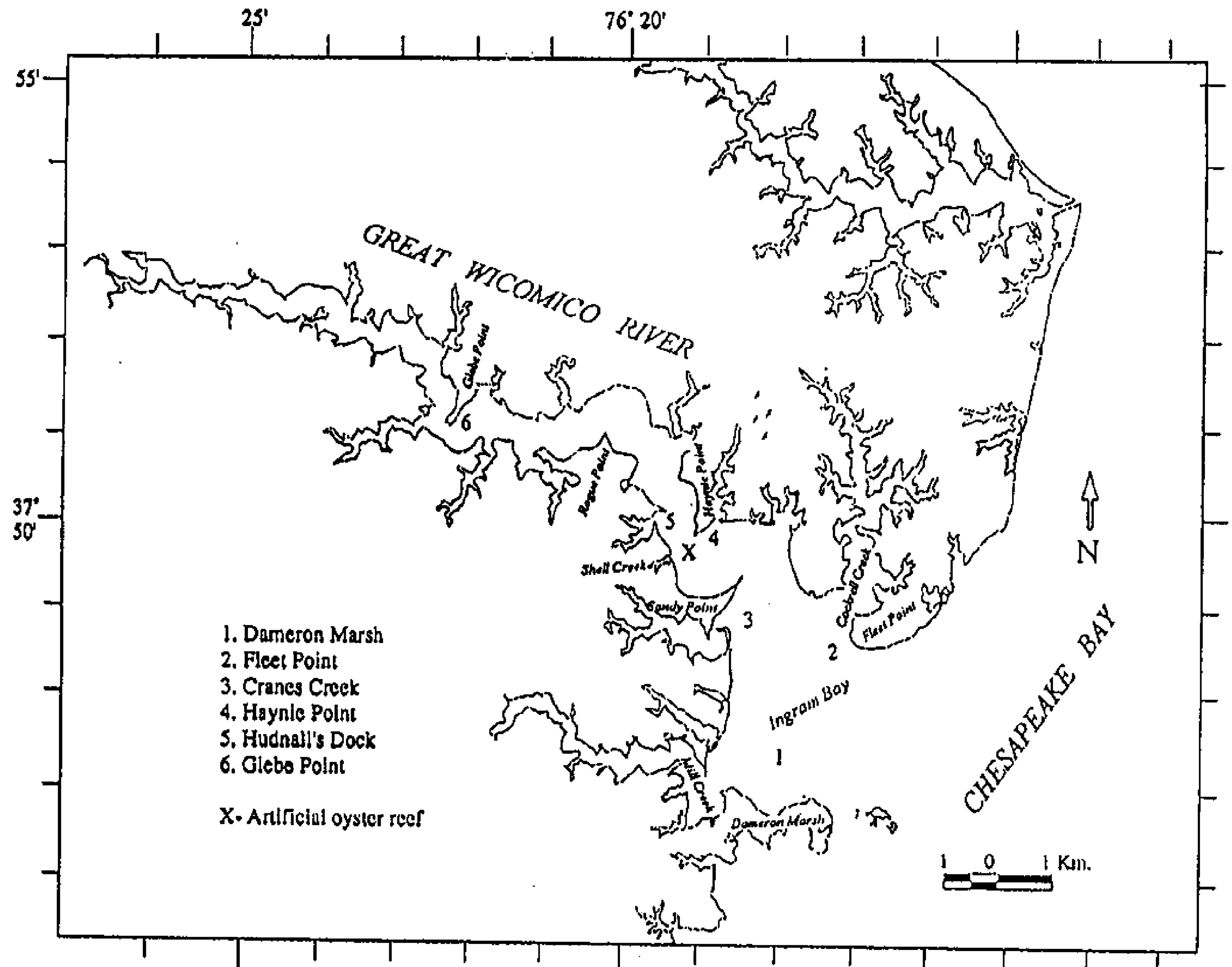

Figure 5. Chart of the Great Wicomico River showing the location of the shellstring stations and of the artificial oyster-shell reef off Shell Creek.

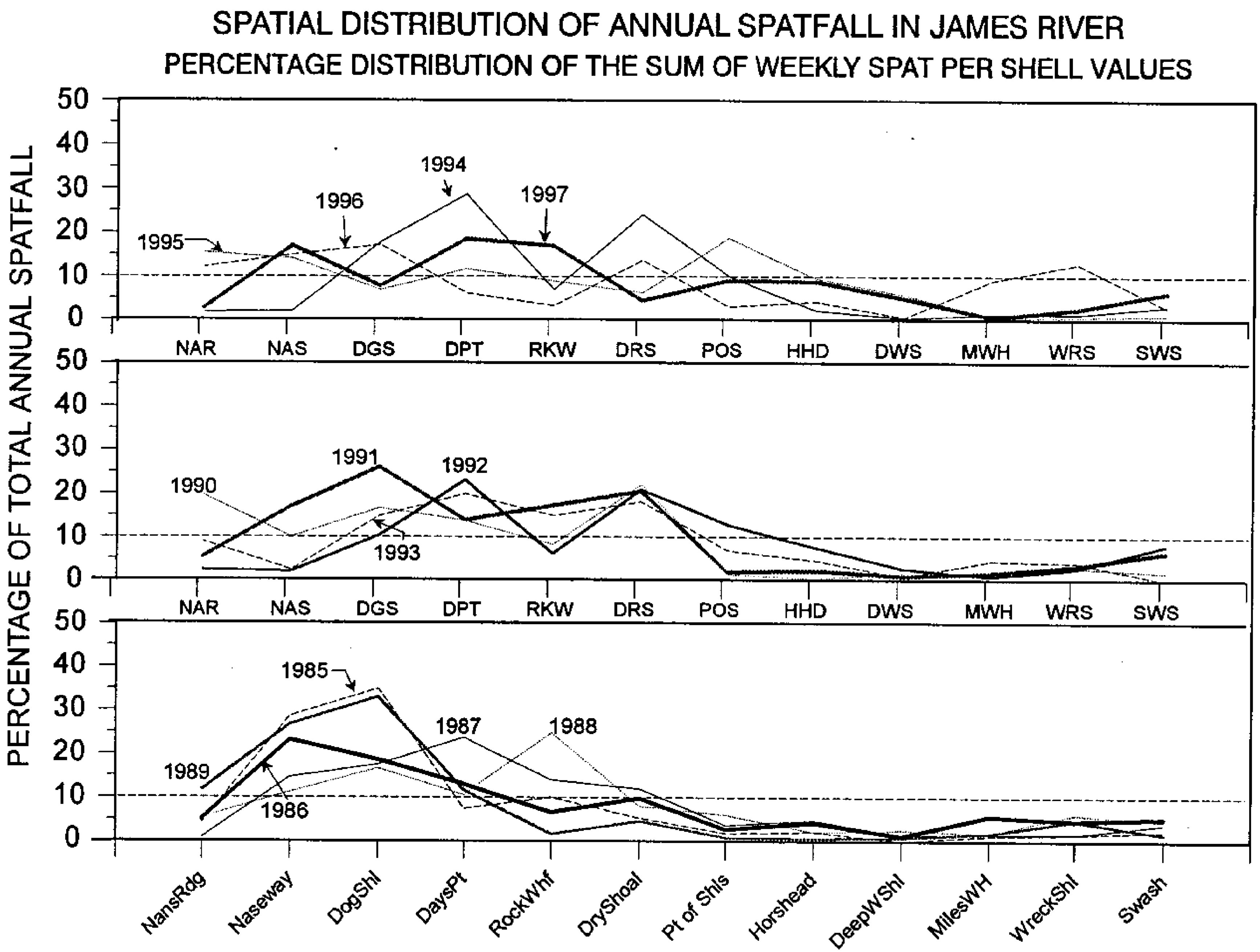

Figure 6. Relative annual spatfall (given as percent frequency) at twelve shellstring stations in the James River from 1985 to 1997. Based on the sum of weekly settlement on shellstring collectors for each year.

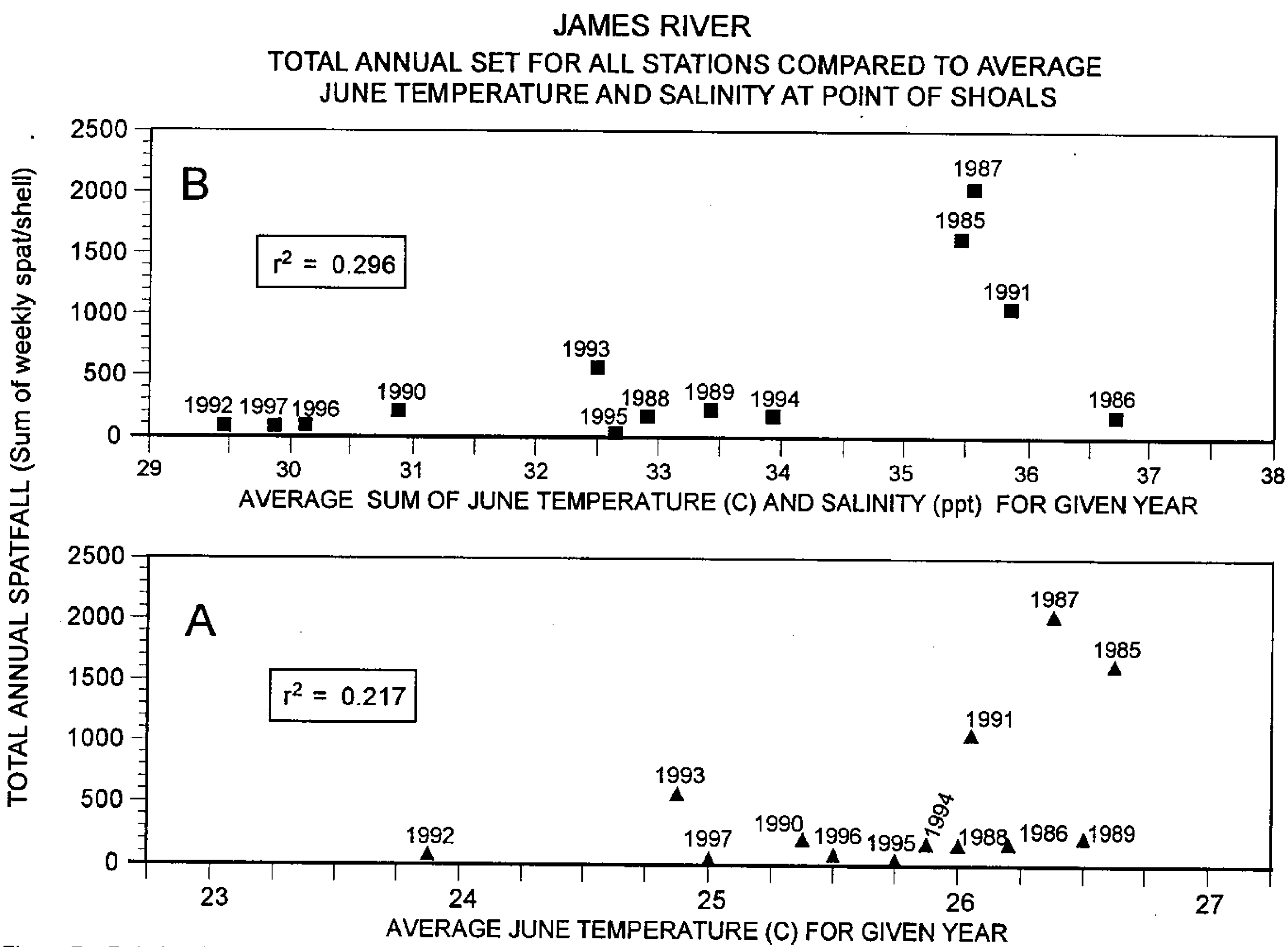

Figure 7. Relationship between sum of annual spatfall at all James River shellstring stations for years 1985-1997 and average June temperature for each year at Point of Shoals (A), and between total annual spatfall at all stations and sum of average temperature and salinity for each year at Point of Shoals (B).

