The Status of Virginia's Public Oyster Resource 2000

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February, 2001
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OYSTERS SPATFALL IN VIRGINIA DURING 2000

INTRODUCTION

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

Results from spatfall monitoring are reflective of the abundance of ready-to-settle oyster larvae in an area, and thus, provide an index of both oyster population reproduction and successful development and survival of larvae to the settlement stage in an estuary. Environmental factors affecting these physiological activities cause seasonal and annual fluctuations in spatfall, which are evident in the data.

Data from spatfall monitoring also serve as an indicator of potential oyster recruitment into a particular estuary. Settlement and subsequent survival of spat on bottom cultch (shell) is affected by many factors, including physical and chemical environmental conditions, the physiological condition of the larvae when they set, predators, disease, and the timing of these factors. Abundance and condition of bottom cultch also affects settlement and survival of spat on the bottom. Therefore, settlement on shellstrings may not directly correspond with recruitment on bottom cultch at all times or places. Under most circumstances, however, the relationship between settlement on shellstrings and bottom cultch is expected to be commensurate.

This report summarizes data collected during the 2000 settlement season in the Virginia portion of the Chesapeake Bay.

METHODS

Spatfall during 2000 was monitored from the last week of May through mid October at all stations. Spatfall stations included eight historical sites in the James River, three historical and five new sites in the Piankatank River, five historical and four new sites in the Great Wicomico River and four sites on the Eastern Shore (Atlantic Ocean side) of Virginia (Figure S1). The new sites in both the Piankatank and Great Wicomico Rivers correspond to those sites that were considered “new” in the 1998 survey. In this report, historical sites refer to those that have been monitored yearly for at least the past ten years whereas “new” sites are stations that were added during 1998 to monitor the effects of replenishment efforts by the Commonwealth of Virginia. Since 1993, the Virginia Marine Resources Commission (VMRC) has built numerous artificial oyster shell reefs in several tributaries of the west-
ern Chesapeake Bay as well as inshore of Fisherman’s Island and in Pungoteague Creek on the Eastern Shore (Figure S2). The change in the number and location of shellstring sites during 1998 was implemented to provide a means of quantitatively monitoring oyster spatfall around these reefs. In particular, broodstock oysters were planted on a reef in the Great Wicomico River during winter, 1996 and on reefs in the Piankatank and Great Wicomico Rivers during winter, every year since 1997, including 2000. The increase in the number of shellstring sites during 1998 in the two rivers coincide with areas of new shell plantings in spring, 1998, 1999, and 2000 and provides means of monitoring the reproductive activity of planted broodstock on the artificial oyster reefs. Continued deployment during 2000 of shellstrings at two Fisherman Island stations, was associated with concurrent ecological studies on artificial (oyster shell, clam shell, and coal ash) reefs at that location. Deployment of a shellstring at Wachapreague, Virginia represents continuation of long-term data collections at that station. Shellstrings were once again deployed at Pungoteague, Virginia during 2000 to continue the monitoring of broodstock oyster production on the artificial oyster reef built in the creek (Figure S2).

Oyster shellstrings were used to monitor oyster spatfall. A shellstring consists of twelve oyster shells of similar size (about 76 mm, (3-in) in length) drilled through the center and strung (inside of shell facing substrate) on heavy gauge wire (Figure S3). Throughout the monitoring period, shellstrings were deployed approximately 0.5 m (18-in) off the bottom at each station. Shellstrings were usually replaced after a one-week exposure and the number of spat that attached to the smooth underside of the middle 10 shells was counted under a dissecting microscope. To get the mean number of spat shell\(^{-1}\) for the corresponding time interval, the total number of spat was divided by the number of shells examined (ten in most cases).

Although shellstring collectors at most stations were deployed for seven day periods, some weather related deviations did occur such that shellstring deployment periods ranged from six to sixteen days. These periods did not usually coincide among the different rivers and areas monitored. Therefore, spat counts for different deployment dates and periods were standardized to correspond to the seven day standard periods specified in Table 1. Standardized spat shell\(^{-1}\) (S) was computed using the formula:

\[ S = \frac{\text{Number of spat shell}^{-1}}{\text{weeks (W)}} \]

where W = number of days deployed / 7. Standardized weekly periods allow comparison of spatfall trends over the course of the season between the various stations in a river as well as between data for different years.

The cumulative spatfall for each station was computed by adding the standardized weekly values of spat shell\(^{-1}\) for the entire season. This value represents the average number of spat that would fall on any given shell if allowed to remain at that station for the entire sampling season. Spat shell\(^{-1}\) / week values were categorized for comparison purposes as follows: 0.10-1.00, light; 1.01-10.00, moderate; and 10.01 or more, heavy. Unqualified references to diseases in this text imply diseases caused by *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Perkinsus, or Dermo).

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

RESULTS

Spatfall on shellstring collectors for 2000 is summarized in Table S1 and is discussed below for each river system monitored. A summary of settlement at the historical stations for the past 11 years appears in Table S2. Unless otherwise specified, the information presented below refers to those two tables. When comparing 2000 data with historical data in the James River, all eight stations were used. Due to the addition of new sites during 1998 in the Piankatank and Great Wicomico Rivers, any comparison made to historical data could not include data from all of the sites sampled during 2000. Historical sites in the Piankatank are Burton Point, Ginney Point, and Palace Bar. Historical sites in the Great Wicomico include Fleet Point, Glebe Point, Haynie Point, Hudnall, and Whaley’s East (Cranes Creek in previous data reports).

James River

Oyster settlement in the James River was first observed during the week of July 8 at Wreck Shoal (Table S1). Settlement began at all other stations during the week of July 15 and continued sporadically at all stations until the end of September. There were two major pulses of oyster set in the James River. The first occurred in mid July, the second occurred in mid September (Figure S4).

Cumulative spat shell$^{-1}$/week for 2000 ranged from a low of 0.7 at Deepwater Shoal and Point of Shoal to a high of 4.3 at Day’s Point. Settlement was light to moderate at all stations, with heavier settlement tending to occur at the stations located nearer to the southern shore of the river.

The slight improvement in spatfall in the James River, which occurred during 1999, did not continue into 2000. Settlement during 2000 was lower at all stations compared to settlement during 1999 (Table S2: Figures S5A and S5B). However, settlement during 2000 was slightly higher when compared with the five year mean at Horsehead and Day’s Point. Settlement at all stations was lower when compared with the ten year mean (Table S2: Figures S5A and S5B).

