Maryland Oyster Population Status Report
2018 Fall Survey

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and the Staff of the Shellfish Division and
Cooperative Oxford Laboratory
DNR 17-070819-154

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Cover Photo: Capt. Dave White at the helm of the R/V* Miss Kay. *(Photo: R. Bussell)

In Memoriam

Capt. David White
(1950 – 2018)

Captain David White, long-time master of the MDNR Shellfish Division's Research Vessel *Miss Kay* and manager of the Deal Island facility, passed away on 13 December 2018 after a yearlong struggle with cancer. Dave came to MDNR after retiring as a Maryland State Trooper, bringing with him a strong sense of duty and dedication to his job.

Dave was born in Brooklyn, New York, but his family soon moved to New Jersey, then relocated to Somerset County, Maryland when he was 12. He earned a Bachelor of Science degree in biology from Salisbury State University. Dave served with the Maryland State Police for 20 years, including a stint as an undercover detective.

After retiring, Dave joined the MDNR Shellfish Program in 2001 as a mate on the *Miss Kay*. He assumed the helm in 2004 after acquiring his captain's license, and was responsible for conducting a wide range of shellfish-related studies, most notably the Fall Oyster Survey. As captain, Dave was extremely safety conscious, reviewing emergency assignments every trip before leaving the dock, and wearing his PFD religiously as an example to everyone working on deck. He was tremendously proud of the *Miss Kay*, and kept the 1979 vintage wooden workboat in top condition. When the rare but inevitable mechanical failure occurred, he was always able to improvise a fix to get back underway. Under his care, there were many improvements and upgrades made to the *Miss Kay*, including a remotoring and fiberglassing of her wooden hull, assuring she would serve as a research and survey platform for many years to come.

In addition to his boat captain duties, Dave took over as the Deal Island Facility Manager in 2008, where he was in charge of the shell acquisition program and was responsible for the regional remote setting operation for the local aquaculture industry. In his spare time Dave gave back to his professional community, serving as an officer stress management instructor at Wor-Wic Community College and teaching CPR at MDNR.

Dave was also the proprietor of White's Market in St. Stephens for over 20 years. A general store in the truest sense, it carried an amazing variety of items jammed into every nook and cranny and served as an informal community center where the locals could get a cup of coffee and exchange gossip about the oyster season. The staff biologists were especially fond of the deli – stopping for a White's sub on the way to the boat was always something to look forward to.

Dave made every scientist and visitor who stepped across the washboards aboard *Miss Kay* welcome and part of the crew. He often placed new hands at the helm on the way back to port at the end of the day, giving them, under his watchful eye, the thrill and responsibility of piloting a big powerboat. On long runs he sparked cabin conversations on a wide range of topics, from the news of the day to philosophical musings. He gave thanks at the end of each day on the water for a safe trip and return home. Dave was the consummate professional – knowledgeable, hard-working, and dedicated to his work. He is missed.

Capt. White putting the finishing touches on the *Miss Kay* (and himself) during the annual maintenance haul-out. (Photo: R. Bussell)

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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: the *Spatfall Intensity Index*, a measure of recruitment success and potential increase of the population obtained from a subset of 53 oyster bars; *Oyster Disease Indices*, which document disease infection levels as derived from a subset of 43 sentinel oyster bars; the *Total Observed Mortality Index*, an indicator of annual mortality rates of post-spat stage oysters calculated from the 43 oyster bar Disease Index subset; the *Biomass Index*, which measures the number and weight of oysters from the 43 Disease Bar subset relative to the 1993 baseline; and the *Cultch Index*, a measure of habitat at the 53 Spat Intensity Index bars.

The 2018 Fall Oyster Survey was conducted from 16 October to 30 November throughout the Maryland portion of Chesapeake Bay and its tributaries, including the Potomac River. A total of 325 samples were collected from 270 oyster bars. Sites monitored included natural oyster bars, oyster seed production areas, seed and shell plantings, and sanctuaries.

Record high freshwater flows during 2018 lowered salinities over an extended time period, affecting spatset, disease, mortality and growth of oysters. These were the highest calendar-year streamflows in at least 82 years.

The Spatfall Intensity Index of 15.0 was below the 34-year median value. Twice as many 2018 Index bars showed decreases in spatfall than increases from the previous year, resulting in a 36% decline from the 2017 Index. As in past years, the higher spatset was observed from the Choptank region downbay, with spat absent from large swaths of the bay. No spat were found from the upper part of the bay through Eastern Bay and the mid-Western Shore, as well as the middle to upper Potomac oyster growing region. The highest spatset (288 spat/bu) was observed on Somerset Sanctuary in Tangier Sound.

Although Dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, being found on 91% of the sentinel bars, the number of infected oysters was much lower than in 2017. The mean prevalence (40%) decreased substantially from the 69% of the previous year, dropping below the 29-year average by 40%. The mean infection intensity for dermo disease (1.2) was half of the 2017 average, and well below the long-term average, tying a record for the lowest average intensity. MSX disease mean prevalence (0.1%) represented a sharp decline. The geographic range of MSX disease also contracted, as the number of sentinel bars with infected oysters dropped more than tenfold to 2%. This represents the lowest number of affected sentinel bars and the lowest average prevalence recorded in the time series (only one oyster on one sentinel bar was infected with MSX disease).

The Observed Mortality Index of 14% was the same as in 2017, remaining below the long-term mean for the fifteenth consecutive year. However, it was still double that of 2012, which was the lowest recorded mortality index value. Elevated freshwater-related mortalities of up to 100% were observed on the uppermost bars of the Potomac River and to a lesser extent in the upper bay. Aside from these areas, regional average observed mortalities were generally low to moderate, the highest being 28% in the Wye River. Mortalities were highly variable among bars within some regions (e.g. within Tangier Sound, observed mortalities ranged from 1% to 52%).

The 2018 Oyster Biomass Index of 1.78 represents the first increase of this index since 2013, despite a decline in harvests. Most of the increase in the Biomass Index (67.1%) can be attributed to the continued growth of oysters protected in the sanctuaries. The 2018 index ranked third highest in the 26-year time series.

The Cultch Index of 0.86 bu/100 ft. was slightly lower than the 14-year average of 0.91 bu/100 ft. The three-year rolling averages of cultch indices have been stable over the past four years. However, 63% of individual index bars were more than 25% lower than their long-term averages. The growth and good survivorship of the 2010 and 2012 year classes contributed substantially to the index during the succeeding years. The subsequent decline may be due to the harvesting of these oysters and lower recruitment, as well as ongoing taphonomic processes acting on the shell substrate such as burial, degradation, etc. 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.

A total of 88 oyster bars within 32 sanctuaries were sampled during the 2018 Fall Survey. Trends in recruitment, disease, and mortality were in keeping with the baywide results and well below their respective Key/Disease Bar averages. Recruitment within sanctuaries was lower than during the previous year, which was consistent with the baywide trend. A comparison of spatset in sanctuaries with adjacent harvest areas had mixed results. The Manokin Sanctuary had the highest average spatset of any region in the bay, and a much smaller sanctuary nearby in mid-Tangier Sound, Somerset Sanctuary, had the highest spatset of any station observed during the 2018 survey. Oysters from monitoring sites in the five designated restoration sanctuaries - Harris Creek, Tred Avon, Little Choptank. Manokin, and St. Marys - showed no evidence of MSX disease. Dermo disease levels trended somewhat higher in the sanctuaries than in adjacent harvest areas, probably because the sanctuaries had a higher proportion of larger, older oysters which tend to accumulate higher burdens of the parasites. Despite the dermo levels, observed mortality rates in sanctuaries were comparable to harvest areas and continued to be well below the long-term average.

With reported harvests of 182,000 bushels with a dockside value of $8.7 million during the 2017-18 season, commercial oyster landings dropped 19% with a loss of $1.9 million from the previous season due to generally unfavorable recruitment in recent years. Power dredging accounted for 39% of the landings, primarily from the lower Eastern Shore and Choptank regions. Hand tongs were the second dominant gear type, harvesting 23% of the total. Once again, the Tangier Sound region was the leading production area with 36% of the Maryland landings, followed by the Choptank Region with 28%.

Captain Dave enjoying a cup of boat coffee while en route to the next station.