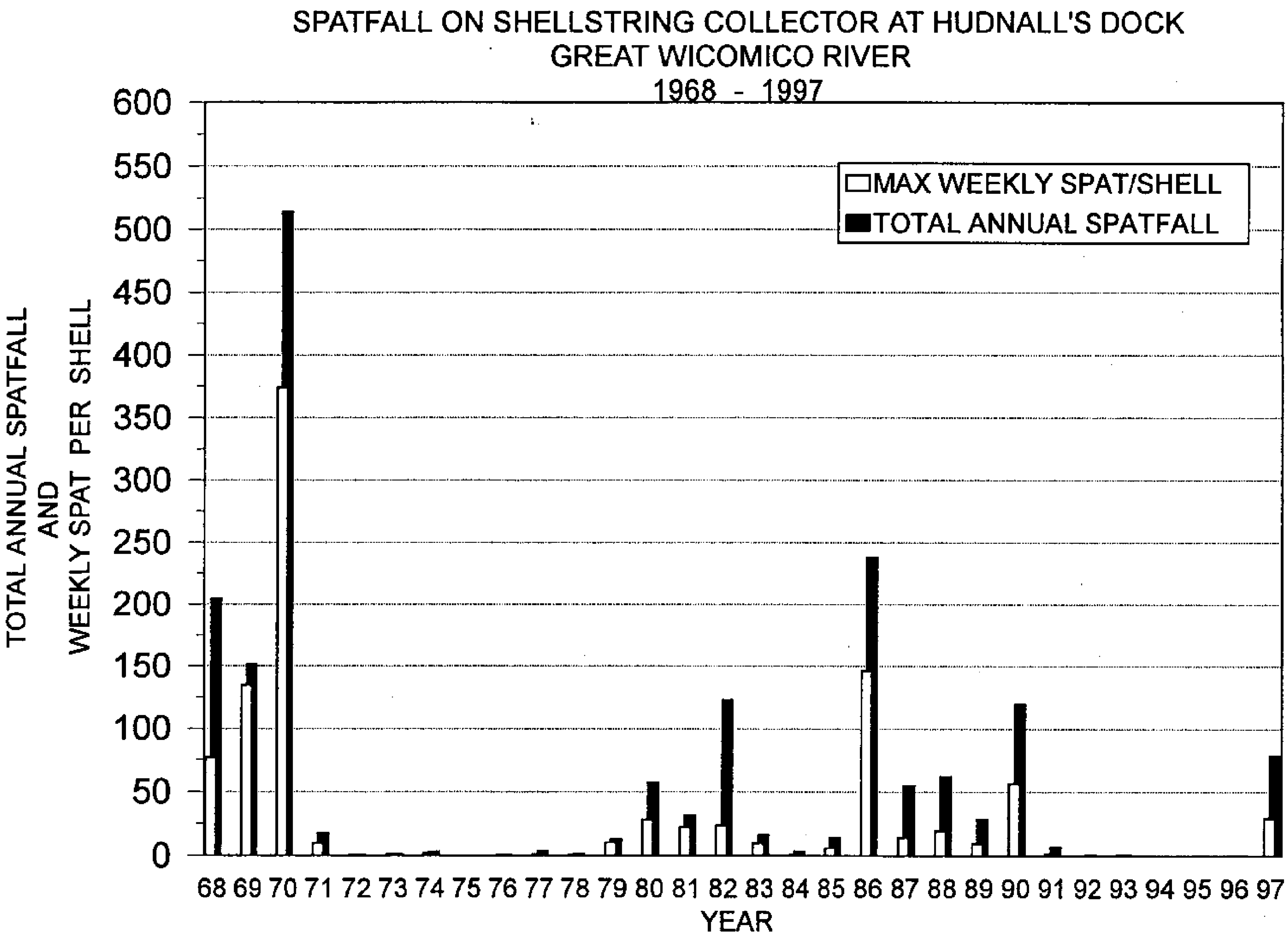

Figure 8. Total annual spatfall and maximum weekly spat/shell value at shellstring station on Hudnall's Dock in the Great Wicomico River for years 1968 to 1997. Hudnall's Dock is located approximately 700 yds (0.6 km) upriver of a man-made oyster shell reef on which were planted 2500 bu of large oysters from Tangier Sound in December 1996.

Part II. Survey of Selected Oyster Bars in Virginia—1997

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 in the late 1880s led to the establishment of 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, USN. 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).

Twice a year, in May and October, the Virginia Institute of Marine Science (VIMS) conducts a survey of selected public oyster bars in Virginia tributaries of the western Chesapeake Bay for the purpose of assessing the status of the resource. Surveys conducted in the spring provide information about mortality and growth since the survey of the previous fall. Surveys conducted in the fall provide information about spatfall and recruitment, summer mortality and changes in abundance of seed and market-size oysters. This section summarizes the findings of the bar surveys conducted in 1997: the spring survey in the James River on May 14 and 28 and the fall survey in all major tributaries on October 14-30.

Spatial variability in distribution of oysters over the bottom can result in wide differences among samples. Large differences frequently found among samples collected on the same day from one bar are an indication that distribution of oysters over the bottom is very variable. An extreme example of that variability is the width of the confidence interval around the average count of market oysters at Mulberry Point in the fall of 1997 (Fig. 2). 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. In recognition of that possibility, the term *apparent* is ocassionally appended to the description of some observed short-term differences in abundance.

Methods

Location of oyster bars sampled is shown in Figure 1. When reference is made in the text to the Burwell Bay area of the James River, it is liberally defined as the area south-southwest of the navigation channel, above Dry Shoal, and which includes Long Rock, Point of Shoals and Horsehead. Sampling dates, times, and geographic coordinates are given in Table 1.

Four samples of bottom material were collected at a single station on each bar using an oyster scrape dredge. In all spring surveys, and in all previous surveys (excluding the fall surveys of 1995, 1996, and 1997), a 24-in wide dredge with 4-in teeth was towed from a 21-ft boat; volume collected in the dredge bag was 1.5 bu. In the fall surveys of 1995, 1996 and 1997, samples were collected with 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 in tables give the average of the four samples collected at each station for oyster and box counts after conversion to a full-bushel measure.

The following counts were obtained from each half-bushel sample: number of market oysters (7.6 cm, or 3 in, or larger), number of small oysters (submarket size, excluding spat), number of spat (those that set in the summer of 1996 in the spring survey and those that set in the summer of 1997 in the fall survey), number of recent, or *New*, boxes (inside of shells perfectly clean; presumed dead for approximately less than one week), and number of old boxes, divided into two categories: *Old2* boxes (inside surface of shells fouled only by microscopic organisms; presumed dead for more than one week but approximately less than one month), and *Old3* boxes (inside of shells fouled by macroscopic organisms large enough to be easily identified by the naked eye; presumed dead for longer than one month). Distinction of old boxes into *Old2* and *Old3* was not done in the spring survey of 1997. Also counted when present was the number of gapers (boxes which still contained oyster meat; presumed dead for one or two days), but those are rarely found because scavengers eat the meat quickly. The presumed time period since death of an oyster associated with the different categories of boxes is an estimate based on experience and is not supported by precise scientific evidence.

Recent (new) mortality of oysters estimated to have occurred within approximately one week of sampling date was calculated as: [*New* boxes and gapers/live oysters + *New* boxes and gapers] x 100. Mortality based on counts of *Old3* boxes was computed in the same manner, but excluding gapers and is referred to as old mortality. A mortality computation that combined *New* and *Old2* boxes was estimated to represent mortality within one month of sampling date.

Temperature and salinity measurements were made on water samples collected just off the bottom at each location. In the 1997 spring survey, temperature was measured with a stem thermometer and salinity was measured with a hand-held refractometer. In the 1997 fall survey, temperature and salinity were measured with a conductivity meter.

Results

A. Spring Survey of James River Bars

The 1997 spring survey was conducted between May 14 and May 28. Seven oyster bars were sampled in the James River (Dry Shoal was not sampled in 1997) and results are summarized in Table 2. Bottom water temperature for all bars ranged from 18.5 to 23.3°C. Bottom water salinity was 1 ppt at Deep Water Shoal, 3 ppt at Point of Shoals and Horsehead, and 10 ppt at Long Rock and Swash. Salinity at Wreck Shoal was 14 ppt.

The average number of market oysters per bu of bottom material was low at all bars sampled (Fig. 2). It was 4 and 6 at Wreck Shoal and Deep Water Shoal, and between 15 and 35 at the other stations. Those averages were not statistically different from values recorded in the fall of 1996 except at Point of Shoals, where there was a significant decline from 63 to 22 market oysters per bu. That decline followed an increase of the same magnitude between the spring and fall of 1996 surveys.

The highest average number of small oysters (submarket size) per bu of bottom material was found at Horsehead (1053) and the lowest at Wreck Shoal (22). The average number at the other stations ranged from 209 at Swash to 629 at Deep Water Shoal. The number at Horsehead was significantly higher than at any of the other stations. There was a significant increase between the fall survey of 1996 and the spring survey of 1997 at only two stations, Horsehead and Mulberry Point, but there was no statistical evidence of a significant change in average number of small oysters between those two surveys at any of the other stations.

The average number of spat per bu was very low at all stations in the spring of 1997 and there was no evidence that they were statistically different from the counts recorded in the fall of 1996, when spatfall on bottom substrate was nearly insignificant. The highest number was recorded at Point of Shoals, 36; at the other stations, it ranged from 2 to 17 per bu.

The average number of new (recent) boxes per bu was low at all stations in the spring of 1997 and ranged from 1 to 6 at Wreck Shoal, Mulberry Point, Long Rock and Swash and from 12 to 21 at Point of Shoals, Horsehead and Deep Water Shoal. Mortality estimates based on new boxes was likewise low, ranging from 0.9 to 3.2%. Mortality based on old boxes was 15.6% at Deep Water Shoal and 32% at Wreck Shoal; at all other stations it only ranged from 3.3% to 8.6%.

B. Fall Survey

Thirty oyster bars were sampled between October 14 and 30, 1997, at six of the major tributaries of the western Chesapeake Bay in Virginia. Bar locations appear in Figure 1 and Table 1. Results of this survey are summarized in Table 3 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 that river.

As in most recent years, the highest average number of oysters of all sizes per bu of bottom material in 1997 was found at Horsehead (738). Number at the other bars sampled was moderate to low. Total number at Deep Water Shoal, Long Rock and Point of Shoals ranged from 370 and 495. At Mulberry Point and Swash, total count averaged 184 to 267, respectively. Numbers at those six bars were made up primarily of small (submarket) oysters, Total counts at Dry Shoal, Wreck Shoal, Thomas Rock and Nansemond Ridge were much lower, ranging from 20 to 69 per bushel, and spat made up a significant percentage of the total at those four stations.

The average number of market oysters per bu ranged from 26 to 46 at the four bars with the highest number: Long Rock, Swash, Mulberry Point, and Point of Shoals, in that order. Number of market oysters was much lower at the remaining stations, ranging from 1 to 10 per bu of bottom material. The number at Long Rock (also known as Cross Rock) was significantly higher statistically than at ten of the other eleven stations; no difference was statistically evident between Long Rock and Mulberry Point because of an extremely large variation among samples at the latter (Fig. 2). No statistical difference was evident among Deep Water Shoal, Horsehead, Dry Shoal, and Wreck Shoal in average number of market oysters.

There was a significant decline in the average number of small oysters at Deep Water Shoal, Mulberry Point and Horsehead between the spring of 1997 and the fall of the same year (Fig. 3). The average number of small oysters per bushel at Horsehead (713) was significantly higher than at any of the other bars sampled in the fall of 1997. There was no difference evident between the number at Deep Water Shoal (423) and the number at Point of Shoals (437), nor between the number at Swash (215) and at Long Rock (241). Large variation among samples at Mulberry Point, which had a lower average number of small oysters (140), prevented detection of a difference between the number there and the number at Swash and Long Rock. The number of small oysters at the remaining four stations was considerably lower than at those listed above: it was 33 at Wreck Shoal and 45 at Dry Shoal, and 9 and 11, respectively at Nansemond Ridge and Thomas Rock. In the six bars with total count of oysters higher than 100 per bu, the percentage of small oysters ranged from 65 to 97%.

Average number of spat was low at all bars sampled in the James River in October 1997. The highest number was found at Long Rock (Cross Rock) where the average was 84 per bu. The average number per bu at all the other stations ranged from 9 to 33.

The highest average number of new boxes per bu (45) was found at Long Rock. The number ranged from 1 to 20 at the other bars sampled. Recent mortality, based on number of new boxes, was low at most bars; the highest was recorded at Dry Shoal (24%) and at Wreck Shoal (19%). At the other bars, it ranged from less than 1% to 14%. Mortality estimates based on the combined sum of *New* and *Old 2* boxes (which are presumed to have occurred within the month preceding sampling) suggest that mortality within that time period was substantial at Dry Shoal, Wreck Shoal and Thomas Rock, where it ranged from 32 to 48%; at the remaining bars, it ranged from 1 to 22%.

Water temperature at time of sampling was between 14 and 15°C in the James River. No extremely low water salinity was recorded at any of the stations. The lowest salinity was recorded at deep Water Shoal (11 ppt); at most bars, salinity ranged between 12 and 16 ppt. At Thomas Rock and Nansemond Ridge, salinity was 19 and 20 ppt, respectively.

✦ *York River*

Although the number of oysters recorded at Bell Rock in October 1997 was low, total number of oysters per bushel of bottom material (70) was much higher than found in previous fall surveys. Most of the oysters in 1997 (52) were in the small (submarket) category and only 5 market oysters per bushel were recorded; the balance, 13, were spat. The distribution in abundance of oysters of the three size categories was fairly even in the three samples collected. Number of oysters at Aberdeen Rock was very low (9) and did not include any market oysters. Very few boxes were found. Temperature at the two stations was similar (16°C), but salinity at Bell Rock was 16 ppt and at Aberdeen Rock it was 21 ppt.

❖ *Mobjack Bay*

Average total number of oysters per bu in Mobjack Bay was low: 58 at Pultz Bar and 38 at Tow Stake in two samples each collected from those bars. Most of the oysters were in the small size-category (88-92%). Very few boxes were found.

❖ *Piankatank River*

The average number of oysters in the three size classes was low at the three bars sampled in the Piankatank River in October 1997 (Ginney Point, Burton's Point and Three Branches). Although higher at Palace Bar, the variation between samples at each bar did not permit a statistical distinction among the three averages. Average total number ranged from 51 at Ginney Point to 100 at Palace Bar. Those low numbers are likely to be associated with extremely low spatfall in the Piankatank River in the last four years. The number of market oysters, which was extremely low, and the number of spat was similar at the three bars. Although the average number of small oysters was higher at Palace Bar than at the other two, a statistical difference was not evident because of large variation among samples; at Palace Bar, small oysters made up 78% of the total count. Number of boxes were low at the three bars sampled, as were the mortality estimates based on those numbers. Temperature (19°C) and salinity (18-19 ppt) were similar at the three bars.