Average river water temperatures reached a maximum in early August (29.1 degrees Celcius: Figure S6A). Water temperatures throughout the 2000 sampling season were normal when compared with the mean for the previous five years (Figure S6A). For the most part, salinity in the James River during the 2000 sampling period was also similar to the previous five year mean. However there were a few weeks (June 10 through July 15) early in the season when a lack of rain caused the salinity to rise 3 to 4 ppt higher than normal. During this time there were large fluctuations in ambient salinities such that salinity changed as much as 8 ppt from one week to the next. On average there was a 6 to 9 ppt salinity difference between Deep Water Shoal (the most upriver station) and Day’s Point (the most downriver station: Figure S1), a slightly higher difference than in previous years.

Piankatank River

Settlement in the Piankatank River was first observed during the week of July 22 at Stove Point and July 29 at Burton Point (Table S1). Settlement began at all other stations except Wilton Creek, during the week of August 12. Settle-
ment was very sporadic throughout the river with only one major pulse occurring in mid August (Figure S7). Cumulative spat shell\(^1\) / week for the year ranged from a low of 1.2 at Cape Toon to a high of 6.8 at Ginney Point. Prior to the 2000 reproductive season (spring, 2000) three events that might affect oyster spatfall occurred in the Piankatank River. Broodstock oysters were placed on oyster reefs near Bland Point, Iron Point, Burton Point, and Palace Bar (Figure S2). Seed/oysters were removed from Cape Toon, Bland Point, Palace Bar, Heron Rock, and Burton Point and clean shells (culch) were then planted on those five bars (Figure S1), to provide clean substrate for larval oysters to set on. Comparing the major spatfall in the two areas with broodstock oysters, the larvae appeared to travel and set upriver and adjacent to the broodstock oysters.

Spatfall during 2000 showed a decrease from 1999 at two out of the three historical stations (Table S2: Figure S8). Ginney Point was the only site (historical and new) that showed an increase when compared with 1999. Spatfall during 2000 showed an increase at Ginney Point and Palace Bar when compared with the five year mean but was still low for all three historical sites when compared with the ten year mean.

The average Piankatank River water temperature ranged from 19 to 28 degrees Celcius throughout the sampling period, reaching a maximum in mid June and again in mid July. Water temperature did not vary much from the average temperatures previously recorded in the river (Figure S9A). Salinity ranged from 11 to 16 ppt throughout the sampling period. There was little difference in salinity in the river when compared with the mean for the previous five years (Figure S9B). During 2000, there was anywhere from a 1 to 4 ppt difference recorded between Wilton Creek (the most upriver station) and Burton Point (the most downriver station: Figure S1).

**Great Wicomico River**

Settlement in the Great Wicomico River was first observed during the week of July 1 (Table S1) at Hudnall and the week of July 22 at Haynie Point. No other settlement was observed until the beginning of August. As in the Piankatank River, settlement in the Great Wicomico was very sporadic, with one major pulse occurring in late August/early September (Figure S10). Glebe Point experienced the biggest pulse in setting during 2000. The pulse at Glebe Point occurred approximately two weeks before it occurred throughout the rest of the system. Prior to the 2000 reproductive season (spring, 2000), oyster shell was planted at Rogue Point, Hilly Wash, Shell Bar, and Harcum Flats (Figure S1). Broodstock oysters were placed on the artificial oyster reef located at Shell Bar (Figure S2).

Cumulative spat shell\(^1\) / week for the year ranged from a low of 0.2 at Whaley’s East to a high of 4.2 at Glebe Point. As observed in 1999, settlement at all stations in 2000 (both historical and new, except Whaley’s East) was higher than during the previous season’s settlement. However, comparing 2000 numbers with those recorded over the past few years, overall settlement in the Great Wicomico was low for the third consecutive year. Settlement at the historical stations during 2000 was also much lower than both the five and ten year means (Table S2: Figure S11).

Average river water temperatures ranged between 21 and 30 degrees Celcius throughout the sampling period (Figure S12A). Water temperature reached a maximum in mid July. Unfortunately, due to lack of historical data for the Great Wicomico neither temperature nor salinity dur-
ing 2000 could be compared with the previous five-year mean as it was in the James and Piankatank Rivers. However, comparing the salinity values recorded during 2000 with those from 1998 and 1999 (Figure S12B) the pattern tends to be on the average (normal) side (as in the James and Piankatank Rivers), as do the temperature values. There was a 1 to 2 ppt difference in salinity between the most upriver station (Glebe Point) and the most downriver station (Fleet Point: Figure S1) throughout a majority of the sampling season.

Eastern Shore of Virginia

As has been observed over the past two years, settlement at the Pungoteague reef site was low, with a total of 0.2 cumulative spat shell\(^{-1}\) / week. One spat set during the week of July 22 and one set during the week of September 30 (Table S1). Water temperature at the Pungoteague site reached a maximum of 28 degrees Celsius in the beginning of August and fluctuated between 22 and 28 degrees Celsius for the majority of the sampling season (Figure S15A). Salinity at the site ranged between 16 and 23 ppt (Figure S15B).

Settlement was first recorded at both Fisherman Island sites during the week of July 22. Spatfall was consistent (at least one spat shell\(^{-1}\) every week) from the end of July through mid September (Figure S13). As has been observed over the previous five years, more spat settled at the northern site when compared to the southern site (Table S1: Figure S14). Settlement at both sites was considerably lower than that recorded over the past three years. The cumulative spat shell\(^{-1}\) / week was 7.2 for Fisherman Island south and 9.9 for Fisherman Island north. Water temperature and salinity were similar for both Fisherman Island sites throughout most of the season. The break in temperature and salinity data in early July (Figures S15A and S15B) for Fisherman Island south, is due to the shellstring at that site being lost for three weeks in a row. Temperature ranged between 19 and 27 degrees Celsius and salinity ranged between 26 and 34 ppt throughout most of the sampling season.

Settlement was first observed at the Wachapreague site during the week of July 22. Spatfall was intermittent from the end of July through the end of the sampling season (Table S1). Prior to 1999, settlement at Wachapreague had been steadily increasing each year since hitting an all time low in 1994. Settlement at Wachapreague was once again low during 2000, lower than any recorded in the previous ten years (Table S2: Figure S14). Water temperature and salinity at the Wachapreague site was similar to the values recorded at the Fisherman Island sites (Figures S15A and S15B).

