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The Status of Virginia's Public Oyster Resource 2016

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Part I. OYSTER RECRUITMENT IN VIRGINIA DURING 2016

INTRODUCTION

The Virginia Institute of Marine Science (VIMS) monitors recruitment of the Eastern oyster, *Crassostrea virginica* (Gmelin, 1791), annually from late spring through early fall, by deploying spatfall (settlement of larval oysters called spat) collectors (shellstrings) at various sites throughout Virginia's western Chesapeake Bay tributaries. The survey provides an estimate of a particular area's potential for receiving a "strike" or settlement (set) of oysters on the bottom and helps describe the timing of settlement events in a given year. Information obtained from this monitoring effort provides an overview of long-term recruitment trends in the lower Chesapeake Bay and contributes to the assessment of the current oyster resource condition and the general health of the Bay. These data are also valuable to parties on both the public side (Virginia Marine Resources Commission (VMRC), Shellfish Replenishment Division) and private industry who are interested in potential timing and location of shell plantings in order to optimize recruitment of spat on bottom cultch (shell that is available for larvae to settle on).

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

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

This report summarizes data collected during the 2016 settlement season in three tributaries in the Virginia portion of the Chesapeake Bay.

METHODS

Settlement during 2016 was monitored in the James, Piankatank and Great Wicomico Rivers from the last week of May (all three rivers) through the last week of September (James River) and the first week of October (Piankatank and Great Wicomico Rivers). Settlement sites included eight historical sites in the James River, three historical and five modern sites in the Piankatank River and five historical and four modern sites in the Great Wicomico River (Figure S1). In this report, "historical" sites refer to those that have been monitored annually for at least the past twenty-five years whereas "modern" sites are sites that were added during 1998 to help monitor the effects of replenishment efforts by the Commonwealth of Virginia. The modern sites in both the Piankatank and Great Wicomico Rivers correspond to those sites that were considered "new" in the 1998 survey. From 1993 through the early 2000s, VMRC built numerous artificial oyster shell reefs in several tributaries of the western Chesapeake Bay as well as in both Pocomoke and Tangier Sounds on the eastern side of the Chesapeake Bay (http://www.vims.edu/research/units/labgroups/ molluscan_ecology/restoration/va_restoration_atlas/index.php). The change in the number and location of shellstring sites during 1998 was implemented to provide a means of quantitatively monitoring oyster spatfall around some of these reefs. In particular, broodstock oysters were planted on a reef in the Great Wicomico River during winter 1996-97 and on reefs in the Piankatank and Great Wicomico Rivers during winter 1997-98. The increase in the number of shellstring sites during 1998 in the two rivers coincided with areas of new shell plantings in spring 1998 and provided a means of monitoring the reproductive activity of planted broodstock on the artificial oyster reefs. Since 1998, many of the reefs and bottom sites in the Piankatank and Great Wicomico Rivers have received shell plants on the bottom surrounding the reefs.

Oyster shellstrings were used to monitor oyster settlement. 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 the substrate) on heavy gauge wire (Figure S2). Throughout the monitoring period, shellstrings were deployed approximately 0.5 m (18-in) off the bottom at each site. Shellstrings were usually replaced after a one-week exposure and the number of spat that attached to the smooth underside of the middle ten shells was counted under a dissecting microscope. To obtain the mean number of spat shell^{-1} for the corresponding time interval, the total number of spat observed was divided by the number of shells examined (ten shells in most cases).

Although shellstring collectors at most sites were deployed for 7-day periods, there were some weather related deviations such that shellstring deployment periods during 2015 ranged from 7 to 14 days. These periods do not always coincide among the different rivers monitored or in different years. Therefore, spat counts for different deployment dates and periods were standardized to correspond to the 7-day standard periods specified in Table 1 to allow for comparison among rivers and years. Standardized spat shell^{-1} (S) was computed using the formula: $S = \sum$ spat shell^{-1} / weeks (W) where W = number of days deployed / 7. Standardized weekly periods allow comparison of settlement trends over the course of the season between various sites in a river as well as between data for different years.