❖ *Rappahannock River*

The highest average total number of oysters (216 to 236 per bu) in the Rappahannock River in October 1997 was found at Bowlers Rock, Middle Ground (in the Corrotoman River) and Off Broad Creek. Size group distribution of oysters was different at each of the bars. The number of market oysters was similar (40-53) at all three, and the number of small oysters (124-160) and spat (39-56) was also similar at Middle Ground and Off Broad Creek. At Bowlers Rock, however, the greatest part (83%) of the oysters were included in the small size-category.

The number of oysters at Drumming Ground, off the mouth of the Corrotoman River, and at Long Rock, just downriver from Bowlers Rock, was lower (86-120) than at the three bars cited above. The highest number of spat was found at Drumming Ground, Middle Ground and Off Broad Creek, but the numbers were still low; they made up between 18 and 32% of the total count of oysters. Average total number of oysters at the remaining bars was very low and ranged from 9 per bu at Smokey Point and Hog House to 43 at Parrot Rock. Bottom water temperature at all but one of the bars (those sampled on October 14) was between 21 and 22°C.

There was no evidence of unususally high recent mortality in samples collected in October 1997. The highest mortality based on the number of boxes found was recorded at Parrot Rock, where it was 13% when only the most recent (*New*) boxes were included and 25% when both *New* and *Old2* boxes were included. Mortality based on combined *New* and *Old2* boxes ranged from 10 to 16% at the four bars with the highest number of oysters. At the remaining bars, it ranged from 0 to 5%.

Temperature at the bar Off Broad Creek, sampled on October 22, was 16.5°C. Bottom water salinity at the three stations furthest upriver (Ross Rock, Bowlers Rock and Long Rock) ranged from 12 to 15 ppt. Salinity range for all others, downriver from Long Rock, ranged from 16 to 18 ppt.

❖ *Great Wicomico River*

The outstanding feature in bottom samples from oyster bars in the Great Wicomico River in the fall of 1997 was the high average number of spat found at Haynie Point (312 per bu). That was about three times higher than the average number found in 1996. There was, however, a large variation in the number of spat per bu among the four samples collected in 1997 at Haynie Point; the individual values recorded were: 162, 426, 230 and 430. Spat made up 71% of the total number of oysters at Haynie Point in 1997; by contrast, they only made 13% of the total in 1996. The number of spat at Whaley's East and Fleet Point was also higher than in 1996 and the difference was statistically significant. The average number of small oysters was similar to the number collected in 1996 and was low, ranging from 71 to 115 oysters per bu. The number of market oysters was very low in 1997, ranging from 10 to 22 per bu, and was not significantly different from the number in 1996. Bottom water temperature at time of sampling was between 15 and 16°C and salinity was 18 ppt.

Discussion

♦ *Market Oysters*

The greatest concentration of market oysters on the public grounds of the western side 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; the lower salinity in those areas reduces mortality associated with the pathogens *Haplosporidium nelsoni* and *Perkinsus marinus*. For that reason, changes in the abundance of market oysters in those areas merit careful consideration. There was a continuous decline to extremely low levels of 10 per bu or less in the number of market oysters in those areas between 1986 and the spring of 1993 (Figures 5 and 6). A trend towards higher counts in the James River started in the spring of 1993 but those numbers declined subsequently. Presently, the abundance of 3-in (76 mm) market oysters in the James and Rappahannock rivers is low. Market oysters made up a small percentage of populations on the bars sampled; at most bars with a total per bu of 100 oysters of all sizes, the percentage of market oysters was under 17%.

In the spring of 1997, there was a significant drop in the number of market oysters at Point of Shoals, down to 22 per bushel (Fig. 2). Mortality estimates from the number of boxes found were too low to account for the decrease. The number observed in the spring of 1997, however, is not significantly different from numbers recorded at Point of Shoals in the fall of 1995, spring of 1996, and fall of 1997, which makes the sharp increase in the fall of 1996 and the sharp decrease in the spring of 1997 an unusual occurrence; some of the decrease in the spring of 1997 can be attributed to harvesting. The average number of market oysters at Long Rock has increased significantly since the spring of 1996, and in the fall of 1997, it and three other bars (Mulberry Point, Swash and Point of Shoals) had the highest number of market oysters in the James River; their averages ranged from 25 to 45 per bu. The average number of market oysters has not changed much at Mulberry Point and Swash since the fall of 1996.

In the Rappahannock River, there has been an increase to levels between 20 and 30 market oysters per bu since 1994, and in the fall of 1997, there were between 40 and 50 per bu at three bars: Long Rock and Bowlers Rock in the lower salinity areas upriver, and off Broad Creek, near the mouth of the river. The number at Long Rock and Bowlers Wharf was apparently **influenced by planting of James River seed there in the fall of 1996 by VMRC. The number off Broad Creek, however, appears to have resulted from growth and survival of oyster stocks already there, because there was no seed planting on that rock in 1996 or 1997.** According to results from the VIMS disease monitoring program, prevalence of oyster diseases off Broad Creek in 1997 was low.

The James River bars above Wreck Shoal (particularly those in the Burwell Bay area) continue to be the only public grounds on the western side of the Chesapeake Bay in Virginia, where oysters can survive the effect of diseases to reach market size in substantial numbers. Consequently, those bars also constitute the primary repository of potential reproduction and recruitment of the eastern oyster in Virginia. Unfortunately, those same bars are also subject to mortality during periods of extremely high freshwater runoff. That effect is greatest at Deep Water Shoal where salinity is usually close to the lower limits tolerated by oysters. Mortality associated with high freshwater runoff and diseases at bars in the Burwell Bay area is not usually catastrophic, but the number of market oysters there remains low because growth rate of oysters in that area is relatively low and moderate mortality due to diseases as well as removal through harvesting contribute to keep their numbers down.

❖ *Small Oysters*

Small oysters constitute the bulk of the population in most of the productive oyster bars in Virginia tributaries of western Chesapeake Bay. At bars sampled in 1997, in which the count of total oysters was greater than 100 per bu, the percentage of small oysters ranged from 65 to 97% in the James River and from 57 to 83% in the Rappahannock and Piankatank rivers. In the Great Wicomico River, the percentage of small oysters was lower (26 to 60%) because of the high number of spat found. The high percentage of small oysters in the bars sampled results from repression of the number of market oysters by either disease mortality, slow growth, commercial harvesting or low spatfall in most areas, or a combination of two or more of those factors. The highest concentration of small oysters was found in areas of the James River, especially in the Burwell Bay area, where low mortality and moderate spatfall allow buildup of the natural populations, but where growth is slow and some harvesting of market oysters persists.

Moderate to high numbers of small oysters were recorded in Burwell Bay and Deep Water Shoal in 1991 and 1992, but there was a steady decline to low and moderate numbers from that time to 1994 (Fig. 7). There was a trend towards higher numbers in the same area between 1994 and 1996, except for a sharp drop at Deep Water Shoal in 1995 due to heavy mortality from high freshwater runoff. Those losses at Deep Water Shoal were recovered by the fall of 1996 through recruitment from a strong 1995 year class.

Changes in abundance of small oysters at Wreck Shoal and at bars upriver of Wreck Shoal since the fall of 1995, are presented in Figure 3. Between the spring and fall of 1997, there was a significant decrease of 65% in small oysters at Mulberry Point, as well as a reduction of 33% at Deep Water Shoal and 32% at Horsehead bar. The average number of small oysters at Long Rock was lower in the spring of 1997 than in the fall of 1996 and also lower in the fall of 1997 than in the spring of the same year, but a large variation among spring of 1997samples did not allow assertion of those differences as statistically significant. Nevertheless, the average number in the fall of 1997 was statistically lower by 42% than the number in the fall of 1996. Those declines in number of small oysters do not appear to have resulted from natural mortality (as estimated from the number of boxes found) because mortality values were much lower than would otherwise be expected, even when *Old3* boxes were included in the computations. Careful observation during future sampling may provide insight into factors that contribute to such a rapid increase and decline in number of oysters. Among those factors could be the patchy distribution of oysters on the bottom, sampling procedures and consistency in distinction between spat and one-year-old small oysters.

The number of small oysters in the Piankatank and Rappahannock rivers has been low since 1986, often averaging 100 per bushel or less (Figure 8). **The number increased sharply to close to 200 in 1997 at Bowlers Rock, but this was probably the result of seed planting on that rock by the VMRC. The numbers recorded at Long Rock in 1996 and 1997 are also probably due to seed planting.** Although the average number of small oysters per bu in the Great Wicomico River has reached 300 several times since 1986 (500 at Haynie Point in 1986), it averaged 100 per bushel or less between 1992 and 1995. In the fall surveys of 1996 and 1997, the average number of small oysters in the Great Wicomico increased to around 100 from very low numbers recorded in 1995. Small oysters were found in low numbers in the upper estuary of the York River and in Mobjack Bay in the fall of 1997, but those numbers represented a substantial increase from what was found in 1996.

❖ *Oyster Spat*

Spat are juvenile oysters that have been recruited into the population during the summer spawning season. Depending on subsequent growth and survival, they could be an important component of the small-oyster segment of the population for 3-5 years and of the market oyster segment afterwards.

With the exception of Haynie Point in the Great Wicomico River, the average number of spat per bu was very low (well below 100) at most bars sampled in 1997. Those low numbers of spat, which are usually accompanied by low numbers of other oysters in rivers other than the James, offer little hope for recovery of populations in those rivers because of continued mortality from diseases. As shown in Figs.10-12, spat numbers fell back to very low levels in 1996 after a slight increase in 1995 at some of the bars and remained there in 1997. An overview of the data in those figures shows that spatfall on bottom substrate has been low since 1991 throughout Virginia tributaries of the western Chesapeake Bay.

Low numbers of spat in the James River in 1997 may have been due in good part to the occurrence in June of low water salinity along with temperatures that may have been less than optimal for gonad development in the Burwell Bay region and Deep Water Shoal, the areas with greatest abundance of oysters, and the likely source of most of the spawn produced in the river. The potential effect of June water temperature and salinity on spatfall in the James River was illustrated in Fig. 7 of Part I of this report. 1997 was the third year in a row in which low water salinity had a negative impact on number of spat on bottom substrate at the Burwell Bay stations, and consequently in the rest of the river. That translates into lowered recruitment into the oyster populations at Burwell Bay, but barring the occurrence of catastrophic freshets, those populations are not threatened with collapse because they are protected from diseases by the existing lower salinity and low intensity of commercial harvesting. The higher number of spat found in the James River in 1995, when compared to what was recorded in 1996 and 1997, may be attributed to an increase in salinity at Burwell Bay to 15 ppt through August and September that year.

The average number of spat per bu in the Great Wicomico River was higher in 1997 than in the previous three years, but it was much lower than the number recorded during the peak years of 1982 and 1986 (Figs. 12). It was also lower or in the same range of magnitude as in all other years between 1976 and 1993, with only a few exceptions. The number of spat found at Haynie Point was considerably higher than that found at any other bar sampled in Virginia tributaries in 1997. That number was statistically higher than in the previous three years at Whaley's East and Fleet Point, but at Haynie Point, the large variation among samples in 1997 did not permit establishment of a statistically significant difference between spat per bu in 1997 and in 1995 (Fig. 13).

It is highly probable that the high average number of spat at Haynie Point in 1997 was associated with massive spawning by large Tangier Sound oysters planted on the artificial reef across the river (see Fig. 5 in Part I of this report), and that, otherwise, spat numbers would not have been so high. It is also possible that the large variation among 1997 samples at Haynie Point was also influenced by oyster spawning over the artificial reef. Information from a study of tidal circulation and larval distribution in the vicinity of that reef by M. J. Southworth (personal communication) leads us to speculate that the effect of tidal currents in that area of the river may have created conditions that resulted in uneven distribution of larval settlement over Haynie Point bar, when those larvae are produced across the river (along with possible spatial variation in quality and quantity of bottom substrate).

The effect of tidal currents on larval distribution in the Great Wicomico River appeared to be substantiated by data from shellstring collectors (M. Southworth, personal communication). High larval settlement was recorded on shellstrings on the same side of the river in the vicinity of the artificial reef and upriver from it, but settlement on collectors across the river at Haynie Point and at stations downriver from that area was not exceptionally high (see Part I of this report).

♦ *Mortality*

Mortality presumed to have occurred within one month of sampling, as estimated from the combined number of *New* and *Old2* boxes found in the samples collected, was very low at all but five of the bars sampled in the fall of 1997. High mortality was recorded at Wreck Shoal and Dry Shoal in the James River. Moderate mortality was recorded at Thomas Rock and Long Rock in the James River and at Parrot Rock in the Rappahannock River. Total mortality estimated from the total of all boxes (new and old) was only slightly higher at four of those same bars but significantly higher at Thomas Rock (52%); it was 56 and 57% at Wreck Shoal and Dry Shoal, 25% at Long Rock (James River) and 38% at Parrot Rock. These four bars are characterized by prevailing salinities above 15% and most of the mortality observed is most likely due to the effect of disease. These data suggest that with very few exceptions, impact of diseases and low salinity on oyster populations in the Virginia tributaries of the western Chesapeake Bay was not very great in 1997.

Detailed information on mortality due to oyster diseases, including prevalence and intensity of both *Perkinsus* and MSX, is available from Dr. Eugene M. Burreson at VIMS.