DISCUSSION

Oyster spatfall during 2000 was low to moderate in all Virginia tributaries of the western shore of the Chesapeake Bay. Low spatfall has been prevalent in Virginia since 1991, with the exception of parts of the James River in 1993, and to some extent the Great Wicomico River in 1997 and the Piankatank River in 1999. Spatfall at all sites during 2000 was lower than the previous ten-year mean (1990-1999). It was also lower than the previous five-year mean (1995-1999), with the exception of Horsehead and Day’s Point in the James River and Ginney Point and Palace Bar in the Piankatank River.

Overall oyster settlement during 2000 in the James River was similar to that observed over the past five years. Spatfall during 2000 for both Horsehead and Day’s Point was slightly higher than the previous five-year mean. Nonetheless,
it was still low throughout the system when compared with observed settlement over the past ten years. Historically, spatfall in the James tends to be highest at the more downriver stations (i.e., those with a higher salinity) and along the southern shore of the river: Day’s Point, Rock Wharf, and Dry Shoal. Settlement at those three sites constituted between 55 and 75% of the total annual spatfall at all stations monitored in eight out of the past thirteen years. When the other three downriver stations that used to be monitored prior to 1998 are included in the analysis, these six sites accounted for 60 to 90% of the total settlement in the river for the years 1988 to 1997. In three of the past thirteen years, the other five sites constituted between 61 and 65% of the total for the year and the other two years were approximately a 50/50 split. While this historical pattern of settlement was not completely mirrored in 2000, with the exception of low spatfall at Rock Wharf and Point of Shoals, settlement did increase in a seaward direction along the southern shore. Rock Wharf has had moderate settlement over the past few years, but for some reason did not see as much success in 2000.

The first peak in settlement in the James River occurred earlier in the year than is normal, mid July vs. mid to late August. This may have been due to the large salinity fluctuations observed in the system early on in the season. From the week of June 10 through July 15, the salinity changed as much as 8 ppt between weeks. While water temperature is thought to play a larger role in timing of the spawn, salinity, specifically rapid changes in salinity, can also affect both spawning and survival in the plankton (Thompson et al., 1996).

While not quite as high as observed during 1999, settlement in the Piankatank River during 2000 was among the highest seen since 1992. The increase in spatfall throughout the Piankatank system starting in 1998, can probably be attributed to the placement of broodstock oysters on the artificial oyster reefs located in the river (Figure S2). The highest settlement of oysters occurred around and upriver of these reefs. The location of settlement of spat during the past few years supports the suggestion that the Piankatank River is a trap-type estuary (Andrews, 1983).

Oyster settlement in the Great Wicomico River was light to moderate. However, all stations except Whaley’s East showed an improvement compared with 1999 spatfall. One major factor in the difference between 1999 and 2000 could be the location of broodstock placement. Broodstock were planted on Cranes Creek Reef in 1999 and on Shell Bar Reef in 2000 (Figure S2). Shell Bar Reef is located upriver of the sand spit at Sandy Point whereas Cranes Creek is located closer to the mouth of the river, downriver of the sand spit. The sand spit at Sandy Point is an important feature in the river in that it contributes to the upriver retention of larvae in the system and the trap-type nature of the estuary (Southworth and Mann, 1998).

The shellstrings on the reef at Pungoteague continue to receive low spatfall (two spat throughout the entire season) as has been prevalent since the reef was constructed in 1997. Similar to what was seen during 1999, Pungoteague Reef had higher settlement than that seen on the shellstrings, although settlement on the reef during 2000 was not as high as 1999 (J. Wesson, VMRC, Shellfish Replenishment Program, Newport News, Virginia; personal communication). The difference in settlement on the reef is most likely due to the absence of “new” broodstock on the reef during 2000 (none were planted), whereas there were broodstock planted during 1999. However, there is still disagreement in
settlement numbers on the reef and settlement numbers on the shellstrings, regardless of whether or not broodstock are planted on the reef. One possible explanation for the lack of settlement on the shellstrings could be the circulation patterns in the area. Often times there are large discrepancies between settlement on the bottom (or just off the bottom in the case of shellstrings) and settlement on the reefs. This difference may be due to small changes in circulation patterns around the shellstring site, flushing the larvae away from the area. The potential for small-scale circulation to affect settlement is supported by discrepancies in settlement location observed on the reef itself. Settlement on the reef during both 1999 and 2000 was highest in the subtidal and mid reef area and very low at depth on the reef, near the bottom where the shellstrings are located.

Compared to the past few years, the remaining Eastern Shore sites had relatively low settlement during 2000. Settlement at Wachapreague was several orders of magnitude lower during 2000 than both the five and ten year means for that site. At the Fisherman Island sites, the spatfall numbers were the lowest recorded since the reefs were built in 1995 and 1996 (Morales-Alamo and Mann, 1998).

Settlement in the James and Piankatank Rivers and on the Eastern Shore was lower during 2000 than during 1999. One possible explanation for low settlement in the Piankatank River is the bloom of the dinoflagellate Prorocentrum minimum that occurred in late spring, early summer (Old Dominion University, unpublished data). This dinoflagellate has been shown to have detrimental effect on oyster reproduction as well as larval development and survival (Luckenbach, et al., 1993). The Great Wicomico River was the only system that appeared to show an improvement in settlement from the previous year. The Great Wicomico had relatively low settlement during 1999, most likely due to high disease prevalence and a large die-off of small and market size oysters early in the spawning season (Calvo and Burreson, 2000). Added to that factor was the lack of broodstock on Shell Bar Reef (Figure S2), which has been shown to be an important area in terms of circulation and larval retention in the system (Southworth and Mann, 1998). Given these two factors, what appears to be an increase in spatfall during 2000, may just be a recovery from the mortality observed in the previous year combined with the added effect of broodstock on Shell Bar Reef.
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|      |      |
| JAMES RIVER            |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Deep Water Shoal       | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.7  |
| Horsehead              | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 2.3  |
| Point of Shoal         | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.7  |
| Swash                  | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 2.6  |
| Dry Shoal              | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 3.7  |
| Rock Wharf             | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 1.0  |
| Wreck Shoal            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.9  |
| Day's Point            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 4.3  |
| PIANKATANK RIVER       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Wilton Creek           | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 3.6  |
| Ginney Point           | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 6.8  |
| Palace Bar             | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 3.9  |
| Blund Point            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 2.7  |
| Heron Rock             | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 3.2  |
| Cape Toon              | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 1.2  |
| Stove Point            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 1.8  |
| Burton Point           | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 2.7  |
| GREAT WICOMICO         |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Glebe Point            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 4.2  |
| Rogue Point            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 2.6  |
| Hilly Wash             | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 3.2  |
| Harcum Flats           | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.8  |
| Hudnall                | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 1.0  |
| Shell Bar              | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.8  |
| Haynie Point           | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 1.1  |
| Whaley's East          | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.2  |
| Fleet Point            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.6  |
| EASTERN SHORE          |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Fisherman Island N     | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 9.9  |
| Fisherman Island S     | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 7.2  |
| Pungoestegue           | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 0.2  |
| Wachapregue            | D    |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      | 1.9  |

D: Date deployed  
N: String was lost (no data).  
- - : String not collected during that week.
### Table 2: Spatial Totals at the Historical Sites for the Years 1990-1999 and the Means for 1990-1999 and 1995-1999

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*+* indicates directional change in 2000 in reference to 1999 and to the 5 and 10 yr. means.