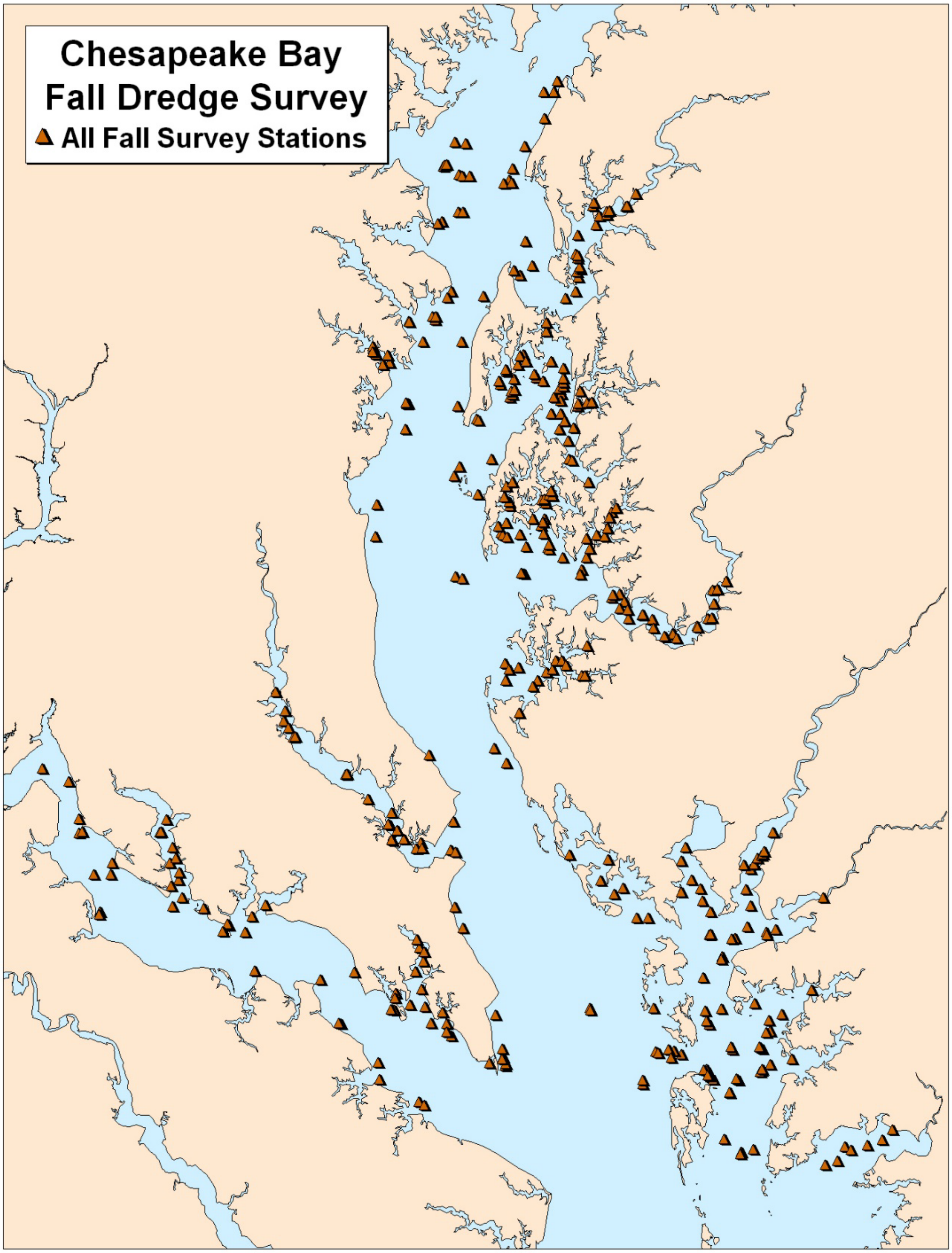

Figure 1a. 2018 Maryland Fall Oyster Survey station locations, all bar types (standard, Key, Disease, seed) included.

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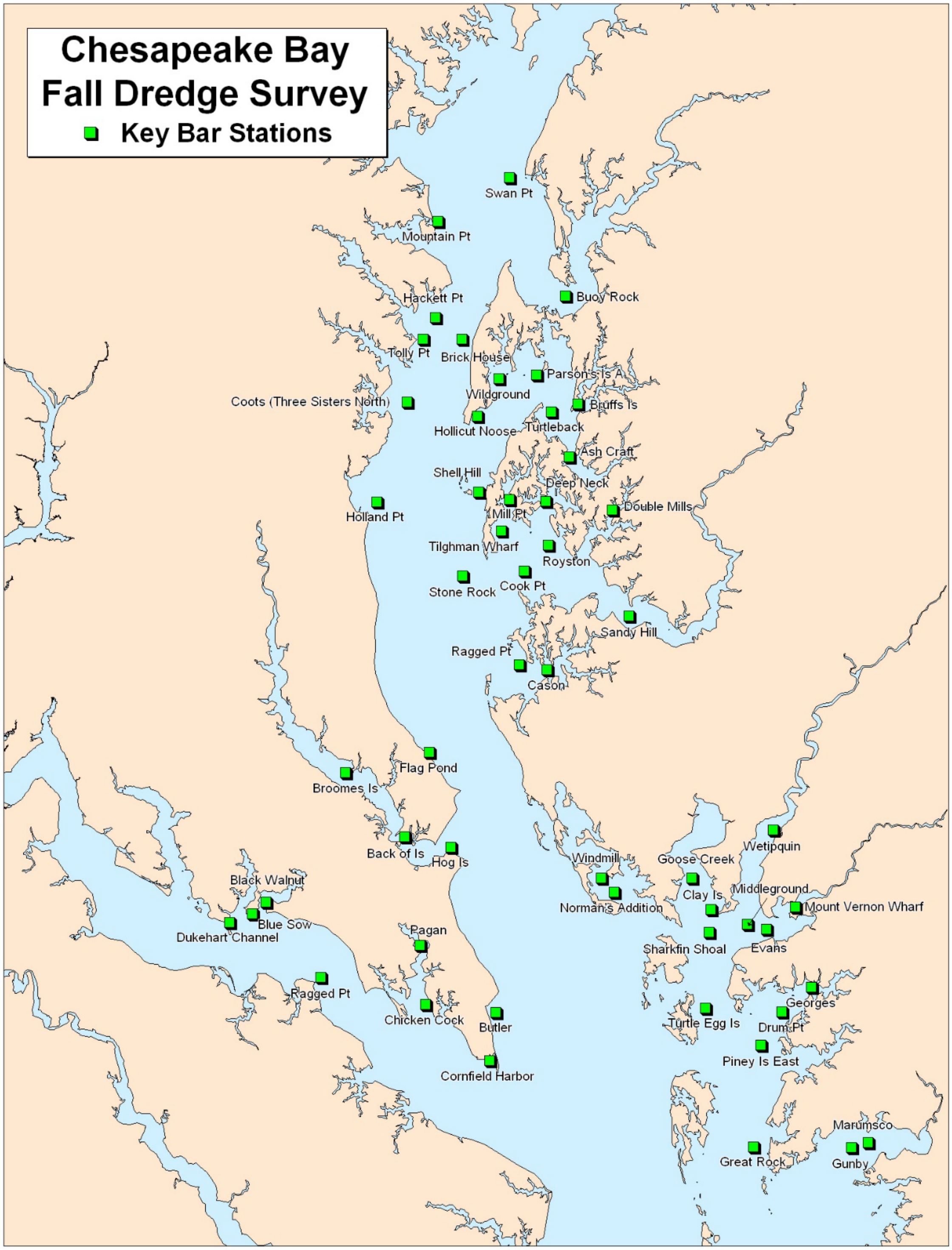

Figure 1b. Maryland Fall Oyster Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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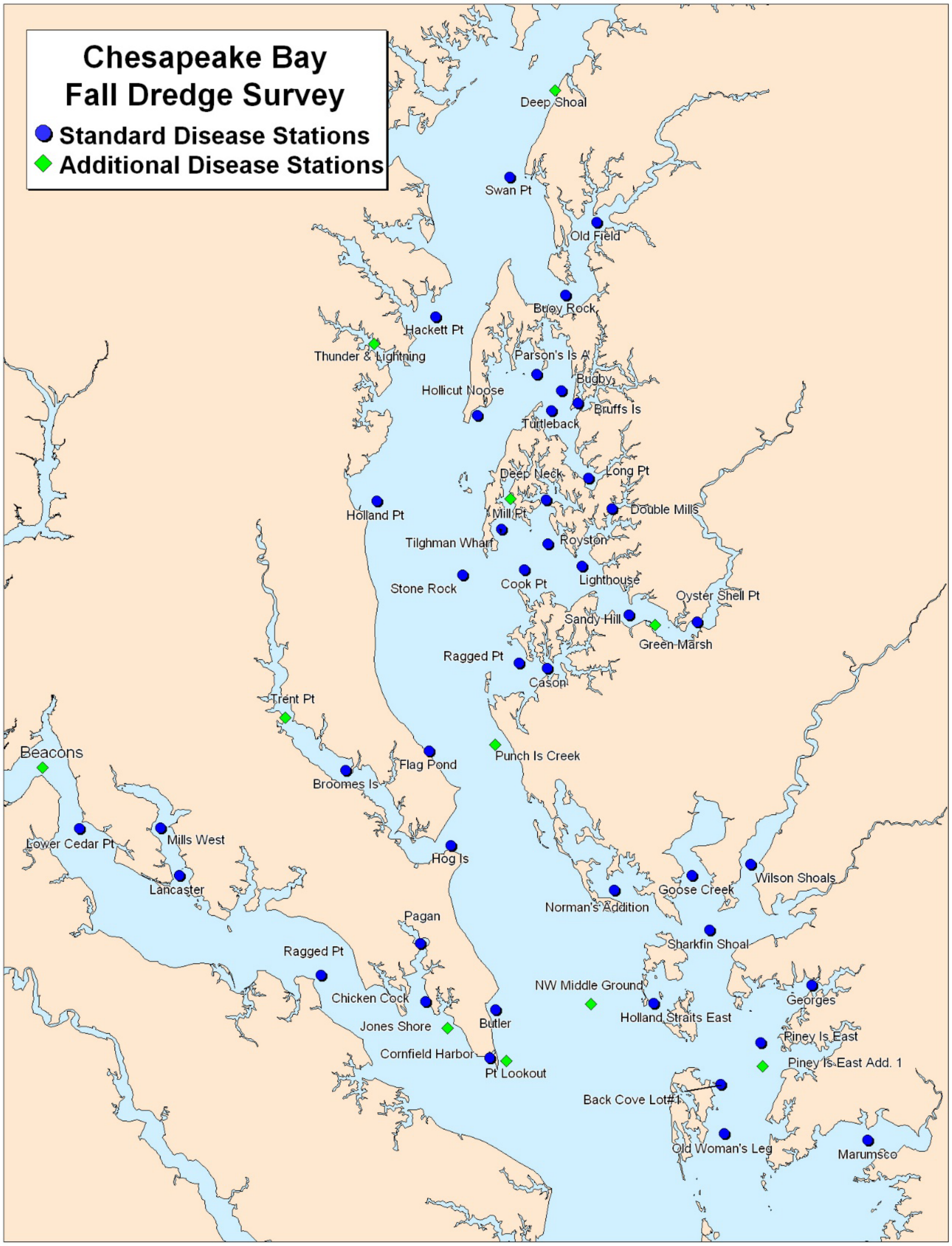

Figure 1c. Maryland Fall Oyster Survey standard Disease Bar monitoring locations and additional disease sample stations. Disease samples could not be obtained from Deep Shoal and Beacons in 2018.