Acknowledgements

These monitoring programs required the assistance of a great number of people, without whose contributions it could not have been completed succesfully. We are deeply grateful to the following: Kenneth S. Walker, for construction of the shellstring collectors, and for examination of shellstrings; to Juli Harding and her collaborators for deployment and retrieval of shellstrings in the Piankatank Rivers; to Jake Taylor and Tamara Hurlock, of the VIMS Wachapreague laboratory, for deployment, retrieval, and examination of the Eastern Shore shellstrings; to Ian Bartol, of the VIMS Molluscan Ecology section, for assistance in collection and examination of samples in the spring of 1997; to the following personnel of the VIMS Vessel Operations Department for boat scheduling and operation throughout the year: George Pongonis (superintendent), Raymond Forrest, Charles Gerdes, Charles Machen, Paul Oliver, Susan Rollins and Larry Ward; to the following members of the Marine Police unit of the Virginia Marine Resources Commission for deployment and retrieval of shellstrings at all other bars: Ray Jewell and Warner Rhodes (supervisors), Richard Haynes, Arthur Walden, Keith Nuttall, Alfred Fisher, Almon Newsome, James VanLandingham, Harry Booth, Dan Eskridge, and Adam Friend; to James A. Wesson, Division Head, Conservation and Replenishment Division of the Virginia Marine Resources Commission for use of the *J. B. Baylor* vessel, for his assistance during the fall survey and for review of this report; to John D. Register, Jr. and Calvin R. Wilson, of the VMRC for their assistance during the fall 1997 survey; to Melissa J. Southworth for contribution of observations from her 1997 study of larval settlement in the Great Wicomico River (MA thesis in preparation) and for review of pertinent sections of this report; to Chris Bonzek and Robert E. Harris, Jr. of the VIMS Fishery Data Management Unit for preparation of data bases and analytical programs; to Susan C. Waters, of the VIMS Department of Advisory Services for editorial assistance; to Kent Forrest, Susan R. Stein and Sylvia Motley of the VIMS Publications Department for artwork, typesetting and printing, respectively, of the report.

R. Morales-Alamo will retire from service at the Virginia Institute of Marine Science, effective June 1, 1998. Any correspondence concerning this report should be addressed to Dr. Roger Mann at VIMS.

Appendix A

Computation of spat counts for standardized weekly periods

Although shellstring collectors at most stations were deployed for 7-day periods, some were frequently deployed for periods that ranged between five and 21 days and deployment dates did not usually coincide among the different rivers and areas monitored. Spat counts for those different deployment dates and periods were, therefore, standardized to correspond to 7-day standard periods starting on the dates specified in Table 1; those periods follow the calendar sequence that begins on June 1.

The average spat count for the standard weekly periods was computed as follows. The average daily count of spat per shell for each of the actual deployment periods at a particular station was obtained by dividing the total number of spat on a shellstring by 10 (the number of shells examined) and division of that quotient by the number of days in the deployment period The resulting sequence of daily averages for the whole season was then split into 7-day periods corresponding to the established standard weeks. The sum of the daily averages thus apportioned to each standard week is the value that appears in Table 1. Whenever there were only one or two daily averages for a station in a given standard week, data for that week were reported as if none had been collected.

There was a difference between computations made in 1996 and 1997 and those made in previous years, which involved the definition of a *deployment day.* In previous years, the initial deployment date of a shellstring was considered to represent the first deployment day in a week. In 1996 and 1997, the first deployment day corresponded to a 24-hr period starting on the initial deployment date; thus, the first (24-hr) deployment day corresponded to the date following first deployment of the shellstring. The method used in previous years would displace the daily averages for 1996 and 1997 back by one day and the sum of the daily averages presented in Table 1 for each standard week would change accordingly. The sum, however, of the weekly averages given as *Year Total* in Table 1 would not change.

TABLE 1

STATION LOCATIONS FOR SPRING AND FALL SURVEYS

STATION	LATITUDE	LONGITUDE
JAMES RIVER		
Deep Water Shoal	37 08.8	76 38.1
Mulberry Point	37 07.1	76 38.0
Swash	37 05.6	76 37.0
Horsehead	37 06.3	76 37.9
Long Rock	37 04.6	76 37.1
Wreck Shoal	37 03.7	76 34.3
Point of Shoals	37 04.5	76 38.7
Dry Shoal	37 03.5	76 36.1
Thomas Rock	37 01.5	76 29.5
Nansemond Ridge	36 55.5	76 27.2
YORK RIVER		
Bell Rock	37 28.7	76 44.8
Aberdeen Rock	37 20.0	76 36.1
MOBJACK BAY		
Pultz Bar	37 21.1	76 21.1
Tow Stake	37 20.2	76 23.7
PIANKATANK RIVER		
Ginney Point	37 32.0	76 24.2
Palace Bar	37 31.6	76 22.2
Burton's Point	37 30.9	76 19.7
RAPPAHANNOCK RIVER		
Ross Rock	37 54.0	76 47.5
Bowlers Rock	37 49.5	76 44.0
Long Rock	37 48.9	76 42.9
Morattico Bar	37 46.9	76 39.3
Smokey Point	37 43.2	76 34.8
Hog House Bar	37 38.4	76 33.2
Drumming Ground	37 38.7	76 27.5
Parrot Rock	37 36.4	76 25.2
Off Broad Creek	37 34.6	76 18.4
CORROTOMAN RIVER		
Middle Ground	37 41.0	76 28.4
GREAT WICOMICO RIVER		
Haynie Point	37 49.8	76 18.7
Whaley's East	37 48.3	76 17.8
Fleet Point	37 48.6	76 17.3

TABLE 2

RESULTS OF PUBLIC OYSTER GROUNDS SURVEY - SPRING 1997

STATION	COLL DATE	TEMP. (C)	SAL. (ppt)	AVERAGE NUMBER OYSTERS PER BUSHEL				BOXES PER BUSHEL		PCT. NEW MORT
				Market	Small	Spat	Total	New	Old	
JAMES RIVER										
Deep Water Shoal	MAY 14	19.0	1	6	629	2	637	21	118	3.2
Mulberry Point	MAY 22	23.3	4	34	400	3	437	4	35	0.9
Horsehead	MAY 22	22.9	3	15	1053	17	1084	17	37	1.5
Point of Shoals	MAY 22	23.3	3	22	531	39	591	12	34	1.9
Long Rock	MAY 28	19.5	10	26	322	9	357	6	30	1.5
Dry Shoal				Not sampled in spring of 1997						
Swash	MAY 28	19.5	10	35	209	7	251	6	23	2.1
Wreck Shoal	MAY 28	18.5	14	4	22	11	36	1	12	1.4

* Total Oysters per Bushel and Percent Mortality were computed as average of total number of oysters in f samples; that, together with rounding off to the nearest whole number, results in slight apparent discrep when computations are made using values in this table.

TABLE 3

RESULTS OF PUBLIC OYSTER GROUNDS SURVEY - FALL 1997

STATION	COLL DATE	TEMP. (C)	SAL. (ppt)	AVERAGE NUMBER OYSTERS PER BUSHEL Markt	Small	Spat	Total *	BOXES ** PER BUSHEL New	Old2	Old3	PCT. New MORT*	PCT. New+Old2 MORT*
JAMES RIVER												
Deep Water Shoal	10/30	14.6	11.2	10	423	48	481	2	4	9	0.4	1.2
Mulberry Point	10/30	14.3	12.1	36	140	9	184	2	3	11	0.6	3.3
Swash	10/30	14.3	13.2	37	215	15	267	7	23	29	2.6	10.2
Horsehead	10/30	14.8	13.5	8	713	18	738	20	21	34	2.6	5.1
Long Rock	10/29	14.6	13.9	46	241	84	370	45	57	27	10.9	21.6
Wreck Shoal	10/29	14.3	15.9	6	33	15	53	13	24	31	19.1	40.7
Point of Shoals	10/30	14.5	14.5	26	437	33	495	15	31	17	2.9	8.4
Dry Shoal	10/29	14.6	14.7	5	45	20	69	20	42	29	23.7	47.7
Thomas Rock ***	10/29	13.7	18.6	2	11	13	25	4	8	15	14.0	32.2
Nansemond Ridge	10/29	14.2	20.1	1	9	10	20	1	2	4	2.8	8.8
YORK RIVER												
Bell Rock	10/27	15.5	16.4	5	52	13	70	3	1	1	5.2	7.0
Aberdeen Rock	10/27	16.3	20.8	0	7	2	9	1	2	2	6.3	15.6
MOBJACK BAY												
Pultz Bar	10/20	--	--	2	51	5	58	1	1	1	1.2	2.3
Tow Stake	10/20	16.4	21.7	1	35	2	38	0	1	1	0.0	2.2
PIANKATANK RIVER												
Ginney Point	10/17	19.4	17.7	4	29	19	51	1	2	1	1.6	4.6
Palace Bar	10/17	19.4	18.3	4	78	19	100	5	4	2	3.3	6.0
Burton's Point	10/17	18.8	18.7	3	35	23	61	1	1	4	1.2	2.3
RAPPAHANNOCK RIVER												
Ross Rock	10/14	21.7	12.2	6	30	1	36	1	0	3	0.9	0.9
Bowlers Rock	10/14	22.2	13.9	40	195	1	236	8	32	6	3.4	14.4
Long Rock	10/14	22.0	14.9	41	46	0	86	2	2	3	1.8	4.6
Morattico Bar	10/14	22.0	16.1	7	9	1	16	1	1	2	1.3	2.5
Smokey Point	10/14	22.2	16.3	2	6	1	9	1	0	1	4.2	4.2
Hog House Bar	10/14	--	--	0	7	2	9	0	0	0	0.0	0.0
Middle Ground (Corrotoman R.)	10/14	21.3	17.0	5	160	56	221	13	22	5	5.6	13.5
Drumming Ground	10/14	21.2	17.8	10	72	39	120	11	11	15	8.4	16.0
Parrot Rock	10/14	21.1	18.1	5	35	4	43	7	7	12	13.0	24.6
Off Broad Creek	10/22	16.5	18.0	53	124	39	216	10	13	12	4.4	9.6
GREAT WICOMICO R.												
Haynie Point	10/22	15.5	17.9	10	115	312	437	7	4	6	1.5	2.3
Whaley's East	10/22	15.8	18.2	22	71	104	197	2	3	2	1.1	2.6
Fleet Point	10/22	16.0	17.9	18	96	47	161	3	7	9	2.0	5.7

* Total Oysters per Bushel and Percent Mortality were computed as average of total number of oysters in four individual samples; that, together with rounding off to the nearest whole number, results in slight apparent discrepancies when computations are made using values in this table.

** Classification of oyster boxes was modified this year. "New" boxes represent death within days of sampling; "Old 2" boxes are presumed to represent death within a month of sampling and "Old 3" boxes are presumed to represent death over several months preceding sampling. Combined "New" and "Old 2" mortality corresponds most closely to the "New" mortality reported for previous years. See text for details.

*** Thomas Rock is location of the Miles Watch House shellstring station.

OYSTER BAR SURVEY STATIONS

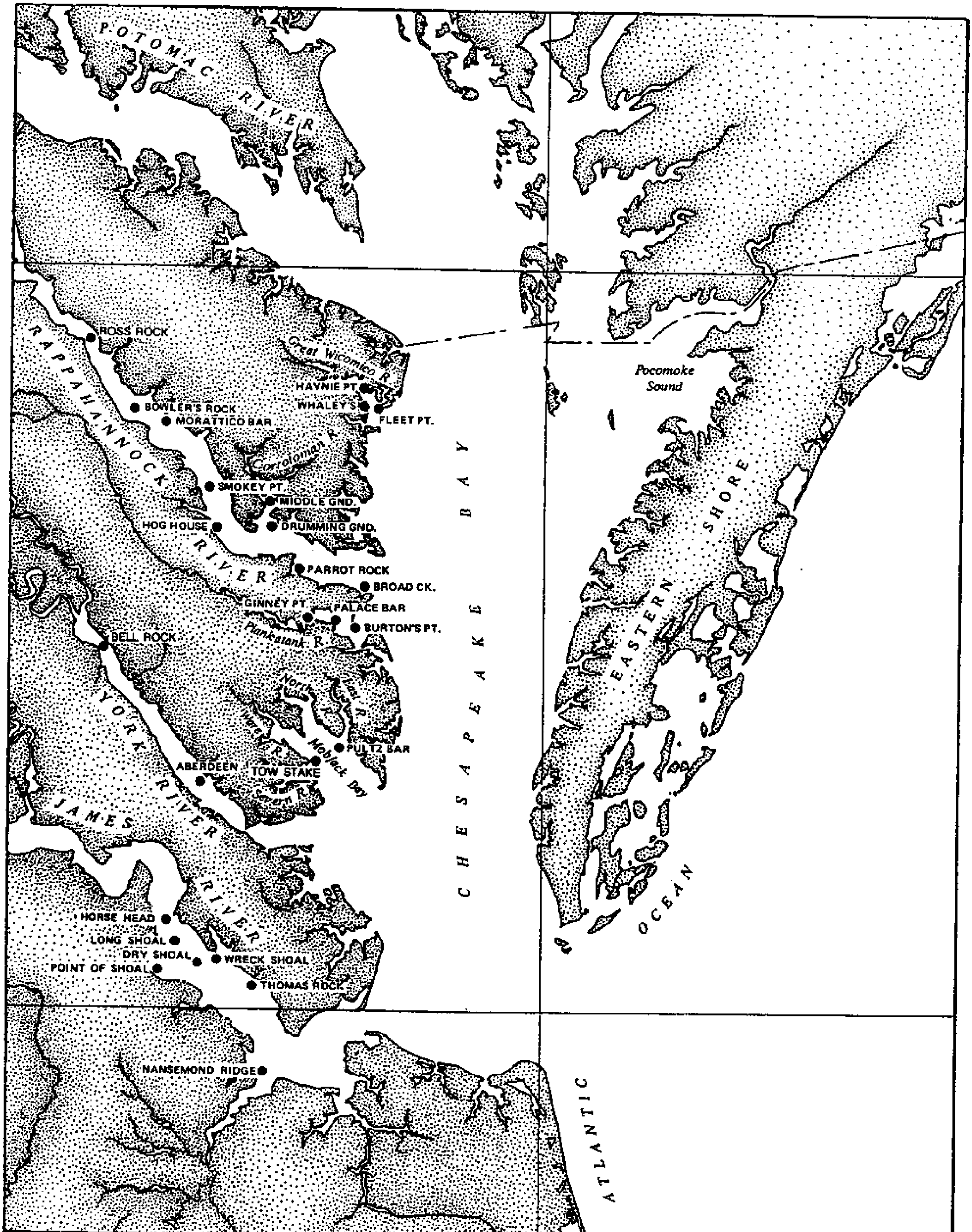

Figure 1. Location of oyster bars sampled.