The cumulative settlement for each site was computed by adding the standardized weekly values of spat shell^{-1} for the entire sampling period. This value represents the average number of spat that would fall on any given shell if allowed to remain at that site for the entire sampling period. Note this assumes that the shell would remain clean and relatively unfouled by other organisms, which is typically not the case when shells are planted on the bottom. Spat shell^{-1} values were categorized for comparison purposes as follows: 0.10-1.00, light; 1.01-10.00, moderate; 10.01 to 100.0, heavy; 100.01 or more, extremely heavy. Unqualified references to diseases in this text imply the two oyster diseases found in the bay, *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (*Perkinsus*, or Dermo).

Water temperature (°C) and salinity measurements were taken approximately 0.5 m off the bottom at all sites on a weekly basis using a handheld electronic probe (YSI Pro2030).

RESULTS

Settlement on shellstring collectors during 2016 is summarized in Table S1 and is discussed below for each river system monitored. Table S2 includes a summary of settlement over the past twenty-five years (1991-2016) at the historical sites in all three-river systems and over the past eighteen years (1998-2016) for the modern sites (as discussed in the methods) in the Piankatank and Great Wicomico Rivers. Unless otherwise specified, the information presented below refers to those two tables. In this report the term "peak" is used to define the period when there was a notable increase in settlement at a particular site or area in the system compared with the other sites or when there was an increase at all sites throughout an entire river system.

When comparing 2016 data with historical data in the James River, all eight sites were used. All of the sites monitored in the James River are considered to be part of the traditional seed area. Historically seed oysters were transplanted from this area to other tributaries in the Chesapeake Bay where recruitment was low (Haven & Fritz 1985). Due to the addition of sites (modern) during 1998 in the Piankatank and Great Wicomico Rivers, any comparison made to historical data could not include data from all of the sites monitored during 2016. Comparisons were made over the past eighteen years for the modern sites whereas the historical sites include twenty-five years of data. Historical sites in the Piankatank River are Burton Point, Ginney Point and Palace Bar. Historical sites in the Great Wicomico River include Fleet Point, Glebe Point, Haynie Point, Hudnall and Whaley's East (labeled Cranes Creek in reports prior to 1997).

James River

Oyster settlement in the James River was first observed during the week of 10 June at four out of the eight sites monitored (Table S1). Settlement occurred throughout the rest of the recruitment period, with at least one spat settling every week at each site (with the exception of Deep Water Shoal during two weeks in mid-July). Settlement during the first two weeks of July accounted for around 69% of the total settlement observed in the river for the year (Figure S3). At both Dry Shoal and Wreck Shoal, settlement during this two-week period accounted for 83% of the total settlement observed in 2016. The largest peak in settlement at Deep Water Shoal occurred a little later than at the other sites, with 41% of the total for the year occurring during the week of 19 August.

Cumulative settlement in the James River during 2016 was heavy at Deep Water Shoal, Horsehead, Point of Shoal, Rock Wharf and Day's Point and extremely heavy at Swash, Dry Shoal and Wreck Shoal. Settlement ranged from a low of 19.5 cumulative spat $shell^{-1}$ at Deep Water Shoal to a high of 149.3 cumulative spat $shell^{-1}$ at Wreck Shoal (Table S1; Figure S4). Settlement during 2016 was higher than the previous year (2015) at Deep Water Shoal, Horsehead, Swash, Dry Shoal and Wreck Shoal. Settlement in 2016 was higher than the five-year mean at seven out of the eight sites (the exception was Day's Point) and higher than the ten-year mean at Horsehead, Swash, Dry Shoal and Wreck Shoal. Settlement was also higher than both the 20 and 25-yr mean at six and seven out of the eight sites, respectively. The exceptions were no change in settlement at Deep Water Shoal compared with the 20-yr mean and lower settlement at Day's Point when compared with both the 20 and 25-yr means. Overall, settlement in the James River during 2016 was in the upper range of that observed during the past twenty-five years of monitoring (second highest at Swash and Wreck Shoal;

third highest at Horsehead; fourth highest at Deep Water Shoal; fifth highest at Point of Shoal and Rock Wharf; sixth highest at Dry Shoal). The long-term means are primarily driven by a few exceptionally high settlement years (1991, 1993, 2002, 2008, 2010 and 2012).