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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 2018, 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. Oyster samples from select locations were provided to a University of Maryland graduate student investigating the interaction between hypoxic conditions and dermo disease in oysters, a senior researcher at Maryland studying microplastics in the bay, and a Columbia University graduate student exploring the genetic impacts of superfund sites on nearby oyster populations. 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 the legislatively mandated Oyster Stock Assessment, a collaborative effort between the department and the University of Maryland Chesapeake Biological Laboratory which was completed in 2018. As an adjunct to the stock assessment, a University of Maryland graduate student developed more refined mortality estimates from the Fall Survey data for her thesis.

METHODS

Field Collection

The 2018 Annual Fall Oyster Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources Fishing and Boating Services from 16 October to 30 November. A total of 325 samples was collected during surveys on 270 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 (GPS) 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/sample.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 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; the data on fouling (mussels, barnacles, tunicates, etc.) and other associated organisms are being converted to a digital format.

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 two sampling sites (Lower Cedar Point, Old Woman's Leg), smaller samples (n = 14, 16 respectively) were collected there. Oyster parasite diagnostic tests were performed by Fishing and Boating Services Aquatic Animal Health Program 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 pathogen, 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 2018 biomass index is derived from the 2018 Fall Survey data.

Biomass 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

Cultch Index

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. If the dredge is full that sample is dropped from the analysis. 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.

Statistical Framework

In previous reports, a non-parametric treatment, Friedman's Two-Way Rank Sum Test, was used in order to provide a statistical framework for some of the Annual Fall Survey data sets (Hollander and Wolfe 1973). This procedure, along with an associated multiple-range test, allowed among-year comparisons for several parameters. 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 these report. Each tier consisted of a set of annual mean ranks that are statistically similar to one another (Tarnowski 2018).

However, with the ever-expanding number of years in the time series of the various parameters, it has become increasingly difficult to discern well-defined tiers, as there is considerable overlap among statistically similar groupings. Given the limited utility of this method due to this issue, it was decided to forego these analyses. Where this method had been most useful was the Spat Index graph, which, for example, showed a record high spat index in 1997 but only ranked a middling tier due to the limited geographic extent of the high spat counts (Tarnowski 2018). To illustrate this point in this report, annual medians of the spat index bars were substituted for the tiers, as explained in the *Spatfall Intensity* section that follows.

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 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 information, 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. However, for applications where gear or oyster bar name is considered critical, the harvester report data source is frequently 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.

Elevated freshwater flows during 2018 lowered salinities over an extended time period, impacting spatset, disease, mortality and growth of oysters. Streamflow into the Maryland portion of the Bay (Sec. "C" in Bue 1968) in 2018 exceeded the 82-year average by 85% (Figure 2a). These were the highest streamflows on record in terms of calendar-year averages, even surpassing 1972, the year of Tropical Storm Agnes, (USGS 2018). Prior to 2018, the last significant high-flow years were in 2011 and 2003/2004. Aside from 2011, the period from 2005 to 2017 was relatively stable - annual streamflows in nine of those years were within the normal range. This is 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.

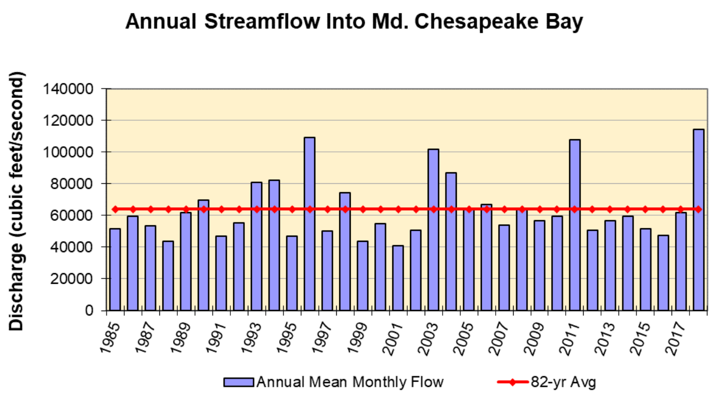

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2018. USGS Section C: all Maryland tributaries and the Potomac River.

The monthly average freshwater flows were well above the long-term averages for most of the year (Figure 2b). Eight of eleven months[1] exceeded the 82-year mean streamflow by at least 55%; August and September were respectively 361% and 486% above the mean. The highest monthly streamflow, 172000 cu ft/sec, occurred in September, normally a month with one of the lowest freshwater inputs.

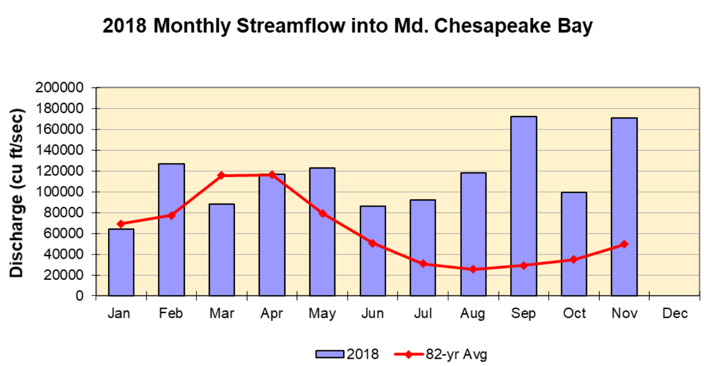

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2018, including the 82-yr monthly average.

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 discharge into the bay.

[1] There is no streamflow data for December due to the federal government shutdown.

Salinities at mid-bay to lower bay stations were close to normal during the first five months of the year, but began to drop below average with the elevated streamflows in May (Chesapeake Bay Program Data Hub). The mid-bay station, CB4.2C off the mouth of the Choptank River, experienced monthly salinities that fluctuated from a high of 14.6 ppt in January all the way down to 5.3 ppt in December, a decrease of 9.3 ppt (Figure 2c). During the period of above normal flows that began in May, salinity deviations from the mean continued to widen, dropping as far as 8.2 ppt below average in December. One important point is that salinities were below 10 ppt for nine months. This is the critical threshold value below which MSX disease is purged from oysters. For perspective, the highest long-term monthly average salinity for this station is 14.9 ppt in October.

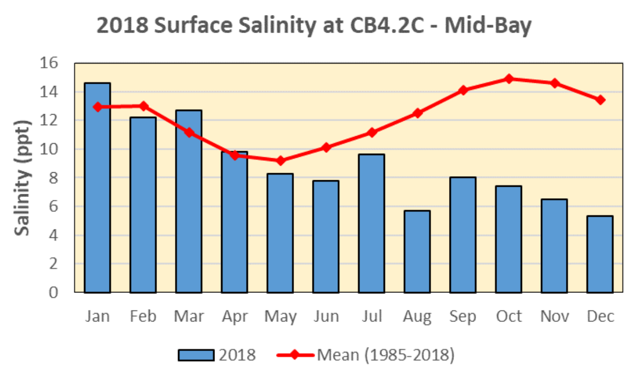

Figure 2c. Monthly surface salinities during 2018 at Station CB4.2C in mid-Chesapeake Bay off the mouth of the Choptank River.

Further downbay at the mainstem station CB5.2 off Point No Point showed the greatest amount of monthly variability as well as the highest deviation from the norm. Intra-annual variation in salinities ranged from 17.1 ppt in January to 6.9 ppt in November, a difference of 10.2 ppt (Figure 2d). Salinities were normal or slightly above normal through May, then fell increasingly below average, with the greatest deviation, 9.8 ppt, in November. Salinities were near or below the 10 ppt threshold for MSX disease for six months.

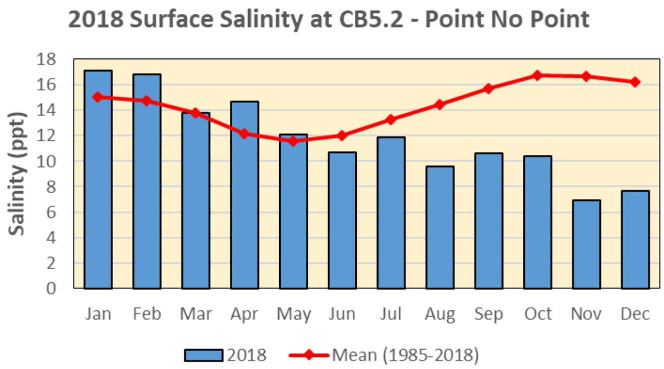

Figure 2d. Monthly surface salinities during 2018 at Station CB5.2 in the lower mainstem of Chesapeake Bay off Point No Point.

Streamflow usually has the least impact on salinity variability in lower Tangier Sound, where salinities average higher than in the mainstem. However, even here the elevated autumn flows were manifested by a steep decline in salinities starting in October (Figure 2e). The lowest monthly mean was 10.0 ppt in December, 7.3 ppt below normal. This contrasts with the beginning of the year, when the salinity peaked at 18.1 ppt in January and February, or as much as 1.7 ppt above average.

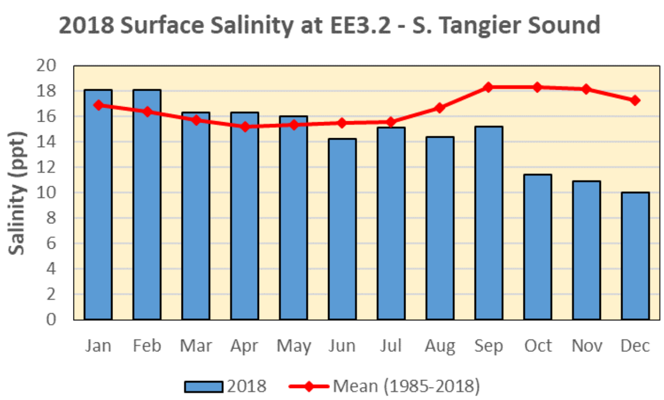

Figure 2e. Monthly surface salinities during 2018 at Station EE3.2 in south Tangier Sound.