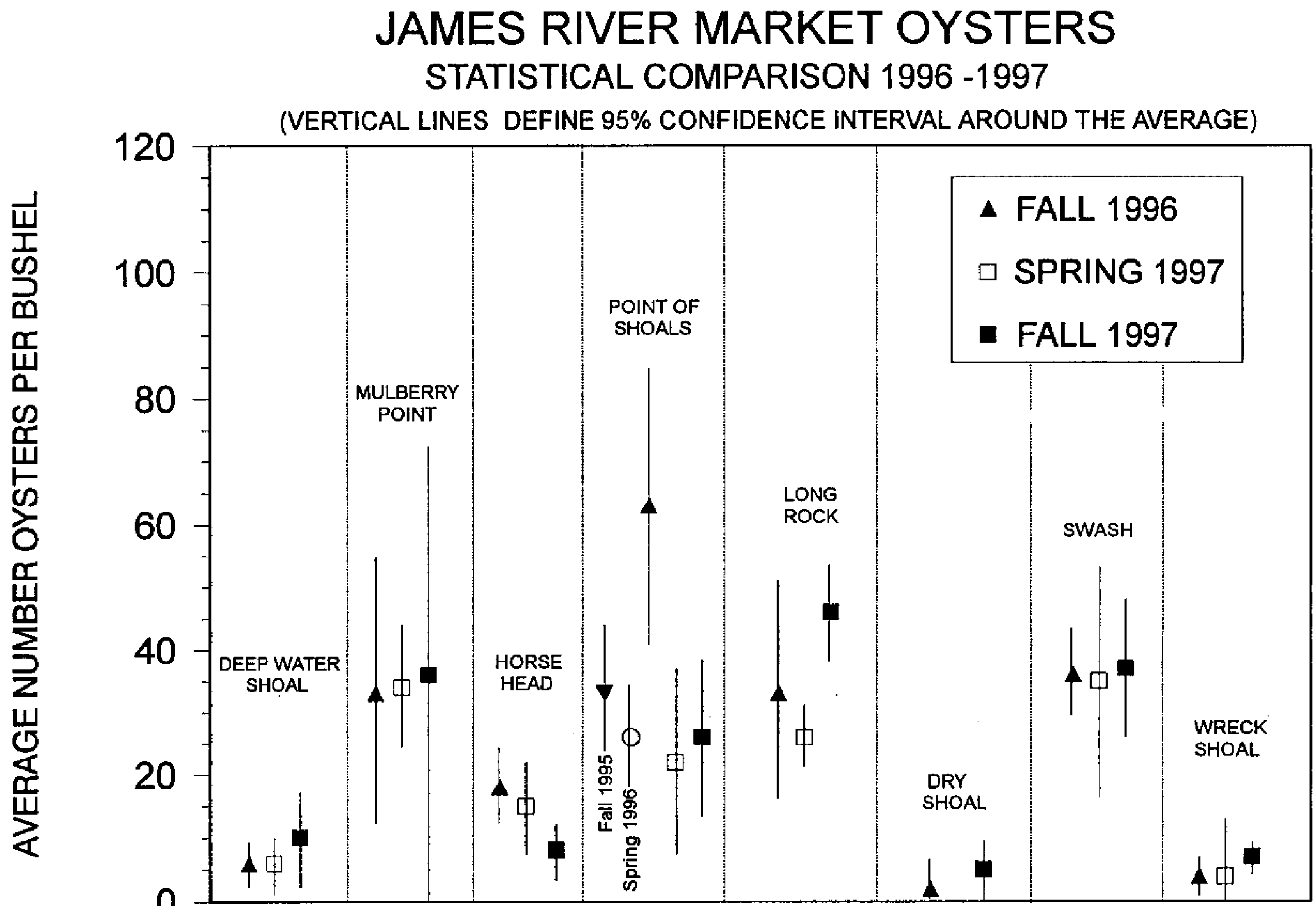

Figure 2. Statistical comparison of the number of market-size oysters (3-in and larger) collected during surveys of selected oyster bars on the public grounds of the James River, VA between the fall of 1996 and the fall of 1997. Presented as the average number in one bushel of dredged bottom material. A 95% probability exists that two averages are significantly different when the vertical line representing the confidence interval around one sample's average does not overlap the symbol for the average of another sample. Spring samples usually collected in May; fall samples usually collected in October. Fall 1995 and spring 1996 values for Point of Shoals included because of the magnitude of changes observed before and after fall 1996.

JAMES RIVER SMALL OYSTERS

STATISTICAL COMPARISON 1995 -1997

(VERTICAL LINES DEFINE 95% CONFIDENCE INTERVAL AROUND THE AVERAGE)

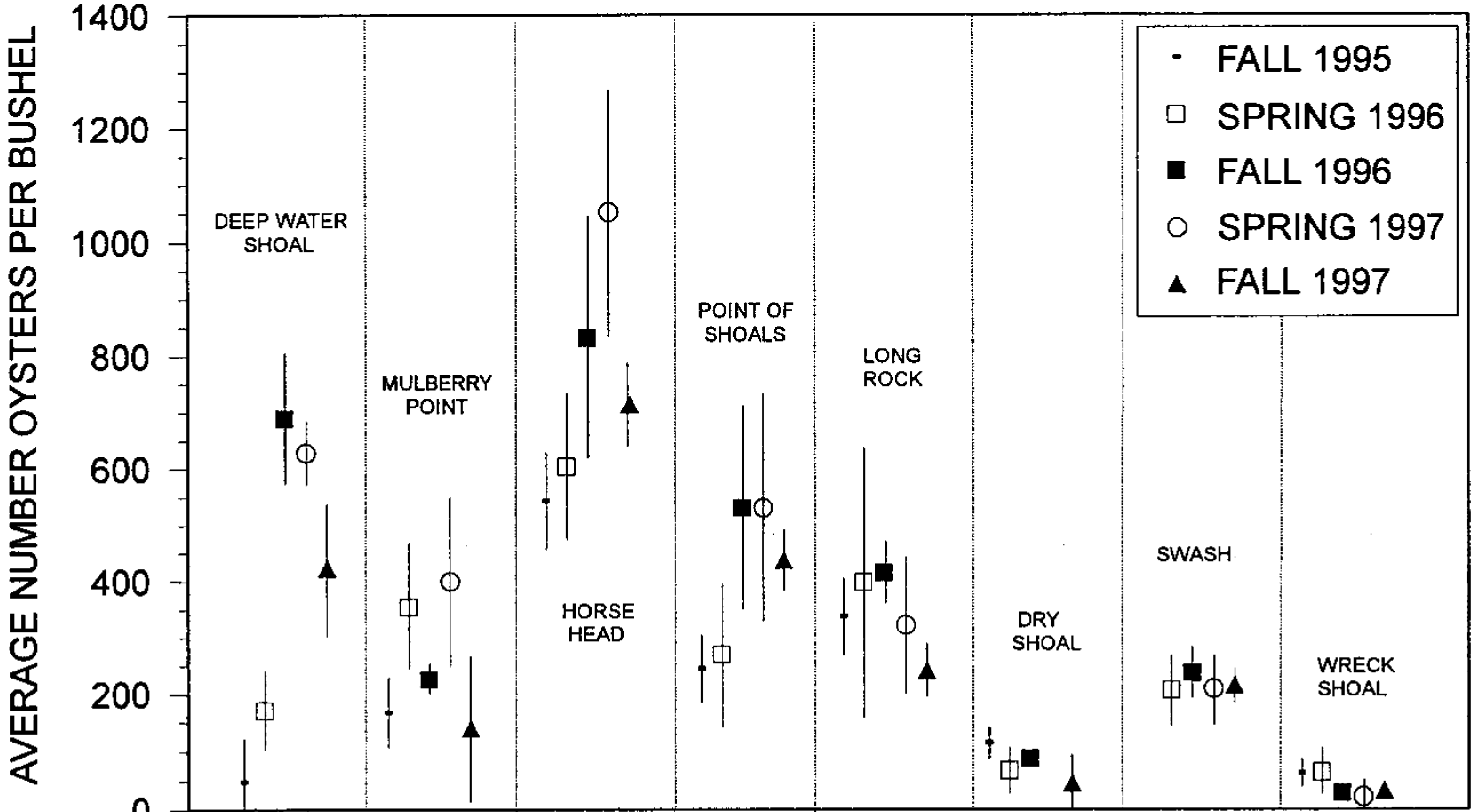

Figure 3. Statistical comparison between the average number of small oysters (under 3 in., excluding spat) collected during surveys of selected oyster bars on the public grounds of the James River, VA between the the fall of 1995 and fall of 1997. A 95% probability exists that two averages are significantly different when the vertical line representing the confidence interval around one sample's average does not overlap the symbol for the average of another sample. Spring samples usually collected in May and fall samples usually collected in October.

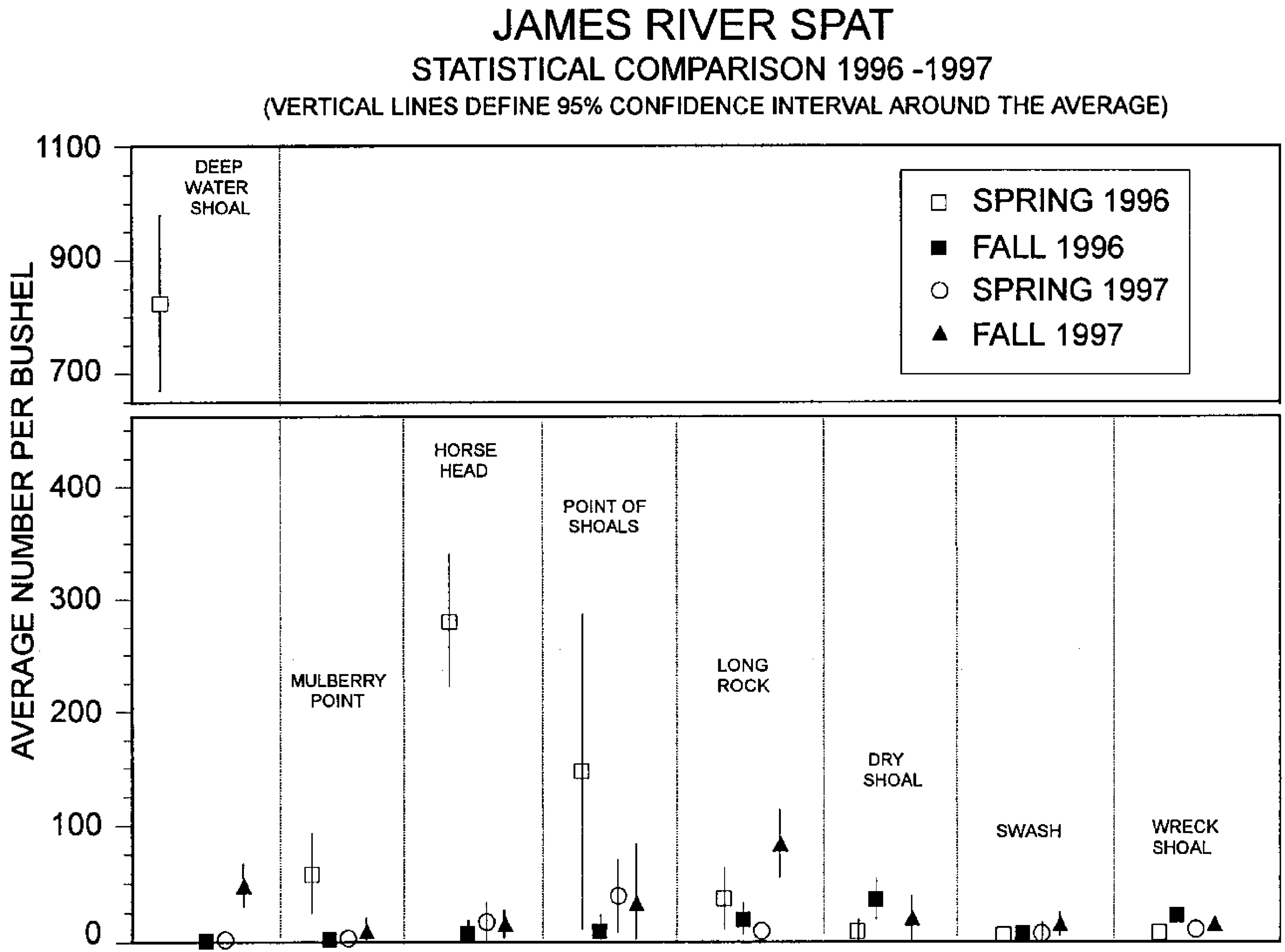

Figure 4. Average and confidence interval of the number of oyster spat per bushel of bottom material collected during surveys of selected oyster bars on the public grounds of the James River, VA. A 95% probability exists that two averages are significantly different when the vertical line representing the confidence interval around one sample's average does not overlap the symbol for the average of another sample. Spring samples usually collected in May; fall samples usually collected in October.