NC: No change
Figure S1: Map showing the location of the 2000 shellstring sites including those sites in the 3 western tributaries and on the Eastern Shore. Numbers in the blown up maps of the Piankatank and Great Wicomico Rivers are represented by the closed black circles on the big map. An “N” following the site name indicates a new site as specified in the text; all other sites are historical.


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

Lynnhaven River: 1) Lynnhaven River Reef.

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

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

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

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


Figure S3: Diagram of shellstring setup on buoys.
FIGURE S4: JAMES RIVER (2000) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL$^{-1}$

Day’s Point
- ■ - Rock Wharf
- ▲ - Dry Shoal
- ▼ - Point of Shoal
- x - Horsehead
- o - Deep Water Shoal
- © - Swash
- • - Wreck Shoal
FIGURE S5: SPATFALL TRENDS IN THE JAMES RIVER OVER THE PAST 10 YEARS
EXPRESSED AS CUMULATIVE WEEKLY SPATFALL

A

- - - - Wreck Shoal
- - - - Days Point
- - - - Dry Shoal
- - - - Rock Wharf

B

- - - - Deep Water Shoal
- - - - Horsehead
- - - - Point of Shoal
- - - - Swash
FIGURE S6: TEMPERATURE AND SALINITY TRENDS IN THE JAMES RIVER OVER THE PAST 5 YEARS COMPARED WITH 2000
(error bars represent standard error of the mean)

A

TEMPERATURE (°C)

B

SALINITY (PPT)

DAY OF THE YEAR

Period of settlement in 2000

Mean 95-99

2000

Period of settlement in 2000
FIGURE S7: PIANKATANK RIVER (2000) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL\(^{-1}\)

- Wilton Creek
- Bland Point
- Heron Rock
- Stove Point
- Burton Point
- Cape Toon
- Palace Bar
- Ginney Point
FIGURE S8: SPATFALL TRENDS IN THE PIANKATANK RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE WEEKLY SPATFALL
FIGURE S9: TEMPERATURE AND SALINITY TRENDS IN THE PIANKATANK RIVER OVER THE PAST 5 YEARS COMPARED WITH 2000
(error bars represent standard error of the mean)
FIGURE S10: GREAT WICOMICO RIVER (2000) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL$^{-1}$. Week was calculated from 1 January to 24 December. Spatfall intensity was calculated as the weekly number of spat per shell.$^{-1}$. The days of the year are represented on the x-axis, and the number of spat per shell.$^{-1}$ is represented on the y-axis.
FIGURE S11: SPATFALL TRENDS IN THE GREAT WICOMICO RIVER OVER THE PAST 10 YEARS EXPRESSED AS CUMULATIVE WEEKLY SPATFALL
FIGURE S12: TEMPERATURE AND SALINITY IN THE GREAT WICOMICO RIVER OVER THE PAST 2 YEARS COMPARED WITH 2000
(error bars represent standard error of the mean)

- **TEMPERATURE (°C)**
- **SALINITY (PPT)**

**Period of settlement in 2000**

**DAY OF THE YEAR**

- JUNE
- JULY
- AUGUST
- SEPTEMBER
FIGURE S13: EASTERN SHORE STATIONS (2000) WEEKLY SPATFALL INTENSITY EXPRESSED AS NUMBER OF SPAT SHELL$^{-1}$

- Wachapreague
- Fisherman Island N
- Fisherman Island S
- Pungoteague
FIGURE S14: SPATFALL TRENDS AT THE EASTERN SHORE STATIONS OVER THE PAST 5 (FISHERMAN ISLAND) TO 10 (WACHAPREAGUE) YEARS

- Fisherman Island N
- Fisherman Island S
- Wachapreague
FIGURE S15: TEMPERATURE AND SALINITY AT THE EASTERN SHORE STATIONS DURING THE 2000 SPAWNING SEASON

TEMPERATURE (°C)

SALINITY (PPT)

Settlement period (except at Pungoteague)

DAY OF THE YEAR

JUNE    JULY    AUGUST    SEPTEMBER
INTRODUCTION

The Eastern oyster, *Crassostrea virginica* (Gmelin 1791), has been harvested from Virginia waters as long as humans have inhabited the area. Depletion of natural stocks during the late 1880s led to the establishment of oyster harvesting regulations by public fisheries agencies. A survey of bottom areas in which oysters grew naturally was completed in 1896 under the direction of Lt. J. B. Baylor, U.S. Coast and Geodetic Survey. These areas (over 243,000 acres) were set aside by legislative action for public use and have come to be known as the Baylor Survey Grounds or Public Oyster Grounds of Virginia; they are presently under management by the Virginia Marine Resources Commission (VMRC).

Every year the Virginia Institute of Marine Science (VIMS) conducts a dredge survey of selected public oyster bars in Virginia tributaries of the western Chesapeake Bay to assess the status of the existing oyster resource. These surveys provide information about spatfall and recruitment, mortality, and changes in abundance of seed and market-size oysters from one year to the next. This section summarizes data collected during bar surveys conducted during October 2000.

Spatial variability in distribution of oysters over the bottom can result in wide differences among dredge samples. Large differences among samples collected on the same day from one bar are an indication that distribution of oysters over the bottom is highly variable. An extreme example of that variability can be found in Southworth et al. (1999) by the width of the confidence interval around the average count of spat at Horsehead (James River, Virginia) during 1998. Therefore, in the context of the present sampling protocol, differences in average counts found at one bar between seasons in the same year or between counts for the same season in different years may be the result of sampling variation rather than actual short-term changes in abundance. If the observed changes persist for several years or can be attributed to well-documented physiological or environmental factors, then they may be considered a reflection of actual changes in abundance with time.

METHODS

Location of the oyster bars sampled by VIMS during October 2000 are shown in Figure D1. Geographic coordinates of the bars are given in Table D1.