The most dramatic decreases in salinities in terms of absolute value were observed in the upper bay and on the uppermost oyster grounds of the Potomac River. A critical threshold for a number of biological processes in oysters is 5 ppt (see *Discussion* section). Swan Point in the upper bay had surface salinities below 5 ppt for seven continuous months, with a minimum of 0.6 ppt in August (Figure 2f).

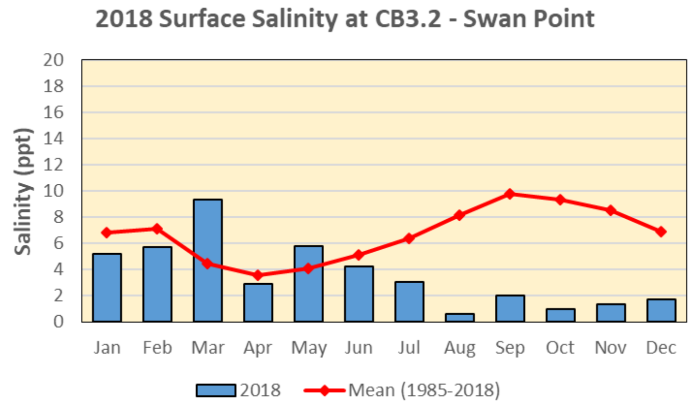

Figure 2f. Monthly surface salinities during 2018 at Station CB3.2 in the upper bay at Swan Point.

Similarly, a Potomac River monitoring station at the Morgantown – Route 301 bridge reported eight continuous months of surface salinities below 5 ppt, with a minimum of 0.4 ppt in August (Figure 2g).

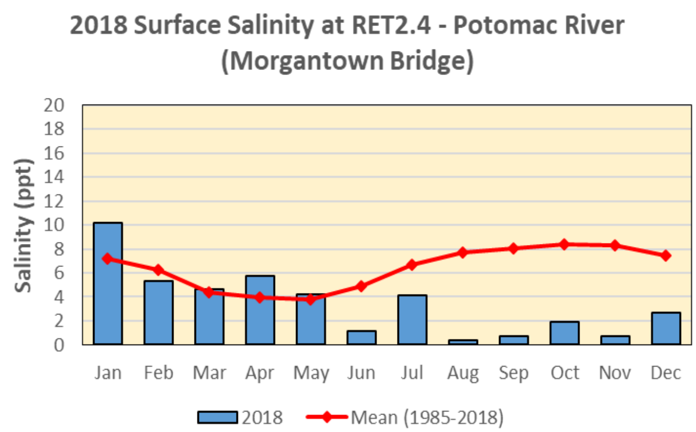

Figure 2g. Monthly surface salinities during 2018 at Station RET2.4 in the Potomac River at Morgantown.

SPATFALL INTENSITY

The Spatfall Intensity Index, a measure of recruitment success and potential increase in the population, was 15.0 spat/bu, well below the 34-year median value (Figure 3a). Spatset intensity declined 36% from the previous year, with more than twice as many 2018 index bars having decreased spatfall when compared with 2017 (Table 2). Two of the previous eight years (2010, 2012) had strong year classes, which boosted the population and increased commercial landings. However, the poor to middling spatsets over the past six years have had implications for population abundance, leading to declining harvests in the most recent years and possibly upcoming seasons as well unless the somewhat more favorable 2015 and 2016 year classes grow and survive to enter the fishery (Figure 3b). The below-median 2018 spatfall forebodes a continuing trend in this decline.

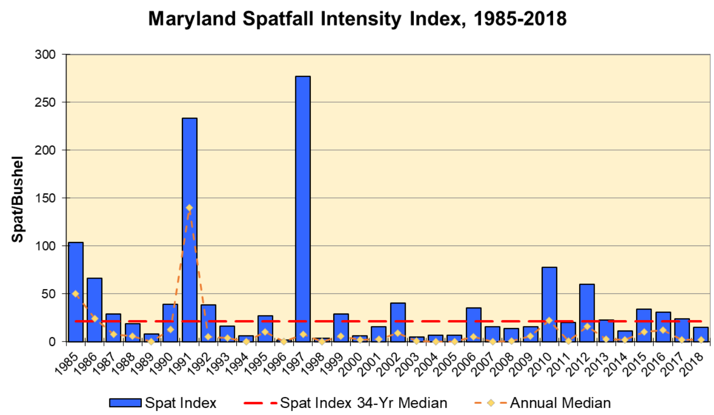

Figure 3a. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including annual median values.

Spatfall distribution among the Key Bars in 2018 was similar to the previous year, albeit at lower intensities. Spat were observed on 32 of the 53 Key Bars, whereas 34 Key Bars had spat in 2017 (Table 2). Only four bars

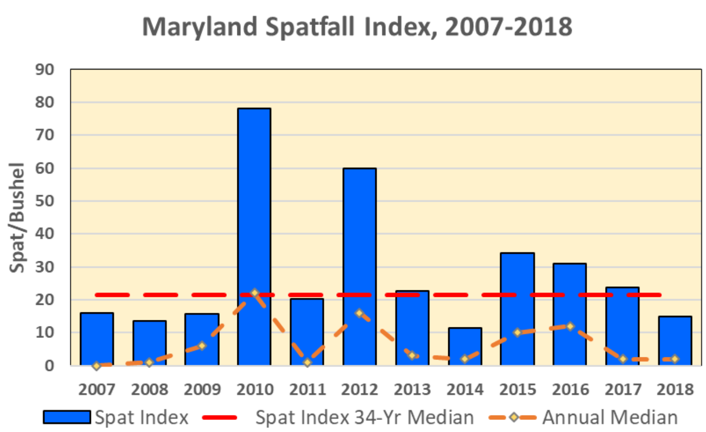

Figure 3b. Recent Maryland spatfall indices, 2007-2018, including annual median values.

accounted for 49% of the index, similar to 2017 and compared with nine bars in 2016. In 2018, nine bars contributed 75% of the spat index (same as 2017; 15 bars in 2016), while 19 bars were needed to reach 95% of the spat index; the remaining 34 bars made up only 5% of the 2018 index. In other words, almost two-thirds of the Index bars were unproductive in 2018. Only two Key Bars reached triple-digit spat counts: 119 spat/bu on Deep Neck in the Broad Creek hand tong harvest area and 110 spat/bu on Drum Point in the Manokin Sanctuary. Over the 34-year time series these bars have ranked consistently near the top of Key Bar spat counts (Table 2).

When considering all bars surveyed in addition to the Key Bars, as in past years the (relatively) better spatset was observed downbay from the Choptank region (specifically Harris and Broad creeks) - primarily in lower Tangier Sound, as well as the remainder of the Tangier Sound region and the St. Marys, Little Choptank and Manokin rivers. The Manokin River Sanctuary had the highest regional average (Figure 4). A light spatset occurred as in the Patuxent, lower Choptank, and lower Potomac rivers. Spat were absent from large swaths of the bay - no spat were found along the Western Shore upbay from about Point No Point, the Eastern Shore from Eastern Bay north, the upriver two-thirds of the Potomac oyster growing region or the upper Choptank River. The highest spatset on an individual bar (288 spat/bu) was observed on Piney Island East Addition 1 Sanctuary in Tangier Sound.

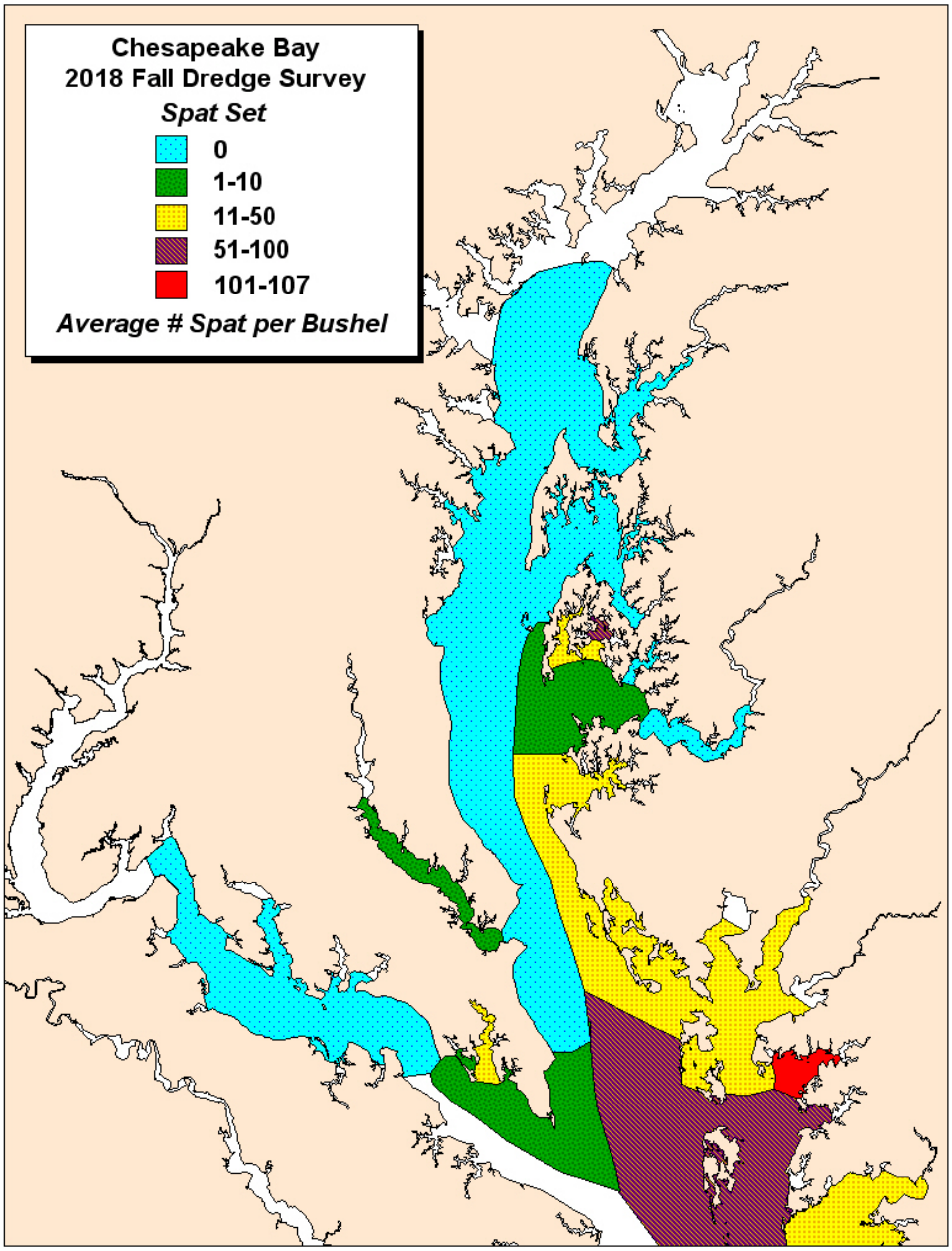

Figure 4. Oyster spatfall intensity and distribution in Maryland, 2018. Intensity ranges represent regional averages.

