Maryland Oyster Population Status Report
2017 Fall Survey

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And the Staff of the Shellfish Division and
Cooperative Oxford Laboratory
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Cover Photo: Processing a sample on the Potomac, Oct. 22, 2013. Dr. Mark Homer is facing the camera. (Photo: R. Bussell)

In Memoriam

Dr. Mark L. Homer
(1948 – 2018)

Dr. Mark Homer, long-time biologist with the Maryland Department of Natural Resources Shellfish Division, passed away on 13 May 2018 at the age of 69. His intellectual acumen and expertise in statistical analysis and survey design produced not only more scientifically rigorous oyster surveys but a diversification of the program to include investigations of most of the commercial molluscan shellfish in Maryland.

While growing up in West New York, New Jersey, he maintained a strong connection with Brooklyn, and Coney Island in particular, where his grandparents lived. His grandfather took him to ball games at Ebbetts Field, and despite the team's move to Los Angeles he bled Dodger blue for the rest of his life. After a stint at the City College of New York, where Mark also served as mate aboard the Research Vessel *Atlantic Twin*, he completed his bachelor's degree at the University of Florida. Following graduation he spent several years working at the Chesapeake Biological Lab. He left to earn his Ph.D. at the University of South Carolina, where his research was on the fish communities of abandoned rice paddies. He returned to the Chesapeake Biological Lab with a post-doctoral position, where he began his work with shellfish issues. During this period he developed and refined statistically sound oyster sampling techniques. Yet despite the fact that he subsequently worked with shellfish for almost thirty years - the majority of his career - he always maintained that he was a finfish biologist in shellfish clothing. While working on oyster sampling problems at CBL, he also found time to develop a winter fish survey for the Fishmap project and write the chapter on spot (*Leiostomus xanthurus*) in *Habitat Requirements for Chesapeake Bay Living Resources*.

Mark moved to the MDNR Shellfish Program in 1990, where he led the Monitoring and Stock Assessment Project. He brought a strong statistical background to the program, and developed the analytical framework used in this report. During his tenure in the Shellfish Program, he was effective at identifying research needs and securing funding to answer key questions. Mark was the principal investigator on several outside grants, bringing in approximately three-quarters of a million dollars to the department. These examined a variety of shellfish topics, including a three-year pilot oyster stock assessment, an artificial reef monitoring and evaluation project, an assessment of softshell and razor clams which documented for the first time a mass mortality event of the latter species, a molluscan inventory of the Maryland Coastal Bays focusing on hard clams, and a bay scallop restoration effort in Chincoteague Bay. He was an avid participant in the Fall Oyster Survey, and worked aboard the R/V *Miss Kay* every date of the 2017 survey, even while his health was failing.

With his deep appreciation for popular culture, sports, and current events, conversations with Mark were stimulating and challenging. Telephone calls were often lengthy, and ranged widely as his active mind made connections across multiple topics. His critiques of colleagues' work were encouraging and supportive, and drew on a broad knowledge of ecology, organismal biology, and statistical analysis. He would vigorously point out shortcomings with the goal of ensuring that the strongest results were presented and substantiated, and weak results were not overstated. And Mark cared deeply about his staff and colleagues; they were of paramount importance to him. His passing has left a huge hole in the Shellfish Division and Cooperative Oxford Laboratory, both on a professional and personal level.

Among the many encomiums Mark received after his passing, Marty Gary, the executive secretary of the Potomac River Fisheries Commission, captured the emotional essence of Mark's death in the following tribute:

God bless you Mark. Nearly a week has gone by since you left, and I still can't get my head around the idea of you not being here. Not being able to call you up and get your advice on oysters. Not being able to see you on the DNR Fall Oyster Survey. Not ever hearing your insightful biological or political analyses of the relationships of all animals and ecosystems, including people. You truly viewed all of this as "An ecology of life." And the void you have left on the Chesapeake shellfish community and DNR family has us all struggling. Your frank candor might have put some off, but for those of us that really knew you, we knew how much you delighted in the drama that was fisheries science and politics, and day to day life in general… You were a special friend and colleague. And my very favorite Doctor of Shellfish. The oysters, myself and so many others will miss you. And I will surely miss your wit and wisdom my friend. Always.

Mark contemplating a sample with one of his ubiquitous unfiltered cigarettes. ***(Photo: R. Bussell)***

TABLE OF CONTENTS

Drs. Mark Homer (l) and Jim Wesson (Virginia Marine Resources Commission) examining a sample on the Potomac R. in 2013 (*Photo: R. Bussell*).

EXECUTIVE SUMMARY

Since 1939, the Maryland Department of Natural Resources and its predecessor agencies have monitored the state's oyster population by means of annual field surveys – one of the longest running programs of this kind in the world.

Integral to the Fall Oyster Survey are five types of indices intended to assess the status and trends in Maryland's oyster populations: spatfall, disease, mortality, biomass, and cultch. The spatfall intensity index is a measure of recruitment success and potential increase of the population obtained from a subset of 53 oyster bars; oyster disease indices document disease infection levels as derived from a subset of 43 sentinel oyster bars; the total observed mortality index is an indicator of annual mortality rates of post-spat stage oysters calculated from the 43 oyster bar disease index subset; and the biomass index measures the number and weight of oysters from the 43 disease bar subset relative to the 1993 baseline. This year a fifth index, the cultch index, was added as a measure of habitat at the 53 spat intensity index bars.

The 2017 Fall Oyster Survey was conducted from Oct. 10 to Nov. 29 throughout the Maryland portion of Chesapeake Bay and its tributaries, including the Potomac River. A total of 323 samples were collected from 265 oyster bars. Sites monitored included natural oyster bars, oyster seed production areas, seed and shell plantings, and sanctuaries.

The spatfall intensity index of 23.6 was slightly above the 33-year median value, but a 24 percent decline from the 2016 index. More than three times as many 2017 index bars showed decreases in spatfall as compared with the previous year. As in past years, the better spatset was observed from the Choptank region downbay, although a scattering of spat occurred as far north as the Eastern Bay region. No spat were found along the mid-Western Shore and upper part of the bay, as well as the upriver two-thirds of the Potomac oyster growing region. The highest spatset (458 spat/bu) was observed on Coppage bar in the St. Marys River.

Dermo disease remained widely distributed throughout the oyster-growing waters of Maryland. Some oysters at all of the standard disease monitoring bars, as well as the supplemental sites, were infected with *Perkinsus marinus,* the parasite which causes dermo disease. The mean prevalence (69 percent) increased slightly from 63 percent the previous year, exceeding the long-term average for the first time since 2007. The mean infection intensity for dermo disease (2.5) remained the same as in 2016, which is slightly above the long-term average. MSX disease mean prevalence (3 percent) declined sharply, ending a three-year trend of increases. The geographic range of MSX disease also contracted, as the number of sentinel bars with infected oysters declined by almost half to 33 percent. Although MSX disease was detected as far upbay as Hackett Point, it was no longer found in Eastern Bay or the Miles River.

The Maryland-wide observed mortality index of 14 percent declined for the first time in five years, remaining below the long-term mean for the 14th consecutive year. However, it was still double that of 2012. Mortalities were highly variable among oysters on bars within some regions (e.g., within the St. Marys River observed mortalities ranged from 3 to 43 percent). Regional average observed mortalities were generally low to moderate, the highest being 28 percent in the Wye River.

The 2017 Maryland oyster biomass index of 1.40 is identical to the 2016 index, although the size distribution shifted to more sublegal oysters relative to market oysters. The 2017 index ranked tied for seventh highest in the 25-year time series, a decrease from the peak index in 2013, reflecting the declining numbers of the strong 2010 and 2012 year classes and mediocre spatsets in many of the regions since then.

The cultch index of 0.83 bu/100 ft. was somewhat lower than the 13-year average of 0.91 bu/100 ft. However, 60 percent of individual index bars showed much steeper declines compared to their long-term averages. The growth and good survivorship of the 2010 and 2012 year classes contributed substantially to the index during the early 2010s. The subsequent decline may be due to the loss of these oysters and lower recruitment, as well as ongoing taphonomic processes such as burial and degradation. Strong regional differences in the cultch index were evident. The areas with the lowest cultch included the entire mainstem of the bay, followed by the combined Chester River/Eastern Bay region. The highest regional cultch indices were in areas with more favorable recruitment and consequent addition to cultch, specifically the Tangier Sound and Choptank River regions.

The major oyster sanctuaries were sampled during the 2017 Fall Survey. Recruitment trends were generally consistent with non-sanctuary areas, although several sanctuaries had higher average spatsets than nearby open-harvest areas, including the Manokin, Little Choptank and St. Marys sanctuaries, which averaged among the highest regional spatsets in the bay. The Harris Creek Sanctuary had a similar spatset average to neighboring Broad Creek, an open-harvest area that is historically a higher recruitment tributary. Oysters from monitoring sites in the three restoration sanctuaries to date - Harris Creek, Tred Avon and Little Choptank - showed no evidence of MSX disease. Mortality rates in sanctuaries continued to be well below the long-term average, including the Manokin River Sanctuary at 10.9 percent. Overall, those sanctuaries that received strong spatfalls in 2010 and 2012, as well as those receiving supplemental oyster seed plantings and further spatsets, continued to do well.

With reported harvests of 225,000 bushels during the 2016-17 season, commercial oyster landings dropped 41 percent from the previous year, yet the dockside value of $10.6 million was the fifth highest since 1987. Power dredging accounted for 36 percent of the landings, primarily from the Lower Eastern Shore and Choptank regions. Patent tongs were the second dominant gear type, harvesting 23 percent of the total. Once again, Tangier Sound was the leading production area with 20 percent of the Maryland landings, followed by Broad Creek with 14 percent.

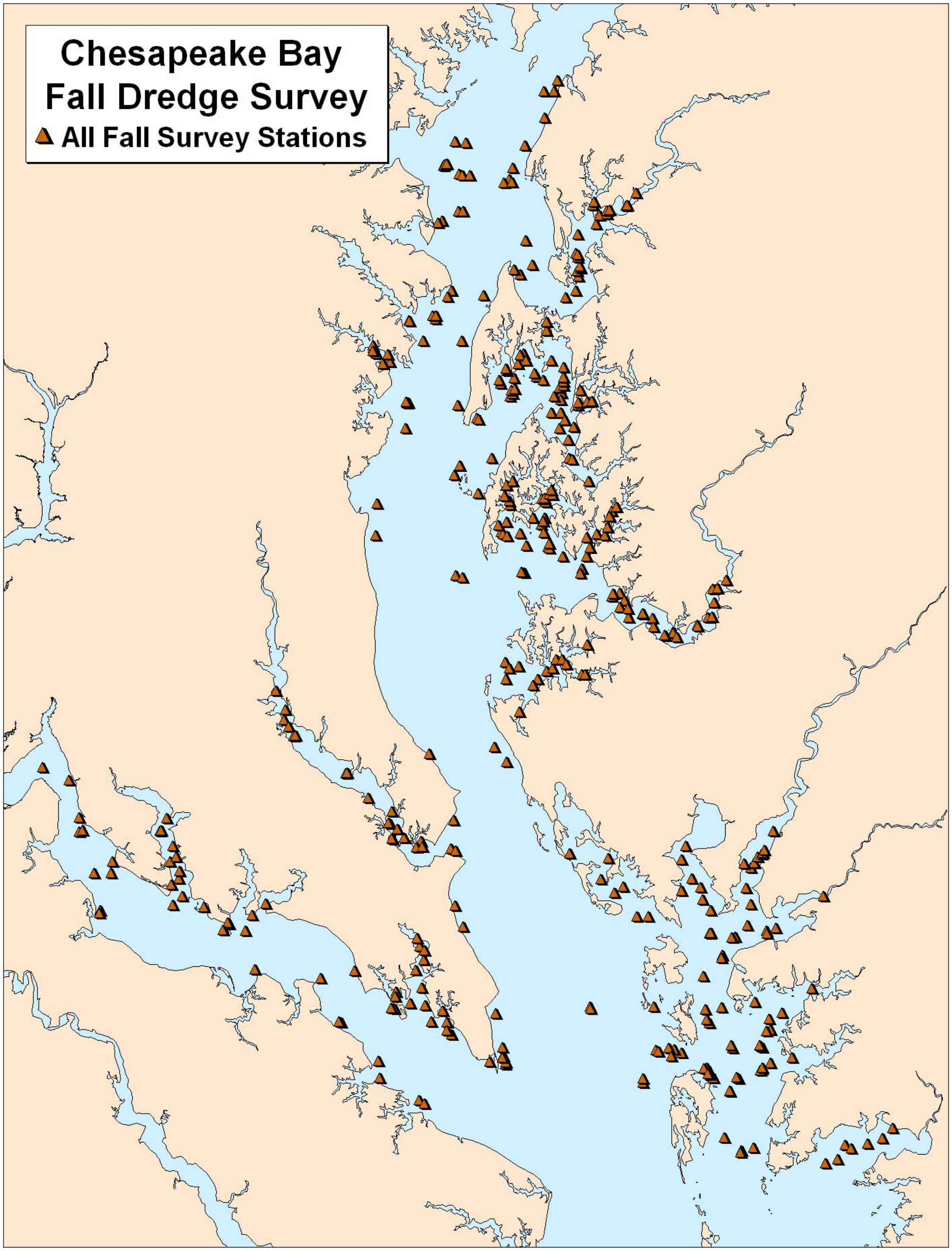

Figure 1a. 2017 Maryland Fall Oyster Survey station locations, all bar types (standard, Key, Disease, seed) included.

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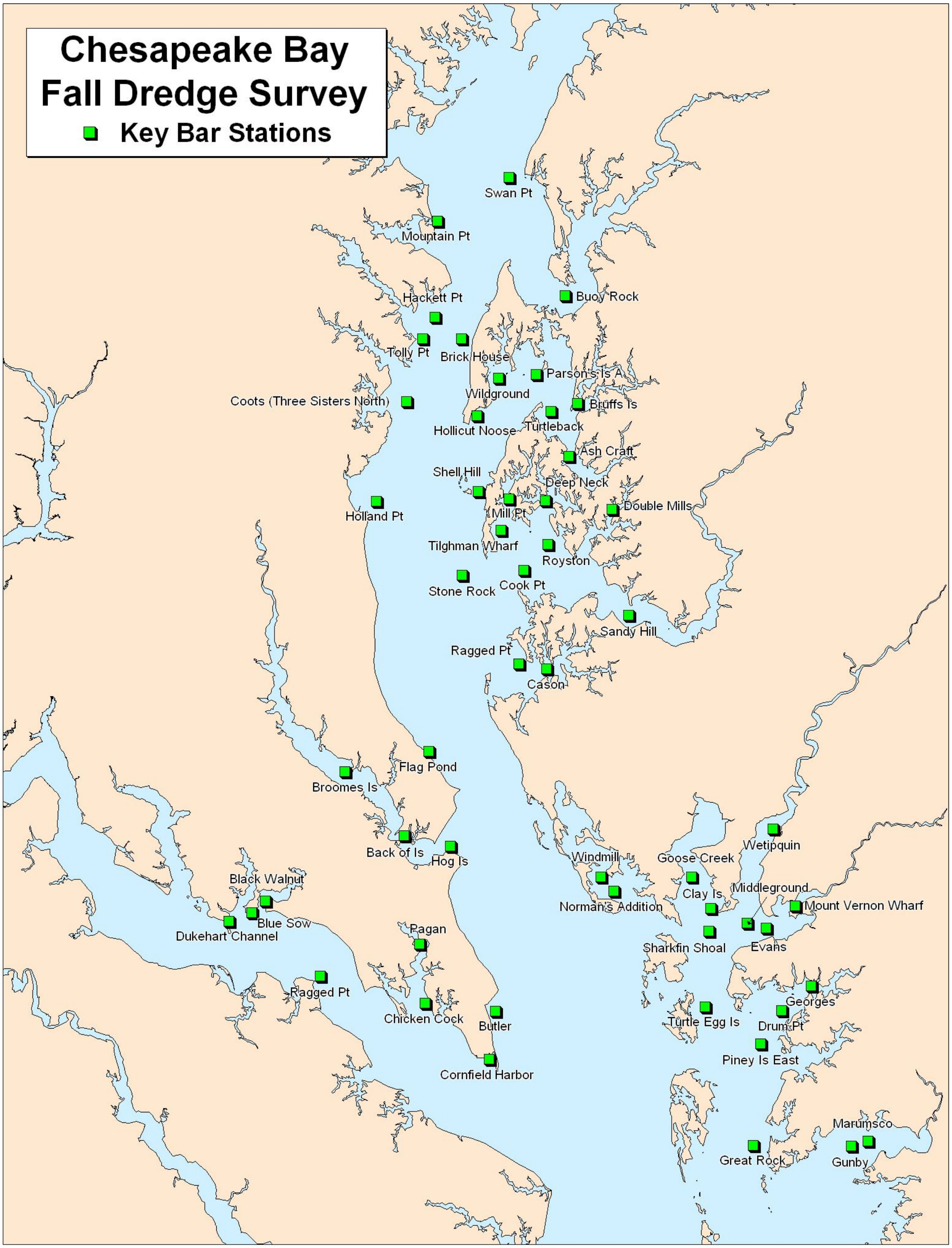

Figure 1b. Maryland Fall Oyster Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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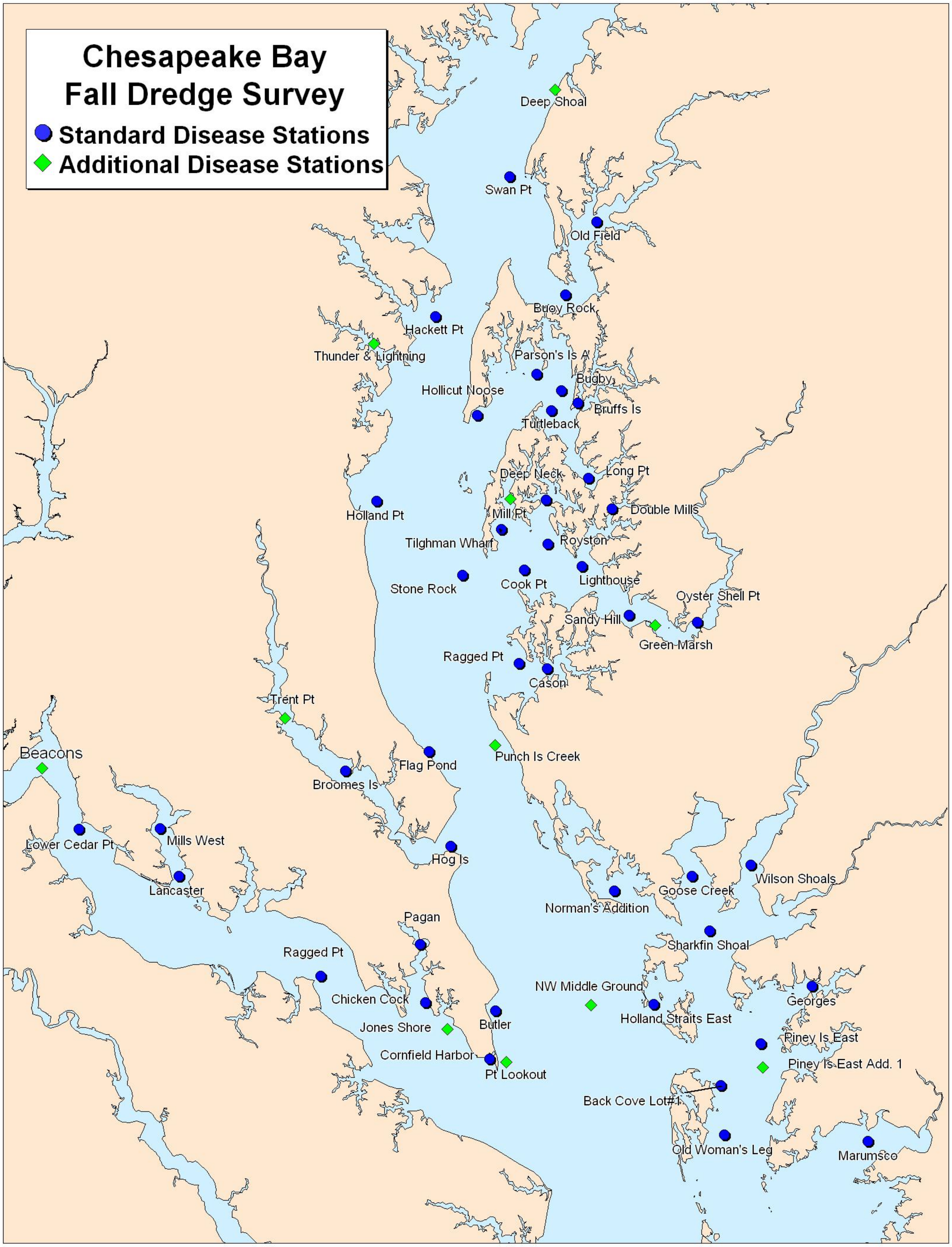

Figure 1c. Maryland Fall Oyster Survey standard Disease Bar monitoring location and additional 2017 disease sample stations.

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INTRODUCTION

Since 1939, a succession of Maryland state agencies has conducted annual dredge-based surveys of oyster bars. These oyster population assessments have provided biologists and managers with information on spatfall intensity, observed mortality, and more recently on parasitic infections and habitat in Maryland's Chesapeake Bay. The long-term nature of the data set is a unique and valuable aspect of the survey that gives a historical perspective and reveals trends in the oyster population. Monitored sites have included natural oyster bars, seed production and planting areas, dredged and fresh shell plantings, and sanctuaries.

Since this survey began, several changes and additions have been made to develop structured indices and statistical frameworks while preserving the continuity of the long-term data set. In 1975, 53 sites and their alternates, referred to as the historical "Key Bar" set, were fixed to form the basis of an annual spatfall intensity index (Krantz and Webster 1980). These sites were selected to provide both adequate geographic coverage and continuity with data going back to 1939. An oyster parasite diagnosis component was added in 1958, and in 1990 a 43-bar subset (Disease Bar set) was established for obtaining standardized parasite prevalence and intensity data. Thirty-one of the Disease Bars are among the 53 spatfall index oyster bars (Key Bars).

Collaborative Studies and Outreach

Throughout the years, the Fall Survey has been a source of collaborative research opportunities for scientists and students within and outside of the Department of Natural Resources. In 2017, the Fall Survey provided a platform for researchers from the University of Maryland Baltimore County and the United States Department of Agriculture to collect water, sediment, and oyster samples as part of a collaborative study on contaminants of emerging concern in Chesapeake Bay. Fall Survey data were provided to University of Maryland researchers working on a National Science Foundation grant in the Choptank River region. A University of Maryland graduate student is looking into refining mortality estimates from the Fall Survey data, and oyster samples from select locations were provided to a second graduate student investigating the interaction between hypoxic conditions and disease in oysters. The Survey continues to assist the Potomac River Fisheries Commission with an innovative fishery management program, examining oyster plantings on two Oyster Management Reserves and evaluating several rotational seed planting areas. Data from the Fall Survey continue to be used extensively by the multi-partner Oyster Restoration Project under the 2014 Chesapeake Bay Watershed Agreement and a legislatively mandated Oyster Stock Assessment, a collaborative effort between the department and the University of Maryland Chesapeake Biological Laboratory.

METHODS

Field Collection

The 2017 Annual Fall Oyster Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources Fishing and Boating Services from 10 October to 29 November. A total of 323 samples was collected during surveys on 265 natural oyster bars (Figure 1a), including Key Bar (Figure 1b) and Disease Bar (Figure 1c) fixed sentinel sites as well as sanctuaries, contemporary seed oyster planting sites, shell planting locations, and former seed production areas.

A 32-inch-wide oyster dredge was used to obtain the samples. Sample volumes were measured in Maryland bushels (bu) (1 Md. bu = 1.3025 U.S. standard bu; Appendix 2).The number of samples collected varied with the type of site. At each of the 53 Key Bar sites and the 43 Disease Bars, two 0.5-bu subsamples were collected from replicate dredge tows. At all other sites, one 0.5-bu subsample was collected. A list of data categories recorded from each sample appears in Table 1. Oyster counts were reported as numbers per Maryland bushel. Since 2005, tow distances have been recorded for all samples using the odometer function of a global positioning system unit, and the total volumes of dredged material per tow were noted before the subsamples were removed. Photos illustrating the collection process can be viewed at:

http://dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

Fall Oyster Survey Indices

Integral to the Fall Oyster Survey are five categories of indices used to assess Maryland oyster populations: spatfall, disease, mortality, biomass, and cultch. The Spatfall Intensity Index is a measure of recruitment success and potential increase of the population obtained from an established subset of 53 oyster bars (Key Bars); it is the arithmetic mean of spat/bushel counts from this subset. Disease levels are documented by oyster disease prevalence indices (dermo and MSX disease) and an infection intensity Index (dermo disease only) as derived from a subset of 43 oyster bars; these indices were established in 1990. The Total Observed Mortality Index is an indicator of annual natural mortality occurring among post-spat stage oysters from the 43 oyster bar Disease Index subset, calculated as the number of dead oysters (boxes and gapers) divided by the sum of live and dead oysters (Appendix 2). Although keyed to the Disease Index subset established in 1990, the Total Observed Mortality Index also includes data from 1985-1989. The Biomass Index measures the number and estimates the weight of post-spat oysters from the 43 Disease Bar subset relative to the 1993 survey year baseline. The Cultch Index is new to this report; it is a relative measure of oyster habitat at the 53 "Key" spat index bars.