Four samples of bottom material were collected at a single station on each bar using an oyster scrape dredge. In all surveys preceding 1995, sampling was effected using a 2-ft wide dredge with 4-in teeth towed from a 21-ft boat; volume collected in the dredge bag was 1.5 bushels. Beginning in 1995, samples were collected using a 4-ft dredge with 4-in teeth towed from the 43-ft long VMRC vessel J. B. Baylor; volume collected in the bag of that dredge is three bushels. In all surveys a half-bushel (25 quarts) subsample was taken from each tow for examination. Data presented give the average of the four samples collected at each station for live oyster and box counts after conversion to a full bushel.

From each half bushel sample, the number of market oysters (76 mm (3-in), in length or larger), small oysters (< 76 mm (3-in), excluding spat), spat (recently settled (2000 recruits)), new boxes (inside of shells perfectly clean; presumed dead for approximately < 1 week), old boxes, and spat boxes were counted. The presumed time period since death of an oyster associated with the two categories of boxes is a qualitative description based on visual observations.

During spring and early summer 2000, the following changes that may have had some effect on settlement and oyster abundance were made
Molluscan Ecology Program, Virginia Institute of Marine Science

(Figure D1 and D2 for locations). Seed was removed from Palace Bar, Burton Point, Bland Point, Cape Toon, and Heron Rock in the Piankatank River and moved to several different bars throughout the Chesapeake Bay including Morattico Bar in the Rappahannock River. Clean shells (culch) were then planted on the five bars (listed above) in the Piankatank River and on Shell Bar, Harcum Flats, Rogue Point, and Hilly Wash in the Great Wicomico River to provide substrate for oyster larvae to settle on. Six new artificial oyster reefs were built in the Rappahannock River at Sturgeon Bar, Mill Creek, Parrot Rock, Temple Bay, Drumming Ground, and Ferry Bar. The reefs at Broad Creek and Butler’s Hole (Figure D2) are slated to be built in spring, 2001. Culch was planted around the Parrot Rock and Drumming Ground Reefs. Prior to this, Drumming Ground was completely cleaned of oysters (all sizes) and for that reason is treated as a “new” site in the 2000 data. The oysters from Drumming Ground were then transplanted to Parrot Rock and Middle Ground. In addition, broodstock oysters were planted on the artificial reefs at Iron Point, Palace Bar, Burton Point, and Bland Point in the Piankatank River and on Shell Bar Reef in the Great Wicomico River. In mid 1999 an artificial oyster reef was built in the York River in Felgates Creek and 2 reefs were built in Mobjack Bay: one in the North River (Cradle Point) and one in the East River (Mobjack Point). A third reef was built in the Ware River during 2000. Temperature (in degrees Celsius) and salinity (in ppt, parts per thousand) were recorded at each of the dredge stations at the time of sampling using an alcohol thermometer and a hand-held refractometer.

RESULTS

Thirty oyster bars were sampled between October 10 and 26, 2000, in six of the major Virginia tributaries on the western shore of the Chesapeake Bay. Bar locations are shown in Figure D1 and Table D1. It should be noted that Bell Rock in the York River is a private bar and is included in this report for historical reasons. Results of this survey are summarized in Table D2 and unless otherwise indicated, the numbers presented below refer to that table.

James River

Ten bars were sampled in the James River, between Nansemond Ridge at the lower end of the river and Deep Water Shoal near the uppermost limit of oyster distribution in the system. The highest average number of oysters bushel\(^{-1}\) of all sizes was found at Horsehead (681), as has been the case for the past several years excluding 1998. The number of oysters at Swash, Point of Shoal, and Long Shoal was moderate ranging from 413 to 487 oysters bushel\(^{-1}\). Total number of oysters at all other bars was relatively low averaging less than 250 bushel\(^{-1}\), with a range of 33 (Dry Shoal) to 218 (Mulberry Point) total oysters bushel\(^{-1}\).

As has been the case during the past few years, the number of market oysters in the James River continues to be low, with the majority of them being found at the most upriver sites (Figure D1). The number of market oysters at the five most upriver sites (Figure D1) ranged between 11 (Swash) and 36 bushel\(^{-1}\) (Deep Water Shoal) whereas the five down river stations had considerably fewer market oysters ranging between zero (Dry Shoal) and 7 (Wreck Shoal) bushel\(^{-1}\). Comparing the data for the numbers of market oysters over the past four years (1997-2000) there appears to be little change at most of the sites monitored (Figure D3, D4A, and D4B). There was a noticeable increase in market oysters at Horsehead from 1997 to 1998 and this trend does appear to be real. There has been a steady decrease in the number of market oysters at Horsehead from 1997 to 1998 and this trend was observed at Dry Shoal and Long Shoal during the past four years (Figure D3). The number of market oysters at Dry Shoal was low but stable for three years in a row until 2000, when it dropped to zero market oysters bushel\(^{-1}\).

The number of small oysters bushel\(^{-1}\) ranged from a low of 14 (Thomas Rock) to a high of 615 (Horsehead). The composition of the oyster populations at all of the sites except Thomas Rock and Nansemond Ridge was made up of greater than 50% small oysters. Horsehead and Long Shoal had the greatest percentage of small oysters at a little over 90% of the total. While the number of small oysters found at
Nansemond Ridge continues to be low, there has been a noticeable increase at the site during the past few years (Figures D3 and D4A). Similar to the change in the number of market oysters at Dry Shoal, there was also a noticeable decrease in small oysters at that site between 1999 and 2000 (Figure D3 and D4B). There has been very little change in numbers of small oysters at any of the other sites during the past few years.

The number of spat bushel^-1 ranged from a low of 11 (Dry Shoal) to a high of 88 (Nansemond Ridge). The number of spat found throughout the system in 2000 was relatively low. There was a noticeable decrease between 1999 and 2000 in the number of spat bushel^-1 seen at all of the sites except Deep Water Shoal and Horsehead (Figure D3; Figure D4A and B). As has been observed in the James River in the past, there is a relationship between location in the river and the composition of live oysters in terms of percentage of oysters found in each size class. As one moves from the most upriver station (Deep Water Shoal) to the most downriver station (Nansemond Ridge; Figure D1), the percentage of small oysters tends to decrease while the percentage of spat tends to increase.

The average number of boxes bushel^-1 ranged from a low of eight (Thomas Rock) to a high of 96 (Dry Shoal). At Dry Shoal and Wreck Shoal, boxes accounted for over 23% of the total oysters found (live and dead). At the remaining eight stations between 10 and 18% of the total number of oysters were boxes. On Dry Shoal, 32% of the total number of oysters (live and dead) were boxes. The high percentage of boxes may account for the overall low number of oysters recorded at that site during 2000.