Skewed Spatfall Distributions and the Spatfall Intensity Index

The annual Spatfall Intensity Index is an arithmetic mean that does not take into account geographic distribution, whereas the discontinued statistical tiers method did (see *Methods* section for explanation of discontinuing this analysis). 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 index years (Tarnowski 2018, Figure 3a). 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.

Another approach to understanding skewed spatfall distributions examines the annual medians of the index (Figure 3a). Medians are generally higher when there is a more uniform geographic distribution. In comparison, medians are lower when the geographic distribution is limited in extent or skewed. In cases such as in 2018, where 64% of the Key Bars accounted for only 5% of the spat index, the median was low, reflecting the disparity between the majority of bars which experienced low to zero spatset and the few relatively productive bars. In years when spatset is more widely distributed, the annual median is much higher, such as in 1985, 1991, and to a lesser extent 2010 and 2012. In contrast, most of the years had more geographically restricted spatset distributions, dominated by a few strong recruitment bars. Again, this is most vividly illustrated in 1997, when despite having the highest spat index of the time series, the median for that year was comparatively low (half of the 2012 median, even though the 1997 spat index was over four times higher than the 2012 index).

OYSTER DISEASES

Dermo disease is caused by the parasite *Perkinsus marinus*. Prevalences and intensities wax and wane seasonally, and infections may persist from year to year before oysters die.

Dermo disease was detected in oysters on 91% of the Disease Bars (Table 3) during 2018, the lowest frequency since the 43-bar subset was standardized in 1990. Although dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, the absolute number of infected oysters was much lower than in 2017. The overall mean infection prevalence in oysters sampled on the Disease Bars was 40%, compared to 69% in 2017 and was the second lowest in the 29-year time series (2011 had the record-low mean prevalence of 38%) (Figure 5). This marks the 14th of the past 16 years when dermo disease mean prevalences were below the long-term average of 67%, and reverses a previously increasing trend in the percentage of infected oysters throughout Maryland waters that began in 2014. The mean infection intensity for dermo disease (1.2) was half of the 2017 average, and well below the long-term average, tying the record for the lowest average intensity.

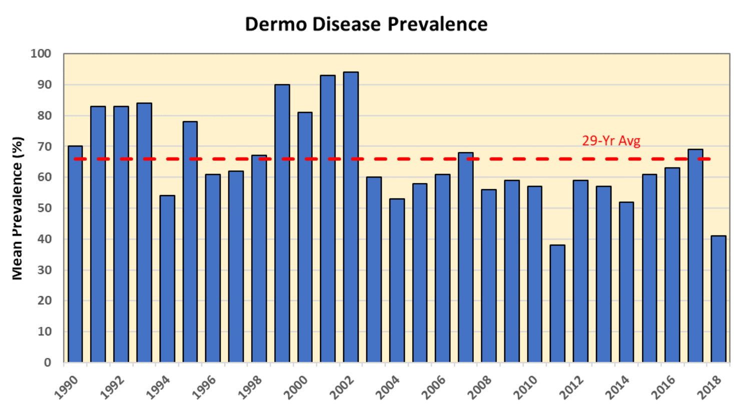

Figure 5. Annual mean *P. marinus* prevalences from Maryland disease monitoring bars.

The geographic distribution of high prevalences (>60%) decreased by half from the previous year to 37% of the Disease Bars, retreating to the lower main stem but remaining in many of the tributaries, including the Miles and Wye rivers, Harris Creek, Tred Avon, lower Choptank, Little Choptank, Honga, and Nanticoke rivers, Fishing Bay, and Pocomoke Sound on the Eastern Shore. (Figure 6). In the Western Shore tributaries, higher prevalences were found further south in the lower Patuxent, lower Potomac, and St. Marys rivers. Outside of the regular disease monitoring sites, dermo disease was detected at all eight of the supplemental sites, with prevalences greater than 60% at three of the bars. The two supplemental bars furthest upstream, Deep Shoal in the mainstem and Beacon bar in the upper reaches of the Potomac River, were not sampled for disease in 2018 because of low oyster densities due to freshet-related mortalities. Dermo disease was undetected at these locations in 2011 when streamflows were also elevated.

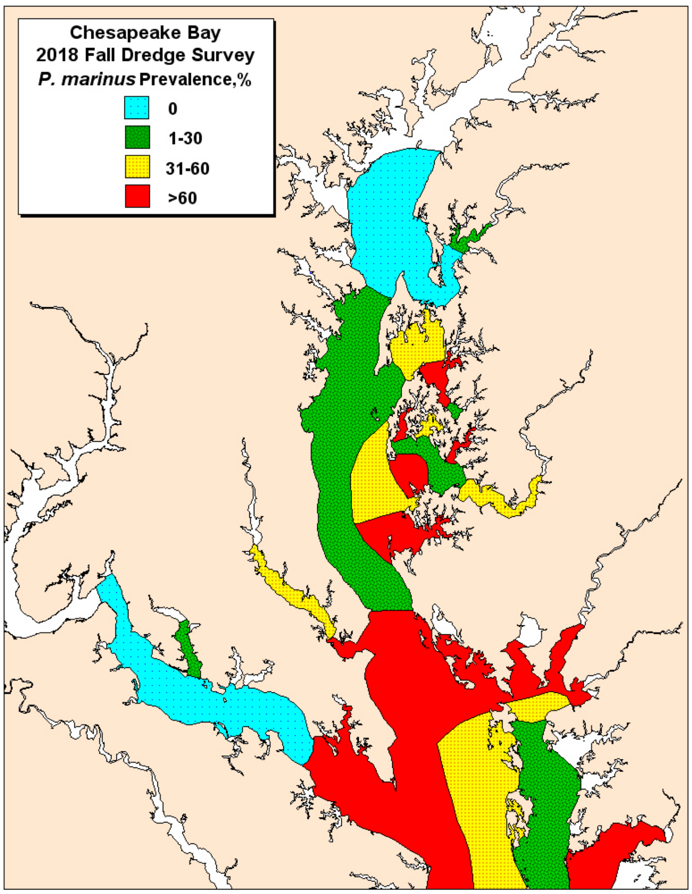

Figure 6. Geographic extent and prevalence of dermo disease in Maryland, 2018.

The 2018 annual mean infection intensity of 1.2 (on a 0-7 scale) was less than half of the previous year's and the lowest on record with 2011 (Table 3). This is the 13th year of the past 16 that the infection intensity index has been below the long-term average (Figure 7). The average infection intensity over the 16 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.

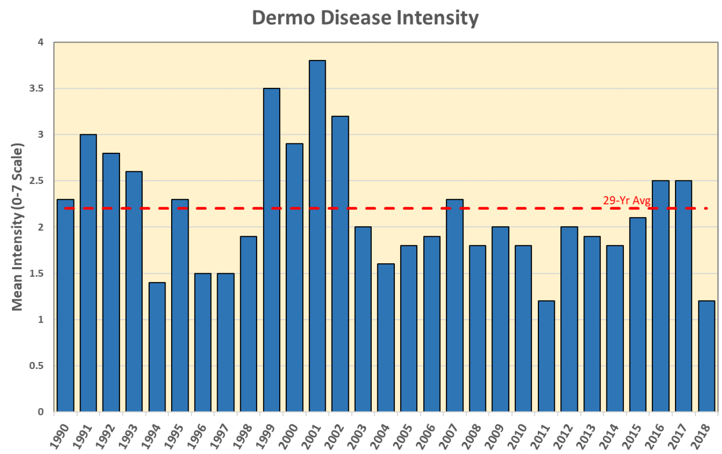

Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars.

The 2018 frequency distributions of sample mean infection intensities shifted dramatically from the previous year (Figure 8). No sentinel bars had a mean intensity of 3.0 or greater, compared with 20 bars (47%) that did in 2017, while 40% of the stations had intensities of less than 1.0 (vs. 14% in 2017). 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. In addition, none of the eight supplemental stations had mean infection intensities of 3.0 or greater in 2018.

Infection intensities in individual oysters that are ≥5 on a 0–7 scale are considered lethal; such infection intensities were detected in 7 % of oysters sampled in 2018, a decrease from 21% in 2017.

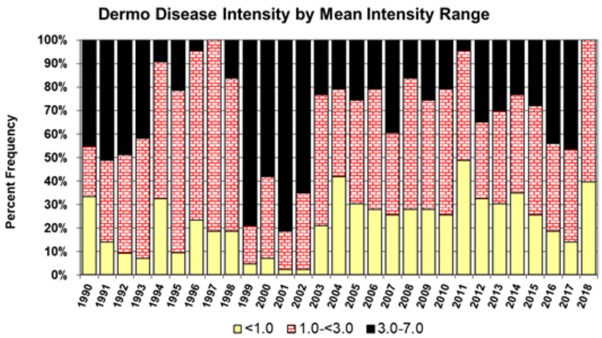

Figure 8. *Perkinsus marinus* infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.