The time series for the Spat Intensity, Diseases, and Mortality Indices are presented in Tables 2 - 5. The majority of Fall Survey data, including supplemental pathology data and disease indices, are entered into digital files. Fouling data and oyster condition are in paper files.

Oyster Disease Analyses

Representative samples of 30 oysters older than one year were taken at each of the 43 Disease Bar sites. Additional samples for disease diagnostics were collected from supplemental sites, sanctuaries, and other areas of special interest. Due to scarcities of oysters at three sampling sites (Long Point, Flag Pond, Old Woman's Leg), smaller samples (n = 14, 23, 12 respectively) were collected there. Oyster parasite diagnostic tests were performed by staff of the Cooperative Oxford Laboratory. Data reported for *Perkinsus marinus* (dermo disease) are from Ray's fluid thioglycollate medium (RFTM) assays of rectum tissues. Prior to 1999, less-sensitive hemolymph (blood) assays were performed. Data reported for *Haplosporidium nelsoni* (MSX disease) have been generated by histology since 1999. Before 1999, hemolymph cytology was the diagnostic method used for every sample, while solid tissue histology preparations were examined for *H. nelsoni* only from selected locations.

In this report, prevalence refers to the percentage of oysters in a sample that were infected by a specific disease, regardless of infection intensity. Infection intensity is calculated only for dermo disease, and categorically ranks the relative abundance of pathogen cells in analyzed oyster tissues from 0-7 (Calvo et al. 1996). Mean infection intensities are calculated for all oysters in a sample or larger group (e.g. Disease Bars set), including zeroes for uninfected oysters. For details of parasite diagnostic techniques and calculations see Gieseker (2001) and Maryland DNR (2018).

Biomass Index

Department of Natural Resources staff at the Cooperative Oxford Laboratory developed the size-weight relationships used in calculating the Biomass Index (Jordan et al. 2002). Oyster shells were measured in the longest dimension and the meats were removed, oven-dried, then weighed. Average dry-meat weights (dmw) were calculated for oysters in each 5-mm grouping used in the field measurements, and those standards have been used to calculate the annual Biomass Index from size-frequency data collected from Fall Survey field samples, as follows:

For each of the 43 disease monitoring stations, the number of small and market oysters (= post-spat or 1+ year classes) in each 5-mm size class was multiplied by the average dry-meat weight (dmw) for that size class to obtain the total weight for each size grouping (Eq. 1). These were summed to get the total dry-meat weight of a 1 bu sample (two 0.5 bu subsamples) from a disease monitoring bar (Eq. 2). The sum of dry-meat weights from the 43 disease monitoring stations, divided by 43, yielded an annual average biomass value from the previous year's survey (Eq. 3). These annual average biomass values were keyed to the biomass value for 1993. The Biomass Index was derived by dividing the year's average biomass value by the 1993 average biomass value (1993 biomass index = 1.0) (Eq. 4).

Note that the baseline data are from the 1993 Fall Survey. Prior to 2012, the biomass index year followed the year the data were actually collected e.g. the 1994 baseline index was from the 1993 Fall Survey. To avoid the confusion this caused, in this report the biomass index refers to the year the data were collected (survey year). Therefore, the baseline index year is now 1993 since the data were collected during the 1993 Fall Survey and the 2017 biomass index is derived from the 2017 Fall Survey data.

Equations
For **each** monitoring station:

1. (# post-spat oysters per size class) x (avg. dmw per size class) = total dmw per size class
2. ∑ dmw per size class = total dmw per 1 bu station sample

For **all** monitoring stations:

3. (∑ dmw per1 bu station sample)/43 = annual average biomass value
4. (annual average biomass value)/(1993 average biomass value) = Biomass Index

Statistical Framework
To provide a statistical framework for some of the Annual Fall Survey data sets, a non-parametric treatment, Friedman's Two-Way Rank Sum Test, was used (Hollander and Wolfe 1973). This procedure, along with an associated multiple-range test, allowed among-year comparisons for several parameters. Additionally, mean rank data can be viewed as annual indices, thereby allowing temporal patterns to emerge. Friedman's Two-Way Rank Sum Test, an analog of the normal scores general Q statistic (Hájek and Šidák 1967), is an expansion of paired replicate tests (e.g. Wilcoxon's Signed Rank Test or Fisher's Sign Test). Friedman's Test differs substantively from a Two-Way ANOVA, in that interactions between blocks and treatments are not allowed by the computational model (See Lehman 1963 for a more general model that allows such interactions). The lack of block-treatment interaction terms is crucial in the application of Friedman's Test to the various sets of Fall Survey oyster data, since it eliminates nuisance effects associated with intrinsic, site-specific characteristics. That is, since rankings are assigned across treatments (in this report - years), but rank summations are made along blocks (oyster bars), intrinsic differences among oyster bars are not an element in the test result. All Friedman's Test results in this report were evaluated at $\alpha = 0.05$.

To quantify annual relationships, a distribution-free multiple comparison procedure, based on Friedman's Rank Sum Test, was used to produce the "tiers" discussed in this report. Each tier consists of a set of annual mean ranks that are statistically similar to one another. This procedure (McDonald and Thompson 1967) is relatively robust, very efficient, and, unlike many multiple comparison tests, allows the results to be interpreted as hypothesis tests. Multiple comparisons were evaluated using "yardsticks" developed from experimental error rates of $\alpha = 0.15$.

Harvest Records

Two data sources are used to estimate seasonal oyster harvests - dealer reports (also called Buy Tickets) and harvester reports. The volume of oysters in Maryland bushels caught each day by each license holder is reported to the Department of Natural Resources on both forms (Appendix 2). Dealer reports are submitted weekly by licensed dealers who buy oysters directly from harvesters on the day of catch. Reported on each buy ticket is the catch per day along with effort information, gear type, and location of catch. Both the dealer and the harvester must sign the buy ticket and include their license numbers. Each dealer is also responsible for paying a one dollar per bushel tax on each bushel purchased and an additional thirty-cent tax on each bushel exported out of state. Harvester reports are submitted monthly by each license holder authorized to catch oysters and include the catch each day along with effort data, gear type, and location of catch.

Buy ticket records are available from 1989 to present and harvester reports are available from 2009 to present. Although the area or river system was often recorded on buy tickets for much of the time series, the completeness of oyster bar- and gear-specific information is much more variable. Generally, harvester reports are more complete with regard to gear type and oyster bar name. Due to the longer time series available from the buy ticket record, this is the standard data source for long-term trends in harvest. For applications where gear or oyster bar name is considered critical, the harvester report data source is often used instead.

RESULTS

FRESHWATER DISCHARGE CONDITIONS

Salinity is a key quantifiable factor influencing oyster reproduction and recruitment, disease, and mortality. Whereas salinity is a site-specific measurement which varies widely throughout the Maryland oyster grounds, freshwater flow, which influences salinity, provides a more synoptic view of baywide conditions and is therefore used as a surrogate for salinity.

According to the U.S. Geological Survey, 2017 was considered to be an average year for streamflow into the entire Chesapeake Bay (USGS 2017). In fact, streamflow into the Maryland portion of the Bay (Sec. "C" in Bue 1968) in 2017 was almost identical to the 81-year average. This represents the return to normal annual streamflow after being well below normal during the two previous years. Annual streamflows in nine of the past thirteen years were within the normal range, in contrast to the sometimes extreme interannual variations in streamflow witnessed during the 1990s and early 2000s, including an extended drought from 1999 to 2002 followed by near-record high flows in 2003 and 2004 (Figure 2a).

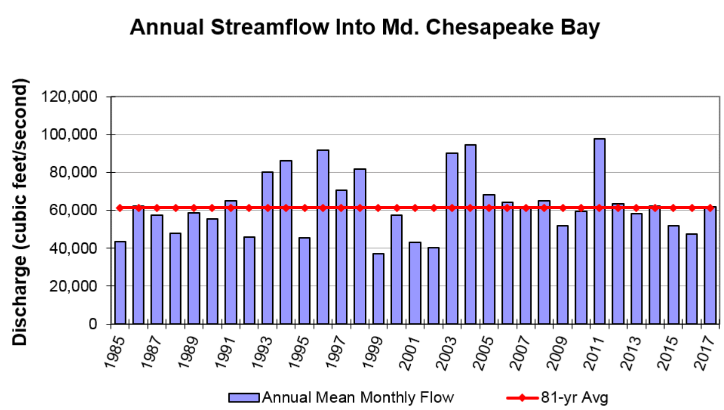


Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2017. USGS Section C: all Maryland tributaries and the Potomac River.

The monthly average freshwater flows give a more variable picture. The spring was shaping up to be a dry period, with March flows at only 67% of the long-term mean (Figure 2b). This was followed, however, by higher than normal streamflows during the biologically critical months of April through August, ranging between 112 - 167% of the 81-year monthly averages. Starting with September, the remainder of the year concluded with three drier than average months. The net result was a cancelling by this variability to yield an average streamflow year (Figure 2a).

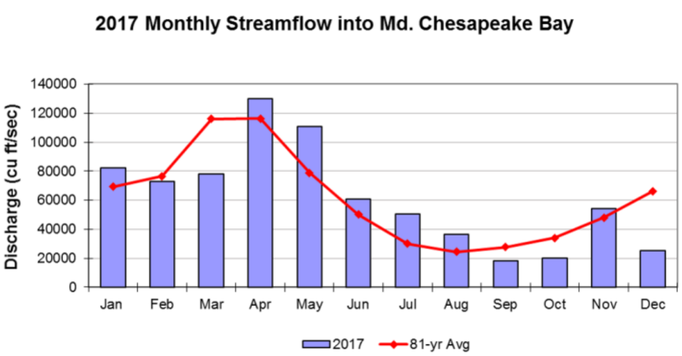


Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2017, including the 81-yr monthly average.

Monthly surface salinities, as seen in the following examples, reflect the influence of streamflow to varying degrees depending on distance from the Susquehanna River, the largest source of freshwater into the bay.

Despite the higher than average freshwater flows from April through August, salinities at midbay to lower bay stations were close to normal (Chesapeake Bay Program Data Hub). The mid-bay station, CB4.2C off the mouth of the Choptank River, showed the greatest amount of monthly variability as well as the highest deviation from the norm (Figure 2c). Monthly salinities fluctuated from a low of 8.0 ppt in May to 16.8 ppt in October, a difference of 8.8 ppt. During the period of above normal flows, salinities dropped to as far as 2.1 ppt below average in August. One important point is that salinities were below 12 ppt for five months, remaining below15 ppt until October. These are critical minimum threshold values for the spread and virulence of MSX disease. In the long term, the highest average salinity for this station is 14.9 ppt in October.

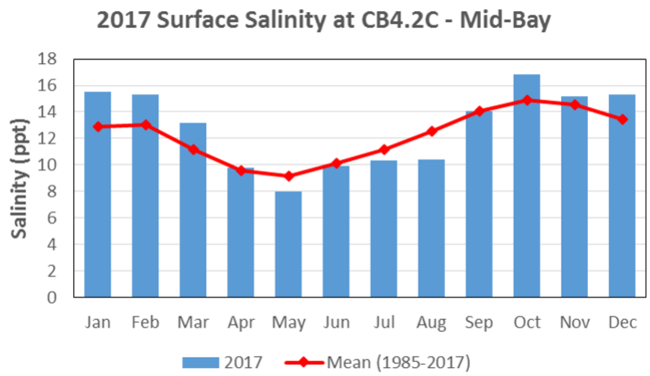


Figure 2c. Monthly surface salinities during 2017 at Station CB4.2C in mid-Chesapeake Bay off the mouth of the Choptank River.

Further downbay at the mainstem station CB5.2 off Point No Point, the effect of streamflow was reduced. Intra-annual variation in salinities were somewhat less, ranging from 11.8 ppt in June to 18.3 ppt in November, a difference of 6.5 ppt (Figure 2d). Salinities were almost normal throughout the summer months, with the largest deviation below the mean, 1.0 ppt, occurring in September. Salinities were above the 12 ppt threshold for MSX disease during all but one month. However, excluding the winter months they did not exceed 15 ppt until October.

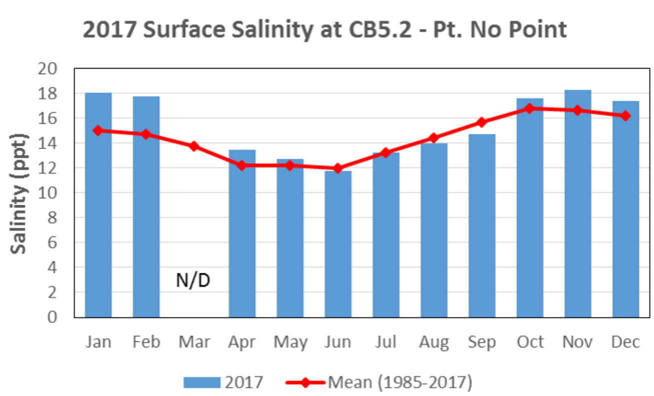


Figure 2d. Monthly surface salinities during 2017 at Station CB5.2 in the lower mainstem of Chesapeake Bay off Point No Point. N/D=no data

Streamflow had the least impact on salinity variability in lower Tangier Sound, where salinities average higher than the mainstem. The lowest monthly mean was 14.8 ppt in July, only 0.8 ppt below normal. This was the only month when the salinity was below15 ppt. The peak salinity was 19.5 ppt in October, a 4.7 ppt difference from the low value in July.

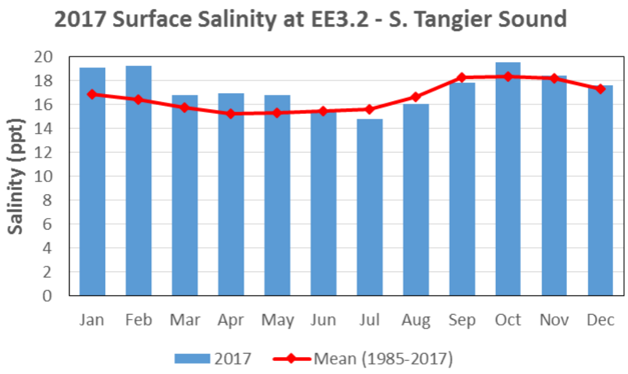


Figure 2e. Monthly surface salinities during 2017 at Station EE3.2 in south Tangier Sound.

SPATFALL INTENSITY

The spatfall intensity index, a measure of recruitment success and potential increase of the population, was 23.6 spat/bu, slightly above the 33-year median value. Spatset intensity declined 24% from the previous year, with more than three times as many 2017 index bars having decreased spatfall when compared with 2016 (Table 2). As a result, the 2017 spat index ranked in the next lower statistical tier than the 2016 index (Figure 3a). Two of the previous seven years (2010, 2012) had strong year classes, which boosted the population and increased commercial landings. However, the poor to middling spatsets over the past five years have had implications for population abundance, leading to declining harvests in the most recent years and possibly upcoming seasons unless the somewhat more favorable 2015 and 2016 year classes survive to enter the fishery (Figure 3b). The average 2017 spatfall forebodes a continuing trend in this decline.

Spatfall intensity was less evenly distributed

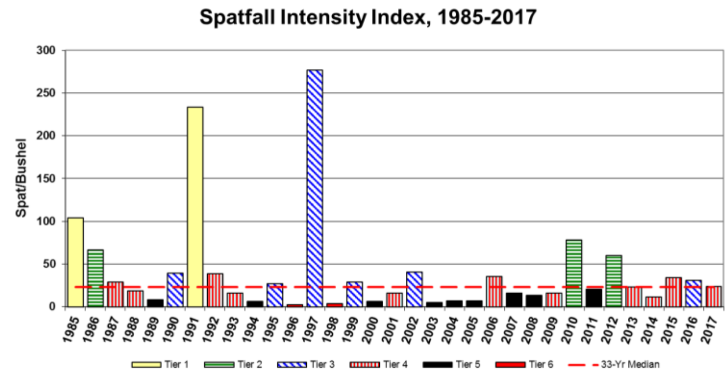


Figure 3a. Spatfall intensity (spat per bushel of cultch) on Maryland “Key Bars” for spat monitoring, including rankings of statistically similar indices.

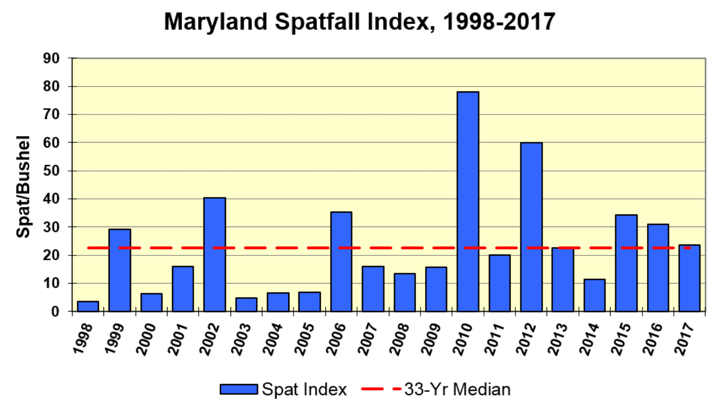


Figure 3b. Recent Maryland spatfall indices, 1998-2017.

among the Key Bars in 2017 than in the previous year. Spat were observed on 34 of the 53 Key Bars, whereas 40 Key Bars had spat in 2016 (Table 2). Only four bars accounted for 53% of the index, compared with nine bars in 2016. In 2017, nine bars contributed 75% of the spat index (15 bars in 2016), while 19 sites were needed to reach 95% of the spat index; the remaining34 bars made up only 5% of the 2017 index. In other words, almost two/thirds of the index bars were unproductive in 2017. Only three Key Bars reached triple-digit spat counts. The highest was 247 spat/bu on Pagan in the St. Marys River oyster sanctuary, followed by Deep Neck in the Broad Creek hand tong harvest area (205 spat/bu) and Georges (137 spat/bu) in the Manokin River sanctuary. Over the years these bars have ranked consistently near the top of Key Bar spat counts (Table 2).

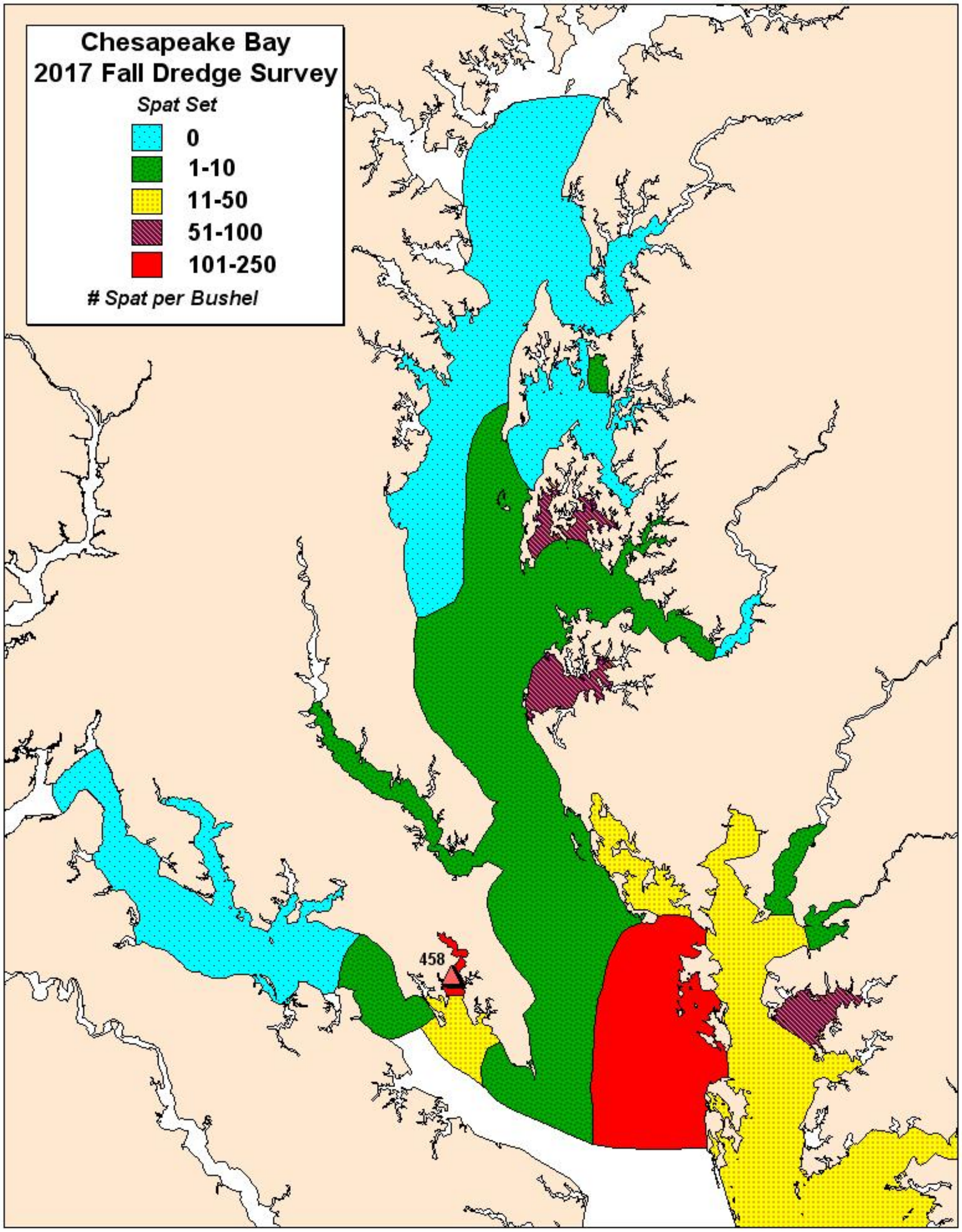


Figure 4. Oyster spatfall intensity and distribution in Maryland, 2017. Intensity ranges represent regional averages.

When considering all bars surveyed in addition to the Key Bars, as in past years the better spatset was observed downbay from the Choptank region (specifically Harris and Broad creeks), primarily in the lower mainstem of the bay as well as the St. Marys, Little Choptank and Manokin rivers (Figure 4). This distribution was somewhat unusual in that the mainstem outperformed Tangier and Pocomoke sounds and most of their surrounding tributaries, which are usually more productive. A light spatset occurred as far north as the Eastern Bay region, although none of the index bars from this region had spat. No spat were found along the mid-Western Shore and upper part of the bay. The highest spatset (458 spat/bu) was observed on Coppage bar in the St. Marys River just outside of the sanctuary. No spat were found along the mid-Western Shore and upper part of the bay, or in as the upriver two-thirds of the Potomac oyster growing region.

A final comment on the annual spatfall intensity index: this index is an arithmetic mean that does not take into account geographic distribution, whereas the statistical tiers do (Figure 3a). For example, the near-record high spatfall intensity in 1997 was actually limited in extent, being concentrated in the eastern portion of Eastern Bay, the northeast portion of the lower Choptank River, and to a lesser extent, in parts of the Little Choptank and St. Marys rivers (Homer & Scott 2001). Over 75% of the 1997 index was accounted for by only five of the 53 Key Bars, and only ten contributed nearly 95% (Table 2). As a result, the 1997 spat index fell into the third statistical tier despite being the second highest index on record and an order of magnitude higher than other Tier 3 indexes. In contrast, the 1991 spatfall (the third highest on record) was far more widespread. Fifteen Key Bars totaled 75% of the index that year, while 28 sites were needed to attain 95% of the spatfall intensity index, placing it in the first statistical tier notwithstanding having a lower spatfall index than 1997. The imbalanced spatfall distribution in 2015 accounts for that index falling into the same statistical Tier 4 as the 2014 index, despite being three times as high (Figure 3a). Conversely, the statistical ranking of the 2016 spatset was above the 2015 ranking despite a lower Spatfall Index because of the higher numbers of spat on a greater number of bars in 2016.

OYSTER DISEASES

Summary Dermo disease remained widely distributed throughout the oyster-growing waters of Maryland. Oysters at all of the standard disease monitoring sites, as well as the supplemental sites, were infected with *Perkinsus marinus*, the parasite which causes dermo disease. The average prevalence increased slightly from the previous year, rising above the long-term average for the first time since 2007. Dermo disease mean intensity was unchanged, remaining above the long-term average for the second consecutive year. MSX disease prevalence fell after three consecutive years of increases. MSX disease markedly decreased or was undetected on several bars in the Choptank River and the Eastern Bay region, but expanded its range upbay, reaching as far north as Hackett bar outside the mouth of the Severn River.