Water temperature during the sampling period remained fairly constant ranging from 17.4 to 18.6 degrees Celsius (Table D2). Salinity was more variable depending on location in the river, increasing in a downriver direction, from 11 ppt at Deep Water Shoal to 17 ppt at Thomas Rock and Nansemond Ridge.

York River

The average total number of live oysters bushel^-1 in the York River were similar for both bars sampled (61 at Aberdeen Rock, 88 at Bell Rock). The oysters found at Aberdeen were predominately small oysters (86% of total), while the oysters at Bell Rock were about a 50/50 split of small and spat, with a slightly higher percentage of spat. There has been a steady increase in the number of small oysters at Aberdeen Rock during the past few years (Figure D5 & D6). There was also a noticeable decrease in the number of spat between 1999 and 2000 at that site. Market oysters were scarce at both bars, accounting for 1 and 18% of the total live oysters at Aberdeen Rock and Bell Rock respectively. The total number of boxes (new and old) bushel^-1 was low at both bars sampled in the river. Water temperature at both stations was 18.9 degrees Celsius on the day of sampling. There was a 5 ppt difference in salinity, 14 ppt at Bell Rock and 19 ppt at Aberdeen Rock.

Mobjack Bay

The average total number of live oysters bushel^-1 in Mobjack Bay was 32 at Pultz Bar and 185 at Tow Stake. Pultz Bar oysters consisted of approximately 50% spat, with the other 50% being an equal mix of small and market size oysters. There was a noticeable decrease in the number of small and market oysters and a slight increase in the number of spat at Pultz Bar compared with 1999 (Figure D5 and D6). Overall the total number of oysters found at Pultz Bar continues to be low. The composition of live oysters at Tow Stake consisted of a 50/50 mixture of small oysters and spat, with very few market size oysters. There was little difference in any size category at Tow Stake between 1999 and 2000. However, the number of market oyster has been consistently increasing for the past few years and the increase in spat observed during 1998 appears to be sustained. The total number of boxes was relatively high, making up 18 and 32% of the total number of oysters found (live and dead) at Tow Stake and Pultz Bar respectively. In contrast to the 1999 dredge survey (Southworth et al., 2000), there were
fewer boxes attributed to oyster drills in the fall 2000 sampling. Water temperature at both stations was 21.1 degrees Celsius on the day of sampling. There was a 1 ppt difference in salinity, 17 ppt at Pultz Bar and 18 ppt at Tow Stake.

**Piankatank River**

The average total number of live oysters bushel\(^{-1}\) in the Piankatank River was moderate at Palace Bar (457) and low to moderate at Burton Point (181) and Ginney Point (371). The number of market size oysters at all three stations was relatively low. There was approximately a 50/50 mixture of spat and small oysters on all 3 bars, with a slightly higher percentage of small being found at Ginney Point and Burton Point and slightly higher percentage of spat being found at Palace Bar. As such, there was a noticeable increase in small oysters and a noticeable decrease in the number of spat at all three sites (Figure D7 and D8) between 1999 and 2000. There was also a slight decrease between 1999 and 2000 of market oysters at all of the sites. There were a relatively high number of boxes at Ginney Point (147) accounting for 28% of the total oysters (live and dead) sampled. The number of boxes at Palace Bar and Burton Point were moderate, accounting for 11 and 18% of the total respectively. On the day of sampling, water temperature at all three sites was 17.5 degrees Celcius and salinity ranged from 13 to 15 ppt (Table D2).

**Rappahannock River**

The average total number of live oysters in the Rappahannock River was low at all nine stations sampled (disregarding Drumming Ground since it was cleaned of oysters in spring 2000 and is now considered a “new” site) ranging from 3 (Hog House) to 239 (Middle Ground) bushel\(^{-1}\). As mentioned in the Methods section, Middle Ground was seeded with oysters in spring 2000, which probably accounts for the relatively high (when compared with the other sites in the river) number of oysters found there. There appears to be no relation between the total number of live oysters and location in the river (i.e. upriver vs. downriver: Figure D1), temperature, or salinity (Table D2). Small oysters made up the highest percentage of oysters at all of the sites ranging from 60 to 94% of the total.

As has been found for the past few years, Broad Creek had the most market oysters with 27 bushel\(^{-1}\). Broad Creek also had the most small oysters (115 bushel\(^{-1}\)) of any of the bars not seeded with oysters in spring 2000 (see Methods). There were little or no spat found at most of the sites sampled. The two sites with the most spat are located near the mouth of and in the Corrotoman River (Drumming Ground and Middle Ground: Figure D1) which had 14 and 16 spat bushel\(^{-1}\) respectively.

There was a noticeable decrease in spat seen at all nine sites (Drumming Ground was not included in the analysis) when compared with 1999 (Figures D9, D10A, and D10B). Long Rock, Smokey Point, and Broad Creek showed a noticeable increase in the number of small oysters compared to 1999, while Ross Rock and Hog House showed a decrease (Figure D9). The decrease in market oysters at Broad Creek seen in 1999, the first in six years at this site, held steady between 1999 and 2000 (Figure D10A). There has been a steady decrease in market oysters at Bowlers Rock over the past few years and a decrease between 1999 and 2000 at Hog House, Long Rock, and Ross Rock.

The number of boxes bushel\(^{-1}\) (new and old) ranged from 1 (Ross Rock and Hog House) to 55 (Smokey Point). A moderate percentage of oysters (live and dead) at all of the stations sampled except Ross Rock were boxes (16 to 33%). There were no spat boxes found at any of the sites.

Water temperature on the day of sampling ranged from 17.2 to 18.3 degrees Celsius. Salinity increased moving from the most upriver station (Ross Rock: 8 ppt) toward the mouth (Broad Creek: 20 ppt).
Great Wicomico River

The average total number of live oysters at all three stations sampled in the Great Wicomico River was low ranging from 68 bushel\(^{-1}\) (Whaley’s East) to 92 bushel\(^{-1}\) (Fleet Point). The live oysters found were predominately small, accounting for 75% (Haynie Point), 81% (Fleet Point), and 84% (Whaley’s East) of the total. This predominance was coupled with a noticeable increase in small oysters and a noticeable decrease in spat at all three stations when compared with 1999 (Figures D11 and D12). There was no difference in the number of market oysters at any of the sites between 1999 and 2000. There appears to be no pattern in any size class at any of the sites observed over the past few years (Figure D11). Boxes made up 29% (Haynie Point) to 39% (Whaley’s East) of the total (live and dead) oysters counted. The total number of boxes was about half the number of live oysters at all three sites. As observed in past years, greater than 88% of the boxes were old. Water temperature was between 17.5 and 18.3 degrees Celsius and salinity was between 19 and 20 ppt on the day of sampling.