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.

In 2018, MSX disease mean prevalence (0.1%) showed a marked decrease, ending a three-year trend of increases. The geographic range of MSX disease also contracted range to limited areas in Tangier Sound and the lower mainstem (Figure 9), as the number of sentinel bars with infected oysters declined more than tenfold. *Haplosporidium nelsoni* was found in only one oyster from one (2%) of the Disease Bars (Piney Island East), compared with 14 bars (33%) in 2017 (Table 4). This represents the lowest number of infected sentinel bars and the lowest average prevalence recorded in the time series. For reference, the parasite occurred on 90% of the bars in 2002. For the 43 disease monitoring bars, the average percentage of oysters with MSX disease was 0.08%, a nearly fourfold decrease from 2017 (Figure 10, Table 4). MSX disease was detected at only two other locations in 2018; one oyster each was infected at the supplemental bars Northwest Middleground

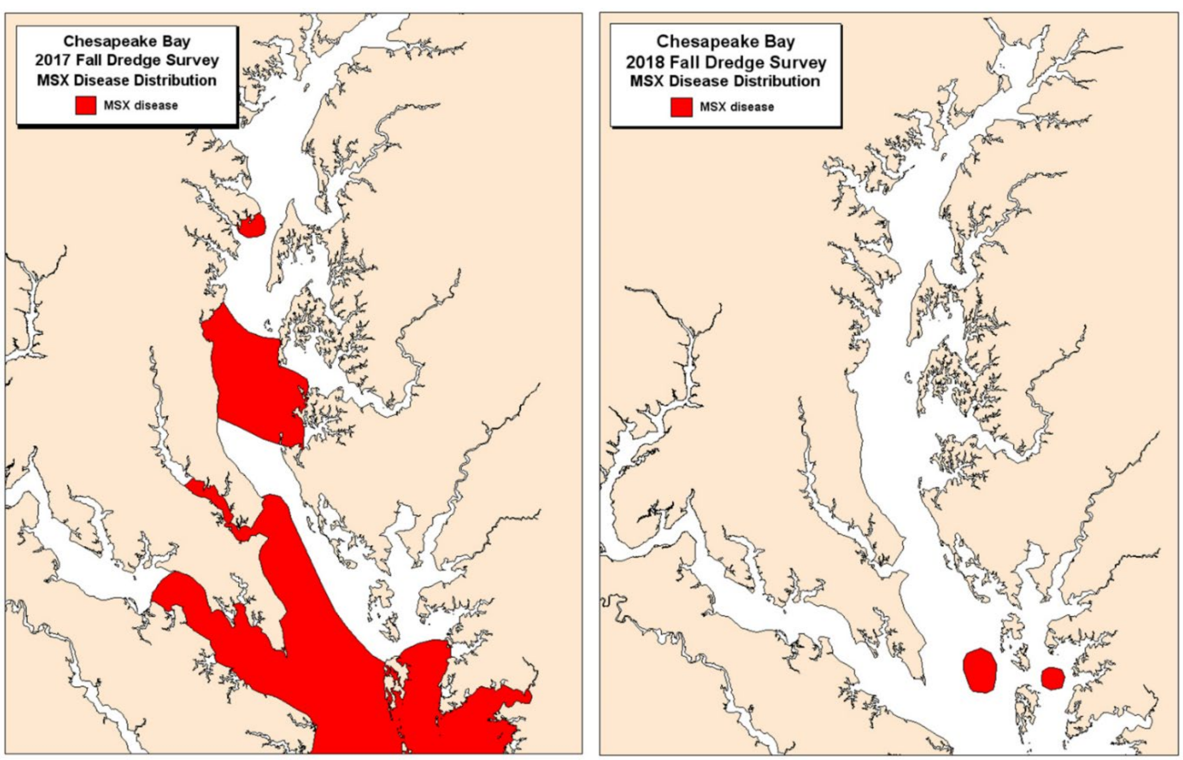

Figure 9. Geographic shifts of MSX disease in Maryland waters between 2017 and 2018.

on the east side of the lower mainstem and Piney Island East Addition 1 (Somerset Sanctuary) in Tangier Sound. (Figure 9).

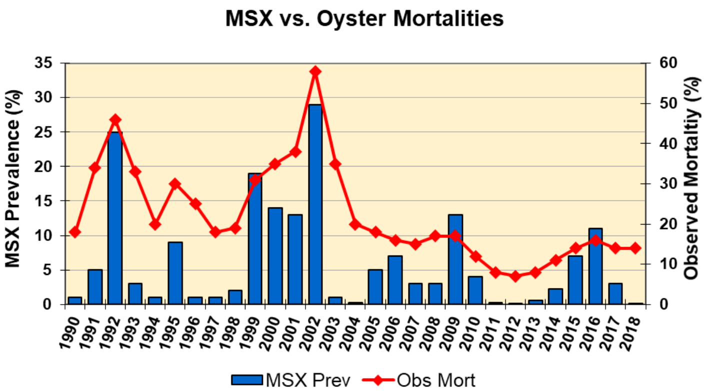

Figure 10. Percentage of Maryland oysters with MSX disease compared to annual means for observed mortalities on the disease monitoring bars from 1990-2018.

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).

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 decrease in *H. nelsoni* infections is associated with well above normal streamflows in 2018.

OBSERVED MORTALITY

Despite locally devastating freshets at some upstream locations (see below), the Maryland-wide Observed Mortality Index remained the same as the previous year (Table 5). At 14%, the 2018 index was well below the 34-year mean of 22.5%, continuing a 15-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 long-term time series. For the 43 disease monitoring bar subset, the average observed mortality of 13.7% over the last 15 years approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (MDNR, unpubl. data). This is in remarkable contrast to 2002 when record-high disease levels devastated Maryland populations, resulting in a 58% observed mortality rate.

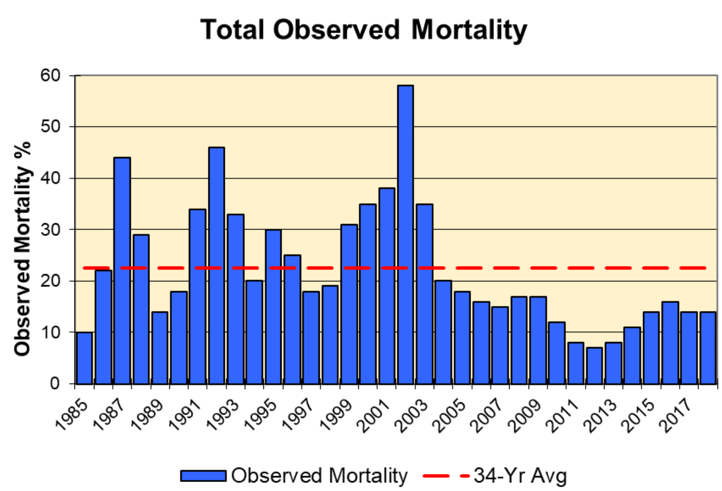

Figure 11. Mean annual observed mortality, small and market oysters combined.

Looking at all Survey sites, mortalities were highly variable among bars within some of the regions (e.g. Tangier Sound, observed mortalities ranged from 1% to 52%). Aside from the upper Potomac River and the upper bay, the highest mortalities observed during the Survey on an individual bar with more than 50 live oysters/bushel[2] were in the lower

[2] Sites with low numbers of live and dead oysters may distort observed mortalities.

Eastern Shore region: 52.1% on Turtle Egg Island bar in Tangier Sound, followed by Evans bar (34.7%) in the lower Wicomico River East and Marumsco bar (34.5%) in Pocomoke Sound. Regional average observed mortalities were generally low to moderate. The north-south gradient in observed mortalities evident in most years was less apparent in 2018, with strikingly low average mortalities throughout most of the mainstem including the lower Western Shore, and parts of the Tangier Sound region (Figure 12a). Higher regional mortalities were in other portions of the Tangier Sound region including the eastern side of the mainstem, and Eastern Bay. The highest Index-bar mortality was observed on Lower Cedar Point in the upper Potomac River, where 96% of the oysters were dead (Table 5).

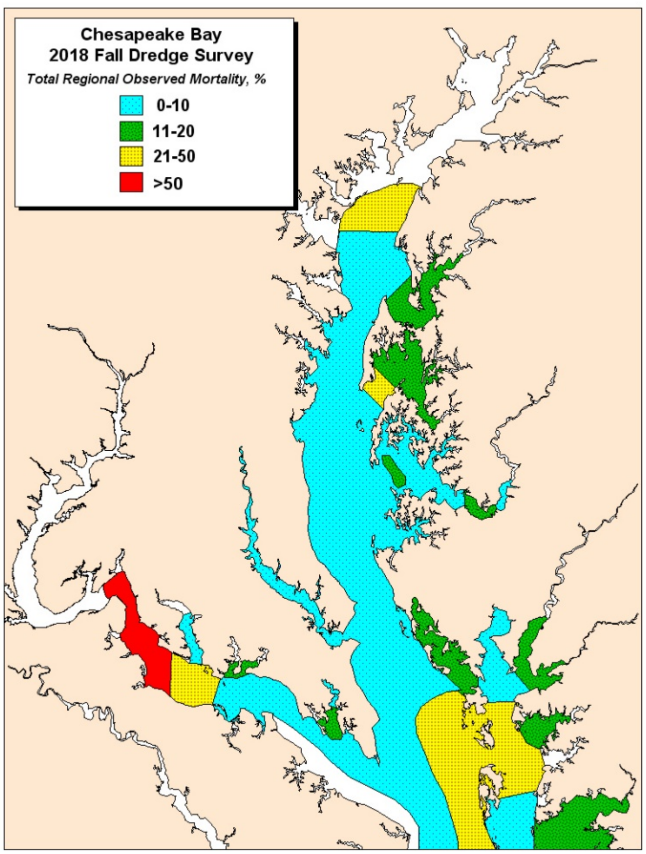

Figure 12a. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2018. Mortality ranges represent regional averages; individual bars may vary substantially.