Dermo disease was detected in oysters on 100% of the Disease Bars (Table 3). The overall mean infection prevalence in oysters sampled on the Disease Bars was 69%, compared to 63% in 2016 and was the highest since 2002, which had the record-high mean prevalence of 94%, ranking 2017 in the third highest statistical grouping (of five) for prevalence (Figure 5). This marks only the second of the past fifteen years when dermo disease mean prevalences exceeded the 28-year average of 67%. Since 2014 there has been an increasing trend in the percentage of infected oysters throughout Maryland waters.

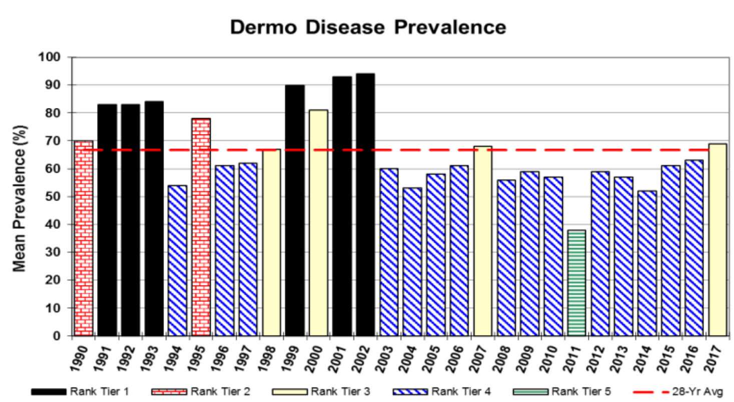


Figure 5. Annual mean *P. marinus* prevalences and statistical groupings from Maryland disease monitoring bars.

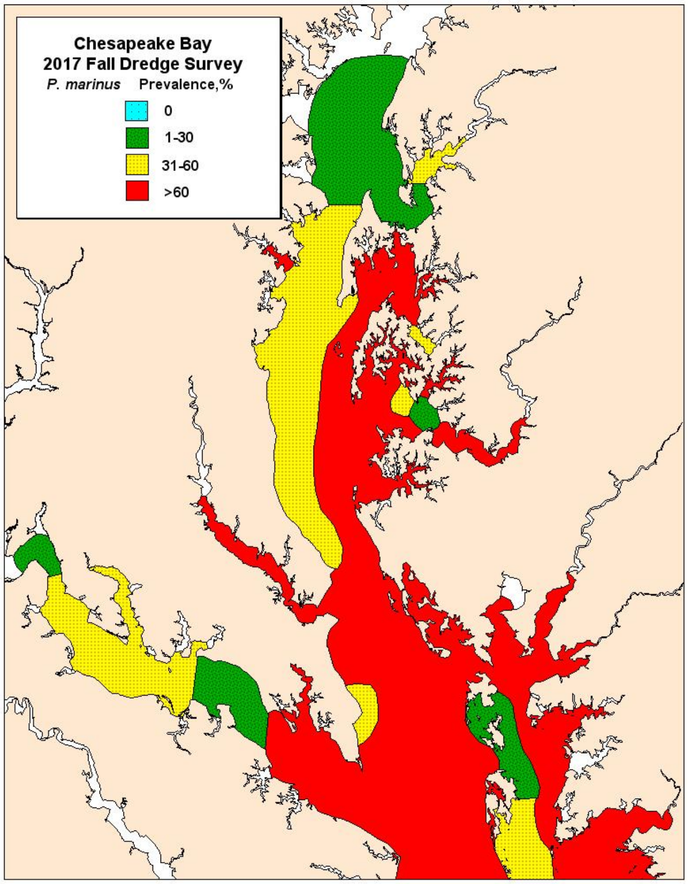


Figure 6. Geographic extent and prevalence of dermo disease in Maryland, 2017.

The geographic distribution of high prevalences (>60%) increased slightly from the previous year to 67% of the Disease Bars, encompassing large areas of the Chesapeake Bay and most of its tributaries, including the mid-bay along the Eastern Shore; most of the lower bay; the Patuxent, lower Potomac, St. Marys and South rivers on the Western Shore; and all of the Eastern Shore tributaries from the upper Chester River southward, as well as Tangier and Pocomoke sounds (Figure 6). Outside of the regular disease monitoring sites, dermo disease was detected at all 11 of the supplemental sites, including Deep Shoal, the furthest up-bay bar examined for disease. In addition, oysters on Beacon bar in the upper reaches of the Potomac River oyster grounds have shown persistently low levels of dermo disease (3% prevalence, 0.03 intensity in 2017) over the past six years, after the disease was undetected there in 2011.

The 2017 annual mean infection intensity of 2.5 (on a 0-7 scale) was identical to the previous year and the highest since 2002, having more than doubled since the record low of 2011 (Table 3). Thus, this is the second year since 2007 that the intensity index has exceeded the long-term average, and only the third such occurrence in the last 15 years. Consequently, the 2017 dermo disease intensity ranking remained in the third statistical grouping (of five tiers) (Figure 7). This is still relatively moderate in contrast to the record high mean intensity of 3.8 in 2001. The average intensity index over the fifteen years since the end of the 1999-2002 drought is 1.9, similar to another extended period of low to moderate dermo disease levels from 1994 to 1998 when annual mean infection intensities averaged 1.7. In comparison, the drought period of 1999-2002 had mean annual intensities that averaged 3.4.

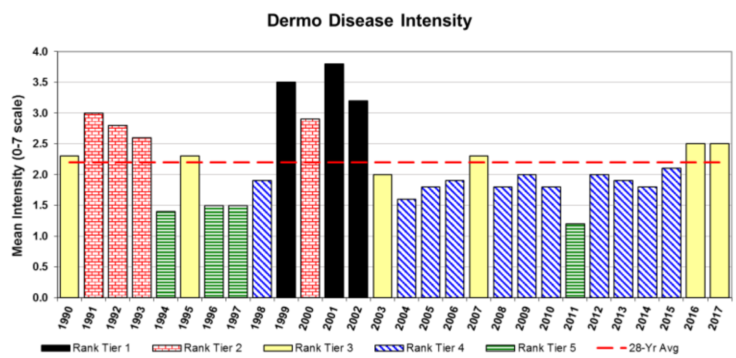


Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars. Rankings are based on statistically similar years.

The 2017 frequency distributions of sample mean infection intensities showed mixed results in frequencies of the highest intensity range (Figure 8). In 2017, samples from 20 bars (47%) had mean intensities of 3.0 or greater, a slight increase from 2016, although there was a decrease in the number of bars with the severest intensities (≥4.0), from nine bars (21%) in 2016 to four bars (9%) in 2017.

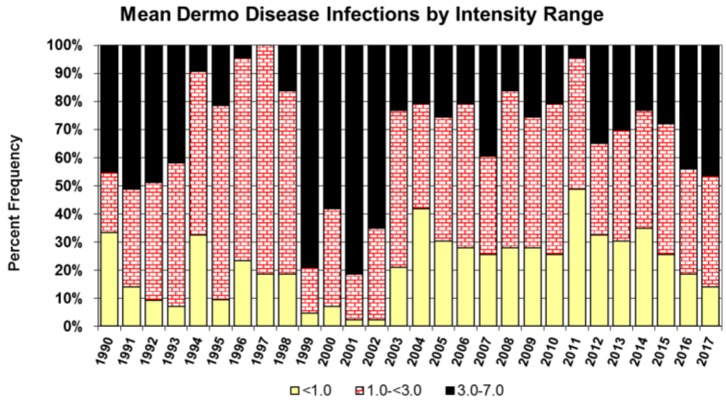


Figure 8. *Perkinsus marinus* infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.

For perspective, during the peak infection intensity year of 2001, 81% of the baywide dermo disease intensities were ≥3.0 and 51% were ≥4.0. Of all bars sampled for disease analysis, the number of oyster populations with elevated intensities (≥3.5) increased nearly fourfold since 2015 from seven to 26 (Jones Shore, the 27th, was not sampled in 2015), especially in the tributaries from the Miles and Wye rivers south (Table 3). Although most of oyster populations with elevated infection intensities were found on the Eastern Shore, Hog Island (4.5) on the lower Western Shore had the second highest value for individual bars and the highest of the 43 Disease Index Bars. Once again, the highest mean intensity for all sampled bars was at Northwest Middleground (4.6).

Infection intensities in individual oysters that are ≥5 on a 0–7 scale are considered lethal; such infection intensities were detected in 21.3% of oysters sampled in 2017, a decrease from 2016 (25.3%), but above the levels found in 2013 (14.8%) through 2014 (15.3%) and 2015 (17.8%).

MSX disease, resulting from the parasite *Haplosporidium nelsoni*, is another potentially devastating oyster disease. This parasite can cause rapid mortality in oysters and generally kills a wide range of year classes, including younger oysters, over a long seasonal period. When MSX disease coincides with elevated dermo disease intensities, mortality levels can be very high, as seen in 2001 and 2002.

Reversing a four-year trend, MSX disease showed a marked decrease in prevalence, retreating from its previous northerly extent in Eastern Bay and the Miles River. Despite the decline in prevalence and the geographic contraction from some areas, the disease expanded its range upstream in the mainstem as far as Hackett Point, although at a prevalence of only 3% (Figure 9). This was the furthest north MSX disease has been detected since 2002. *Haplosporidium nelsoni* was found in oysters from 14 (33%) of the Disease Bars, compared with 24 bars (56%) in 2016 (Table 4). For comparison, the parasite occurred on 90% of the bars in 2002. For the 43 disease monitoring bars, the average percentage of oysters infected with MSX disease was 3%, a nearly fourfold decrease from 2016 (Figure 10, Table 4).

MSX disease prevalences were highest in the Tangier Sound region, where they ranged from 13% to 25%. In contrast, the highest prevalence in 2016 was 60% on Chickencock bar in the lower St. Marys River, a tributary of the Potomac (Table 4).

The abatement of MSX disease in 2003-2004 due to two consecutive years of record freshwater flows into the bay signified the end of the most severe *H. nelsoni* epizootic on record in Maryland waters. The 2002 epizootic set record high levels for both the frequency of affected disease monitoring bars (90%) and the mean annual prevalence within the oyster populations (28%), leaving in its wake observed oyster mortalities approaching 60% statewide. Since 1990, there have been four *H. nelsoni* epizootics: 1991-92, 1995, 1999-2002, and 2009. The first three were associated with spikes in observed mortalities (Figure 10), while the 2009 outbreak was accompanied by a modest mortality increase which was ameliorated by timely freshwater flows (Tarnowski 2011).

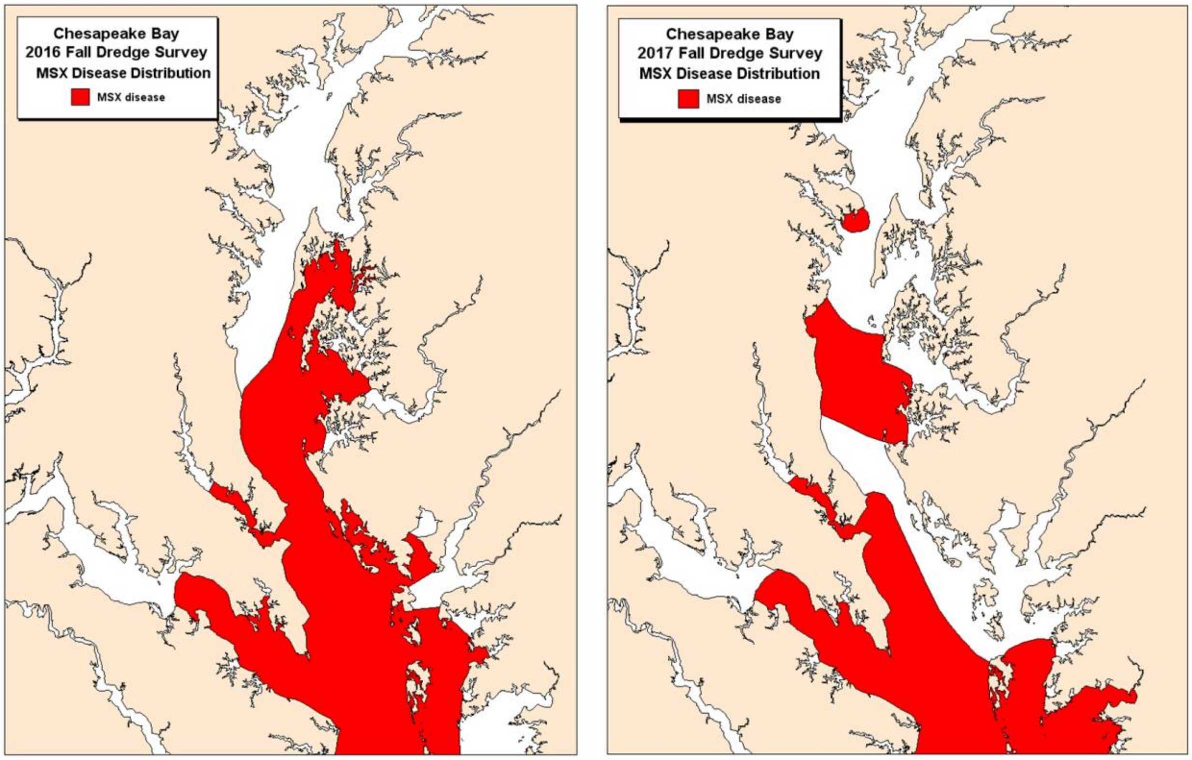


Figure 9. Geographic shifts of MSX disease in Maryland waters between 2016 and 2017.

All four of these epizootics coincided with dry years (Figure 2a). These were followed closely by periods of unusually high freshwater inputs into parts of Chesapeake Bay, which resulted in the purging of *H. nelsoni* infections from most Maryland oyster populations (Homer & Scott 2001; Tarnowski 2005, 2011). The current increase in *H. nelsoni* infections is associated with below normal streamflows since the latter portion of 2014.

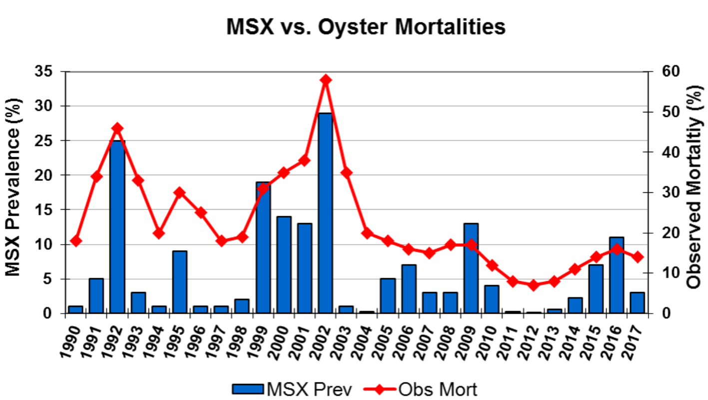


Figure 10. Percentage of Maryland oysters with MSX disease compared to annual means for observed mortalities on the disease monitoring bars from 1990-2017.

OBSERVED MORTALITY

The Maryland-wide observed mortality index declined for the first time in five years (Table 5). At 14%, the 2017 index remained well below the 33-year mean of 22.8%, continuing a 14-year trend as a consequence of low to moderate disease pressure (Figure 11). Nevertheless, the index was double that of 2012, which had the lowest index in the 33-year time series. For the 43 disease monitoring bar subset, the average observed mortality of 13.7% over the last 14 years approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (MDNR, unpubl. data). The 2017 observed mortality on the Disease Bars remained in the second lowest statistical grouping over the 33-year period; the past eight years were in the lowest or second lowest mortality tier (Figure 11). This is in remarkable contrast to 2002 when record-high disease levels devastated Maryland populations, resulting in a 58% observed mortality rate.

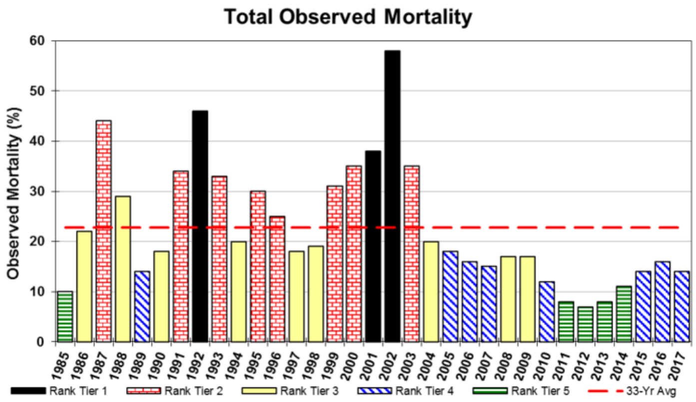


Figure 11. Mean annual observed mortality, small and market oysters combined. Ranking tiers are based on statistically similar years.

Looking at all survey sites, mortalities were highly variable among bars within some of the regions (e.g. within the St. Marys River, observed mortalities ranged from 3% to 43%). The highest mortality observed during the survey on an individual bar with more than 50 live oysters/bu was 44.9% on Cook Point index bar in the Choptank River, followed closely by Gravelly Run/Green Pond bar (42.9%) in the St. Marys River. Regional average observed mortalities were generally low to moderate. The north-south gradient in observed mortalities evident in most years was less apparent in 2017, with strikingly low average mortalities in the lower bay, parts of the Tangier Sound region, and Pocomoke Sound (Figure 12). The highest regional mortalities were in the Wye River, averaging 28%. The highest Index-bar mortalities were observed on Flag Pond in the Western Shore mainstem and Old Woman's Leg in Tangier Sound, which tied at 50% (Table 5). However, both these sites had low numbers of live and dead oysters (n=16 and 8 live, respectively) which may exaggerate observed mortalities.

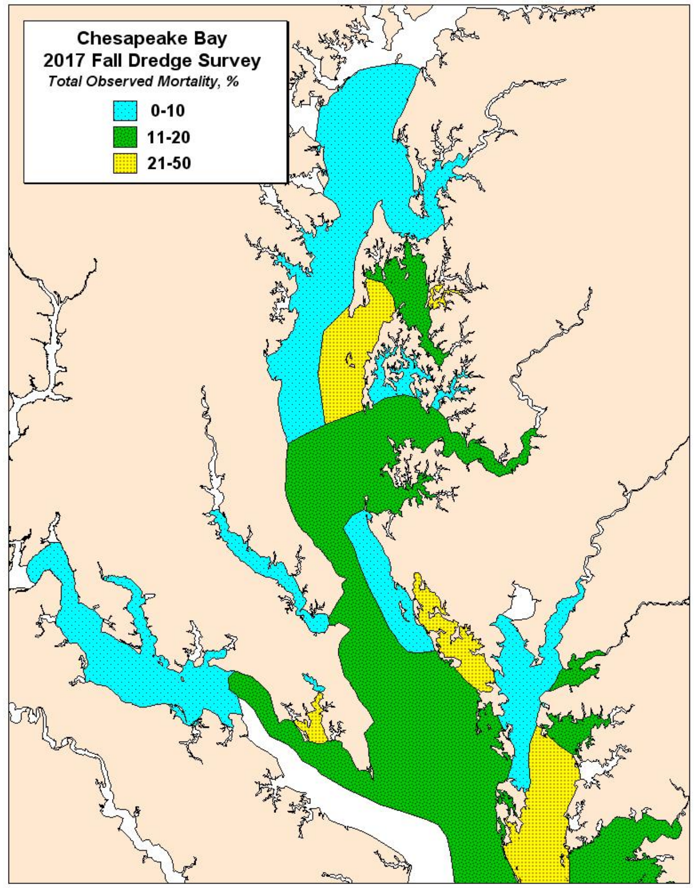


Figure 12. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2017. Mortality ranges represent regional averages.

BIOMASS INDEX

The biomass index is a relative measure of how the oyster population is doing over time. It accounts for recruitment, individual growth, natural mortality, and harvesting in a single metric. In assessing the size of the population, the biomass index integrates both the abundance of oysters and their collective body weight (another way of looking at how large they are). For example, when examining two groups of oysters with the same abundance, the group with the greater number of larger oysters would have the higher biomass.

The 2017 Maryland oyster biomass index of 1.40 is identical to the 2016 index (Figure 13), although the size distribution shifted to more sublegal oysters relative to market oysters. This was evidenced by the change in the sublegal to market oyster ratio from

1.18 sublegals for every market oyster in 2016 to 1.82 sublegals per market oyster in 2017. The 2017 index ranked tied for seventh highest in the 25-year time series, although it continues a declining trend from the peak index in 2013 (2.09), reflecting the depletion of the strong 2010 and 2012 year classes and unexceptional spatsets in many of the regions since then.

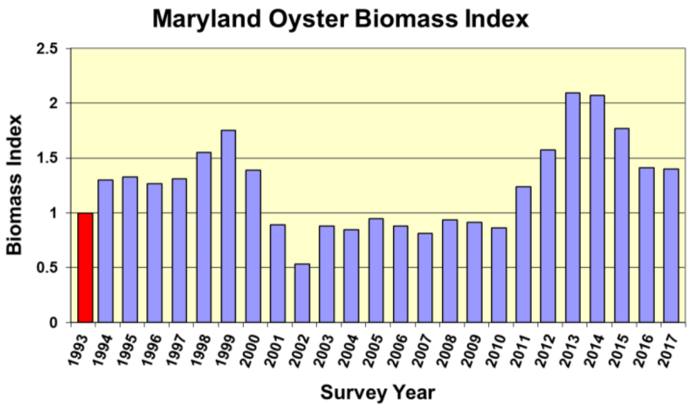


Figure 13. Maryland oyster Biomass Index. The year 1993 represents the baseline index of (1).

The oyster population had been slow to recover since its nadir in 2002, the last year of the devastating four-year epizootic. The biomass index remained below one[1] for eight consecutive years despite low disease pressure and high oyster survivorship over this period. Spatfall during this timeframe was sufficient to maintain the population at this level but not increase it. It was not until the strong recruitment event in 2010 - bolstered by another good spatset in 2012 - that the population began to grow, as mirrored in the increase in the biomass index.

CULTCH INDEX

The cultch index is new to this report; it is a relative measure of oyster habitat. Cultch is crucial for providing hard substrate for oyster setting as well as habitat for the myriad other organisms associated with the oyster community. For the purpose of the Fall Oyster Survey, cultch is defined as primarily both oysters (live and dead) and shell.

The collection of quantitative cultch data was initiated during the 2005 Fall Oyster Survey. During a sampling tow, the distance covered by the dredge while sampling on the bottom is measured using a handheld geographic positioning system (gps) unit with an odometer function. After the dredge is retrieved, the total volume of oysters and shell is measured in bushel units. Since tow distances vary, the volume is standardized to a 100 ft. tow by dividing 100 by the actual tow distance and multiplying the result by the total cultch volume. The cultch index is calculated as the annual average of the standardized cultch volumes from the 53 “Key Bars” used in the spat index. Because the dredge is less than 100% efficient in catching oysters and shells, this is not an absolute measure of cultch but provides a relative index for temporal and spatial comparisons.

The 2017 cultch index of 0.83 bu/100 ft. was somewhat lower than the 13-year average of 0.91 bu/100 ft. However, individual bars showed much steeper declines. Of the 51 bars used in this analysis, 30 had standardized volumes that were more than 25% below their respective 13-year averages, while 13 bars were similar to their 13-year averages and eight bars were more than 25% above their long-term averages (Figure 14).

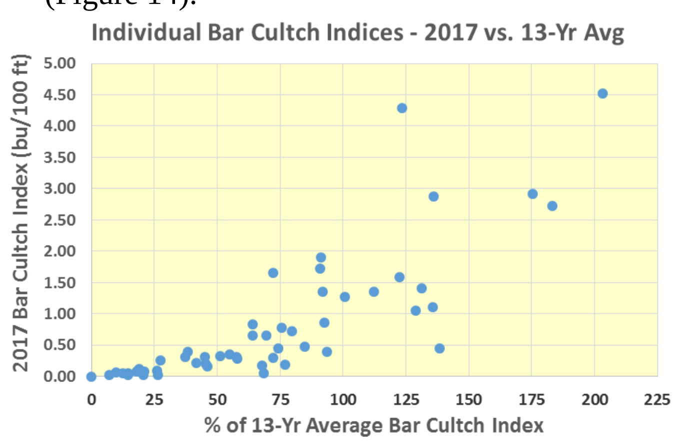


Figure 14. Range of cultch index values for individual Key bars in 2017 and the percent difference from their 13-year averages.

[1] The baseline (Biomass Index = 1) year of 1993 was chosen because it had the lowest harvest on record up to that point.

Although 13 years is a comparatively short time frame for discerning long-term trends in the cultch index, a distinctive pattern emerged over this period (Figure 15). A three-year rolling average was used to smooth the interannual variability inherent in the index (the rolling average is assigned to the terminal or third year of the grouping). The increase in the cultch index during the early 2010s reflects improvements in recruitment and survivorship during this period, especially the strong spatsets in 2010 and 2012 (Figures 3b, 11). The growth and good survivorship of these year classes contributed substantially to the index. The subsequent decline may be due to the removal of these oysters and lower recruitment, as well as ongoing taphonomic processes such as shell burial and degradation.