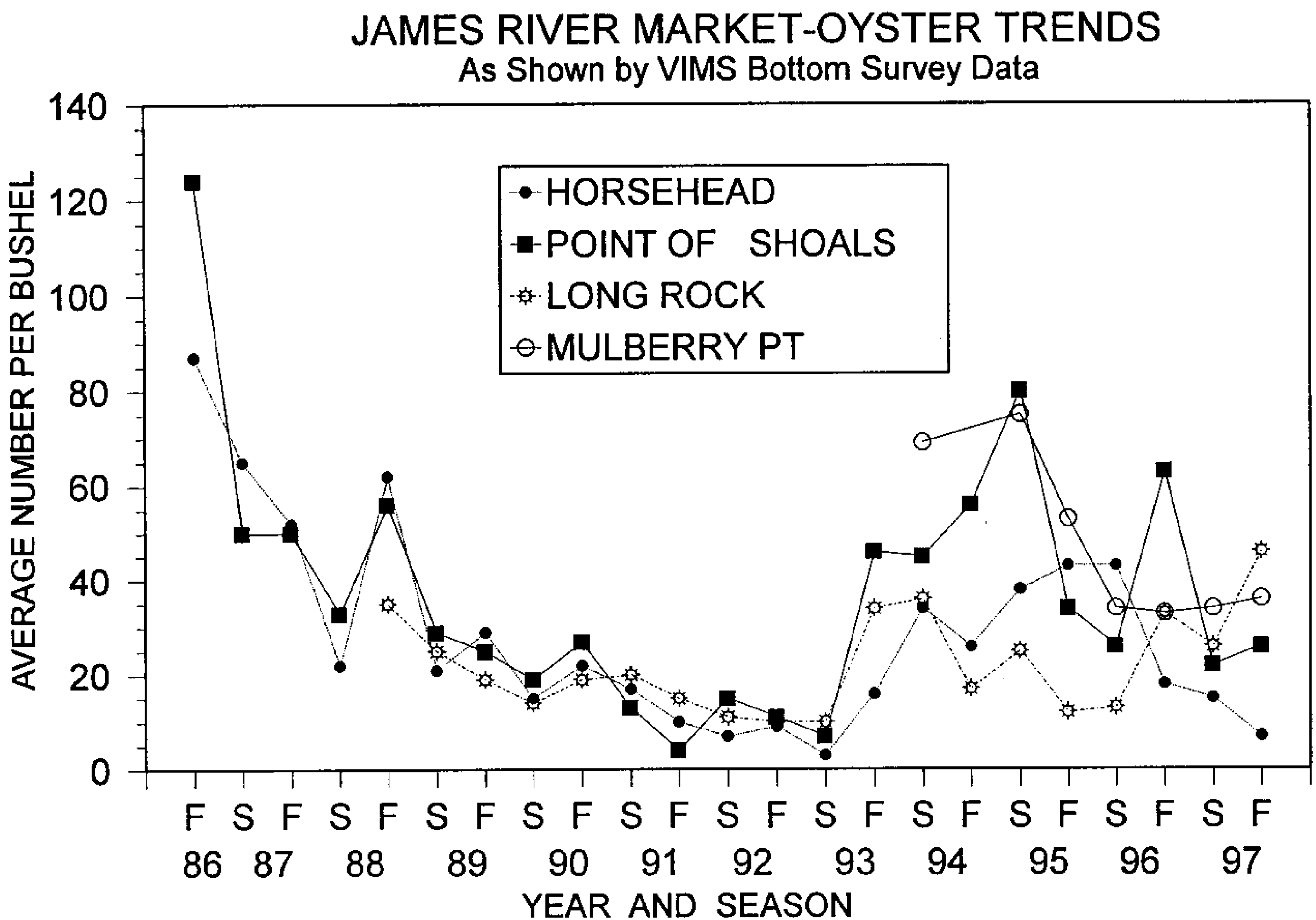

Figure 5. Trend in abundance of market oysters at four stations in the James River sampled during VIMS oyster bottom surveys in the spring and fall of successive years between 1986 and 1997. Spring samples usually collected in May and fall samples usually collected in October. Long Rock is also known as Cross Rock. F=Fall, S=Spring.

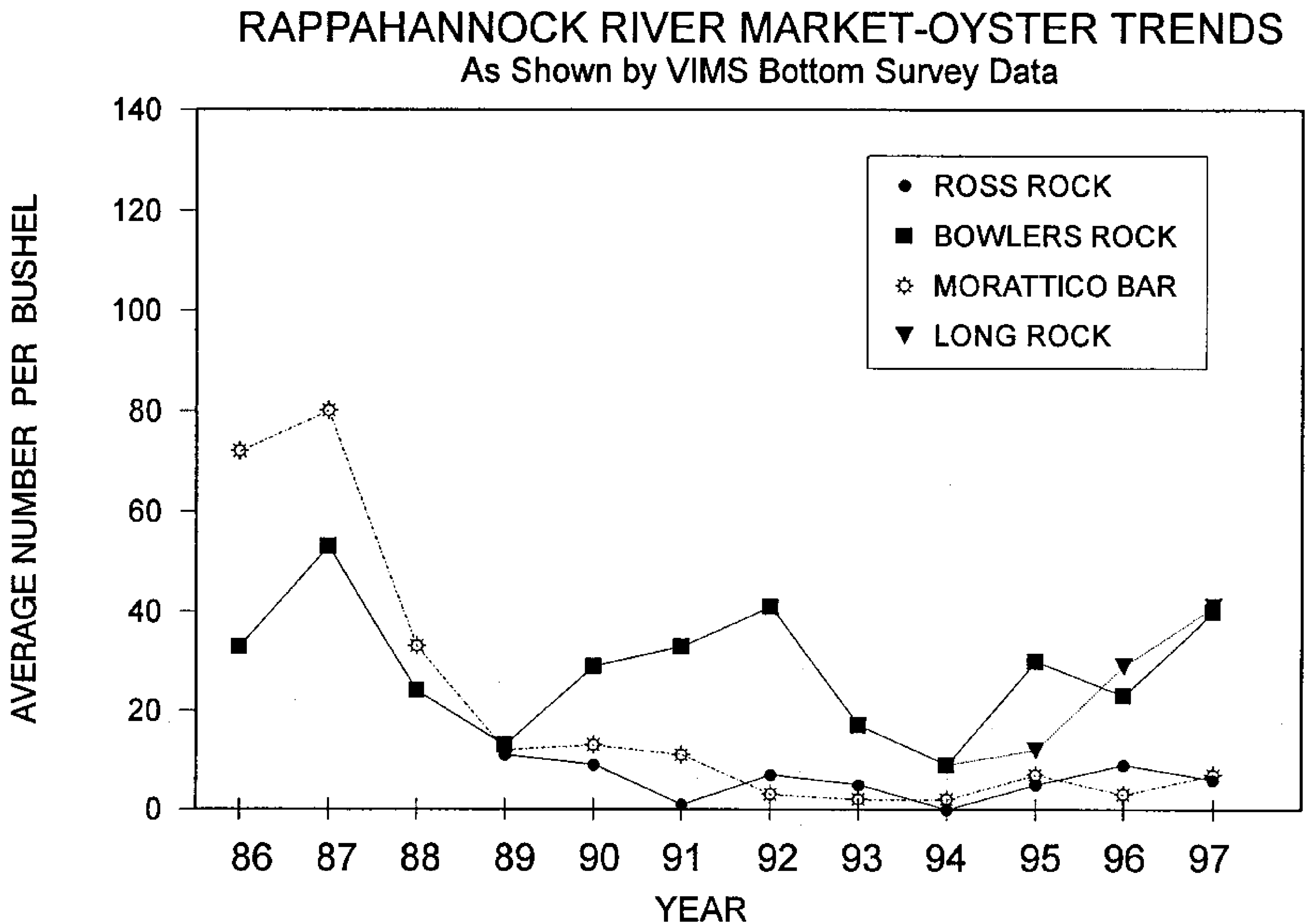

Figure 6. Trend in abundance of market oysters at four stations in the Rappahannock River sampled during VIMS oyster bottom surveys in the fall of successive years between 1986 and 1997. Samples usually collected in October.

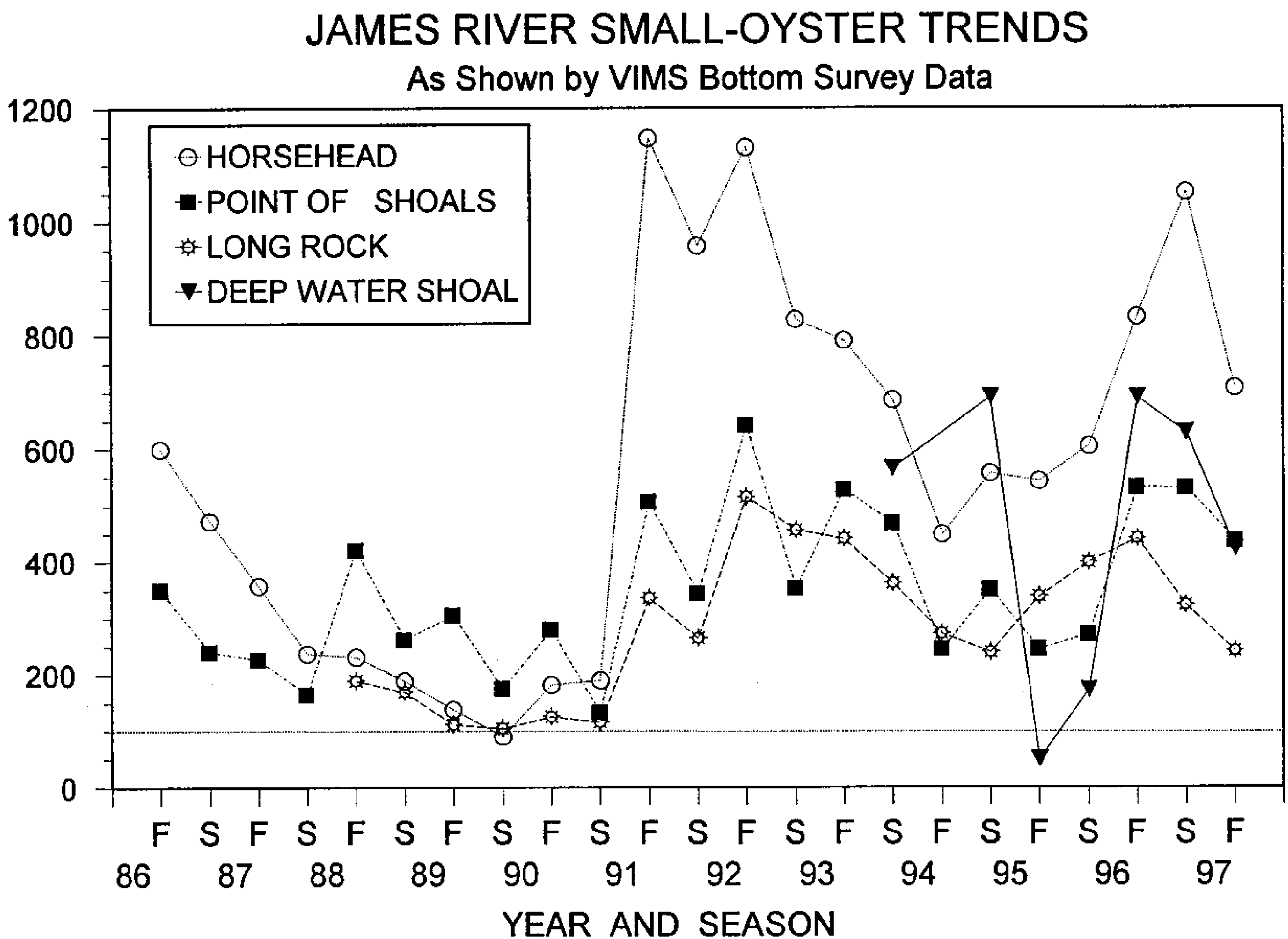

Figure 7. Trend in abundance of small oysters at four stations in the James River sampled during VIMS oyster bottom surveys in the spring and fall of successive years between 1986 and 1997. Spring samples usually collected in May and fall samples usually collected in October. The 100 per bushel level highlighted with a broken line to ease comparison with data on Figure 8. Long Rock is also known as Cross Rock. F=Fall, S=Spring.