DISCUSSION

As is well known, the abundance of market oysters throughout the Chesapeake Bay region has been in serious decline since the turn of the century. In recent years the greatest concentration of market oysters on Virginia public grounds has been found at the upper limits of oyster distribution (lower salinity areas) in the James River and Rappahannock River, with the exclusion of Broad Creek in the Rappahannock River. Presently, the abundance of market oysters in the Virginia tributaries of the Chesapeake remains low. Of the Virginia bars sampled during the 2000 survey, the highest number observed was 36 market oysters bushel\(^{-1}\) (Deep Water Shoal). At the bars where the total number of live oysters was greater than 100 bushel\(^{-1}\), market oysters constituted between 1 and 18% of that total.

As in recent years, the bulk of the oyster population during 2000 consisted primarily of small oysters. Thomas Rock and Nansemond Ridge in the lower James River, Bell Rock in the York River, Pultz Bar in Mobjack Bay, and Palace Bar in the Piankatank River, were the only bars with a higher percentage of spat than small oysters. The oyster populations at the other 25 sites all had a greater percentage of small oysters, with the exception of Ginney Point in the Piankatank, which had a 50/50 mixture of small and spat. Similar to historical patterns of oyster abundance in the James River, as one moves toward the mouth, the number of spat increases while the number of small oysters decreases. Circulation in the system is such that oyster larvae from the upper limits of oyster abundance (lower salinity areas) are flushed further down river to set at the higher salinity sites (Haven and Fritz, 1985). One would expect that over time this would translate into an increase in small and market oysters at the higher salinity sites. The most likely explanation for why this does not appear to be the case is disease. Both *Perkinsus marinus* and *Haplosporidium nelsoni* increase in intensity and prevalence as salinity increases (Calvo and Burreson, 2000).

The 1998 dredge survey in the James River showed an increase in spat from the previous year. In general this increase was not observed again during 1999 or 2000 (there was an even further decrease between 1999 and 2000), nor was it reflected in the number of small oysters observed. As discussed in the 1998 dredge report (Southworth et al., 1999), one must look at the timing of set when interpreting the data. In years when spatfall occurs earlier (as in 1999 and 2000), the natural mortality that occurs post-settlement occurs over a longer time frame (in terms of time from set to sampling). For example, say overall 1000 spat bushel\(^{-1}\) set during both years. However during 1999 they didn’t all set until the end of September, whereas during 2000, they were all set by the end of August, creating a difference of one-month post-settlement mortality time. Assuming a mortality rate of 50% each month, by sampling time during 2000 there would be 500 spat bushel\(^{-1}\), whereas during 1999 there would only be 250 spat bushel\(^{-1}\). During 1998, the majority of the spatfall occurred later in the season (September),
allowing for less time for post-settlement mortality to occur. Given the lack of an increase in small oysters and spat in both the 1999 and 2000 samples, the apparent increase in spatfall recorded in the 1998 samples was most likely not a true increase in spat, but rather a discrepancy due to a change in temporal scale.

Overall, oyster settlement on all of the bars sampled during 2000 was low, much lower than that recorded during 1999. One possible explanation for the lack of spatfall, in comparison to 1999 could be temporal changes in timing of the set, as previously mentioned. Settlement on the shellstrings during 2000 occurred earlier in the year than usual in the James, Piankatank, and Great Wicomico Rivers. Another component that may have caused low settlement during 2000 could have been the bloom of the dinoflagellate *Prorocentrum minimum*. This dinoflagellate bloom occurred in late spring/early summer, in the upper reaches of several of the tributaries of the Chesapeake Bay including the Piankatank and Great Wicomico Rivers (Old Dominion University, unpublished data). This dinoflagellate has been shown to limit spawning in adult oysters and can impair larval development causing high mortalities in larval cultures (Luckenbach et al., 1993). Other factors could also have been involved such that 1999 was simply an unusually good year for spatfall. Salinity during 1999 was 4 to 6 ppt higher than normal throughout most of the spawning season (Southworth et al., 2000) and while temperature is thought to have a greater role in spawning success and timing, salinity can also have an effect (Thompson et al., 1996). The combination of average temperatures and high salinity throughout most of the season during 1999 may have acted together to produce exceptionally favorable spawning conditions.

There was a noticeable increase in the number of small oysters observed at all of the bars sampled in both the Piankatank and Great Wicomico Rivers. This is promising for those rivers in that it means survival of the 1999 spat was relatively high. Given that seed/oysters were removed from several bars (see above for details), survival of the 1999 spat was probably even higher than the numbers suggest. The number of market oysters in the Piankatank River decreased for the first time in five years. This decrease was also probably a result of seed/oyster removal during spring 2000. Over the past several years, there has been a steady increase in oyster populations in both the Piankatank and Great Wicomico Rivers (Mann, 2000). This may be due to the building of three-dimensional reefs (beginning in 1993 in the Piankatank and 1996 in the Great Wicomico). Studies of Palace Bar Reef in the Piankatank, showed that three-dimensional reefs enhance oyster survival (Mann et al., 1996). In another study of artificial oyster reefs in the Great Wicomico River it was found that broodstock enhancement on a reef, gives the reef a “jump start” in terms of producing a viable, active spawning oyster population (Southworth and Mann, 1998). The data collected in both the Piankatank and Great Wicomico Rivers over the past few years tend to suggest that the first year after broodstock addition is the most productive year in terms of the amount of spatfall. However, with continued broodstock addition and oyster shell plants in surrounding areas in subsequent years, the reefs can produce favorable numbers of larvae and hence spat (in comparison to pre-reef/pre-broodstock conditions). The decrease in spatfall during 2000 is hopefully a reflection of poor setting conditions (i.e. harmful phytoplankton populations, low oxygen content, etc.) and not an indication that the artificial reefs are only capable of sustaining viable oyster populations for a few years. The historical implications of the success of oyster reefs throughout the Chesapeake Bay region suggest that spawning/setting conditions during 2000 were simply poor.