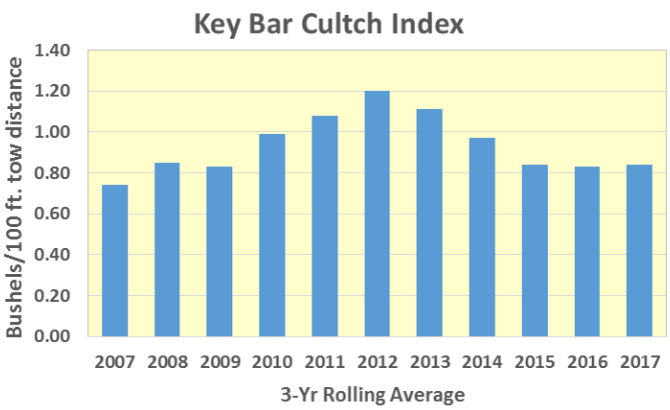


Figure 15. Three-year rolling average of annual means for the Key Bar cultch index, 2005-2017. The average is represented by the third year of the grouping (e.g. the 2005-07 average is graphed as 2007).

Strong regional differences in cultch mean volumes were evident (Figure 16). The areas with the lowest standardized cultch averages included the entire mainstem of the bay, followed by the combined Chester River/Eastern Bay region. The highest cultch indices were in areas with more favorable recruitment and consequent additions to cultch, specifically the Tangier Sound and Choptank River regions. Four of the six regions experienced declines averaged over the last three years when compared to the 13-year average (Figure 16). The largest decline in regional indices occurred in the Chester River/Eastern Bay region, followed by the Patuxent River. Tangier Sound saw a slight improvement in its index, while the Choptank region remained stable.

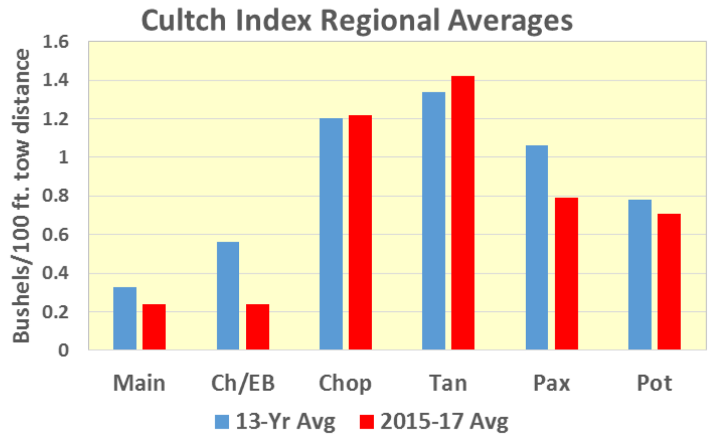


Figure 16. Regional cultch index averages for the thirteen year time series and most recent three years. *Main=bay mainstem; Ch/EB=Chester River/Eastern Bay region; Chop=Choptank River region; Tan=Tangier Sound region; Pax=Patuxent River; Pot=Potomac River tributaries*

COMMERCIAL HARVEST

With reported harvests of 225,000 bushels during the 2016-17 season, commercial oyster landings were 41% lower than the previous harvest season (Table 6, Figure 17a). This was the lowest total since the 2011-12 harvest season and was 25% below the 32-yr average of 299,000 bu/yr. At an average reported price of $47.21 per bushel, the dockside value of $10.6 million was a decrease of $4.3 million (-29%) from the previous year (Table 7a.).

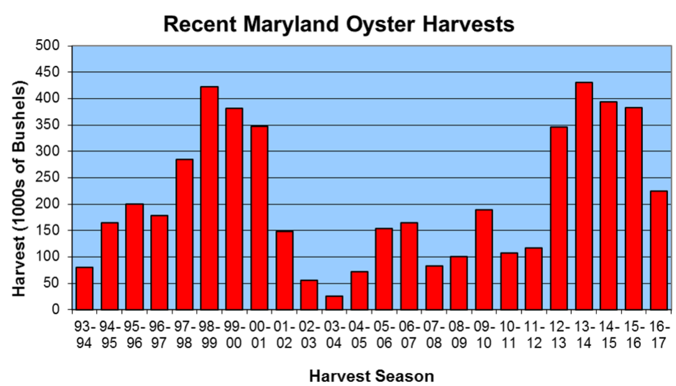


Figure 17a. Maryland oyster landings over the most recent 24 seasons.

Until this season, commercial oyster landings over the previous 15 years have followed a similar pattern as the biomass index. Prior to the 2012-13 season, the fishery struggled to rebound from the devastating oyster blight of 2002, with a record low of 26,000 bu taken in 2003-04. The sizeable harvest increases of the previous four seasons, following the below-average landings of the previous eleven years, were due to the strong 2010 and 2012 year-classes and subsequent good survivorship, allowing a larger proportion of the cohorts to attain market size. This abundance of oysters led to an increase in the number of harvesters and fishing effort, resulting in higher landings. However, mediocre spat sets following 2012 were insufficient to sustain harvests, leading to the substantial drop in landings during the 2016-17 season. The biomass index did not track this decline but remained the same as the previous year because of an influx of smaller oysters into the population, which compensated for the loss of market oysters. If mortality rates remain about the same as the previous several years, these younger oysters should recruit to the fishery and stabilize landings in the short-term.

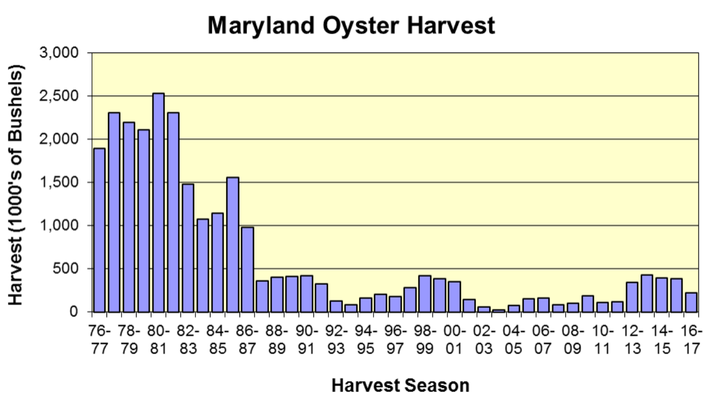


Figure 16b. Maryland seasonal oyster landings, 1976-77 to 2016-17.

Taken in the longer historical context, the average landings over the last five years remain only a fraction of the harvests prior to the disease epizootics of the mid-1980s (Figure 17b). Since the heyday of the Maryland oyster fishery in the 19th century, annual landings below 100,000 bushels have been reported in only five seasons, all within the past 24 years (and four of these in the most recent 15 years).

The Tangier Sound region, including the Nanticoke, Wicomico and Honga rivers, Pocomoke Sound and Fishing Bay, was again the dominant harvest area, accounting for 40% of the 2016-17 landings, about the same as the previous season (Table 6). Outside of Tangier Sound proper, which contributed 20.0% of the landings, the highest percentage of the harvests (14.3%) came from Broad Creek, a tributary of the Choptank River with a much smaller area. Almost all of the regions experienced declines in landings. The most substantial changes in Maryland landings between the 2015-16 and 2016-17seasons were:

Broad Creek
-decreased 35,312 bushels (-52%)
Upper Tangier Sound
-decreased 28,784 bushels (-45%)
Lower Tangier Sound
-decreased 18,798 bushels (-66%)
Patuxent River
-decreased 27,379 bushels (-55%)
Lower Choptank River
-decreased 11,162 bushels (-50%)

The combined harvests in the Tangier Sound region decreased by 69,345 bushels or 44% from 2015-2016 and 146,793 bushels (62%) from the recent peak season of 2013-14. The heaviest losses from the previous year occurred in the Choptank River region, the lower Eastern Shore and Patuxent River. Although the upper Bay and Eastern Bay showed modest gains this year, relatively speaking the northern portion of the mainstem and associated tributaries continued to perform poorly due to a lack of recruitment and repletion activity. For example, the combined percentage of landings from the upper Bay and Chester River, which in a couple of seasons in the 1990s and early 2000s accounted for over half of Maryland's total landings, was a mere 2.3% or 5,262 bu in 2016/17 (Table 6). The 32-year harvest average for these two regions was 35,000 bu/year, primarily sustained by numerous seed plantings that were made until about 2005. Likewise, harvests from the once-productive Eastern Bay region are only about half of the 32-year average.

For the tenth consecutive season, power dredging was the predominant method of harvesting, accounting for 36% of the total landings (Table 7b). The actual landings from power dredging are about one-third of those during the 2013-14 season (Table 7a). This activity was mainly in the Lower Eastern Shore and Choptank regions. Hand tonging produced 20% of the total harvests, primarily from Broad Creek, well below 74% of the landings during the 1996-97 season when power dredging was largely prohibited. Patent tonging declined slightly to 23% of the total, while sail dredging (skipjacks) and diving had minor changes.

OYSTER SANCTUARIES

An in-depth analysis of the performance of Maryland's oyster sanctuary system is beyond the scope of this report and will be provided at a future date in a stand-alone document examining longer-term trends. However, some salient points are considered here to provide a snapshot of the sanctuary oyster populations, focusing on the more important (e.g. large-scale restoration) sanctuaries.

A total of 88 oyster bars within 33 sanctuaries were sampled during the 2017 Fall Survey (Table 8). Recruitment within sanctuaries was lower than the previous year, in keeping with the baywide results. A comparison of spatset in sanctuaries with adjacent harvest areas is mixed. For example, Harris Creek sanctuary stations averaged 79 spat/bu. This was similar to the adjacent Broad Creek open harvest area, historically a higher recruitment tributary, which averaged 71 spat/bu (Table 2). In contrast, there were strong differences in recruitment intensities between some primary sanctuaries and adjacent harvest areas. Recruitment in the open harvest area of the Little Choptank River averaged 25 spat/bu compared with 66 spat /bu inside the sanctuary, and the St. Marys River spatfall averaged 93 spat/bu in the open area and 217 spat/bu in the sanctuary. Likewise, the open harvest area of Tangier Sound averaged 22 spat/bu with a high count of 120 spat/bu (Back Cove bar), while the mean spatfall in the Manokin sanctuary averaged 90 spat/bu with a high count of 137 spat/bu on Georges bar. Looking at individual bars, the highest spatset on a Key (spat index) Bar and the second highest spatset for all bars in the 2017 survey was observed on Pagan bar in the St. Marys River sanctuary (247 spat/bu); the highest 2017 survey spatset was on Coppage bar (458 spat/bu) about 1.5 mi downstream of this sanctuary.

Oyster disease samples were obtained from 19 sanctuaries. The average dermo disease levels in these sanctuaries were virtually unchanged from the previous year (prevalences of 83.8% in 2016 vs. 83.9% in 2017; intensities of 3.4 in 2016 vs. 3.3 in 2017). Of the 13 Disease Bars within oyster sanctuaries, dermo disease prevalences and intensities were above the 28-year site averages at 11 bars. Meanwhile, the average MSX disease prevalence declined 73% from 2016. The disease was detected at only two of the 13 Disease Bars within sanctuaries at low prevalences (Table 4), as well as at three of the six non-index bars in sanctuaries. Monitoring sites in the three restoration sanctuaries to date - Harris Creek, Tred Avon, and Little Choptank - showed no evidence of MSX disease (Table A). Regarding some of the adjacent open harvest areas, MSX disease was not found in Broad Creek (Deep Neck), a tributary located between the Harris Creek and the Tred Avon River sanctuaries, but was detected at a low prevalence (3%) on Ragged Point outside of the Little Choptank sanctuary. The highest MSX disease prevalences (Table 4) were observed in Tangier Sound, but the disease was not detected in the nearby Manokin sanctuary.

Mortality rates for the most part continue to be well below the long-term averages (Table 5). Ten of the 13 mortality index bars within sanctuaries had observed mortalities below the 32-year individual bar average. Of the exceptions, Cook Point sanctuary experienced the highest observed mortalities (48%) of any of the index sites. Despite anecdotal reports of high oyster mortalities in the Manokin River sanctuary, the measured average observed mortality was only 10.9%, comparable to the Tangier open harvest bars (8.9%) and well below the long-term index mean.

Overall, oysters in sanctuaries that received strong spatfalls in 2010 and 2012 along with those receiving supplemental oyster seed plantings and further spatsets continued to do well. Those include the sanctuaries in Harris Creek, and Little Choptank, Manokin, and St. Marys rivers.

Table A. Disease Levels at Three Restoration Sanctuaries and Adjacent Open-Harvest Areas

Tributary	Status	Bar	MSX Prev.%	Dermo Prev.%	Dermo Int.
Harris C.	Sanc.	Mill Pt.	0	97	4.1
Harris C.	Open	Tilghman Wharf	0	70	2.2
Tred Avon R.	Sanc.	Double Mills	0	97	3.9
Broad C.	Open	Deep Neck	0	77	2.4
L. Chop. R.	Sanc.	Cason	0	97	3.3
L. Chop. R.	Open	Ragged Pt.	3	97	3.7

DISCUSSION

The Importance of Oyster Shell

The importance of shell as habitat for maintaining oyster populations and associated organisms has long been recognized. Oyster reefs and their faunal assemblages were the basis in developing the concept of an ecological community during the late nineteenth century (Möbius 1883). In 1890, the Maryland legislature passed the "cull law" requiring harvesters to return not only undersized oysters (at that time less than 2.5 inches) but also the shell that was caught incidentally to the oyster bar of origin (Laws of Maryland 1890, Ch. 602). During the 1920s, Maryland established a routine bar replenishment program planting shells from shucking houses. This was greatly expanded in 1960 with a large-scale buried shell dredging and planting effort which lasted until 2005.

Shell adds structure and firm substrate to the estuary, contributing habitat that is in stark contrast to the otherwise soft bottom environment of the bay. These shell reefs enhance recruitment and survival of shellfish species, increase species diversity and abundance, and create vertical features on the bay bottom (Powell and Klinck 2007), which alter water circulation patterns, reduce sedimentation, and provide an elevated refuge from deeper water hypoxia. In the Chesapeake Bay the most important source of shell substrate is oyster shell.

Oysters are unique among the species in Chesapeake Bay in that they create their own habitat. Larvae of *C. virginica* require a firm, sediment-free surface upon which to settle and attach (Kennedy 1996). Also, the structural complexity that shell provides creates refuges from predation for the young oyster spat as well as other species. The larvae's gregarious settlement response produces dense aggregations of oysters coexisting with a diverse and abundant assortment of associated organisms in communities. Thus oysters are considered a keystone species because as ecological engineers the structures they build support a vast array of species which are the foundation for complex food webs within the estuary (Mann and Powell 2007).

A shell budget is an accounting of shell accumulation balanced against shell loss, much like a bank account. Shell accretion is dependent on oyster recruitment, growth, and death (Mann and Powell 2007). Under natural conditions, shell degradation is due to a combination of taphonomic factors, where shell is lost through chemical (e.g., dissolution), physical (e.g., sedimentation, subsidence, breakage, dislodgement from the bar), and biological (e.g., shells riddled by boring sponges, polychaete worms, etc.) processes (Soniat et al. 2014). For reefs to build, the rate of shell accretion must exceed the rate of shell loss, which under natural conditions occurs by some small amount (Mann and Powell 2007). The extraordinary outbreaks of disease epizootics in recent decades and two centuries of harvesting have disrupted this balance (Soniat et al. 2014, Powell and Klinck 2007).

Recruitment is a key factor in reef accretion, in that small changes in recruitment can produce large changes in shell abundance (Powell and Klinck 2007). The issue in Maryland is that recruitment is notoriously variable, as was evident in the boost to the cultch index following the strong recruitment of 2010 and 2012 and its subsequent decline after a series of indifferent spatsets. Furthermore, there are distinct regional differences in recruitment, resulting in disparities in the cultch index between low recruitment regions such as the upper bay and higher spatset areas like the lower Eastern Shore around Tangier Sound.

Oysters must die in place in order to add shell to the bar, which in the absence of disease is a natural mortality rate of about 10% annually (Powell and Klink 2007). Although shell is added to the bar in the short term during high mortality events such as the 1999-2002 disease epizootics, unless the bar repopulates with oysters the amount of shell will eventually decline. Catastrophic mortalities are especially problematic in low recruitment regions such as the upper bay, for example, where killing freshets in 2011 resulted in mortalities of up to 100% on some bars (Tarnowski 2012). Little if any spatset has been observed in this region since then to replace the lost oysters, meaning no new shell has been added naturally to the bars. Because taphonomic processes are constantly degrading the shell base, the bar will slowly disappear unless shell is continuously replaced, either naturally or through management intervention. Over a period of time, shell either taphonomically degrades, is removed, or is incorporated into the core of the reef by the overgrowth of new oysters. For example, the half-life of shell in Delaware Bay has been estimated to be between two and ten years (Powell et al. 2006). Whatever the pathway, it eventually becomes unavailable as substrate for oyster larval settlement. Therefore, rebuilding oyster populations entails more than simply putting oysters in the water; it requires concomitantly rebuilding habitat as well (Mann and Powell 2007).

Powell and Klink (2007) assert that the decline of oysters in the Chesapeake is associated with a decline in the shell resource. Large swaths of formerly productive oyster bars in Maryland now have little if any shell. The problem is especially acute in the mainstem, but shell loss is occurring on many bars throughout the bay. Even in areas that have shown net gains recently, such as the Tangier Sound region, individual bars are degrading (e.g., Old Woman’s Leg, Back Cove Lot #1). The deterioration of the oyster bars has undoubtedly had a profound effect on the Chesapeake ecosystem. In the soft bottom estuaries of the mid-Atlantic region, hard substrate for the attachment of epibenthic organisms is at a premium, provided mainly by biogenic processes. Chief among these are oyster reefs, contributing structure and substrate that sustain the rich community of organisms associated with them. The decline of the Chesapeake oyster over the past three decades has resulted in the reduction of a critical functional component of the ecosystem and the gradual disappearance of a significant structural element as well.

LITERATURE CITED

Bue, C.D. 1968. Monthly surface-water inflow to Chesapeake Bay: U.S. Geological Survey Open-File Report, Arlington, Va., October 1968, 45 pp.

Chesapeake Bay Program Data Hub. CBP Water Quality Database (1984-present). http://www.chesapeakebay.net/data

Coen, L.D., and M.W. Luckenbach. 2000. Developing successful criteria and goals for evaluating oyster reef restoration: Ecological restoration or resource exploitation? *Ecological Engineering* 15: 323-343.

Gieseker, C.M. 2001. Year 2000 Maryland Oyster Disease Status Report. MDNR, Cooperative Oxford Lab. FS-SCOL-01-1. Oxford, Md. 27 pp. http://dnr.maryland.gov/fisheries/Documents/2000_oyster_disease.pdf

Hájek, J. and Z. Šidák. 1967. Theory of Rank Tests. Academic Press, New York.

Hollander, M. and D.A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, New York, N.Y.

Homer, M. and R. Scott. 2001. Maryland Oyster Population Status Report. 1996-2000 Fall Surveys. Md. Dept. of Natural Resources, Annapolis, Md.

Jordan, S.J., K.N. Greenhawk, C.B. McCollough, J. Vanisko, and M.L. Homer. 2002. Oyster biomass, abundance, and harvest in northern Chesapeake Bay: Trends and forecasts. *J. Shellfish Res.* 21: 733-741.

Kennedy, V.S. 1996. Biology of Larvae and Spat pp 371-411 in: The Eastern Oyster-*Crassostrea virginica*, V.S. Kennedy, R.I.E. Newell, and A.F. Eble. Maryland Sea Grant College Program, College Park.

Krantz, G.E. and D.W. Webster. 1980. Maryland Oyster Spat Survey – Fall 1979. Md. Sea Grant Prog. Tech. Rept. No. UM-SG-TS-80-01. College Park, Md.

Lehman, E.L. 1963. Asymptotically nonparametric inference in some linear models with one observation per cell. *Ann. Math. Statist*. 34: 1494-1506.

Mann, R., and E.N. Powell. 2007. Why oyster restoration goals in the Chesapeake Bay are not and probably cannot be achieved. *J. Shellfish Res.* 26(4): 905-917.

Maryland DNR. 2018. Ray's fluid thioglycollate medium (RFTM) assays for dermo disease in oysters and Perkinsus sp. infections in other molluscs: Maryland DNR methods used at the Cooperative Oxford Laboratory. 7 pp. http://dnr.maryland.gov/fisheries/documents/RFTM_assays_for_dermo_disease.pdf

McDonald, B.J. and W.A. Thompson, Jr. 1967. Rank sum multiple comparisons in one- and two-way classifications. *Biometrika*. 54: 487-497.

Möbius, K. 1883. The oyster and oyster culture. U.S. Comm. Fish. Rep. No. 8: 683-752.

Powell, E. N., and J. M. Klinck. 2007. Is oyster shell a sustainable estuarine resource? *J. Shellfish Res.* 26: 181–194.

Powell, E.N., J.N. Kraeuter, and K.A. Ashton-Alcox. 2006. How long does oyster shell last on an oyster reef? *Estuarine Coastal Shelf Sci*. 69: 531-542.

Soniat, T.M., N. Cooper, E.N. Powell, J.M. Klink, M. Abdelguerfi, S. Tu, R. Mann, and P.D. Banks. 2014. Estimating sustainable harvests of eastern oysters, *Crassostrea virginica.* J. Shellfish Res. 33: 381-394.

Tarnowski, M. 2011. Maryland Oyster Population Status Report – 2010 Fall Survey. MDNR Publ. No. 17-7292011-517. Annapolis, Md. 47 pp. http://dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

Tarnowski, M. 2012. Maryland Oyster Population Status Report – 2011 Fall Survey. MDNR Publ. No. 17-8152012-598. Annapolis, Md. 51 pp. http://dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

USGS. 2015. Estimated streamflow entering Chesapeake Bay above selected cross sections. United States Geological Survey Inflow Database. http://md.water.usgs.gov/waterdata/chesinflow/

MDNR Deputy Secretary Joanne Throwe and Dr. Mark Homer aboard the MDNR Research Vessel Miss Kay during the 2016 Fall Oyster Survey. *(Photo: R. Bussell)*

TABLES

Table 1. Listing of data recorded during the Annual Fall Dredge Survey.

Physical Parameters

-Latitude and longitude (deg., min., decmin.)

-Depth (ft.)

-Temperature (°C; surface at all stations, 1 ft. above bottom at Key & Disease Bars)

-Salinity (ppt; surface at all stations, 1 ft. above bottom at Key & Disease Bars)

-Tow distance (ft.) (2005-present)

Biological Parameters

-Total volume of material in dredge (Md. bu.) (2005-present)

-Counts of live and dead oysters by age/size classes (spat, smalls, markets) per Md. bushel of material

-Stage of oyster boxes (recent, old)

-Observed (estimated) average and range of shell heights of live and dead oysters by age/size classes (mm)

-Shell heights of oysters grouped into 5-mm intervals (Disease Bars, 1990-2009) or 1-mm intervals (Disease Bars and other locations totaling about 30% of all surveyed bars, 2010-present)

-Oyster condition index and meat quality

-Type and relative index of fouling and other associated organisms

-Type of sample and year of activity (e.g. 1997 seed planting, natural oyster bar, 1990 fresh shell planting, etc.)

The time series for the Spat Intensity, Diseases, and Mortality Indices are presented in Tables 2 - 5. The majority of Fall Survey data, including supplemental disease results, are archived in digital files. Fouling data and oyster condition are in paper files.

(Return to Text)

Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 "Key" spat monitoring bars, 1985-2017. (S) = bar within an oyster sanctuary since 2010.