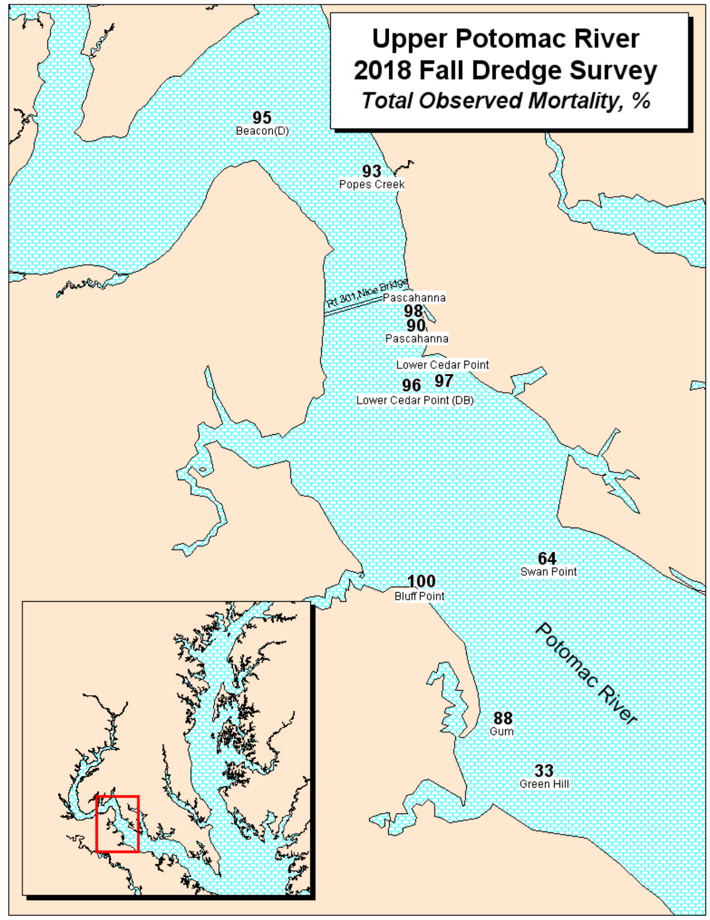

Figure 12b. Observed mortalities on the upper oyster bars of the Potomac River sampled in October 2018.

Freshet-Related Mortalities

The prolonged period of elevated streamflows and consequent drop in salinity had a severe impact on the upper Potomac bars and to a lesser extent the upper bay oysters. In the Potomac River above Cobb Island, observed mortalities ranged from 88% to 100% (Figure 12b). Several of these bars had been planted with seed oysters over the past few years and their loss was a devastating blow to the fishery. The most dramatic impact to these seed plantings was evident on Bluff Point bar, where in a one bushel sample there were 226 dead oysters and no live oysters. Mortalities may yet be higher as salinities too low to support oysters lasted past the survey to at least through the end of the year (Figure 2g). There were also less tangible consequences from the freshet. The oysters on Beacon, one of the furthermost-upstream bars in the Potomac, were conditioned to low salinity and had weathered several deluges over the past three decades, including the wet years in the 1990s, 2003/04, and 2011 (Figure 2a). This unique oyster population suffered 95% mortality in 2018.

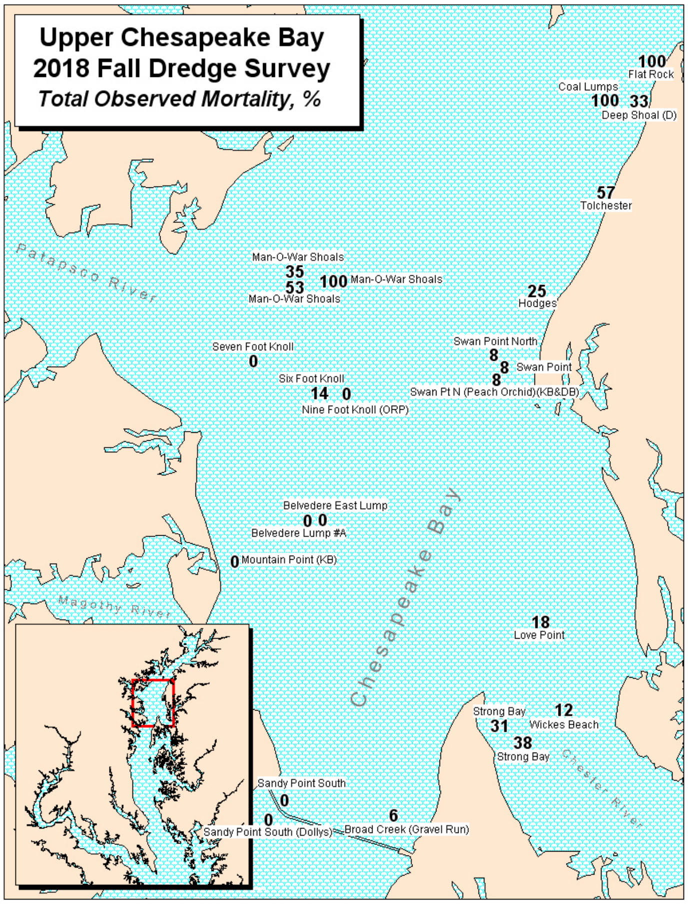

Figure 12c. Observed oyster mortalities in the upper bay, November 2018.

The upper bay oyster populations fared somewhat better (Figure 12c). On the Eastern Shore side, the highest observed mortalities ranged from 25% to 100%, but unlike in the Potomac these were bars with extremely low numbers of oysters – less than 10 oysters/bu. But Swan Point, where there has been considerable planting activity of late, had a much lower observed mortality of 8%. Only one bar on the Western Shore side had elevated mortalities. Two oyster seed plantings on Man-O-War Shoals had mortalities of 35% and 53%, while a third sample site had only four dead but no live oysters, resulting in an exaggerated observed mortality for that sample. The combined observed mortality on Man-O-War Shoals was 42.5%, in contrast with the 2011 freshet, when 100% of the oysters died on this bar. However, mortalities may have continued after the survey as this area was sampled in early November when temperatures were still warm enough (12.3° C) for oysters to still be metabolically active while depressed salinity conditions persisted (Figure 2f). Even if the oysters survive into their winter quiescence, they may be in such a depleted condition that they may die when they become active again in the spring (Andrews et al. 1959)

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 2018 Maryland Oyster Biomass Index of 1.78 represents the first increase of this index since 2013 (Figure 13a), despite a decline in harvests. The size distribution remained shifted to more sublegal oysters relative to market oysters at a ratio of 1.32 sublegals to one market oyster. Most of the increase in the Biomass Index (67.1%) can be attributed to the continued growth of oysters protected in the sanctuaries, accounting for this discrepancy between increased biomass and decreased harvests (Figure 13b). This increase was also boosted by the above-median recruitment in 2015 and 2916. The 2018 index ranked third highest in the 26-year time series.

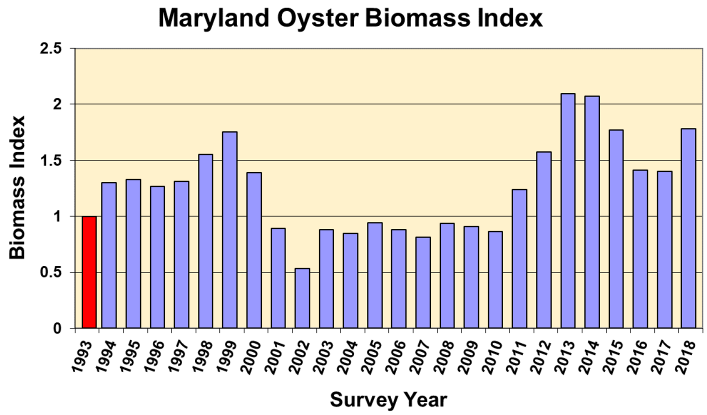

Figure 13a. Maryland oyster Biomass Index. The year 1993 represents the baseline index of (1).

The oyster population had been slow to recover since its nadir in 2002, the last year of the devastating four-year disease epizootic. The Biomass Index remained below one[3] 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.

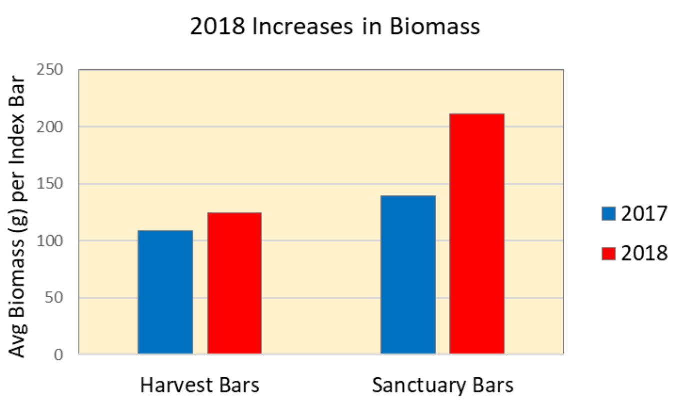

Figure 13b. Increases in oyster biomass between 2017 and 2018 on harvest and sanctuary index bars.

CULTCH INDEX

The Cultch Index 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.

The 2018 Cultch Index of 0.86 bu/100 ft. was somewhat lower than the 14-year average of 0.91 bu/100 ft. However, individual bars showed much steeper declines. Of the 52 bars used in this analysis, 26 had standardized volumes that were more than 25% below their respective 14-year averages, while 16 bars were similar to their 14-year averages and 10 bars were more than 25% above their long-term averages (Figure 14).