Average river water temperatures in the James River during the 2016 monitoring period ranged from a low of 20.2 to a high of 30.7°C (Figure S5A). Prior to reaching the maximum for the season in the third week of July, water temperature was similar to the long-term means (5, 10, 20 and 25-yr; Figure S5) for the system. The temperature maximum for the season was around 3°C higher than the long-term means and after reaching the maximum for the season water temperature remained 1 to 3°C higher than the long-terms means throughout most of the rest of the sampling period (Figure S5A).

Average salinities in the James River ranged from 4.8 to 15.9, generally increasing over the course of the sampling period (Figure S5B). However, due to significant rain events there were several periods when average salinity decreased 1 to 2 from one week to the next, such that there was anywhere from a 3 to 5 difference in salinity when compared with the 5, 10, 20 and 25-yr means. The two most notable periods when this occurred was during the weeks of 3 June and 1 July (Figure S5B). Following the second rain event in early July, salinity in the James made a remarkable recovery increasing from an average of 7.0 on 1 July to an average of 14.7 by 22 July. However, salinity then decreased again and was 1 to 3 lower than the long-term means during the last week of July into the first part of August. Salinity increased toward the end of the sampling period such that it remained 1 to 2 higher than the long-term means during the last few weeks of the sampling period. Throughout the sampling period, the difference in salinity between the most upriver site (Deep Water Shoal) and the most downriver sites (Day's Point and/or Wreck Shoal; Figure 1) ranged between 5 and 12.

Piankatank River

Settlement in the Piankatank River was first observed during the week of 10 June at Wilton Creek, Ginney Point and Bland Point (Table S1; Figure S6). Settlement was relatively consistent (at least one spat at each of the sites in any given week) throughout the system from the week of 24 June through the rest of the monitoring period. There was a large peak in settlement observed throughout the system, during the weeks of 1 July and 8 July. Settlement during this two-week period accounted for approximately 90% of the total settlement observed on the shellstrings during the monitoring period (Figure S6).

Cumulative spat shell^{-1} for the year was heavy at Ginney Point and extremely heavy at the other seven sites, ranging from a low of 64.1 at Ginney Point to a high of 815.0 at Bland Point (Table S1). It should be noted that the shellstring at Ginney Point was lost during the week of 1 July, which as previously mentioned was one of two weeks in which peak settlement occurred in the system. This is most likely why settlement at this site in 2016, while heavy was not as heavy as what was observed throughout the rest of the system. Settlement during 2016 was higher than that observed during 2015 and higher than the 5-yr mean at every site except Ginney Point and Cape Toon and higher than the 10-yr mean at all eight sites monitored. Settlement at the three historical sites was also higher than the 20 and 25-yr means (Table S2; Figure S7A). Settlement during 2016 was the highest recorded over the past twenty-five years of monitoring at Burton Point. Settlement at Palace Bar was the second highest recorded over the past twenty-five years. Even at Ginney Point, despite missing the count from one of the two weeks when peak settlement occurred, cumulative settlement during 2016 was the fourth highest recorded over the past twenty-five years of monitoring. At the modern sites, settlement during 2016 ranked the highest (Bland Point, Heron Rock and Stove Point), second highest (Wilton Creek) and fifth highest (Cape Toon) observed since monitoring began at those sites in 1998. Settlement in 2016 at Bland Point was twice as high as the next highest settlement year (2015).

The average water temperature during the 2016 sampling period in the Piankatank River ranged from 20.2 to 30.7°C (Figure S8A). Water temperature in the Piankatank River was similar (within 1°C) to the long-term means (5, 10, 20 and 25-yr) from late May through early July (Figure S8A). Similar to what was observed in the James River, the maximum for the season was 2 to 3°C higher than the long-term means and after reaching the maximum toward the end of July, temperature generally remained 1 to 3 °C above the long-term means for the rest of the monitoring period (Figure S8A).

Salinity in the Piankatank River during 2016 ranged from 13.3 to 18.7 generally increasing over the course of the sampling period. During the first few weeks of sampling, salinity was relatively variable. From the first week of June through the remainder of the sampling period, salinity generally remained 1 to 2 higher than the long-term (5, 10, 20 and 25-yr) means (Figure S8B). On average salinity was 1 higher throughout most of June and July, and 2 higher throughout most of August and September. In any given week, the difference recorded between the most upriver site (Wilton Creek) and the most down river site (Burton Point; see Figure S1) was less than 3.