Region	Oyster Bar	Spatfall Intensity (Number per Bushel)					
		1985	1986	1987	1988	1989	1990
Upper Bay	Mountain Point	6	0	0	0	0	0
	Swan Point	4	0	2	2	0	0
Middle Bay	Brick House	78	0	4	8	0	3
	Hackett Point	0	4	0	0	0	0
	Tolly Point	2	2	2	0	0	0
	Three Sisters	10	2	8	0	0	0
	Holland Point (S)	6	5	0	0	0	0
	Stone Rock	136	20	0	50	22	37
	Flag Pond (S)	52	144	128	0	0	4
Lower Bay	Hog Island	116	32	58	29	4	7
	Butler	nd	197	142	16	2	24
Chester River	Buoy Rock	16	0	6	0	0	1
Eastern Bay	Parsons Island	78	4	4	2	0	7
	Wild Ground	46	8	4	8	0	18
	Hollicutt Noose	24	8	12	6	0	2
Wye River	Bruffs Island (S)	82	0	0	2	0	2
Miles River	Ash Craft	10	2	0	10	0	2
	Turtle Back	382	40	12	52	6	11
Poplar I. Narrows	Shell Hill	50	6	0	6	0	48
Choptank River	Sandy Hill (S)	74	16	2	0	0	28
	Royston	440	8	8	0	0	57
	Cook Point (S)	66	82	4	28	0	17
Harris Creek	Eagle Pt./Mill Pt. (S)	258	92	2	6	6	18
	Tilghman Wharf	156	28	38	4	4	109
Broad Creek	Deep Neck	566	114	6	22	4	48
Tred Avon River	Double Mills (S)	332	24	2	0	0	1
Little Choptank R.	Ragged Point	134	82	34	112	0	65
	Cason (S)	102	24	46	50	0	143
Honga River	Windmill	34	112	28	22	16	155
	Norman Addition	56	214	38	17	34	82
Fishing Bay	Goose Creek	34	97	16	18	4	4
	Clay Island	4	78	14	48	18	19
Nanticoke River	Wetipquin (S)	34	10	0	0	0	3
	Middleground	8	12	26	9	16	40
	Evans	18	10	12	17	2	13
Wicomico River	Mt. Vernon Wharf	nd	0	0	0	0	0
Manokin River	Georges (S)	26	98	14	4	16	4
	Drum Point (S)	48	186	48	90	78	16
Tangier Sound	Sharkfin Shoal	18	44	22	24	2	16
	Turtle Egg Island	154	90	12	26	26	204
	Piney Island East	182	192	194	160	82	64
	Great Rock	2	6	4	6	10	66
Pocomoke Sound	Gunby	124	24	50	4	8	21
	Marumsco	26	50	18	5	12	6
Patuxent River	Broome Island	15	0	0	0	0	3
	Back of Island	42	0	8	4	4	15
St. Mary's River	Chicken Cock	620	298	96	62	18	29
	Pagan (S)	140	34	52	36	6	613
Breton Bay	Black Walnut (S)	16	12	0	0	0	1
	Blue Sow (S)	55	40	0	0	0	1
St. Clement Bay	Dukehart Channel	20	7	0	0	0	1
Potomac River	Ragged Point	69	35	4	0	0	2
	Cornfield Harbor	383	908	362	28	14	36
	Spat Index	**103.8**	**66.1**	**29.1**	**18.7**	**7.8**	**39.0**

Table 2 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)							
	1991	1992	1993	1994	1995	1996	1997	1998
Mountain Point	0	0	3	0	0	0	1	0
Swan Point	1	0	3	0	0	0	0	0
Brick House	0	0	0	0	5	0	0	0
Hackett Point	0	0	0	0	0	0	0	0
Tolly Point	0	0	0	0	0	0	0	0
Three Sisters	0	0	0	0	0	0	0	0
Holland Point (S)	0	0	0	0	0	0	0	0
Stone Rock	355	9	4	4	16	0	18	0
Flag Pond (S)	330	0	8	0	10	0	7	0
Hog Island	169	0	0	0	17	0	5	2
Butler	617	3	2	1	7	1	8	0
Buoy Rock	0	0	0	0	6	0	8	0
Parsons Island	127	18	2	0	44	0	3375	3
Wild Ground	205	8	2	0	54	0	990	0
Hollicutt Noose	11	1	0	0	7	0	56	0
Bruffs Island (S)	12	8	0	0	15	0	741	4
Ash Craft	12	0	0	0	60	1	2248	0
Turtle Back	168	15	0	0	194	0	3368	5
Shell Hill	79	0	0	0	15	0	19	1
Sandy Hill (S)	179	2	0	0	4	0	55	0
Royston	595	20	10	0	10	0	289	0
Cook Point (S)	171	1	0	2	14	0	20	0
Eagle Pt./Mill Pt. (S)	387	4	15	0	62	0	168	2
Tilghman Wharf	719	10	59	4	64	0	472	0
Deep Neck	468	22	94	12	294	3	788	1
Double Mills (S)	129	0	13	0	15	0	40	0
Ragged Point	1036	53	9	1	25	0	106	0
Cason (S)	1839	43	37	28	48	5	228	4
Windmill	740	46	22	19	13	2	5	1
Norman Addition	1159	53	33	17	25	0	8	0
Goose Creek	153	41	43	27	3	0	5	0
Clay Island	256	46	58	31	11	1	20	2
Wetipquin (S)	3	6	1	4	1	0	0	10
Middleground	107	63	14	28	2	6	27	0
Evans	20	27	6	30	3	1	5	0
Mt. Vernon Wharf	15	0	18	0	3	0	0	1
Georges (S)	52	42	19	9	5	0	8	6
Drum Point (S)	140	185	45	13	14	10	16	11
Sharkfin Shoal	43	97	18	11	6	0	7	0
Turtle Egg Island	289	591	37	31	6	35	70	3
Piney Island East	429	329	22	25	23	25	45	16
Great Rock	208	44	27	11	3	7	0	1
Gunby	302	149	68	7	5	9	0	24
Marumsco	142	34	60	5	6	0	0	57
Broome Island	8	0	0	0	58	0	0	1
Back of Island	49	5	0	1	17	0	3	0
Chicken Cock	182	5	45	4	78	2	36	10
Pagan (S)	190	62	15	7	54	0	1390	6
Black Walnut (S)	6	0	1	0	1	0	2	0
Blue Sow (S)	22	0	1	0	7	0	0	0
Dukehart Channel	19	0	3	0	0	0	0	0
Ragged Point	26	0	2	0	19	0	2	0
Cornfield Harbor	212	2	29	0	49	0	4	11
Spat Index	**233.6**	**38.6**	**16.0**	**6.3**	**26.8**	**2.0**	**276.7**	**3.5**

Table 2 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)							
	1999	2000	2001	2002	2003	2004	2005	2006
Mountain Point	0	0	0	1	0	0	0	0
Swan Point	0	0	0	0	0	0	0	0
Brick House	1	1	3	97	0	0	0	0
Hackett Point	0	1	0	13	0	0	0	0
Tolly Point	2	2	1	10	0	0	0	0
Three Sisters	0	0	1	0	0	0	0	0
Holland Point (S)	0	0	1	4	0	0	0	0
Stone Rock	3	34	2	17	1	0	0	3
Flag Pond (S)	1	5	5	7	0	0	0	4
Hog Island	6	1	28	10	5	1	6	1
Butler	6	1	27	33	3	0	3	7
Buoy Rock	0	0	2	1	1	1	0	0
Parsons Island	6	6	6	5	2	0	3	0
Wild Ground	2	5	5	6	4	0	1	0
Hollicutt Noose	6	2	1	15	3	0	0	0
Bruffs Island (S)	5	9	6	0	4	0	0	0
Ash Craft	14	2	10	0	8	0	0	0
Turtle Back	13	4	45	9	72	1	5	0
Shell Hill	4	4	0	0	0	0	0	0
Sandy Hill (S)	4	0	1	1	0	2	0	5
Royston	39	0	3	10	0	14	0	44
Cook Point (S)	1	5	5	3	1	4	0	9
Eagle Pt./Mill Pt. (S)	16	0	5	4	1	12	0	19
Tilghman Wharf	49	1	1	4	0	15	0	22
Deep Neck	211	3	11	31	1	167	0	30
Double Mills (S)	1	0	0	0	0	3	0	3
Ragged Point	43	3	5	0	1	2	0	6
Cason (S)	53	5	2	9	1	5	1	93
Windmill	37	0	21	9	0	0	0	21
Norman Addition	31	1	30	33	2	0	6	80
Goose Creek	0	0	0	1	0	0	0	73
Clay Island	5	4	8	16	0	0	0	139
Wetipquin (S)	0	0	0	3	1	0	0	6
Middleground	9	1	0	14	0	0	1	54
Evans	1	0	0	12	0	1	0	13
Mt. Vernon Wharf	0	0	0	0	0	0	0	0
Georges (S)	50	6	1	280	15	4	5	75
Drum Point (S)	157	27	44	124	13	8	40	202
Sharkfin Shoal	9	5	0	57	0	2	4	63
Turtle Egg Island	180	33	33	207	25	7	90	181
Piney Island East	118	28	167	127	1	27	116	420
Great Rock	82	6	140	1	3	19	28	92
Gunby	54	32	6	108	0	29	24	36
Marumsco	27	27	4	89	0	14	11	22
Broome Island	7	0	1	15	1	0	3	4
Back of Island	22	9	44	27	11	0	0	1
Chicken Cock	132	16	12	151	56	2	2	6
Pagan (S)	95	42	117	535	9	6	10	125
Black Walnut (S)	3	0	1	2	0	0	0	0
Blue Sow (S)	11	0	2	4	1	0	0	0
Dukehart Channel	1	0	0	1	0	0	0	1
Ragged Point	1	1	0	1	0	0	0	1
Cornfield Harbor	25	5	35	31	9	0	8	6
Spat Index	**29.1**	**6.4**	**15.9**	**40.3**	**4.8**	**6.5**	**6.9**	**35.2**

Table 2 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)							
	2007	2008	2009	2010	2011	2012	2013	2014
Mountain Point	0	0	0	0	0	0	0	0
Swan Point	0	0	0	0	0	1	0	0
Brick House	0	0	6	4	1	7	0	0
Hackett Point	0	0	0	5	0	0	0	1
Tolly Point	0	0	0	2	0	1	0	0
Three Sisters	0	0	0	3	0	0	0	0
Holland Point (S)	0	0	0	1	0	0	0	0
Stone Rock	0	1	4	22	1	46	2	1
Flag Pond (S)	0	0	0	15	4	8	2	6
Hog Island	1	1	4	4	8	42	11	3
Butler	1	8	1	15	3	7	0	14
Buoy Rock	0	0	0	3	0	1	0	0
Parsons Island	0	0	8	2	0	13	0	1
Wild Ground	0	1	1	3	0	7	0	2
Hollicutt Noose	0	0	0	5	0	8	0	0
Bruffs Island (S)	0	0	0	3	0	18	0	0
Ash Craft	0	0	2	39	0	1	3	0
Turtle Back	0	0	13	13	0	16	1	1
Shell Hill	0	0	0	1	0	4	0	0
Sandy Hill (S)	3	1	5	5	0	6	1	1
Royston	2	5	20	27	0	46	9	19
Cook Point (S)	1	10	18	37	2	41	6	1
Eagle Pt./Mill Pt. (S)	0	2	17	44	0	29	4	1
Tilghman Wharf	0	6	15	72	0	183	20	46
Deep Neck	1	23	100	144	1	331	14	9
Double Mills (S)	1	3	11	4	0	5	2	1
Ragged Point	0	2	12	33	0	14	5	2
Cason (S)	0	13	9	50	0	65	14	4
Windmill	4	79	7	85	12	88	114	19
Norman Addition	0	102	6	155	27	138	145	38
Goose Creek	0	35	20	75	83	98	128	8
Clay Island	1	94	29	342	26	103	56	6
Wetipquin (S)	0	2	2	8	4	8	5	22
Middleground	0	21	6	92	23	78	59	7
Evans	0	14	9	27	10	98	3	1
Mt. Vernon Wharf	0	0	8	2	4	16	0	9
Georges (S)	5	28	22	753	243	133	117	35
Drum Point (S)	56	124	34	524	248	219	92	58
Sharkfin Shoal	1	16	14	169	23	65	46	24
Turtle Egg Island	7	32	17	202	23	153	47	24
Piney Island East	44	23	0	160	109	199	6	14
Great Rock	64	38	5	12	5	111	0	2
Gunby	4	5	24	317	25	251	20	43
Marumsco	14	12	24	261	44	81	43	19
Broome Island	0	3	5	52	2	8	4	2
Back of Island	2	7	8	47	7	70	6	3
Chicken Cock	9	1	16	37	11	27	15	38
Pagan (S)	616	0	321	227	110	325	196	64
Black Walnut (S)	0	0	0	1	0	0	0	0
Blue Sow (S)	0	0	3	0	0	0	0	0
Dukehart Channel	0	0	1	0	0	1	0	0
Ragged Point	2	1	2	0	1	0	0	2
Cornfield Harbor	7	1	1	28	3	7	7	46
Spat Index	**15.9**	**13.5**	**15.7**	**78.0**	**20.1**	**59.9**	**22.7**	**11.3**

Table 2 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)			
	2015	2016	2017	*33-Yr Avg*
Mountain Point	0	0	0	*0.3*
Swan Point	0	0	0	*0.4*
Brick House	0	0	0	*6.6*
Hackett Point	0	0	0	*0.7*
Tolly Point	0	2	0	*0.8*
Three Sisters	0	0	0	*0.7*
Holland Point (S)	0	0	0	*0.5*
Stone Rock	2	17	0	*25.1*
Flag Pond (S)	10	12	28	*23.9*
Hog Island	9	22	1	*18.3*
Butler	68	90	2	*40.9*
Buoy Rock	0	0	0	*1.4*
Parsons Island	8	0	0	*112.8*
Wild Ground	15	0	0	*42.3*
Hollicutt Noose	1	0	0	*5.1*
Bruffs Island (S)	0	0	0	*27.6*
Ash Craft	0	0	0	*73.5*
Turtle Back	13	4	0	*135.2*
Shell Hill	4	2	1	*7.4*
Sandy Hill (S)	0	3	1	*12.1*
Royston	21	13	23	*52.5*
Cook Point (S)	1	21	2	*17.4*
Eagle Pt./Mill Pt. (S)	34	68	55	*40.3*
Tilghman Wharf	45	58	13	*67.2*
Deep Neck	83	91	205	*118.1*
Double Mills (S)	9	12	3	*18.6*
Ragged Point	19	125	35	*59.5*
Cason (S)	11	60	67	*92.7*
Windmill	16	9	9	*52.9*
Norman Addition	34	60	44	*80.8*
Goose Creek	11	44	27	*31.8*
Clay Island	43	68	41	*48.1*
Wetipquin (S)	2	6	0	*4.3*
Middleground	12	32	66	*25.2*
Evans	14	18	1	*11.7*
Mt. Vernon Wharf	1	3	1	*2.5*
Georges (S)	29	61	137	*69.8*
Drum Point (S)	59	172	78	*96.3*
Sharkfin Shoal	57	53	32	*28.7*
Turtle Egg Island	64	57	15	*90.0*
Piney Island East	3	0	2	*101.6*
Great Rock	13	4	14	*31.3*
Gunby	95	73	34	*59.8*
Marumsco	141	69	31	*41.0*
Broome Island	6	21	6	*6.8*
Back of Island	18	42	5	*14.5*
Chicken Cock	712	33	19	*84.2*
Pagan (S)	24	91	247	*174.7*
Black Walnut (S)	3	4	0	*1.6*
Blue Sow (S)	0	10	0	*4.8*
Dukehart Channel	0	3	0	*1.8*
Ragged Point	1	11	2	*5.6*
Cornfield Harbor	100	92	6	*74.4*
Spat Index	**34.2**	**30.9**	**23.6**	***40.6***

(Return to Text)

Table 3. *Perkinsus marinus* prevalence and mean intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2017. NA = insufficient quantity of oysters for analytical sample. (S) = bar within an oyster sanctuary since 2010.

Region	Oyster Bar	***Perkinsus marinus*** **Prevalence (%) and Mean Intensity (I)**									
		1990		1991		1992		1993		1994	
		%	I	%	I	%	I	%	I	%	I
Upper Bay	Swan Point	7	0.1	27	0.7	23	0.4	37	0.8	3	0.1
Middle Bay	Hackett Point	0	0.0	27	0.8	57	1.2	97	3.2	23	0.5
	Holland Point (S)	20	0.5	47	1.1	80	2.4	93	3.0	36	1.1
	Stone Rock	47	0.5	27	0.9	100	4.4	100	3.5	90	2.5
	Flag Pond (S)	30	0.8	97	2.6	97	5.7	88	2.7	30	0.8
Lower Bay	Hog Island	90	3.0	97	4.5	100	4.2	93	2.4	37	1.0
	Butler	100	4.0	100	4.0	81	2.4	97	3.3	80	2.1
Chester River	Buoy Rock	23	0.5	80	2.5	97	2.8	93	3.3	10	0.3
	Old Field (S)	17	0.2	20	0.5	37	0.9	83	2.4	20	0.6
Eastern Bay	Bugby	100	3.4	100	4.0	73	1.8	100	3.0	43	0.8
	Parsons Island	20	0.5	97	3.6	80	2.1	100	3.3	93	3.1
	Hollicutt Noose	30	0.3	73	2.0	82	2.1	97	2.7	70	1.7
Wye River	Bruffs Island (S)	83	2.8	83	2.8	93	3.0	83	2.6	63	1.3
Miles River	Turtle Back	100	3.8	100	3.3	77	1.6	100	3.3	60	1.2
	Long Point (S)	73	2.3	94	4.3	86	3.0	77	2.6	60	2.0
Choptank River	Cook Point (S)	17	0.2	23	0.3	87	3.7	97	4.2	90	3.0
	Royston	NA	NA	100	4.5	97	4.8	100	3.3	80	2.0
	Lighthouse	90	2.3	100	4.0	100	4.6	93	3.2	47	1.2
	Sandy Hill (S)	100	5.0	100	5.7	100	4.2	100	3.8	83	2.3
	Oyster Shell Pt. (S)	3	0.1	60	1.7	100	3.9	93	2.8	10	0.3
Harris Creek	Tilghman Wharf	100	3.2	97	3.0	100	3.4	100	3.2	63	1.9
Broad Creek	Deep Neck	100	4.9	100	5.6	100	3.7	100	3.8	67	2.3
Tred Avon River	Double Mills (S)	97	3.6	100	4.9	100	4.1	100	3.8	90	2.0
Little Choptank R.	Cason (S)	100	3.4	100	4.4	90	2.6	93	2.8	83	2.2
	Ragged Point	100	4.8	100	4.6	100	5.0	100	3.9	87	2.3
Honga River	Norman Addition	100	4.2	100	3.4	83	2.0	96	3.6	93	3.3
Fishing Bay	Goose Creek	60	1.8	100	3.1	100	3.6	87	2.1	53	1.1
Nanticoke River	Wilson Shoals (S)	93	2.9	100	2.8	90	2.5	83	1.6	40	0.9
Manokin River	Georges (S)	83	1.9	93	2.9	58	1.4	30	0.7	50	1.2
Holland Straits	Holland Straits	100	4.2	100	4.0	100	3.4	76	2.3	57	1.6
Tangier Sound	Sharkfin Shoal	23	0.3	60	1.2	97	2.8	93	2.2	63	1.4
	Back Cove	100	2.7	100	4.2	97	3.3	36	1.0	80	2.2
	Piney Island East	93	2.7	97	3.1	87	2.7	83	2.2	87	3.1
	Old Woman's Leg	57	1.1	100	4.5	100	4.0	82	2.0	73	2.1
Pocomoke Sound	Marumsco	97	3.5	93	3.3	60	1.3	87	2.5	72	1.6
Patuxent River	Broome Island	97	3.4	100	2.8	63	1.5	87	3.0	40	0.6
St. Mary's River	Chicken Cock	100	4.2	97	3.1	93	3.2	96	2.6	40	1.0
	Pagan (S)	93	3.3	97	2.3	100	3.0	93	2.1	10	0.3
Wicomico R. (west)	Lancaster	97	3.6	97	2.8	67	1.4	67	1.6	20	0.2
	Mills West	13	0.2	80	2.0	90	2.9	63	1.8	20	0.2
Potomac River	Cornfield Harbor	97	3.4	83	2.3	100	3.8	93	2.9	77	1.9
	Ragged Point	97	3.8	90	2.8	40	0.9	50	1.4	10	0.2
	Lower Cedar Point	40	0.7	10	0.3	23	0.6	7	0.1	7	0.1
	Annual Means	**69**	**2.3**	**82**	**3.0**	**83**	**2.8**	**84**	**2.6**	**54**	**1.4**
Frequency of Positive Bars (%)		**98**		**100**		**100**		**100**		**100**	

Table 3 - Dermo (continued).

Oyster Bar	*Perkinsus marinus* Prevalence (%) and Mean Intensity (I)											
	1995		1996		1997		1998		1999		2000	
	%	I	%	I	%	I	%	I	%	I	%	I
Swan Point	20	0.2	0	0.0	3	0.1	43	1.2	97	3.4	80	1.2
Hackett Point	90	2.5	30	0.7	43	1.3	43	1.1	97	3.3	97	3.7
Holland Point (S)	87	2.9	47	1.4	37	1.1	37	0.9	93	2.8	87	3.4
Stone Rock	87	2.2	93	2.7	90	2.3	100	3.5	100	4.0	93	3.6
Flag Pond (S)	87	3.3	63	2.0	53	1.2	73	2.3	NA	NA	NA	NA
Hog Island	93	2.7	43	1.2	47	1.3	97	3.2	93	5.5	83	3.9
Butler	87	2.5	60	1.6	57	1.0	97	3.3	93	3.2	83	2.7
Buoy Rock	67	1.7	13	0.4	7	0.7	33	0.9	93	3.0	97	3.5
Old Field (S)	83	2.3	0	0.0	10	0.2	33	0.8	97	3.0	93	3.0
Bugby	83	2.6	80	2.0	70	1.8	60	1.4	100	3.9	100	4.0
Parsons Island	70	2.1	73	2.8	63	1.4	80	2.5	100	4.7	100	3.5
Hollicutt Noose	90	2.8	60	1.4	50	1.0	83	2.5	90	3.0	100	4.1
Bruffs Island (S)	73	2.1	67	1.4	17	0.2	57	1.6	100	3.7	97	3.2
Turtle Back	100	2.8	83	2.1	83	1.8	50	1.6	100	4.3	97	3.1
Long Point (S)	67	2.2	20	0.4	23	0.6	100	2.7	100	3.6	97	3.3
Cook Point (S)	NA	NA	60	1.5	70	2.4	87	2.8	93	3.4	40	1.2
Royston	63	2.0	50	1.1	67	1.5	90	2.5	97	3.5	97	4.7
Lighthouse	90	3.3	77	1.8	57	1.5	43	1.5	87	2.3	100	3.4
Sandy Hill (S)	89	3.4	30	0.7	60	1.3	40	1.0	97	3.4	87	3.6
Oyster Shell Pt. (S)	68	1.8	13	0.2	50	0.9	20	0.3	83	2.3	73	2.2
Tilghman Wharf	93	2.5	67	1.3	60	1.0	67	2.0	87	2.5	93	3.4
Deep Neck	97	3.0	83	2.1	100	2.6	97	2.9	97	4.5	100	4.0
Double Mills (S)	75	2.5	70	1.2	83	2.0	100	3.0	100	4.8	100	4.7
Cason (S)	93	2.3	87	1.9	93	2.4	50	1.4	97	3.8	100	3.6
Ragged Point	93	2.5	97	2.6	97	2.1	87	1.4	100	4.0	97	3.7
Norman Addition	87	2.8	93	2.4	73	1.6	73	2.3	93	3.5	80	3.4
Goose Creek	87	2.5	97	4.0	83	2.0	100	3.0	100	5.4	97	3.1
Wilson Shoals (S)	63	1.1	83	1.8	80	1.9	70	1.6	100	4.3	70	2.1
Georges (S)	87	2.8	93	2.0	93	2.2	83	2.4	93	3.5	80	2.3
Holland Straits	93	3.1	83	2.0	67	1.8	57	1.2	80	2.5	30	0.9
Sharkfin Shoal	90	3.0	97	2.1	93	2.6	80	2.7	100	4.3	80	2.3
Back Cove	83	3.0	97	3.2	93	2.9	90	2.3	100	5.5	40	1.2
Piney Island East	93	2.5	63	1.7	73	2.2	83	1.9	63	2.4	86	2.3
Old Woman's Leg	100	4.2	80	2.3	57	1.3	90	3.2	87	3.9	70	1.7
Marumsco	100	4.2	90	2.4	61	2.1	80	2.8	90	3.4	93	2.7
Broome Island	43	1.0	17	0.4	83	2.1	83	3.0	100	4.6	93	4.0
Chicken Cock	83	1.9	77	1.4	73	1.7	80	1.7	100	5.0	63	1.8
Pagan (S)	93	2.2	82	1.4	86	1.7	73	1.7	97	3.4	68	1.6
Lancaster	27	0.6	56	1.2	80	1.6	37	0.7	83	2.5	90	2.7
Mills West	57	1.4	60	1.2	60	1.2	20	0.4	90	3.2	97	3.6
Cornfield Harbor	93	2.5	87	2.0	83	1.8	83	2.0	97	3.9	80	2.1
Ragged Point	33	0.8	7	0.2	0	0.0	0	0.0	17	0.5	13	0.7
Lower Cedar Point	13	0.2	3	0.3	0	0.0	0	0.0	0	0.0	17	0.5
Annual Means	**78**	**2.3**	**61**	**1.5**	**62**	**1.5**	**67**	**1.9**	**90**	**3.5**	**81**	**2.9**
Bar Freq. (%)	**100**		**95**		**95**		**95**		**98**		**100**	

Table 3 - Dermo (continued).