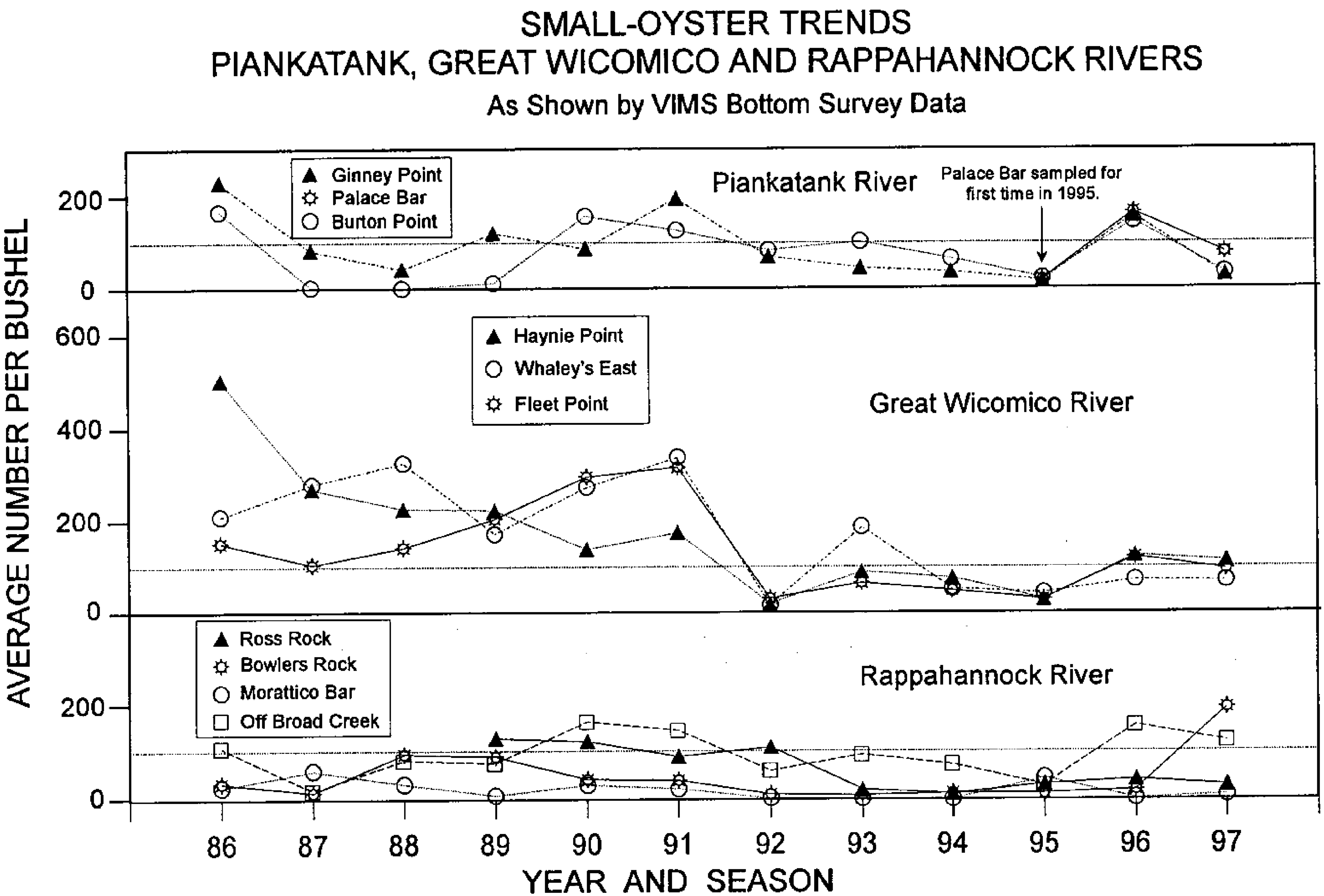

Figure 8. Trend in abundance of small oysters at stations in the Piankatank, Great Wicomico, and Rappahannock Rivers sampled during VIMS oyster bottom surveys in the fall of successive years between 1986 and 1997. Samples usually collected in October. The 100-per-bushel level highlighted with a broken line to ease comparison of data for different rivers.

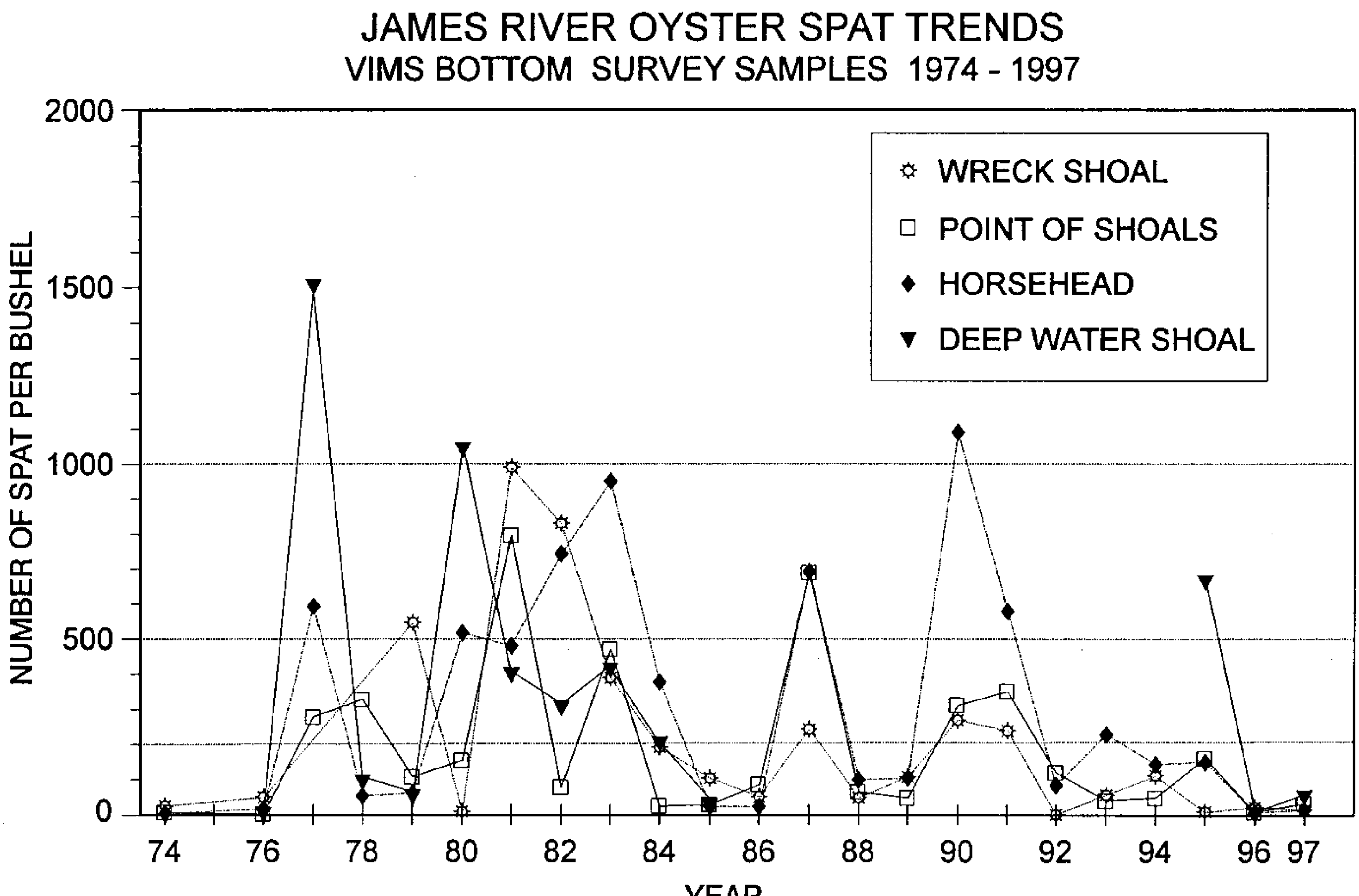

Figure 9. Average number of spat per bushel of natural cultch collected at four oyster bars in the James River during annual fall surveys (usually conducted in October), 1974-1997. Bars selected for the length of their data records. No data collected at Deep Water Shoal between 1986 and 1994. Data for 1948 to 1973 available in the report for 1995 (published June 1996).

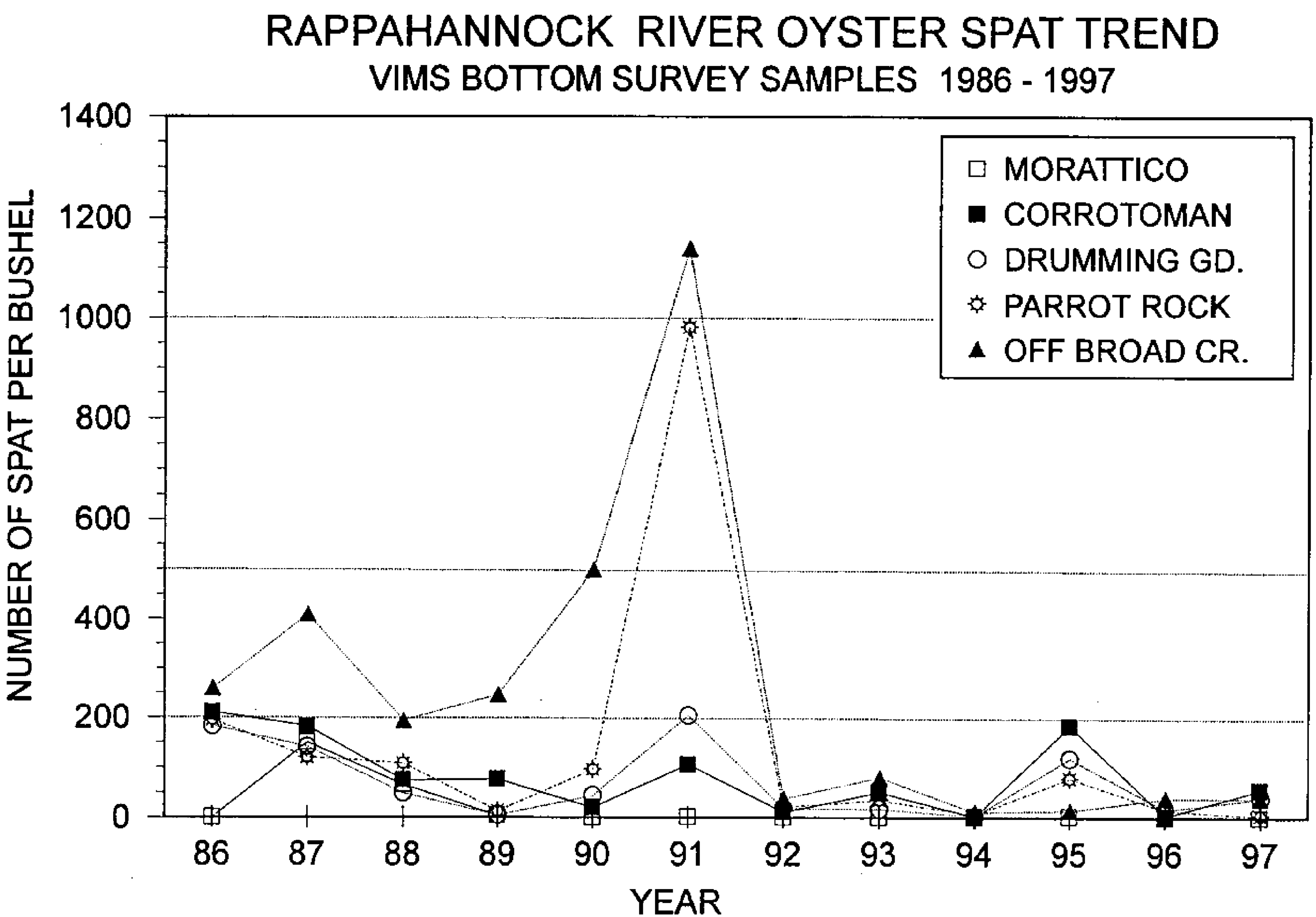

Figure 10. Average number of spat per bushel of natural cultch collected at three oyster bars in the Rappahannock River during annual fall surveys (usually conducted in October) between 1986 and 1997. Grid lines across figure drawn to ease comparison among years and with other figures.