On the positive side, there was a relatively low number of boxes bushel⁻¹ at most of the bars during 2000 when compared with 1999. During 1999, as high as 58% of the total number of oysters (live and dead) consisted of boxes, whereas 39% of the total was the highest recorded during 2000. The relatively high numbers of boxes observed in the Piankatank and Great Wicomico Rivers, especially in the upper reaches of the Piankatank, were most likely due to the dinoflagellate (*P. minimum*) bloom mentioned.
earlier. In hatchery experiments bloom densities of *P. minimum* were shown to cause 100% mortality by day 14 of the bloom (Luckenbach et al., 1993). The overall number of spat boxes recorded during 2000 decreased when compared with 1999, especially at Tow Stake in the Mobjack Bay and Burton Point in the Piankatank River. In contrast to 1999, there were no spat boxes found with gastropod bore holes in them at Tow Stake. However at Burton Point, the percentage of the total spat boxes found to have small holes in them remained relatively high similar to 1999. These holes were most likely caused by the oyster drills *Urosalpinx cinera* and *Eupleura caudata* which are common in the lower Chesapeake Bay. Both of these species have been shown to be voracious predators of oyster spat causing mortality throughout most of the Chesapeake Bay up until the occurrence of Hurricane Agnes (1972) which wiped them out in all but the lower reaches of the James River and mainstem Bay (Carriker, 1955; Haven, 1974). However, individuals of both of these species and drill eggmasses have been found in recent years in the mouths of the Piankatank and Rappahannock Rivers, including some in both the 1999 and 2000 dredge samples.
<table>
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<th>STATION</th>
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<th>LONGITUDE</th>
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<tr>
<td>Mulberry Point</td>
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<td>76 37 55</td>
</tr>
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<td>76 36 14</td>
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<td>Wreck Shoal</td>
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## TABLE D2
### RESULTS OF THE VIRGINIA PUBLIC OYSTER GROUNDS DREDGE SURVEY
#### FALL 2000

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<th>Station</th>
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</table>

* Private Bar
** Located in the Corrotoman River (part of the Rappahannock River system)
# Based on only 3 samples
N/A Not applicable; Bar was cleaned of seed and new shell planted in spring, 2000
Figure D1: Map showing the location of the oyster bars sampled during the 2000 dredge survey. Numbers in the blown up maps of the Piankatank and Great Wicomico Rivers represent the closed black circles on the big map.


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


The Status of Virginia's Public Oyster Resource 2000
Figure D2: Map showing the location of the artificial oyster reefs in the Virginia portion of the Chesapeake Bay.

Lynnhaven River: 1) Lynnhaven River Reef.

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

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


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


FIGURE D3: COMPARISON OF OYSTER ABUNDANCE IN THE JAMES RIVER 1997-2000
(error bars represent standard error of the mean)

Average number of oysters per bushel.

- MARKET
- SMALL
- SPAT

Sites:
- Deep Water Shoal
- Mulberry Point
- Horsehead
- Point of Shoal
- Long Shoal
- Dry Shoal
- Wreck Shoal
- Nansemond Ridge
FIGURE D4A: JAMES RIVER OYSTER TRENDS OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)
FIGURE D4B: JAMES RIVER OYSTER TRENDS OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

- Horsehead
- Deep Water Shoal
- Point of Shoal
- Mulberry Point
- Long Shoal

MARKET

AVERAGE NUMBER OF OYSTERS BU⁻¹

SMALL

SPAT

YEAR

90 91 92 93 94 95 96 97 98 99 00
FIGURE D5: COMPARISON OF OYSTER ABUNDANCE IN THE YORK RIVER AND MOBJACK BAY 1997-2000
(error bars represent standard error of the mean)

- MARKET
- SMALL
- SPAT

- Bell Rock (York)
- Aberdeen Rock (York)
- Pultz Bar (Mobjack)
- Tow Stake (Mobjack)
FIGURE D6: YORK RIVER AND MOBJACK BAY OYSTER TRENDS OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

- - - - - Bell Rock (York)  - - - - - Pultz Bar (Mobjack)
- - - - Aberdeen Rock (York) - - - - Tow Stake (Mobjack)

MARKET

SMALL

SPAT

AVERAGE NUMBER OF OYSTER BU$^{-1}$

YEAR

90 91 92 93 94 95 96 97 98 99 00
FIGURE D7: COMPARISON OF OYSTER ABUNDANCE IN THE PIANKATANK RIVER 1997-2000
(error bars represent standard error of the mean)

MARKET

SMALL

SPAT

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

MARKET

AVERAGE NUMBER OF OYSTERS BU$^{-1}$

YEAR

90 91 92 93 94 95 96 97 98 99 00

SMALL

SPAT
FIGURE D9: COMPARISON OF OYSTER ABUNDANCE IN THE RAPPAHANNOCK RIVER 1997-2000 (error bars represent standard error of the mean)

- **MARKET**
  - 1997
  - 1998
  - 1999
  - 2000

- **SMALL**
  - 1997
  - 1998
  - 1999
  - 2000

- **SPAT**
  - 1997
  - 1998
  - 1999
  - 2000

**Locations:**
- Ross Rock
- Bowlers Rock
- Long Rock
- Morattico Bar
- Smokey Point
- Hog House
- Middle Ground
- Parrot Rock
- Broad Creek

**Abundance Measurements:**
- BUSHEL$^{-1}$
- NUMBER OF OYSTERS
- AVERAGE SPAT
FIGURE D10A: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

- Broad Creek
- Hog House
- Middle Ground
- Parrot Rock
- Drummimg Ground

AVERAGE NUMBER OF OYSTERS BU\(^{-1}\)

YEAR

90 91 92 93 94 95 96 97 98 99 00
FIGURE D10B: RAPPAHANNOCK RIVER OYSTER TRENDS OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

- Morattico Bar
- Bowling Rock
- Ross Rock
- Long Rock
- Smokey Point

AVERAGE NUMBER OF OYSTERS BU\(^{-1}\)

YEAR

90 91 92 93 94 95 96 97 98 99 00
FIGURE D11: COMPARISON OF OYSTER ABUNDANCE IN THE GREAT WICOMICO RIVER 1997-2000
(error bars represent standard error of the mean)

MARKET

SMALL

SPAT

Haynie Point Whaley's East Fleet Point
FIGURE D12: GREAT WICOMICO RIVER OYSTER TRENDS OVER THE PAST 10 YEARS
(error bars represent standard error of the mean)

- Fleet Point
- Haynie Point
- Whaley's East

MARKET

AVERAGE NUMBER OF OYSTER BU-1

SMALL

SPAT

YEAR
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REFERENCES