Oyster Bar	***Perkinsus marinus* Prevalence (%) and Mean Intensity (I)**											
	2001		2002		2003		2004		2005		2006	
	%	I	%	I	%	I	%	I	%	I	%	I
Swan Point	93	3.3	97	2.7	33	1.0	33	0.7	47	1.2	20	0.6
Hackett Point	97	3.4	100	3.3	33	1.1	30	0.8	13	0.4	70	1.3
Holland Point (S)	93	3.2	100	3.6	33	1.1	30	0.6	53	1.6	10	0.4
Stone Rock	83	2.8	100	2.3	77	2.4	10	0.2	50	1.3	77	1.9
Flag Pond (S)	NA	NA	37	0.5	0	0.0	3	0.03	13	0.3	43	0.9
Hog Island	93	3.4	87	2.9	53	2.3	53	1.4	93	3.4	93	4.4
Butler	80	2.4	80	1.4	10	0.3	7	0.1	30	1.1	40	1.2
Buoy Rock	93	3.5	100	2.6	97	3.7	50	1.5	77	2.4	63	1.8
Old Field (S)	100	3.3	97	2.5	80	2.5	33	0.7	57	1.1	63	1.4
Bugby	100	4.6	97	3.1	97	3.4	63	1.7	53	1.8	87	2.7
Parsons Island	100	4.5	100	4.4	90	3.3	93	2.8	87	2.6	87	2.1
Hollicutt Noose	100	4.8	100	3.6	80	2.7	40	1.5	40	1.0	83	2.9
Bruffs Island (S)	100	3.8	100	3.6	73	1.8	80	2.5	73	1.8	53	1.6
Turtle Back	100	4.2	100	4.7	100	3.6	80	2.8	100	3.3	97	3.8
Long Point (S)	100	4.2	100	3.1	97	2.8	97	3.2	90	2.7	80	2.1
Cook Point (S)	77	2.2	NA	NA	66	2.1	0	0.0	13	0.3	40	0.5
Royston	100	5.2	100	4.2	48	1.8	13	0.3	3	0.2	47	0.9
Lighthouse	100	3.3	100	4.6	20	0.6	43	1.2	27	0.6	30	0.4
Sandy Hill (S)	100	4.5	100	5.0	93	3.5	87	3.3	80	2.5	70	2.3
Oyster Shell Pt. (S)	100	3.6	100	3.0	43	1.0	43	0.8	17	0.3	30	1.1
Tilghman Wharf	100	3.5	90	3.2	87	2.4	43	0.8	0	0.0	50	0.7
Deep Neck	97	4.8	100	3.2	97	3.7	27	0.5	20	0.4	50	1.1
Double Mills (S)	100	5.5	97	2.9	53	1.7	53	2.1	53	1.6	40	1.1
Cason (S)	100	4.3	94	4.4	17	0.4	3	0.03	33	0.5	23	0.4
Ragged Point	100	4.3	100	3.5	43	1.0	13	0.2	10	0.3	23	0.4
Norman Addition	90	3.0	67	1.9	37	1.3	93	3.3	90	3.8	57	2.0
Goose Creek	100	4.1	93	4.0	57	2.0	77	2.0	63	2.2	8	0.3
Wilson Shoals (S)	100	4.0	100	3.6	83	2.3	97	2.3	90	3.0	93	3.7
Georges (S)	100	5.2	100	4.0	83	2.6	100	4.2	90	3.3	97	3.8
Holland Straits	43	1.4	50	1.1	40	0.7	70	1.7	83	3.0	83	2.1
Sharkfin Shoal	90	3.7	97	3.6	47	3.4	100	4.4	87	3.2	83	3.4
Back Cove	100	5.0	97	3.8	100	4.6	97	3.7	100	3.1	77	2.5
Piney Island East	60	1.5	100	3.1	100	3.9	100	3.9	100	3.7	80	3.4
Old Woman’s Leg	100	5.0	100	3.7	100	4.4	93	3.7	80	2.4	57	1.8
Marumsco	100	5.0	97	4.1	90	2.3	87	2.8	93	3.3	67	2.8
Broome Island	100	4.8	97	3.8	47	1.3	47	1.4	37	0.9	77	2.5
Chicken Cock	93	3.6	100	2.9	23	0.7	40	0.9	87	3.5	90	3.4
Pagan (S)	100	4.6	93	4.0	60	1.3	83	2.3	83	2.9	80	3.1
Lancaster	100	4.5	97	2.7	50	1.5	37	0.9	57	1.5	73	2.2
Mills West	100	4.8	93	3.1	60	1.6	57	1.5	50	1.3	87	2.6
Cornfield Harbor	80	2.9	97	1.7	27	0.7	30	0.5	80	2.6	100	3.3
Ragged Point	33	0.5	93	2.6	24	0.7	9	0.1	37	0.9	0	0.0
Lower Cedar Point	90	2.3	97	2.5	13	0.5	17	0.4	13	0.2	10	0.1
Annual Means	**93**	**3.8**	**94**	**3.2**	**60**	**2.0**	**53**	**1.6**	**57**	**1.8**	**60**	**1.9**
Bar Freq. (%)	**100**		**100**		**98**		**98**		**98**		**98**	

Table 3 - Dermo (continued).

Oyster Bar	*Perkinsus marinus* Prevalence (%) and Mean Intensity (I)											
	2007		2008		2009		2010		2011		2012	
	%	I	%	I	%	I	%	I	%	I	%	I
Swan Point	17	0.4	20	0.6	23	0.4	3	0.1	7	0.1	3	0.03
Hackett Point	87	2.9	80	2.7	73	1.9	63	1.3	33	1.0	33	0.8
Holland Point (S)	33	0.6	23	0.8	33	0.8	13	0.4	17	0.4	0	0.0
Stone Rock	93	3.5	47	1.3	30	0.9	53	1.2	17	0.4	57	2.0
Flag Pond (S)	87	2.0	67	2.3	57	2.1	33	1.2	38	0.9	53	1.5
Hog Island	80	3.1	50	2.0	67	2.7	70	2.0	40	1.0	77	2.2
Butler	77	1.7	43	1.2	43	1.3	77	2.7	60	1.9	90	3.4
Buoy Rock	80	3.2	70	2.2	64	1.5	65	2.2	20	0.5	10	0.3
Old Field (S)	100	4.0	90	3.3	87	3.3	70	2.2	40	0.8	67	2.2
Bugby	100	3.9	93	2.9	100	3.8	67	2.0	27	0.6	73	2.3
Parsons Island	97	4.0	87	3.1	100	2.5	60	1.8	10	0.4	23	0.7
Hollicutt Noose	87	3.0	93	3.3	43	1.4	53	1.4	20	0.9	13	0.3
Bruffs Island (S)	100	3.8	93	3.0	83	2.6	73	1.6	47	1.1	33	0.9
Turtle Back	100	4.4	100	4.1	97	2.9	73	1.8	23	0.6	50	0.9
Long Point (S)	93	3.8	87	3.1	46	1.6	50	1.3	31	0.7	46	1.5
Cook Point (S)	17	0.3	13	0.4	7	0.1	43	1.0	40	1.0	93	3.2
Royston	23	0.7	17	0.4	27	0.7	3	0.1	13	0.4	27	0.8
Lighthouse	0	0.0	0	0.0	10	0.1	10	0.1	0	0.0	13	0.2
Sandy Hill (S)	87	2.5	17	0.5	13	0.2	30	0.7	40	1.5	80	2.5
Oyster Shell Pt. (S)	27	0.7	0	0.0	0	0.0	0	0.0	3	0.1	0	0.0
Tilghman Wharf	23	0.5	3	0.1	10	0.2	3	0.1	0	0.0	0	0.0
Deep Neck	90	2.7	67	2.2	70	2.4	67	1.9	43	1.1	100	3.2
Double Mills (S)	87	2.9	67	2.2	80	2.1	63	1.5	53	1.7	83	3.4
Cason (S)	60	1.9	100	2.9	100	3.2	97	3.8	70	2.2	93	3.3
Ragged Point	93	2.7	37	1.0	80	2.5	83	2.3	60	1.7	93	3.1
Norman Addition	23	0.9	37	0.7	57	1.8	100	3.9	87	3.3	100	4.3
Goose Creek	0	0.0	20	0.2	0	0.0	10	0.2	10	0.3	50	1.3
Wilson Shoals (S)	93	2.7	80	2.3	87	2.9	80	1.9	62	2.0	97	4.1
Georges (S)	83	3.8	57	2.2	57	1.6	73	2.4	50	1.2	100	3.9
Holland Straits	80	3.0	50	2.0	47	1.5	70	2.2	37	1.4	83	3.0
Sharkfin Shoal	70	1.9	70	1.7	90	3.6	97	3.6	90	3.3	100	4.2
Back Cove	93	3.2	80	2.6	87	3.3	93	3.6	80	2.7	90	3.0
Piney Island East	67	2.5	90	3.3	90	3.4	97	4.1	70	2.7	80	2.5
Old Woman’s Leg	73	2.2	90	2.8	97	4.7	70	3.0	47	1.9	77	2.7
Marumsco	37	1.1	57	1.7	90	3.0	73	2.7	67	2.5	97	3.2
Broome Island	97	3.6	93	2.5	100	4.2	90	3.3	67	2.3	87	3.0
Chicken Cock	90	4.0	40	1.3	90	3.5	83	3.3	20	0.6	50	1.3
Pagan (S)	90	2.5	57	1.8	93	2.7	97	3.9	53	2.0	87	2.8
Lancaster	97	4.2	77	2.1	73	2.4	60	2.0	37	0.8	47	1.1
Mills West	47	1.6	57	1.9	50	1.3	27	0.9	27	0.5	80	2.5
Cornfield Harbor	97	3.5	73	2.6	87	3.7	83	2.5	40	1.3	83	3.0
Ragged Point	0	0.0	8	0.1	0	0.0	4	0.1	0	0.0	3	0.03
Lower Cedar Point	30	0.6	7	0.1	10	0.3	40	0.9	20	0.4	20	0.3
Annual Means	**68**	**2.3**	**56**	**1.8**	**59**	**2.0**	**57**	**1.8**	**38**	**1.2**	**59**	**2.0**
Bar Freq. (%)	**93**		**95**		**93**		**98**		**93**		**93**	

Table 3 - Dermo (continued).

Oyster Bar	***Perkinsus marinus* Prevalence (%) and Mean Intensity (I)**											
	2013		2014		2015		2016		2017		*28-Yr Avg*	
	%	I	%	I	%	I	%	I	%	I	*%*	*I*
Swan Point	27	0.4	3	0.0	33	0.3	3	0.0	3	0	*28.8*	*0.7*
Hackett Point	13	0.6	0	0.0	10	0.3	40	1.2	56	1.6	*51.3*	*1.5*
Holland Point (S)	5	0.1	0	0.0	0	0.0	27	0.6	47	1.2	*42.2*	*1.3*
Stone Rock	67	2.0	100	4.0	93	4.5	97	4.4	83	3.4	*73.6*	*2.5*
Flag Pond (S)	23	0.8	10	0.3	18	0.5	50	1.9	52	1.6	*48.1*	*1.5*
Hog Island	27	0.9	43	1.2	87	3.0	97	4.3	100	4.5	*74.4*	*2.8*
Butler	70	2.4	73	2.4	60	2.0	37	1.5	63	2.2	*67.0*	*2.1*
Buoy Rock	27	0.6	13	0.4	17	0.2	20	0.7	30	0.8	*53.9*	*1.7*
Old Field (S)	57	1.5	47	1.5	57	1.7	63	2.1	60	2.1	*59.3*	*1.8*
Bugby	73	2.5	83	2.8	87	3.3	90	3.3	97	3.3	*82.0*	*2.7*
Parsons Island	30	0.9	15	0.4	53	1.3	77	2.2	83	2.9	*73.9*	*2.5*
Hollicutt Noose	13	0.4	23	0.6	33	0.7	50	1.5	57	1.8	*62.6*	*2.0*
Bruffs Island (S)	37	1.2	23	0.7	77	2.0	100	4.2	97	4.3	*73.5*	*2.3*
Turtle Back	63	2.2	80	2.5	100	4.2	83	3.5	83	3.2	*85.0*	*2.9*
Long Point (S)	37	1.2	10	0.4	20	0.5	73	2.6	36	1.1	*67.5*	*2.2*
Cook Point (S)	97	3.2	80	3.1	90	3.3	100	4.6	90	3.5	*58.8*	*2.0*
Royston	60	2.0	60	2.0	63	2.1	47	1.5	43	1.5	*56.9*	*2.0*
Lighthouse	10	0.3	10	0.3	23	0.5	10	0.4	17	0.4	*46.7*	*1.5*
Sandy Hill (S)	93	2.8	77	2.4	93	3.3	93	4.0	96	3.9	*76.3*	*2.9*
Oyster Shell Pt. (S)	7	0.2	3	0.0	40	1.0	80	2.6	77	2.8	*40.8*	*1.2*
Tilghman Wharf	10	0.2	7	0.1	20	0.6	47	1.5	70	2.2	*53.2*	*1.6*
Deep Neck	80	3.1	67	1.8	93	2.9	80	3.1	77	2.4	*80.9*	*2.9*
Double Mills (S)	83	3.1	73	2.6	70	2.9	87	3.6	97	3.9	*80.5*	*2.9*
Cason (S)	80	2.8	90	2.8	93	2.8	100	4.2	97	3.3	*79.9*	*2.6*
Ragged Point	97	3.0	83	2.3	100	3.2	93	4.0	97	3.7	*80.8*	*2.7*
Norman Addition	80	3.1	87	3.7	77	2.7	93	3.6	93	3.2	*80.0*	*2.8*
Goose Creek	80	2.6	83	2.5	100	3.4	93	4.3	80	3	*67.4*	*2.3*
Wilson Shoals (S)	93	3.0	90	3.4	80	2.8	90	3.2	87	3.2	*84.8*	*2.6*
Georges (S)	83	3.4	97	3.9	93	3.9	83	3.4	97	3.9	*81.6*	*2.9*
Holland Straits	90	3.7	80	3.6	83	3.0	13	0.3	30	0.6	*67.0*	*2.2*
Sharkfin Shoal	93	3.5	90	3.4	77	2.8	90	4.1	93	4.1	*83.6*	*3.0*
Back Cove	93	3.9	80	3.1	77	3.2	30	0.9	30	0.9	*82.9*	*3.0*
Piney Island East	63	2.0	40	1.4	53	1.8	60	2.4	70	2.3	*79.6*	*2.7*
Old Woman's Leg	52	1.3	60	2.6	67	2.1	11	0.2	50	1.6	*75.7*	*2.7*
Marumsco	100	4.4	80	3.5	90	3.6	93	3.7	100	3.9	*83.6*	*3.0*
Broome Island	93	3.2	70	1.9	80	2.6	90	3.8	93	4	*77.5*	*2.7*
Chicken Cock	50	1.2	67	1.9	67	2.1	73	2.4	97	3.1	*73.6*	*2.4*
Pagan (S)	77	2.4	83	2.1	83	2.9	83	3.1	80	3.1	*81.2*	*2.5*
Lancaster	30	1.2	20	0.8	3	0.2	37	1.6	47	1.8	*59.4*	*1.8*
Mills West	70	2.1	53	1.8	57	1.7	40	1.8	60	2	*59.5*	*1.8*
Cornfield Harbor	90	3.1	80	3.1	57	1.8	63	2.6	97	3.6	*79.9*	*2.5*
Ragged Point	0	0.0	3	0.0	0	0.0	3	0.0	7	0.1	*20.8*	*0.6*
Lower Cedar Point	20	0.4	3	0.1	55	1.6	33	1.1	50	1.6	*23.1*	*0.6*
Annual Means	**57**	**1.9**	**52**	**1.8**	**61**	**2.1**	**63**	**2.5**	**69**	**2.5**	*66.7*	*2.2*
Bar Freq. (%)	**98**		**95**		**95**		**100**		**100**		***97.4***	

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2017. NA=insufficient quantity of oysters for analytical sample. ND= sample collected but diagnostics not performed; prevalence assumed to be 0. (S) = bar within an oyster sanctuary since 2010.

Region	Oyster Bar	***Haplosporidium nelsoni* Prevalence (%)**							
		1990	1991	1992	1993	1994	1995	1996	1997
Upper Bay	Swan Point	0	0	0	0	ND	0	0	0
Middle Bay	Hackett Point	0	0	3	0	0	0	0	0
	Holland Point (S)	0	3	13	0	0	0	0	0
	Stone Rock	0	0	43	0	0	3	0	0
	Flag Pond (S)	0	0	53	0	0	27	0	0
Lower Bay	Hog Island	0	0	43	0	0	14	0	0
	Butler	0	0	50	0	0	23	0	7
Chester River	Buoy Rock	ND	0	0	0	ND	0	0	0
	Old Field (S)	ND	0	0	0	ND	0	0	0
Eastern Bay	Bugby	0	7	3	0	0	0	0	0
	Parsons Island	ND	0	7	0	0	0	0	0
	Hollicutt Noose	0	0	17	0	0	0	0	0
Wye River	Bruffs Island (S)	0	0	0	0	0	0	0	0
Miles River	Turtle Back	0	0	0	0	0	23	0	0
	Long Point (S)	0	0	0	0	0	0	0	0
Choptank River	Cook Point (S)	0	7	73	0	0	NA	0	3
	Royston	NA	0	33	0	0	0	0	0
	Lighthouse	0	0	53	0	0	0	0	0
	Sandy Hill (S)	0	0	13	0	ND	0	0	0
	Oyster Shell Pt. (S)	0	0	30	0	ND	0	0	0
Harris Creek	Tilghman Wharf	0	0	40	0	0	0	0	0
Broad Creek	Deep Neck	0	0	30	0	0	0	0	0
Tred Avon River	Double Mills (S)	0	0	17	0	0	0	0	0
Little Choptank R.	Cason (S)	0	0	43	0	0	0	0	0
	Ragged Point	0	20	57	0	0	0	0	0
Honga River	Norman Addition	3	0	53	0	0	33	0	0
Fishing Bay	Goose Creek	0	10	27	7	0	20	0	0
Nanticoke River	Wilson Shoals (S)	0	0	57	0	ND	7	0	0
Manokin River	Georges (S)	10	7	23	0	0	33	0	0
Holland Straits	Holland Straits	0	20	13	13	0	52	0	10
Tangier Sound	Sharkfin Shoal	20	43	40	17	0	33	0	0
	Back Cove	0	17	27	33	7	20	3	3
	Piney Island East	7	23	17	20	13	10	7	13
	Old Woman's Leg	0	33	23	30	10	43	20	4
Pocomoke Sound	Marumsco	0	20	20	0	0	20	0	11
Patuxent River	Broome Island	0	ND	20	0	0	0	0	0
St. Mary's River	Chicken Cock	0	0	57	0	ND	0	0	0
	Pagan (S)	0	0	0	0	ND	0	0	0
Wicomico R. (west)	Lancaster	0	0	0	0	ND	0	0	0
	Mills West	0	0	0	0	ND	0	0	0
Potomac River	Cornfield Harbor	0	0	57	0	0	37	0	0
	Ragged Point	0	0	0	0	0	0	0	0
	Lower Cedar Point	ND	ND	0	0	ND	0	0	0
Average Prevalence (%)		**1.1**	**5.1**	**24.5**	**2.8**	**0.9**	**9.5**	**0.7**	**1.2**
Frequency of Positive Bars (%)		**9**	**28**	**74**	**14**	**7**	**40**	**7**	**16**

Table 4 – MSX (continued).

Oyster Bar	*Haplosporidium nelsoni* Prevalence (%)									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Swan Point	0	0	0	0	0	0	0	0	0	0
Hackett Point	0	0	0	0	13	0	0	0	0	0
Holland Point (S)	0	0	3	7	40	0	0	0	0	0
Stone Rock	0	30	47	40	30	3	0	0	0	0
Flag Pond (S)	0	NA	NA	NA	20	0	0	0	0	0
Hog Island	0	60	27	27	20	0	0	0	0	0
Butler	3	47	17	27	20	3	3	0	3	10
Buoy Rock	0	0	0	0	0	0	0	0	0	0
Old Field (S)	0	0	0	0	0	0	0	0	0	0
Bugby	0	0	0	0	27	0	0	0	0	0
Parsons Island	0	0	0	3	17	0	0	0	0	0
Hollicutt Noose	0	7	10	17	37	0	0	0	0	0
Bruffs Island (S)	0	0	0	3	17	0	0	0	0	0
Turtle Back	0	0	0	7	33	0	0	0	0	0
Long Point (S)	0	0	0	0	3	0	0	0	0	0
Cook Point (S)	0	13	33	37	NA	0	0	3	0	0
Royston	0	3	7	0	60	0	0	0	0	0
Lighthouse	0	13	7	3	67	0	0	0	0	0
Sandy Hill (S)	0	0	0	10	53	0	0	0	0	0
Oyster Shell Pt. (S)	0	0	0	0	7	0	0	0	0	0
Tilghman Wharf	0	3	27	7	60	0	0	0	0	0
Deep Neck	0	3	7	0	63	0	0	0	0	0
Double Mills (S)	0	3	0	0	33	0	0	0	0	0
Cason (S)	0	7	27	33	59	0	0	0	0	0
Ragged Point	0	20	47	40	30	0	0	0	0	0
Norman Addition	3	63	37	37	20	7	0	0	0	7
Goose Creek	0	47	17	13	33	0	0	0	0	3
Wilson Shoals (S)	0	4	10	10	27	0	0	0	0	7
Georges (S)	0	40	20	13	30	0	0	0	0	7
Holland Straits	3	73	40	47	57	7	0	0	0	23
Sharkfin Shoal	20	53	37	20	27	7	0	0	0	10
Back Cove	10	33	37	10	7	7	0	7	13	33
Piney Island East	17	43	53	40	17	10	3	0	3	17
Old Woman’s Leg	23	53	30	13	13	3	3	13	13	13
Marumsco	7	37	30	17	30	0	0	0	0	10
Broome Island	0	3	10	0	13	0	0	0	0	0
Chicken Cock	0	77	7	17	30	3	0	0	0	3
Pagan (S)	0	3	13	10	40	0	0	0	0	0
Lancaster	0	0	0	0	10	0	0	0	0	0
Mills West	0	3	0	0	43	0	0	0	0	0
Cornfield Harbor	3	53	17	33	50	10	0	0	0	7
Ragged Point	0	13	10	7	60	0	0	0	0	0
Lower Cedar Point	0	0	0	0	0	0	0	0	0	0
Avg. Prev. (%)	**2.1**	**19.2**	**14.9**	**13.0**	**29.0**	**1.4**	**0.2**	**0.5**	**0.7**	**3.1**
Pos. Bars (%)	**19**	**67**	**64**	**67**	**90**	**23**	**7**	**7**	**9**	**30**

Table 4 - MSX (continued).

Oyster Bar	*Haplosporidium nelsoni* Prevalence (%)										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	*28-Yr Avg*
Swan Point	0	0	0	0	0	0	0	0	0	0	*0.0*
Hackett Point	0	0	0	0	0	0	0	0	0	3	*0.7*
Holland Point (S)	0	0	3	0	0	0	0	0	0	3	*2.6*
Stone Rock	10	23	3	0	0	0	0	7	13	10	*9.4*
Flag Pond (S)	3	13	7	0	0	0	0	12	10	0	*5.8*
Hog Island	7	17	0	0	0	0	0	10	40	3	*9.6*
Butler	7	37	17	0	0	0	3	13	48	0	*12.1*
Buoy Rock	0	0	0	0	0	0	0	0	0	0	*0.0*
Old Field (S)	0	0	0	0	0	0	0	0	0	0	*0.0*
Bugby	0	0	0	0	0	0	0	3	3	0	*1.5*
Parsons Island	0	0	0	0	0	0	0	0	7	0	*1.3*
Hollicutt Noose	0	13	0	0	0	0	0	0	10	0	*4.0*
Bruffs Island (S)	0	3	0	0	0	0	0	0	3	0	*0.9*
Turtle Back	0	0	0	0	0	0	0	3	7	0	*2.6*
Long Point (S)	0	0	3	0	0	0	0	0	0	0	*0.2*
Cook Point (S)	7	43	10	0	0	0	0	13	30	3	*10.6*
Royston	0	0	0	0	0	0	0	7	30	0	*5.2*
Lighthouse	0	13	3	0	0	0	0	0	37	0	*7.0*
Sandy Hill (S)	0	0	0	0	0	0	0	0	0	0	*2.8*
Oyster Shell Pt. (S)	0	0	0	0	0	0	0	0	0	0	*1.4*
Tilghman Wharf	0	3	0	0	0	0	0	7	27	0	*6.2*
Deep Neck	0	13	0	0	0	0	0	3	0	0	*4.3*
Double Mills (S)	0	0	0	0	0	0	0	0	0	0	*1.9*
Cason (S)	0	20	0	0	0	0	0	23	0	0	*7.6*
Ragged Point	0	13	10	0	0	0	0	20	17	3	*9.9*
Norman Addition	10	33	10	0	0	0	3	3	7	0	*11.8*
Goose Creek	7	27	0	0	0	0	0	13	7	0	*8.3*
Wilson Shoals (S)	0	7	0	0	0	0	0	3	0	0	*4.9*
Georges (S)	0	10	0	0	0	0	0	3	0	0	*7.0*
Holland Straits	7	33	23	0	0	0	3	10	13	0	*16.0*
Sharkfin Shoal	17	17	10	0	0	0	10	10	0	0	*14.0*
Back Cove	13	27	7	0	0	3	10	17	37	13	*14.1*
Piney Island East	0	33	7	0	0	10	27	33	10	13	*15.9*
Old Woman's Leg	0	27	20	7	3	3	20	23	17	25	*17.3*
Marumsco	0	17	3	0	3	0	10	10	0	3	*8.9*
Broome Island	0	3	0	0	0	0	0	0	7	7	*2.3*
Chicken Cock	13	57	10	0	0	0	0	23	60	7	*13.5*
Pagan (S)	0	30	0	0	0	0	0	0	0	0	*3.6*
Lancaster	0	0	0	0	0	0	0	0	0	0	*0.4*
Mills West	0	0	0	0	0	0	0	0	0	0	*1.7*
Cornfield Harbor	10	30	7	0	0	10	10	30	33	7	*14.4*
Ragged Point	0	0	0	0	0	0	0	0	3	10	*3.7*
Lower Cedar Point	0	0	0	0	0	0	0	0	0	0	*0.0*
Avg. Prev. (%)	**2.7**	**13.0**	**3.6**	**0.2**	**0.1**	**0.6**	**2.2**	**7.0**	**11**	2.6	*6.2*
Pos. Bars (%)	**30**	**60**	**40**	**2**	**5**	**9**	**21**	**56**	**56**	33	*31.8*

(Return to Text)

Table 5. Oyster population mortality estimates from the 43 disease monitoring bars, 1985-2017.
NA=unable to obtain a sufficient sample size. (S) = bar within an oyster sanctuary since 2010.