Great Wicomico River

Settlement in the Great Wicomico River was first observed during the week of 3 June at Glebe Point and Shell Bar. Settlement was then consistent (at least one spat set during each week at most of the sites) from then through the end of the monitoring period (Table S1; Figure S9). Similar to the Piankatank River, the majority of settlement for the season occurred during a two-week period from 1 July through 8 July. Settlement during this two-week period accounted for 90% of the total settlement for the year in the system (Table S1; Figure S9). This peak in settlement was extended at Fleet Point to include the week of 15 July. This three-week period (1 July through 15 July) accounted for 93% of the total settlement observed at Fleet Point during 2016. Settlement for the rest of the sampling period was relatively light throughout the system.

Cumulative spat $shell^{-1}$ for the year was extremely heavy at all nine sites, ranging from a low of 525.6 at Hilly Wash to a high of 1,117.3 at Glebe Point (Table S1; Figure S10). Settlement in the Great Wicomico River in 2016 was higher than that observed in 2015 at all nine sites (Table S2; Figure S10). Settlement in 2016 was also higher than the 5 and 10-yr means at all nine sites and higher than the 20 and 25-yr means at all five historical sites. When compared with the past twenty-five years, settlement in 2016, was the highest recorded at Hudnall, Haynie Point, Whaley's East and Fleet Point and the second highest at Glebe Point. Settlement during 2016 at Whaley's East and Fleet Point was approximately 5 and 8 times higher, respectively, than the next highest observed during the previous twenty-five years. Settlement in 2016 at the modern sites ranked the highest (Shell Bar) and second highest

(Hilly Wash, Harcum Flats and Rogue Point) observed since monitoring began at those sites in 1998. Settlement at Shell Bar was approximately twice as high as that observed in 2012, the next highest year.

Average river water temperatures in the Great Wicomico River during the 2016 sampling period ranged from 21.0 to 30.9°C throughout the sampling period, reaching the maxima during the week of 22 July (Figure S11A). From late May, when sampling began through early July, water temperature in general was around 1°C lower than the long-term (5, 10 and 18-yr) means. Following the temperature max in late July, which was around 2°C higher than is typical for the system, temperature decreased for two weeks, before again increasing, and then remained 1 to 2°C higher than the long-term means through the end of August (Figure S11A).

Salinity in the Great Wicomico River during the 2016 sampling period ranged from 13.0 to 18.1, generally increasing over the course of the monitoring period (Figure S11B). Salinity throughout the entire sampling period was consistently higher than the long-term (5, 10 and 18-yr) means (Figure S11B). This difference ranged between 0.5 and 2.6. There was typically a 1 to 2 difference in salinity between the most upriver site (Glebe Point) and the most downriver site (Fleet Point: Figure S1) throughout the monitoring period.

DISCUSSION

During the fourteen-year period between 1994 and 2007, settlement on the shellstrings was low to moderate; with 83% of all of the year/site combinations having a seasonal cumulative total of less than 10 spat $shell^{-1}$. However, settlement on the shellstrings over the past nine years (2008-2016) has been on the rise such that 82% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat $shell^{-1}$) and 34% of all of the year/site combinations had extremely heavy spatfall (seasonal cumulative total of > 100 spat $shell^{-1}$; Table S2). This trend of increased spat set has been especially notable in the Great Wicomico River, where since 2006, 88% of all of the year/site combinations had heavy spatfall (seasonal cumulative total of > 10 spat $shell^{-1}$) and 44% of the total year/site combinations had extremely heavy spatfall (seasonal cumulative total of > 100 spat $shell^{-1}$; Table S2). In 2016, for the second year in a row, settlement on the shellstrings was heavy to extremely heavy at all twenty-five sites monitored.