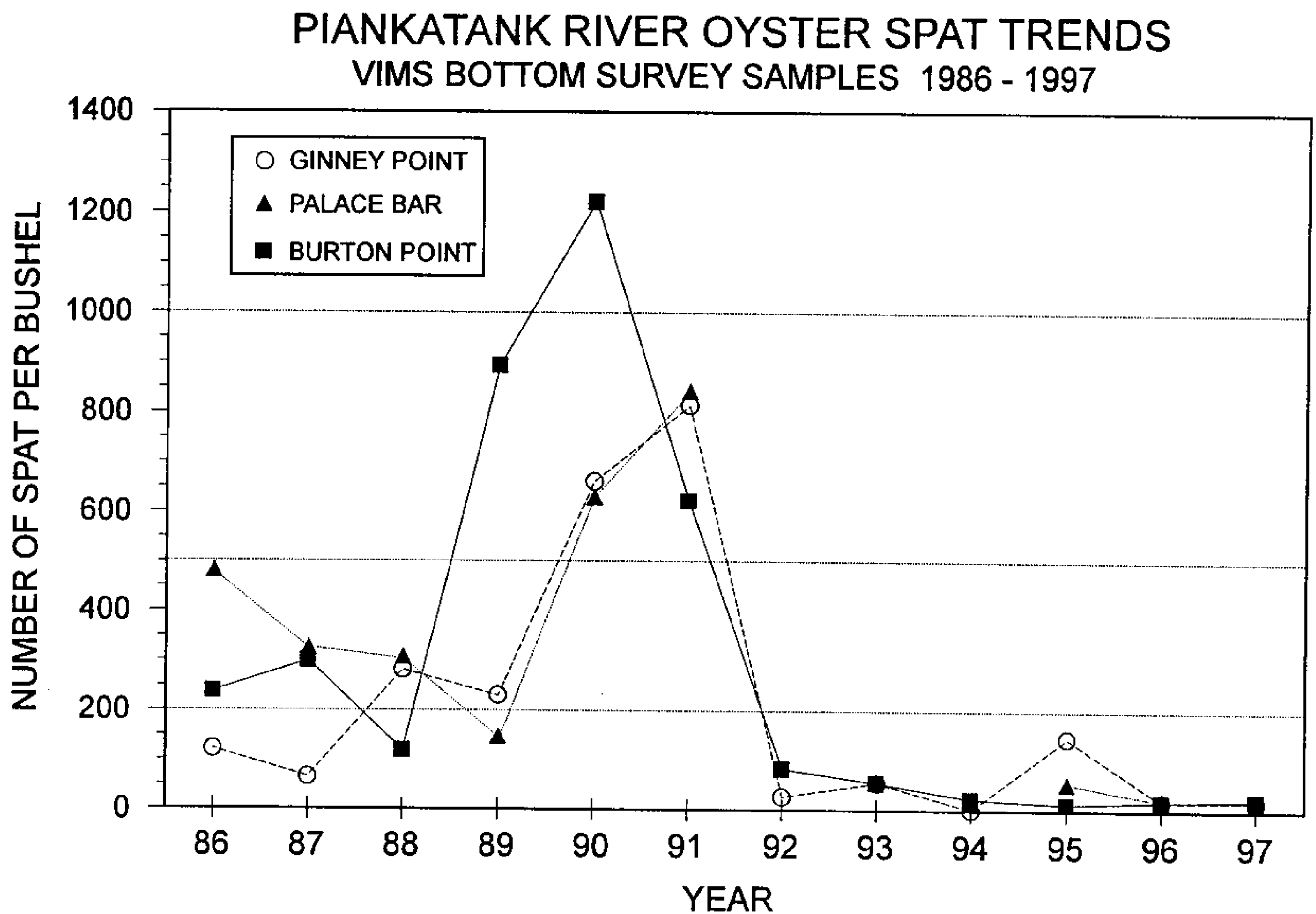

Figure 11. Average number of spat per bushel of natural cultch collected at three oyster bars in the Piankatank River during annual fall surveys (usually conducted in October) between 1986 and 1997. Palace Bar not sampled between 1992 and 1994. Grid lines across figure drawn to ease comparison among years and with other figures.

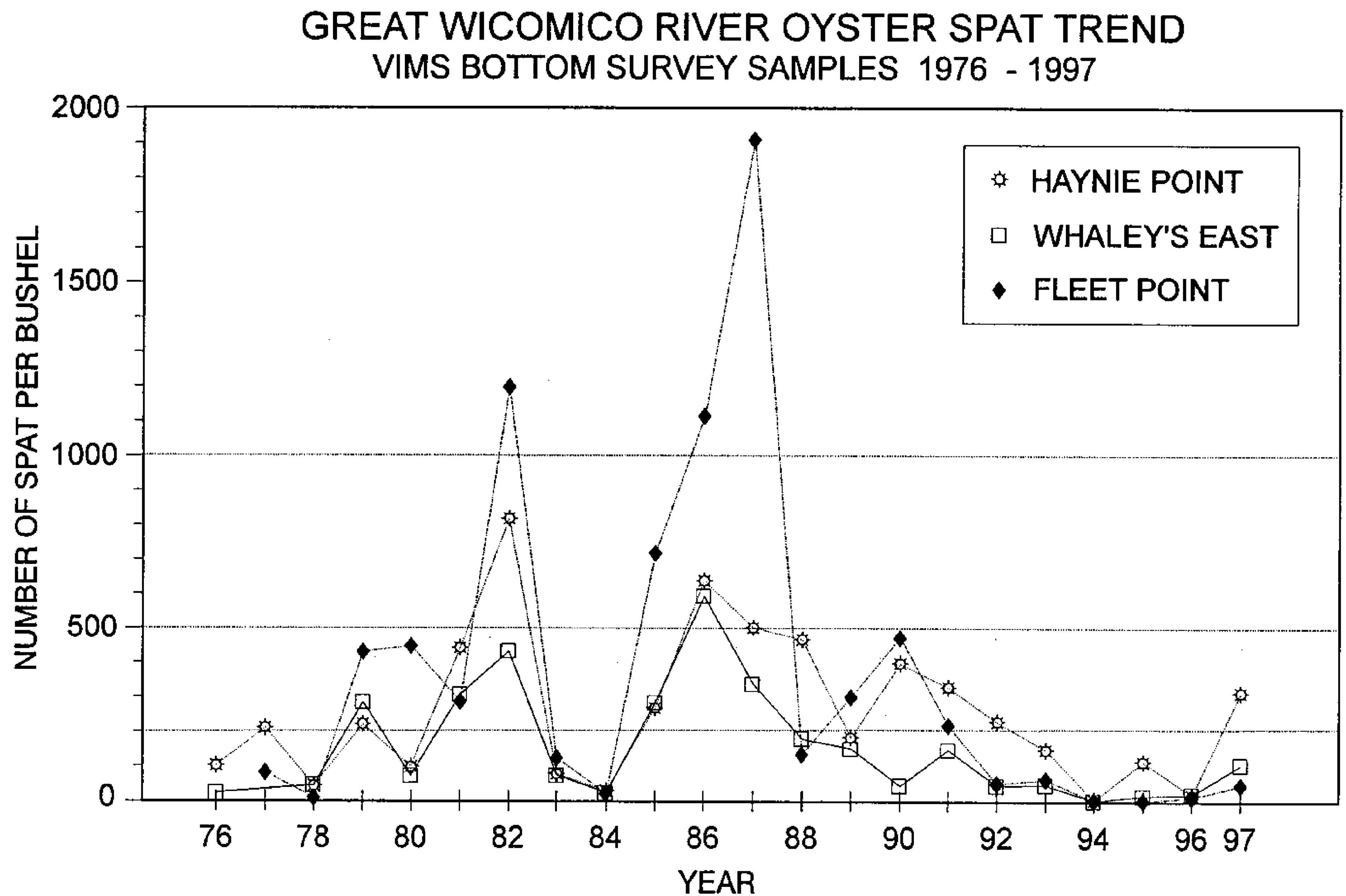

Figure 12. Average number of spat per bushel of natural cultch collected at three oyster bars in the Great Wicomico River during annual fall surveys (usually conducted in October) between 1976 and 1997. Grid lines across figure drawn to ease comparison among years and with other figures.

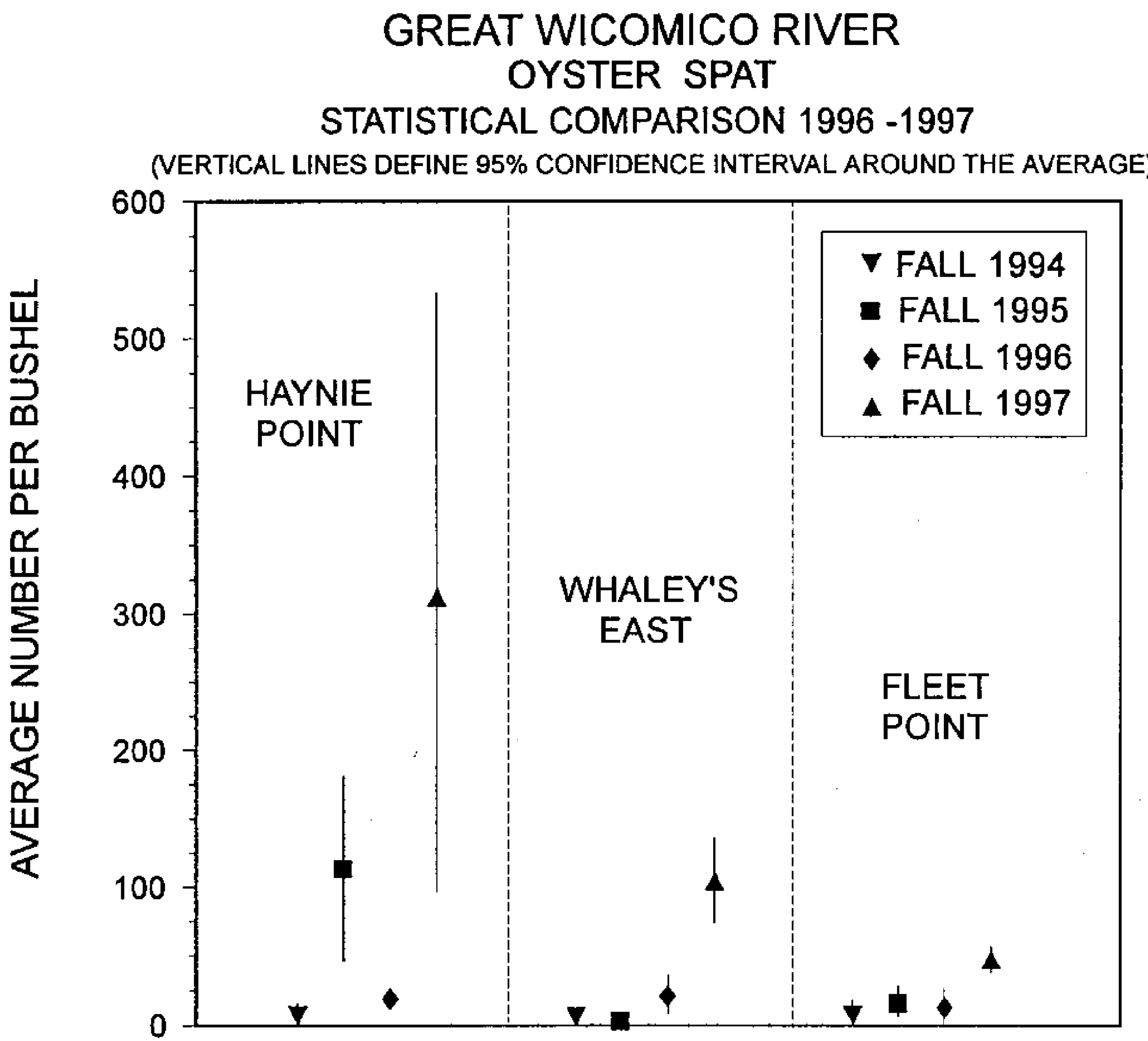

Figure 13. Average and confidence interval of the number of oyster spat per bushel of bottom material collected during surveys of selected oyster bars on the public grounds of theGreat Wicomico River, VA. A 95% probability exists that two averages are significantly different when the vertical line representing the confidence interval around one sample's average does not overlap the symbol for the average of another sample. Fall samples usually collected in October.

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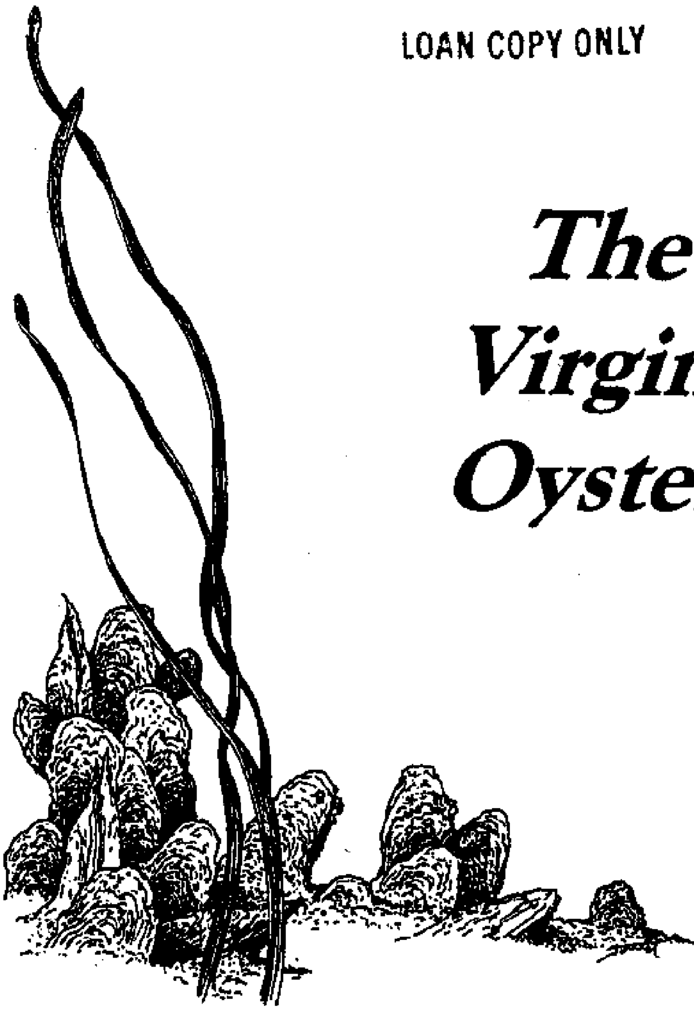

The Status of Virginia's Public Oyster Resource 1997

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