Region	Oyster Bar	**Total Observed Mortality (%)**							
		1985	1986	1987	1988	1989	1990	1991	1992
Upper Bay	Swan Point	14	1	2	1	9	4	4	3
Middle Bay	Hackett Point	7	0	10	9	5	2	2	12
	Holland Point (S)	4	21	19	3	19	3	14	45
	Stone Rock	6	NA	NA	NA	NA	2	9	45
	Flag Pond (S)	NA	48	30	39	37	10	35	77
Lower Bay	Hog Island	NA	26	47	25	6	19	73	85
	Butler	NA	23	84	15	7	30	58	84
Chester River	Buoy Rock	10	0	0	1	10	5	11	16
	Old Field (S)	8	3	3	4	2	7	3	9
Eastern Bay	Bugby	8	25	46	33	25	39	53	18
	Parsons Island	19	1	26	13	2	7	43	27
	Hollicutt Noose	2	32	42	25	14	1	7	9
Wye River	Bruffs Island (S)	2	1	45	12	9	12	50	77
Miles River	Turtle Back	NA	1	19	27	15	27	51	23
	Long Point (S)	17	8	23	8	12	11	53	73
Choptank River	Cook Point (S)	40	20	45	63	6	11	2	88
	Royston	4	21	19	11	14	14	33	43
	Lighthouse	3	14	59	14	8	8	45	52
	Sandy Hill (S)	12	6	29	34	7	11	75	48
	Oyster Shell Pt. (S)	9	0	1	2	2	3	2	19
Harris Creek	Tilghman Wharf	2	36	57	NA	20	30	34	26
Broad Creek	Deep Neck	2	25	37	32	47	66	48	40
Tred Avon River	Double Mills (S)	4	7	13	9	6	28	82	50
Little Choptank R.	Cason (S)	4	22	60	37	40	63	25	48
	Ragged Point	5	31	84	38	7	23	53	49
Honga River	Norman Addition	15	53	82	NA	11	11	48	49
Fishing Bay	Goose Creek	6	26	84	59	19	7	23	63
Nanticoke River	Wilson Shoals (S)	23	65	51	41	38	10	29	60
Manokin River	Georges (S)	5	24	84	55	23	31	50	55
Holland Straits	Holland Straits	19	51	85	90	15	27	35	71
Tangier Sound	Sharkfin Shoal	25	61	94	80	8	0	10	63
	Back Cove	NA	NA	NA	NA	NA	11	49	88
	Piney Island East	21	16	88	11	5	23	57	55
	Old Woman's Leg	4	17	79	21	8	5	50	80
Pocomoke Sound	Marumsco	3	27	77	NA	20	8	31	44
Patuxent River	Broome Island	10	29	31	6	4	24	53	70
St. Mary's River	Chicken Cock	18	43	63	43	24	27	31	51
	Pagan (S)	9	30	27	13	20	39	24	19
Wicomico R. (west)	Lancaster	13	6	4	4	6	28	20	8
	Mills West	18	0	2	1	1	2	11	9
Potomac River	Cornfield Harbor	17	59	92	51	11	16	29	77
	Ragged Point	10	14	29	79	54	63	34	63
	Lower Cedar Point	6	9	2	1	6	6	7	5
Annual Means		**10**	**22**	**44**	**29**	**14**	**18**	**34**	**46**

Table 5 - Mortality (continued).

Oyster Bar	Total Observed Mortality (%)									
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Swan Point	5	35	18	43	20	3	7	13	12	14
Hackett Point	18	30	30	16	10	26	22	13	30	60
Holland Point (S)	43	42	35	49	36	36	8	33	42	67
Stone Rock	30	29	40	25	15	33	46	66	30	86
Flag Pond (S)	43	28	24	16	13	33	50	NA	NA	23
Hog Island	76	16	45	20	16	33	67	67	14	31
Butler	66	37	63	17	20	20	48	67	32	11
Buoy Rock	51	33	22	17	7	7	6	25	43	61
Old Field (S)	8	12	8	17	8	5	8	21	36	47
Bugby	29	18	18	27	15	8	5	29	48	63
Parsons Island	29	18	36	22	25	8	16	29	60	59
Hollicutt Noose	29	32	30	13	15	14	13	38	55	85
Bruffs Island (S)	47	47	33	6	6	11	16	33	44	50
Turtle Back	24	40	51	21	9	9	26	38	48	54
Long Point (S)	44	8	28	8	3	9	14	33	34	66
Cook Point (S)	63	40	22	16	11	20	35	63	28	100
Royston	37	10	17	9	9	6	32	31	51	91
Lighthouse	57	27	18	15	5	6	20	33	44	92
Sandy Hill (S)	45	36	29	23	22	4	15	27	50	77
Oyster Shell Pt. (S)	20	14	18	25	6	2	1	15	28	55
Tilghman Wharf	36	6	10	9	15	6	12	19	34	85
Deep Neck	32	1	23	14	8	13	37	23	37	85
Double Mills (S)	24	10	20	9	8	10	38	40	50	85
Cason (S)	53	6	7	12	11	18	28	32	62	98
Ragged Point	71	17	16	12	13	19	34	37	70	94
Norman Addition	51	28	39	55	31	54	35	38	29	29
Goose Creek	38	7	38	69	64	20	64	63	81	85
Wilson Shoals (S)	23	10	17	11	11	9	29	25	26	52
Georges (S)	16	0	55	33	36	12	32	60	50	44
Holland Straits	18	16	45	43	20	18	35	35	17	12
Sharkfin Shoal	16	7	66	59	47	28	62	61	39	61
Back Cove	4	6	46	33	29	50	59	20	46	38
Piney Island East	13	20	65	56	49	67	38	27	12	20
Old Woman's Leg	15	25	63	46	33	38	42	15	53	27
Marumsco	21	8	78	53	49	26	40	22	35	45
Broome Island	53	27	8	0	13	11	44	25	59	72
Chicken Cock	33	28	15	10	7	24	82	63	28	63
Pagan (S)	17	11	9	27	15	3	14	35	51	84
Lancaster	7	4	19	25	8	8	18	48	58	52
Mills West	2	4	21	18	17	16	24	36	40	75
Cornfield Harbor	47	25	56	24	7	27	78	62	44	33
Ragged Point	28	35	8	11	4	25	10	8	33	NA
Lower Cedar Point	47	28	5	23	3	26	8	0	3	44
Annual Means	**33**	**20**	**30**	**25**	**18**	**19**	**31**	**35**	**38**	**58**

Table 5 - Mortality (continued).

Oyster Bar	Total Observed Mortality (%)									
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Swan Point	13	10	11	8	10	9	33	20	27	1
Hackett Point	17	10	2	5	11	26	15	14	0	13
Holland Point (S)	50	29	5	0	0	11	0	8	50	7
Stone Rock	13	5	5	20	5	25	16	8	2	2
Flag Pond (S)	0	0	2	4	0	14	26	20	11	0
Hog Island	11	6	12	25	42	14	18	12	8	14
Butler	9	2	3	23	0	9	8	8	12	4
Buoy Rock	41	28	6	21	20	24	43	8	4	2
Old Field (S)	34	10	38	12	12	17	17	11	21	12
Bugby	50	14	2	20	52	42	50	12	4	9
Parsons Island	37	11	8	35	50	34	36	16	10	4
Hollicutt Noose	25	3	6	48	43	27	12	23	0	0
Bruffs Island (S)	50	12	5	4	12	36	33	28	0	7
Turtle Back	43	11	12	51	57	55	34	5	11	4
Long Point (S)	54	10	10	14	38	46	17	33	0	33
Cook Point (S)	21	0	0	0	12	22	7	8	6	5
Royston	69	14	0	0	9	5	10	0	1	3
Lighthouse	89	47	0	0	0	0	4	1	3	4
Sandy Hill (S)	88	59	44	24	4	5	5	0	8	6
Oyster Shell Pt. (S)	48	20	0	4	0	4	4	2	1	3
Tilghman Wharf	62	17	0	1	10	14	2	2	3	0
Deep Neck	54	14	1	3	8	9	3	6	4	3
Double Mills (S)	59	23	8	0	7	4	19	6	4	14
Cason (S)	57	4	0	2	4	16	17	33	10	13
Ragged Point	52	5	4	13	13	2	22	15	4	2
Norman Addition	9	14	40	5	3	2	6	15	9	10
Goose Creek	53	59	50	50	1	2	6	0	3	1
Wilson Shoals (S)	19	27	7	21	7	30	10	3	5	8
Georges (S)	4	24	44	76	16	48	10	12	2	11
Holland Straits	11	18	43	48	17	27	12	14	5	7
Sharkfin Shoal	23	32	54	22	10	3	18	20	12	13
Back Cove	22	23	32	12	5	8	6	15	4	10
Piney Island East	28	48	50	23	6	18	20	26	17	11
Old Woman's Leg	35	56	26	0	12	14	37	38	26	0
Marumsco	4	11	29	20	10	21	7	13	4	15
Broome Island	14	19	6	6	20	20	11	14	3	6
Chicken Cock	2	38	50	20	20	7	27	22	11	1
Pagan (S)	7	29	66	9	4	11	29	13	5	11
Lancaster	35	27	14	7	31	17	24	0	0	0
Mills West	48	11	0	7	33	0	16	10	11	12
Cornfield Harbor	1	7	20	2	9	25	44	16	9	8
Ragged Point	76	NA	NA	NA	0	0	0	0	0	10
Lower Cedar Point	55	22	17	3	11	5	4	7	14	10
Annual Means	**35**	**20**	**17**	**16**	**15**	**17**	**17**	**12**	**8**	**7**

Table 5 - Mortality (continued).

Oyster Bar	Total Observed Mortality (%)					
	2013	2014	2015	2016	2017	*33-yr Avg*
Swan Point	4	0	3	0	0	*10.8*
Hackett Point	0	0	0	3	19	*13.2*
Holland Point (S)	12	40	29	0	0	*23.0*
Stone Rock	2	5	31	36	30	*23.0*
Flag Pond (S)	15	13	5	6	50	*22.4*
Hog Island	2	2	12	38	27	*28.4*
Butler	7	7	10	11	4	*25.0*
Buoy Rock	5	9	3	12	4	*16.8*
Old Field (S)	0	3	0	5	33	*13.2*
Bugby	8	31	21	21	13	*25.9*
Parsons Island	2	4	15	2	10	*21.6*
Hollicutt Noose	1	9	6	7	29	*21.1*
Bruffs Island (S)	0	4	5	16	20	*22.2*
Turtle Back	0	8	14	18	3	*25.3*
Long Point (S)	20	0	0	17	0	*22.5*
Cook Point (S)	9	12	16	48	45	*26.8*
Royston	1	6	9	16	4	*18.2*
Lighthouse	1	1	2	9	7	*20.8*
Sandy Hill (S)	3	13	11	15	15	*25.8*
Oyster Shell Pt. (S)	2	5	2	11	11	*10.3*
Tilghman Wharf	5	1	5	11	1	*17.8*
Deep Neck	5	7	16	8	2	*21.6*
Double Mills (S)	11	12	10	20	13	*21.3*
Cason (S)	11	8	17	26	33	*26.6*
Ragged Point	15	13	21	45	14	*27.7*
Norman Addition	9	7	13	14	15	*25.9*
Goose Creek	5	15	22	27	6	*33.8*
Wilson Shoals (S)	5	4	7	17	6	*21.4*
Georges (S)	15	5	8	23	15	*29.6*
Holland Straits	9	48	71	18	4	*30.4*
Sharkfin Shoal	16	18	24	19	3	*32.5*
Back Cove	11	19	14	1	2	*23.7*
Piney Island East	7	10	9	21	25	*29.2*
Old Woman's Leg	50	75	15	0	50	*32.0*
Marumsco	13	13	17	13	20	*24.9*
Broome Island	7	8	14	21	3	*21.5*
Chicken Cock	1	7	16	32	20	*28.1*
Pagan (S)	4	13	22	28	6	*21.3*
Lancaster	13	0	3	1	1	*15.4*
Mills West	20	9	5	14	0	*14.9*
Cornfield Harbor	10	16	10	36	8	*29.6*
Ragged Point	0	0	50	10	8	*22.8*
Lower Cedar Point	0	0	6	8	27	*12.7*
Annual Means	**8**	**11**	**14**	**16**	**14**	*22.8*

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland from buy tickets, 1985-86 through 2016-17 seasons.

Maryland Oyster Harvests (bu)						
Region/Tributary	1985-86	1986-87	1987-88	1988-89	1989-90	1990-91
Upper Bay	5,600	30,800	19,100	17,700	15,700	19,800
Middle Bay	73,400	37,900	42,500	10,500	15,900	17,700
Lower Bay	32,500	5,900	70	0	3,600	37,900
Total Bay Mainstem	*111,500*	*74,600*	*61,700*	*28,200*	*35,200*	*75,400*
Chester R.	21,300	20,600	30,900	49,900	54,000	60,400
Eastern Bay	216,100	149,100	28,700	15,700	20,400	33,200
Miles R.	40,400	20,600	17,100	13,600	1,400	1,700
Wye R.	20,100	2,200	700	3,800	8,000	2,300
Total Eastern Bay Region	*276,600*	*171,900*	*46,500*	*33,100*	*29,800*	*37,200*
Upper Choptank R.	29,000	42,400	36,500	51,900	27,700	42,200
Middle Choptank R.	144,500	89,700	66,400	66,400	71,000	49,700
Lower Choptank R.	225,100	52,500	26,200	9,100	32,100	9,000
Tred Avon R.	67,700	60,900	13,700	42,400	92,100	22,000
Broad Cr.	12,900	58,700	8,500	13,500	8,100	4,300
Harris Cr.	3,500	16,700	6,900	7,800	8,800	3,300
Total Choptank R. Region	*482,700*	*320,900*	*158,200*	*191,100*	*239,800*	*130,500*
Little Choptank R.	27,100	10,500	21,500	15,000	19,000	8,800
Upper Tangier Sound	84,000	30,400	40	0	0	1,000
Lower Tangier Sound	64,400	22,200	90	0	0	1,600
Honga R.	29,400	49,300	7,700	300	1,100	5,600
Fishing Bay	107,600	87,300	90	20	20	900
Nanticoke R.	21,300	5,100	1,500	900	2,600	3,000
Wicomico R.	3,600	200	100	40	20	60
Manokin R.	40,800	47,400	500	70	10	60
Big Annemessex R.	90	10	10	0	40	0
Pocomoke Sound	32,700	22,300	0	0	0	300
Total Tangier Sound Region	*383,900*	*264,200*	*10,000*	*1,300*	*3,800*	*12,500*
Patuxent R.	96,300	16,800	1,400	3,700	8,900	48,400
Wicomico R., St. Clement and Breton Bays	16,000	23,400	23,000	47,600	22,200	36,000
St. Mary's R. and Smith Cr.	80,700	30,700	2,300	500	1,100	1,700
Total Md. Potomac Tribs	*96,700*	*54,100*	*25,300*	*48,100*	*23,300*	*37,700*
Total Maryland (bu.)[1]	**1,500,000**	**976,000**	**360,000**	**390,000**	**414,000**	**418,000**

[1] Includes harvests from unidentified regions. Not all harvest reports provided region information, but were included in the Md. total.

Table 6 - Landings (continued).

Maryland Oyster Harvests (bu)						
Region/Tributary	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97
Upper Bay	35,200	18,200	8,900	7,800	26,600	2,600
Middle Bay	39,200	9,000	4,400	4,900	12,600	20,000
Lower Bay	9,300	90	0	1,100	800	300
Total Bay Mainstem	*83,800*	*27,300*	*13,300*	*13,800*	*40,000*	*22,800*
Chester R.	55,100	53,800	51,300	29,100	42,600	5,400
Eastern Bay	20,600	3,600	2,400	3,700	1,500	1,100
Miles R.	100	300	0	200	200	500
Wye R.	300	20	30	50	0	0
Total Eastern Bay Region	*21,000*	*3,900*	*2,400*	*4,000*	*1,700*	*1,600*
Upper Choptank R.	29,200	9,500	2,600	2,500	11,600	3,200
Middle Choptank R.	25,000	3,100	1,600	4,900	15,000	4,700
Lower Choptank R.	14,200	1,700	900	600	900	300
Tred Avon R.	800	0	0	5,900	1,300	3,800
Broad Cr.	40	50	10	400	1,000	4,000
Harris Cr.	100	20	0	14,200	5,000	13,600
Total Choptank R. Region	*69,300*	*14,400*	*5,100*	*28,500*	*34,800*	*29,600*
Little Choptank R.	3,800	50	300	19,300	1,900	40,800
Upper Tangier Sound	11,300	70	0	17,600	12,100	8,100
Lower Tangier Sound	1,700	40	0	5,400	500	10,100
Honga R.	600	20	100	1,700	400	200
Fishing Bay	6,400	500	30	11,900	20,900	8,800
Nanticoke R.	12,500	7,700	2,500	10,500	15,200	23,000
Wicomico R.	600	500	500	80	100	1,400
Manokin R.	200	40	10	100	0	900
Big Annemessex R.	10	0	0	0	0	0
Pocomoke Sound	500	0	0	100	0	300
Total Tangier Sound Region	*33,800*	*8,900*	*3,100*	*47,400*	*49,200*	*52,800*
Patuxent R.	24,500	0	0	30	100	20
Wicomico R., St. Clement and Breton Bays	29,600	14,900	4,000	18,200	27,500	7,300
St. Mary's R. and Smith Cr.	100	60	30	3,900	900	16,200
Total Potomac Md. Tribs	*29,000*	*15,000*	*4,000*	*22,100*	*28,400*	*23,500*
Total Maryland (bu.)[1]	**323,000**	**124,000**	**80,000**	**165,000**	**200,000**	**178,000**

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

Maryland Oyster Harvests (bu)						
Region/Tributary	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03
Upper Bay	18,800	13,100	28,100	31,150	16,100	18,930
Middle Bay	15,300	55,800	31,500	16,400	4,550	2,410
Lower Bay	4,800	8,300	3,800	2,050	600	50
Total Bay Mainstem	*38,900*	*77,200*	*63,400*	*49,600*	*21,250*	*21,390*
Chester R.	43,000	21,000	70,100	20,800	29,450	11,830
Eastern Bay	3,800	30,900	75,800	120,500	33,400	4,650
Miles R.	30	800	35,700	20,150	6,600	50
Wye R.	400	900	9,400	11,300	1,800	60
Total Eastern Bay Region	*4,200*	*32,600*	*120,900*	*151,950*	*41,800*	*4,760*
Upper Choptank R.	4,800	3,100	7,100	1,100	7,450	10
Middle Choptank R.	5,600	2,800	1,900	8,150	5,600	520
Lower Choptank R.	200	2,400	8,300	350	1,500	40
Tred Avon R.	6,900	11,700	3,700	8,950	1,000	40
Broad Cr.	27,600	46,200	18,200	36,850	4,900	700
Harris Cr.	21,400	67,000	18,200	26,200	3,300	30
Total Choptank R. Region	*66,500*	*133,200*	*57,400*	*81,600*	*23,750*	*1,340*
Little Choptank R.	36,100	84,100	33,600	27,850	2,400	190
Upper Tangier Sound	6,000	3,500	1,500	100	5,050	3,570
Lower Tangier Sound	4,200	8,500	2,800	1,450	13,200	5,960
Honga R.	1,300	300	50	0	50	590
Fishing Bay	3,800	700	90	0	0	390
Nanticoke R.	30,300	21,700	8,800	600	2,700	540
Wicomico R.	2,200	1,400	500	50	50	10
Manokin R.	600	300	90	200	1,850	970
Big Annemessex R.	0	0	200	0	0	0
Pocomoke Sound	400	80	100	10	20	0
Total Tangier Sound Region	*48,800*	*36,500*	*14,100*	*2,400*	*22,920*	*12,030*
Patuxent R.	60	5,600	2,000	10	0	0
Wicomico R., St. Clement and Breton Bays	10,200	13,700	8,800	2,600	1,400	220
St. Mary's R. and Smith Cr.	36,700	16,400	4,500	6,150	1,650	0
Total Potomac Md. Tribs	*46,900*	*30,100*	*13,300*	*8,750*	*3,050*	*220*
Total Maryland (bu.)[1]	**285,000**	**423,000**	**381,000**	**348,000**	**148,000**	**56,000**

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

Maryland Oyster Harvests (bu)						
Region/Tributary	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Upper Bay	2,210	1,632	17,420	14,052	13,601	7,020
Middle Bay	750	295	17,346	17,004	3,728	1,870
Lower Bay	187	1,801	269	642	2,077	5,554
Total Bay Mainstem	*3,147*	*3,728*	*35,035*	*31,698*	*19,406*	*14.444*
Chester R.	557	3,239	4,385	7,201	4,685	4,826
Eastern Bay	5,446	16,767	49,120	36,268	8,582	7,390
Miles R.	56	353	3,660	1,133	27	910
Wye R.	0	173	122	0	0	12
Total Eastern Bay Region	*5,502*	*17,293*	*52,902*	*37,401*	*8,609*	*8,312*
Upper Choptank R.	0	78	591	11	95	15
Middle Choptank R.	30	67	967	2,510	597	597
Lower Choptank R.	0	267	1,250	3,037	2,426	2,535
Tred Avon R.	0	139	149	157	61	112
Broad Cr.	954	1,342	14,006	53,577	20,413	6,097
Harris Cr.	12	71	4,429	5,342	3,308	1,900
Total Choptank R. Region	*996*	*1,964*	*21,392*	*64,634*	*26,900*	*11,256*
Little Choptank R.	1,150	144	3,534	4,218	1,516	1,163
Upper Tangier Sound	7,630	13,658	2,874	3,856	4,614	12,454
Lower Tangier Sound	5,162	15,648	5,828	1,996	8,970	19,600
Honga R.	378	2,744	270	154	860	17,305
Fishing Bay	24	106	6	0	197	3,320
Nanticoke R.	57	965	387	97	97	134
Wicomico R.	0	0	0	30	11	118
Manokin R.	1,638	2,816	737	91	364	184
Big Annemessex R.	0	5	108	17	5	13
Pocomoke Sound	0	2,676	1,071	277	1,051	765
Total Tangier Sound Region	*14,889*	*38,618*	*11,281*	*6,518*	*16,169*	*53,893*
Patuxent R.	0	466	17,808	7,316	831	1,258
Wicomico R., St. Clement and Breton Bays	13	18	1,414	80	698	808
St. Mary's R. and Smith Cr.	0	91	1,863	2,069	1,252	1,643
Total Potomac Md. Tribs	*13*	*109*	*3,277*	*2,149*	*1,950*	*2,451*
Total Maryland (bu.)[1]	**26,000**	**72,000**	**154,000**	**165,000**	**83,000**	**101,000**