Overall, settlement on shellstrings in the James River during 2016 was heavy (five sites) to extremely heavy (three sites). Since 2008, the James River has had several very strong year classes (2008, 2010, 2012 and 2016). The mean cumulative spat $shell^{-1}$ over all eight sites from 1991 to 2007 was 12.7, whereas the mean for all eight sites over the past nine years (2008 to 2015) was 81.9. This translates to almost a seven-fold increase in settlement over the past nine years compared with the previous seventeen years. Since 2008, at least three out of the eight sites experienced heavy to extremely heavy settlement each year. The one exception was during 2009, when all eight sites monitored had moderate settlement (Table S2). In recent years, the timing of settlement in the James River has been getting progressively earlier (Southworth & Mann 2004). Once settlement began in late-June, at least some settlement occurred each week throughout the rest of the 2016 monitoring season. However, similar to what Southworth and Mann (2004) observed, the majority of this settlement occurred in the first half of the season, such that at six out of the eight sites monitored, at least 55% of the total settlement for the season had occurred by the week of 8 July. One exception to this was Deep Water Shoal. This may have been due to the significant rain events that occurred in the watershed in the month of June. Due to its location in the river, Deep Water Shoal is especially susceptible to low salinity following large rain events and salinity at the site was less than 5 throughout June, into early July, potentially affecting settlement. The other exception was Point of Shoals. This was most likely due to continued issues at that site, such that the shellstring was unable to be collected from 8 July to 22 July, which was when the majority of the settlement was occurring throughout the rest of the system.

Overall, settlement on the shellstrings in the Piankatank River was heavy (one site) to extremely heavy (seven sites), with cumulative number of spat shell^{-1} for the season at the three historical sites and at the five modern sites being among the highest observed over the past twenty-six and nineteen years of monitoring respectively. Similar to the James River, the Piankatank River has had several very strong year classes in recent years (2012, 2015 and 2016). From 1993 to 2006 (historical sites) and 1998 to 2006 (modern sites), settlement in the Piankatank River was consistently low to moderate at most of the sites monitored. At the three historical sites the mean from 1993 to 2006 was 2.8 cumulative spat shell^{-1}, whereas from 2007 to 2016 the mean at those three sites was 73.8 cumulative spat shell^{-1}, a 26-fold increase over the previous fourteen-year mean. Since the addition of the modern sites in 1998, the mean across the river increased from 4.6 cumulative spat shell^{-1} (1998 to 2006) to 75.1 cumulative spat shell^{-1} (2007 to 2015), a sixteen-fold increase. For the past several years potential broodstock (small plus market) in the system has been on the rise. At the three Piankatank River sites monitored during the fall dredge survey, the total number of small and market oysters combined during 2016 was among the highest observed over the past twenty-five years of monitoring (Part II of this report). Density and abundance of broodstock is an important factor in determining fertilization success (Mann & Evans 1998) and the increase in small and market oysters in the system over the past few years may help to explain at least some of the spawning success observed in the system during that time.

Settlement on the shellstrings in the Great Wicomico has been especially good for the past eleven years, with 2016 marking the first year with extremely heavy (>100 cumulative spat shell^{-1}) settlement recorded at all nine sites monitored. Settlement at the two most downriver sites (Whaley's East and Fleet Point; Figure S1) was the highest recorded at those two sites since regular monitoring began in 1970 (http://www.vims.edu/research/units/labgroups/molluscan_ecology/publications/topic/shellstring/index.php). In contrast to what was observed during most of the 1990s and the early 2000s, settlement in the Great Wicomico River over the past eleven years has been especially good. For the five historical sites the mean cumulative spat shell^{-1} from 1991 to 2005 ranged from 1.2 (Whaley's East) to 21.7 (Glebe Point), whereas the mean from 2006 and 2016 ranged from 76.1 (Fleet Point) to 434.4 (Glebe Point). This corresponds to a 20 (Glebe Point) to 83 (Whaley's East) fold increase in settlement at these sites during the past eleven years compared with the previous fifteen years. At the modern sites, the mean cumulative spat shell^{-1} from 1998 to 2005 ranged from 3.2 (Shell Bar) to 5.4 (Harcum Flats), whereas the mean from 2006 to 2016 ranged from 226.4 (Shell Bar) to 265.0 (Rogue Point). This corresponds to a 49 (Harcum Flats) to 71 (Shell Bar) fold increase at these sites during the past eleven years compared with the previous eight years.