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

Maryland Oyster Harvests (bu)						
Region/Tributary	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15
Upper Bay	8,723	6,310	297	19	45	606
Middle Bay	4,012	2,054	439	4,310	9,218	7,321
Lower Bay	14,927	2,759	2,249	8,134	13,670	12,298
Total Bay Mainstem	*27,662*	*11,123*	*2,985*	*12,463*	*22,933*	*20,224*
Chester R.	2,874	5,290	119	102	556	3,493
Eastern Bay	2,662	1,957	221	4,966	15,650	8,763
Miles R.	11	12	81	82	727	1,871
Wye R.	227	0	9	0	0	73
Total Eastern Bay Region	*2,900*	*1,969*	*311*	*5,048*	*16,377*	*10,707*
Upper Choptank R.	42	412	0	149	213	73
Middle Choptank R.	661	523	1,598	1,725	4,032	5,548
Lower Choptank R.	3,424	3,534	3,402	11,336	12,934	26,008
Tred Avon R.	0	68	402	1,095	2,038	2,850
Broad Cr.	5,328	7,646	11,382	72,643	76,125	62,436
Harris Cr.	1,227	191	100	3,043	3,353	8,112
Total Choptank R. Region	*10,682*	*12,374*	*16,884*	*89,991*	*98,695*	*105,028*
Little Choptank R.	923	0	568	1,216	2,137	5,044
Upper Tangier Sound	24,553	19,098	24,076	40,143	57,853	53,270
Lower Tangier Sound	61,771	27,849	29,578	38,802	45,301	25,660
Honga R.	24,696	10,213	10,391	20,182	24,594	22,122
Fishing Bay	14,949	10,174	13,852	51,038	61,909	39,054
Nanticoke R.	2,168	5,300	10,121	8,385	6,558	14,924
Wicomico R.	109	1,140	3,587	5,551	4,253	3,748
Manokin R.	888	1,477	1,731	84	1,863	3,158
Big Annemessex R.	0	1,036	546	79	730	576
Pocomoke Sound	1,165	855	3,859	35,193	33,343	18,262
Total Tangier Sound Region	*130,299*	*77,142*	*97,741*	*199,457*	*236,404*	*180,773*
Patuxent R.	3,456	6,535	8,419	13,764	19,984	45,781
Wicomico R., St. Clement and Breton Bays	712	2,132	1,931	4,504	6,383	3,822
St. Mary’s R. and Smith Cr.	3,186	2,275	1,454	11,345	7,909	10,775
Total Potomac Md. Tribs	*3,898*	*4,407*	*3,385*	*15,849*	*14,292*	*14,597*
Total Maryland (bu.)[1]	**185,245**	**123,613**	**137,317**	**341,232**	**416,578**	**388,658**

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

Maryland Oyster Harvests (bu)			
Region/Tributary	2015-16	2016-17	*32-yr Avg*
Upper Bay	3,648	4,693	*12,952*
Middle Bay	13,019	11,072	*15,825*
Lower Bay	4,285	4,314	*5,760*
Total Bay Mainstem	*20,952*	*20,079*	*34,087*
Chester R.	1,547	569	*22,186*
Eastern Bay	13,091	15,576	*29,738*
Miles R.	3,335	1,666	*5,417*
Wye R.	18	17	*1,938*
Total Eastern Bay Region	*16,444*	*17,259*	*37,092*
Upper Choptank R.	192	42	*9,805*
Middle Choptank R.	8,420	5,749	*18,737*
Lower Choptank R.	22,141	10,979	*15,271*
Tred Avon R.	4,007	2,403	*11,137*
Broad Cr.	67,375	32,063	*21,167*
Harris Cr.	7,072	2,704	*8,029*
Total Choptank R. Region	*109,207*	*53,940*	*84,145*
Little Choptank R.	2,027	2,048	*11,812*
Upper Tangier Sound	64,305	35,521	*17,132*
Lower Tangier Sound	28,269	9,471	*14,564*
Honga R.	13,241	11,114	*8,030*
Fishing Bay	20,195	13,608	*14,934*
Nanticoke R.	7,095	7,430	*7,317*
Wicomico R.	10,122	4,735	*1,400*
Manokin R.	1,431	1,128	*3,490*
Big Annemessex R.	4,037	473	*250*
Pocomoke Sound	10,261	6,131	*5,366*
Total Tangier Sound Region	*158,956*	*89,611*	*72,481*
Patuxent R.	50,048	22,669	*12,692*
Wicomico R., St. Clement and Breton Bays	5,596	5,130	*10,621*
St. Mary's R. and Smith Cr.	10,537	8,716	*8,335*
Total Potomac Md. Tribs	*16,133*	*13,846*	*18,934*
Total Maryland (bu.)[1]	**383,534**	**224,758**	***299,092***

[1] Includes harvests from unidentified regions.

(Return to Text)

Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2016-17 seasons. Dockside value is in millions of dollars.

Season	Hand Tongs	Diver	Patent Tongs	Power Dredge	Skipjack	*Total Harvest*[1]	*Dockside Value*
1989-90	309,723	47,861	31,307	11,424	14,007	*414,445*	*$ 9.9 M*
1990-91	219,510	74,333	105,825	4,080	14,555	*418,393*	*$ 9.4 M*
1991-92	124,038	53,232	108,123	6,344	31,165	*323,189*	*$ 6.4 M*
1992-93	71,929	24,968	18,074	1,997	8,821	*123,618*	*$ 2.6 M*
1993-94	47,309	19,589	11,644	787	133	*79,618*	*$ 1.4 M*
1994-95	99,853	29,073	31,388	1,816	2,410	*164,641*	*$ 3.2 M*
1995-96	115,677	25,657	46,040	6,347	7,630	*199,798*	*$ 3.2 M*
1996-97	130,861	16,780	15,716	8,448	6,088	*177,600*	*$ 3.8 M*
1997-98	191,079	37,477	30,340	14,937	10,543	*284,980*	*$ 5.7 M*
1998-99	294,342	58,837	36,151	25,541	8,773	*423,219*	*$ 7.8 M*
1999-2000	237,892	60,547	44,524	18,131	12,194	*380,675*	*$ 7.2 M*
2000-01	193,259	75,535	43,233	18,336	8,820	*347,968*	*$ 6.8 M*
2001-02	62,358	30,284	26,848	17,574	8,322	*148,155*	*$ 2.9 M*
2002-03	11,508	9,745	18,627	12,386	2,432	*55,840*	*$ 1.6 M*
2003-04	1,561	5,422	3,867	13,436	1,728	*26,471*	*$ 0.7 M*
2004-05	5,438	14,258	6,548	37,641	4,000	*72,218*	*$ 1.1 M*
2005-06	28,098	38,460	49,227	30,824	3,576	*154,436*	*$ 4.7 M*
2006-07	55,906	36,271	31,535	35,125	3,250	*165,059*	*$ 5.0 M*
2007-08	24,175	11,745	15,997	25,324	4,243	*82,958*	*$ 2.6 M*
2008-09	11,274	9,941	15,833	50,628	5,370	*101,141*	*$ 2.7 M*
2009-10	7,697	6,609	48,969	107,952	12,479	*185,245*	*$4.5 M*
2010-11	13,234	5,927	27,780	65,445	10,550	*123,613*	*$4.3 M*
2011-12	4,885	12,382	22,675	84,950	11,305	*137,317*	*$4.6M*
2012-13	53,622	8,107	48,095	212,837	18,471	*341,132*	*$10.9 M*
2013-14	67,093	21,510	75,937	242,964	9,074	*416,578*	*$14.1 M*
2014-15	57,289	25,126	98,187	154,716	33,518	*388,658*	*$17.1 M*
2015-16	71,296	31,110	91,852	107,781	32,815	*383,534*	*$14.9 M*
2016-17	45,929	24,434	52,740	80,586	17,724	*224,758*	*$10.6 M*

[1] Harvest reports without gear information were not included in harvest by gear type totals but were included in total harvest.

(Return to Text)

Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2016-17 seasons. Some years may not total 100% due to incomplete data.

Season	Hand Tongs	Diver	Patent Tongs	Power Dredge	Skipjack
1989-90	75	12	8	3	3
1990-91	52	18	25	1	3
1991-92	38	16	33	2	10
1992-93	57	20	14	2	7
1993-94	60	25	15	<1	<1
1994-95	61	18	19	1	1
1995-96	57	13	23	3	4
1996-97	74	9	9	5	3
1997-98	67	13	11	5	4
1998-99	69	14	9	6	2
1999-2000	62	16	12	5	3
2000-01	56	22	12	5	3
2001-02	41	20	18	12	6
2002-03	21	17	33	22	4
2003-04	6	20	15	51	7
2004-05	8	20	9	52	6
2005-06	18	25	32	20	2
2006-07	34	22	19	21	2
2007-08	29	14	19	30	5
2008-09	12	11	17	54	6
2009-10	4	4	26	58	7
2010-11	11	5	23	53	8
2011-12	4	9	17	62	8
2012-13	16	2	14	62	5
2013-14	16	5	18	58	2
2014-15	16	7	27	42	9
2015-16	21	9	27	32	10
2016-17	20	11	23	36	8

(Return to Text)

Table 8. Oyster bars within sanctuaries sampled during the 2017 Fall Survey.

Region	Oyster Sanctuary	Surveyed Bars Within Sanctuary
Upper Bay	Man O War/Gales Lump	Man O War Shoals
Middle Bay	Poplar Island	Poplar I.
	Herring Bay	Holland Pt.[1,2]
	Calvert Shore	Flag Pond[1,2]
Lower Bay	Lower Mainstem East	Northwest Middleground
	Cedar Point	Cedar Point Hollow
	Point Lookout	Pt. Lookout
Chester River	Lower Chester River	Love Pt., Strong Bay, Wickes Beach
	Upper Chester River	Boathouse, Cliff, Drum Pt., Ebb Pt., Emory Hollow, Old Field[2], Sheep, Spaniard Pt.
	Chester ORA Zone A	Shippen Creek
Eastern Bay	Mill Hill	Mill Hill
	Cox Creek	Ringold Middleground
Wye River	Wye River	Bruffs I. [1,2], Mills, Race Horse, Whetstone, Wye River Middleground
Miles River	Miles River	Long Pt. [2]
Choptank River	Cook Point	Cook Pt. [1,2]
	Lower Choptank River	Chlora Pt.
	Sandy Hill	Hambrooks, Sandy Hill[1,2]
	Howell Point - Beacons	Beacons
	States Bank	Green Marsh, Shoal Creek
	Upper Choptank River	Bolingbroke Sand, The Black Buoy, Oyster Shell Pt. [2], Dixon, Mill Dam
	Choptank ORA Zone A	Tanners Patch, Cabin Creek, Drum Pt.
Harris Creek	Harris Creek	Change, Mill Pt. [1], Seths Pt., Walnut, Little Neck, Rabbit I.
Tred Avon River	Tred Avon River	Pecks Pt., Mares Pt., Louis Cove, Orem, Double Mills[1,2], Maxmore Add. 1
Little Choptank River	Little Choptank River	Little Pollard, Susquehanna, Cason[1,2], Butterpot, McKeils Pt., Grapevine, Town, Pattison
Hooper Straits	Hooper Straits	Applegarth, Lighthouse
Nanticoke River	Nanticoke River	Roaring Pt. East, Wilson Shoals[2], Bean Shoal, Cherry Tree, Cedar Shoal, Old Woman's Patch, Hickory Nut, Wetipquin[1]
Manokin River	Manokin River	Piney I. Swash, Mine Creek, Marshy I., Drum Pt. [1], Georges[1,2]
Tangier Sound	Somerset	Piney I. East Add. 1
Severn River	Severn River	Chinks Pt.
Patuxent River	Upper Patuxent	Thomas, Broad Neck, Trent Hall, Buzzard I., Holland Pt.
	Neal Addition	Neale
St. Marys River	St. Marys River	Pagan[1,2], Horseshoe
Breton Bay	Breton Bay	Black Walnut[1]

[1] Key Spat Bar [2] Disease Bar

(Return to Text)

APPENDIX 1
OYSTER HOST & OYSTER PATHOGENS

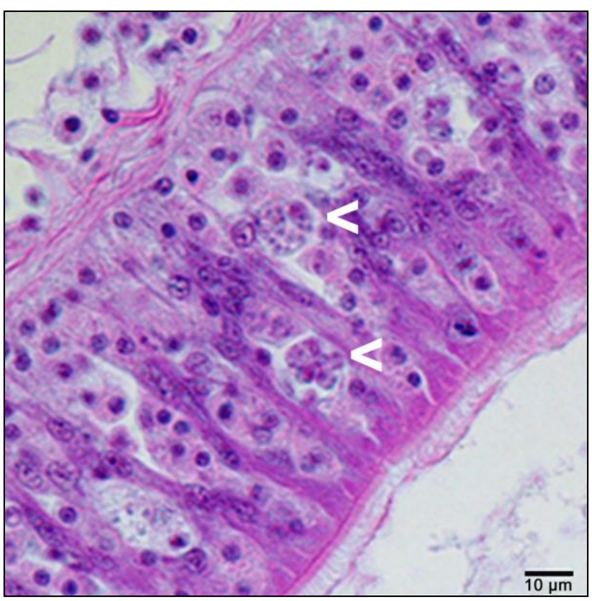
Chris Dungan, Maryland DNR

Oysters

The eastern oyster *Crassostrea virginica* is found in waters with temperatures of -2°C to 36°C (28 - 97°F) and sustained salinities of 4 ‰ to 40 ‰ (ppt), where ocean water has 35 ‰ salinity. Oysters reproduce when both sexes simultaneously spawn their gametes into Chesapeake Bay waters. Spawning occurs from May - September, and peaks during June - July. Externally fertilized eggs develop into swimming planktonic larvae that are transported by water currents for 2-3 weeks, while feeding on phytoplankton as they grow and develop. Mature larvae seek solid benthic substrates, preferably oyster shells, to which they attach as they metamorphose to become sessile juvenile oysters. Unlike fishes and other vertebrates, oysters do not regulate the salt content of their tissues; instead, oyster tissue salt contents conform to the broad and variable range of salinities in oyster habitats. Thus, oyster parasites with narrow salinity requirements may be exposed to low environmental salinities when shed into environmental waters, as well as while infecting oysters in low-salinity waters. At death, an oyster's shell valves spring open passively, exposing its tissues to predators and scavengers. However, the resilient hinge ligament holds the articulated valves together for months after death. Vacant, articulated oyster shells (boxes) in our samples are interpreted to represent oysters that died during the previous year, and the numbers of dead and dying (gaper) oysters are compared to those of live oysters in dredge samples to estimate proportions for natural mortalities in sampled populations.

Dermo disease

Although the protozoan parasite that causes dermo disease is now known as *Perkinsus marinus*, it was first described as *Dermocystidium marinum* in Gulf of Mexico oysters (Mackin, Owen & Collier 1950), and its name was colloquially abbreviated then as 'dermo'. Almost immediately, dermo disease was also reported in Chesapeake Bay oysters (Mackin 1951). *Perkinsus marinus* is transmitted through the water to uninfected oysters in as few as three days, and such infections may prove fatal in as few as 18 days. Heavily infected oysters are emaciated; showing reduced growth and reproduction (Ray & Chandler 1955).

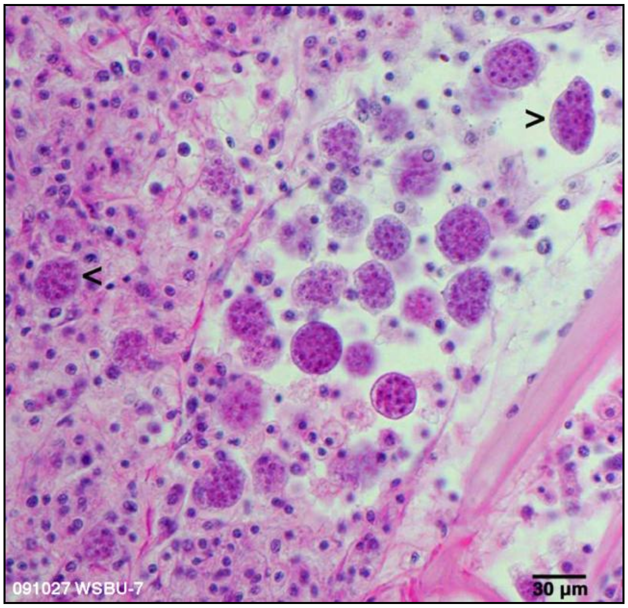


Ciliated oyster stomach epithelium infected by clusters of proliferating *P. marinus* cells (<).

Although *P. marinus* survives low temperatures and low salinities, its proliferation is highest in the broad range of temperatures (20-35°C) and salinities (10-30 ‰) that are typical of Chesapeake Bay waters during oyster dermo disease mortality peaks (Dungan & Hamilton 1995). Over several years of drought during the 1980s, *P. marinus* expanded its Chesapeake Bay distribution into upstream areas where it had been previously rare or absent (Burreson & Ragone Calvo 1996). Since 1990, at least some oysters in 93-100% of all regularly tested Maryland populations have been infected. Annual mean prevalences for dermo disease have ranged at 38-94% of all tested oysters, with a 28-year average of 67%.

MSX disease

The high-salinity protozoan oyster pathogen *Haplosporidium nelsoni* was first detected and described as a *multinucleated sphere unknown* (MSX) from diseased and dying Delaware Bay oysters during 1957 (Haskin et al. 1966), and it also infected oysters in lower Chesapeake Bay during 1959 (Andrews 1968). Although the common location of lightest *H. nelsoni* infections in oyster gill tissues suggests waterborne transmission of infectious pathogen cells, the complete life cycle and actual infection mechanism of the MSX parasite remain unknown.



Oyster gill vein with large *Haplosporidium nelsoni* (MSX) multinucleate plasmodia (>) circulating with smaller hemocyte blood cells.

Despite numerous experimental attempts, MSX disease has rarely been transmitted to uninfected oysters in laboratories. However, captive experimental oysters reared in enzootic waters above 14 ‰ salinity are frequently infected, and may die within 3-6 weeks. In Chesapeake Bay, MSX disease is most active in higher salinity waters with temperatures of 5-20°C (Ewart & Ford 1993). MSX disease prevalences typically peak during June, and deaths from such infections peak during August. In Maryland waters, annual average prevalences for MSX disease have ranged at 0.1-28%, with a 28-year average of 6%.

Since MSX disease is rare in oysters from waters below 10 ‰ salinity, the distribution of *H. nelsoni* in Chesapeake Bay varies as salinities change with variable freshwater inflows. During a recent 1999-2002 drought, consistently low freshwater inflows raised salinities of Chesapeake Bay waters to foster upstream range expansions by MSX disease during each successive drought year (Tarnowski 2003). The geographic ranges for MSX disease also expanded widely during a recent epizootics of 2009 and of 2014-2016. During 2003-2008 and 2010-2012, freshwater inflows near or above historic averages reduced salinities of upstream Chesapeake Bay waters to dramatically limit the geographic range and effects of MSX disease (Tarnowski 2017). During 2017, the distribution of MSX disease contracted and its mean prevalence decreased.

References

Andrews, J.D. 1968. Oyster mortality studies in Virginia VII. Review of epizootiology and origin of *Minchinia nelsoni*. Proc. Natl. Shellfish. Assn. 58**:**23-36.

Burreson, E.M. and L.M. Ragone Calvo. 1996. Epizootiology of *Perkinsus marinus* disease in Chesapeake Bay, with emphasis on data since 1985. J. Shellfish Res. 15**:**17-34.

Dungan, C.F. and R.M. Hamilton. 1995. Use of a tetrazolium-based cell proliferation assay to measure effects of in vitro conditions on *Perkinsus marinus* (Apicomplexa) proliferation. J. Eukaryot. Microbiol. 42:379-388.

Ewart, J.W. and S.E. Ford. 1993. History and impact of MSX and dermo diseases on oyster stocks in the Northeast region. NRAC Fact Sheet No. 200, 8 pp. Univ. of Massachusetts, North Dartmouth, Ma.

Haskin, H.H., L.A. Stauber, and J.G. Mackin. 1966. *Minchinia nelsoni* n. sp. (Haplosporida, Haplosporidiidae): causative agent of the Delaware Bay oyster epizootic. Science 153**:**1414-1416.

Ray, S.M. and A.C. Chandler. 1955. Parasitological reviews: *Dermocystidium marinum*, a parasite of oysters. Exptl. Parasitol. 4**:**172-200.

Mackin, J.G., H.M. Owen, and A. Collier. 1950. Preliminary note on the occurrence of a new protistan parasite, *Dermocystidium marinum* n. sp. in *Crassostrea virginica* (Gmelin). Science 111**:**328-329.44

Mackin, J.G. 1951. Histopathology of infection of *Crassostrea virginica* (Gmelin) by *Dermocystidium marinum* Mackin, Owen, and Collier. Bull Mar. Sci. Gulf and Caribbean 1**:**72-87.

Tarnowski, M. 2003. Maryland Oyster Population Status Report: 2002 Fall Survey. Maryland Department of Natural Resources, Annapolis, MD. 32 pp. http://dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

Tarnowski, M. 2017. Maryland Oyster Population Status Report: 2016 Fall Survey. Maryland Department of Natural Resources Publ. No. 17-582017-662. Annapolis, MD. 58 pp. http://dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

(Return to Text)

APPENDIX 2
GLOSSARY

box oyster	Pairs of empty shells joined together by their hinge ligaments. These remain articulated for months after the death of an oyster, providing a durable estimator of recent oyster mortality (see **gaper**). **Recent boxes** are those with no or little fouling or sedimentation inside the shells, generally considered to have died within the previous two to four weeks. **Old boxes** have heavier fouling or sedimentation inside the shells and the hinge ligament is generally weaker.
bushel	Unit of volume used to measure oyster catches. The official Maryland bushel is equal to 2,800.9 cu. in., or 1.0194 times the U.S. standard bushel (heaped) and 1.3025 times the U.S. standard bushel (level). (Return to Text)
cultch	Hard substrate, such as oyster shells, spread on oyster grounds for the attachment of spat.
dermo disease	The oyster disease caused by the protozoan pathogen *Perkinsus marinus.*
dredged shell	Oyster shell dredged from buried ancient (3000+ years old) shell deposits. Since 1960 this shell has been the backbone of the Maryland shell planting efforts to produce seed oysters and restore oyster bars.
fresh shell	Oyster shells from shucked oysters. It is used to supplement the dredged shell plantings.
gaper	Dead or moribund oyster with gaping valves and tissue still present (see **box oyster**).
Haplosporidium nelsoni	The protozoan oyster parasite that causes MSX disease.
infection intensity, individual	*Perkinsus* sp. parasite burdens of individual oysters, estimated by RFTM assays and categorized on an eight-point scale. Uninfected oysters are ranked 0, heaviest infections are ranked 7, and intermediate-intensity infections are ranked 1-6. Oysters with infection intensities of 5 or greater are predicted to die imminently.
infection intensity, mean sample	Averaged categorical infection intensity for all oysters in a sample: *sum of all categorical infection intensities (0-7) ÷ number of sample oysters* Oyster populations whose samples show mean infection intensities of 3.0 or greater are predicted to experience significant near-term mortalities.
infection intensity, annual mean	Average of mean intensities for annual survey samples from constant sites: *sum of all sample mean intensities ÷ number of annual samples*
intensity index, sample	Categorical infection intensities averaged only for infected oysters: *sum of individual infection intensities(1-7) ÷ number of infected oysters*

intensity index, annual	Categorical infection intensities averaged for all infected survey oysters: *sum of all sample intensity indices ÷ number of annual samples*
market oyster	An oyster measuring 3 inches or more from hinge to mouth (ventral margin).
MSX disease	The oyster disease caused by the protozoan pathogen *Haplosporidium nelsoni.*
MSX % frequency, annual	Percent proportion of sampled populations infected by *H. nelsoni* (MSX): *100 x (number of sample with MSX infections ÷ total sample number)*
observed mortality, sample	Percent proportion of annual, natural oyster population mortality estimated by dividing the number of dead oysters (boxes and gapers) by the sum of live and dead oysters in a sample: *100 x [number of boxes and gapers ÷ (number of boxes and gapers + number of live)]*
observed mortality, annual	Percent proportion of annual, bay-wide, natural oyster mortality estimated by averaging population mortality estimates from the 43 Disease Bar (DB) samples collected during an annual survey: *sum of sample mortality estimates ÷ 43 DB samples*
Perkinsus marinus	The protozoan oyster parasite that causes dermo disease.
prevalence, sample	Percent proportion of infected oysters in a sample: *100 x (number infected ÷ number examined)*
prevalence, mean annual	Percent proportion of infected oysters in an annual survey: *sum of sample percent prevalences ÷ number of samples*
RFTM assay	Ray's fluid thioglycollate medium assay. Method for enlargement, detection, and enumeration of *Perkinsus marinus* cells in oyster tissue samples. This diagnostic assay for dermo disease has been widely used and refined for over sixty years to date.
seed oysters	Young oysters produced by planting shell as a substrate for oyster larvae to settle on in historically productive areas. If the spatfall is adequate, the seed oysters are subsequently transplanted to growout (seed planting) areas, generally during the following spring.
small oyster	An oyster equal to or greater than one year old but less than 3 inches (see market oyster, spat).
spat	Oysters younger than one year old.
spatfall, spatset, set	The process by which swimming oyster larvae attach to a hard substrate such as oyster shell. During this process the larvae undergo metamorphosis, adopting the adult form and habit.
spatfall intensity, sample site	The number of spat per bushel of cultch. This is a relative measure of oyster spat density at a specific location, which may be used to calculate the annual spatfall intensity index.

spatfall intensity index The arithmetic mean of spatfall intensities from 53 fixed reference sites or Key Bars:

sum of Key Bar spatfall intensities ÷ number of Key Bars

(Return to Text)

Dr. Mark Homer (r) and friends, Assateague National Seashore, November 1993. *(Photo: C. Judy)*