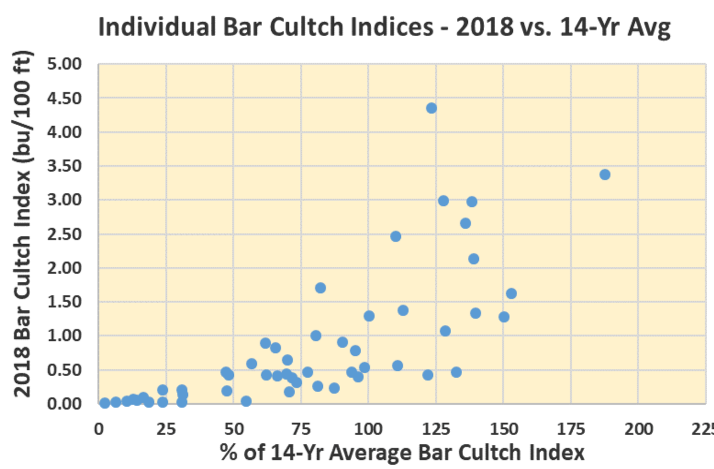

Figure 14. Range of cultch index values for individual Key bars in 2018 and the percent difference from their 14-year averages.

Although 14 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 each grouping).

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

The increase in the Cultch Index during the early 2010s reflects improvements in recruitment and survivorship during that period, especially the strong spatsets in 2010 and 2012 (Figures 3b, 11). The growth and high survivorship of these year classes contributed substantially to the index. The subsequent decline may be due to harvesting and lower recruitment, as well as ongoing taphonomic processes such as shell burial and degradation.

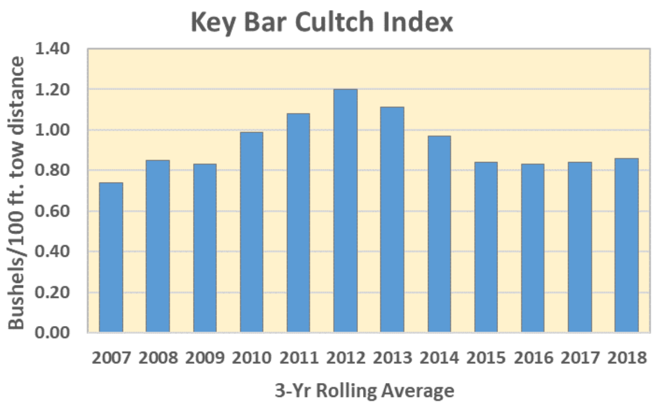

Figure 15. Three-year rolling average of annual means for the Key Bar Cultch Index, 2005-2018. The average is represented by the third year of the grouping (e.g. the 2005-07 average is graphed as 2007).

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 of varying degrees averaged over the last three years when compared to the 14-year average (Figure 16). The largest decline in regional indices occurred in the Chester River/Eastern Bay region. Tangier Sound saw improvement in its index, while the Choptank region and Patuxent River remained relatively stable. The Potomac/tributaries index is somewhat deceptive since it is largely driven by Pagan bar, whose 3-year average is five times as high as the 3-year average of the six other bars in this region; if not for Pagan the index would be 33% lower.

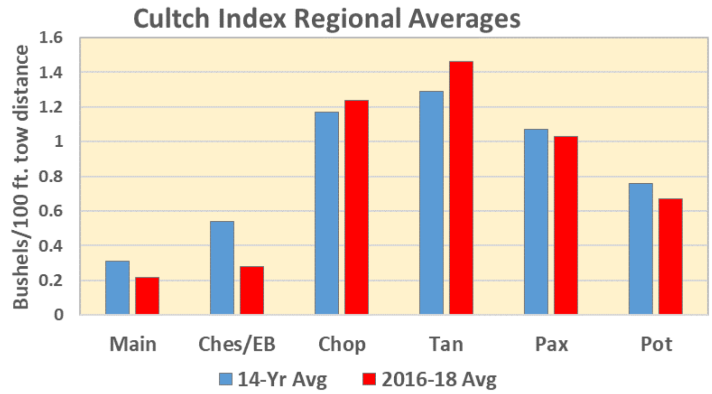

Figure 16. Regional cultch index averages for the 13-year time series and most recent three years. *Main=bay mainstem; Ch/EB=Chester River/Eastern Bay region; Chop=Choptank River region; Tan=Tangier Sound region; Pax=Patuxent River; Pot=Potomac River tributaries*

COMMERCIAL HARVEST

With reported harvests of 182,000 bushels during the 2017-18 season, commercial oyster landings were 19% lower than the previous harvest season, extending a declining trend to four years (Table 6, Figure 17a). This was the lowest harvest total since the 2011-12 season and was 38% below the 33-yr average of 296,000 bu/yr. At an average reported price of $47.88 per bushel, the dockside value of $8.7 million was a decrease of $1.9 million (-18%) from the previous year (Table 7a.).

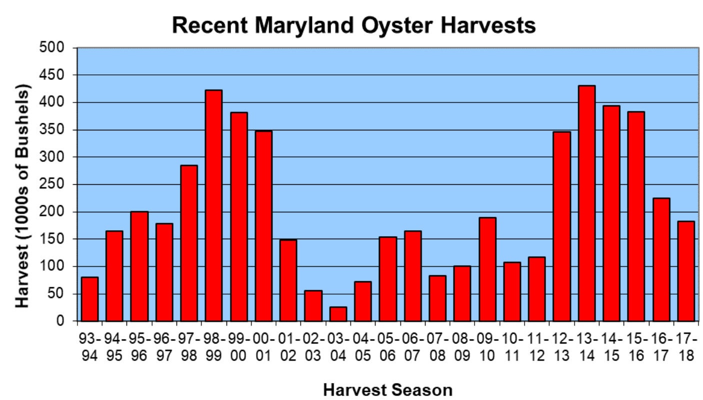

Figure 17a. Maryland oyster landings over the most recent 25 seasons.

In the 15 years before the 2016-17 season, commercial oyster landings 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 recent seasons, following the below-average landings of the 11 years beforehand, were due to the strong 2010 and 2012 year-classes and subsequent good survivorship, allowing a larger proportion of those 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 in 2011, 2013, and 2014 were insufficient to sustain harvests, leading to the substantial drop in landings during the last two seasons. The Biomass Index did not track this decline but actually increased because of above-median spatfalls in 2015 and 2016. The subsequent growth as sublegal-size oysters as well as continued growth of oysters protected in sanctuaries contributed to the Biomass Index. If mortality rates remain about the same as the previous several years, these younger oysters should continue to grow and recruit to the fishery.

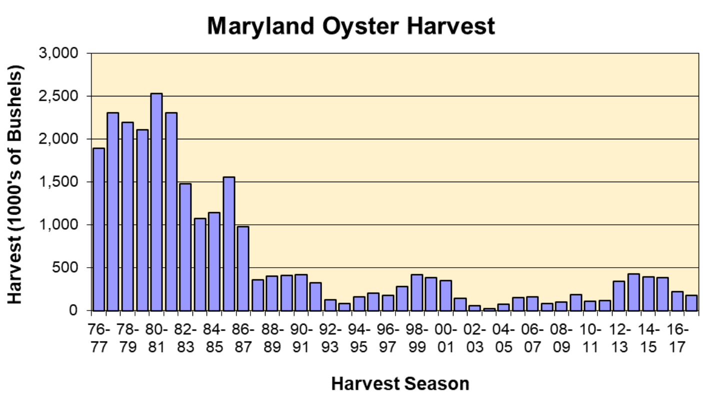

Figure 17b. Maryland seasonal oyster landings, 1976-77 to 2017-18.

Taken in the longer historical context, the average landings over the last several 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 25 years (and four of these in the most recent 16 years) following the onset of disease epizootics in the mid-1980s.

The Tangier Sound region, including the Nanticoke, Wicomico and Honga rivers, Pocomoke Sound and Fishing Bay, was again the dominant harvest area, accounting for 36% of the 2017-18 landings, the majority of which came from Tangier Sound proper (Table 6). The second most productive region was the Choptank (28% of landings), primarily from Broad Creek. Almost all of the regions experienced declines in landings. The most substantial changes (>5,000 bu) in Maryland landings between the 2016-17 and 2017-18 seasons were:

Patuxent River
-decreased 13,223 bushels (-58%)
Honga River
-decreased 9,063 bushels (-82%)
Fishing Bay
-decreased 6,167 bushels (-45%)
Middle Bay Mainstem
-decreased 5,938 bushels (-54%)
Eastern Bay
-decreased 5,913 bushels (-38%)
St. Marys River
-increased 10,043 (+115%)

The combined harvests in the Tangier Sound region decreased by 23,219 bushels or -26% from 2016-2017 and 170,012 bushels (-72%) from just four years earlier (the recent peak season of 2013-14). The heaviest losses from the previous year occurred in the Honga and Patuxent rivers. Overall, the Choptank region was relatively stable; even though the lower part of the river experienced a loss, there was a modest gain in the non-sanctuary portion of Harris Creek as well as other areas. 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 4.2% or 7,715 bu in

2017/18 (Table 6). The 33-year harvest average for these two regions was 34,000 bu/year, primarily sustained by numerous seed plantings from the MDNR Repletion Program. Likewise, harvests from the once-productive Eastern Bay region are less than one-third of the 33-year average.

For the 11th consecutive season, power dredging was the predominant method of harvesting, accounting for 39% of the total landings (Table 7b). The actual landings from power dredging are about one-quarter of those during the peak 2013-14 season (Table 7a). This activity was mainly in the lower Eastern Shore and Choptank regions. Hand tonging produced 23% 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 to 17% 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 concise view of the sanctuary oyster populations, focusing on the more important (i.e. large-scale restoration) sanctuaries.

A total of 88 oyster bars within 32 sanctuaries were sampled during the 2018 Fall Survey (Table 8). Recruitment within sanctuaries was lower than the previous year, in keeping with the baywide results and well below their respective Key Bar averages, with the exception of the Manokin Sanctuary (Table A). A comparison of spatset in sanctuaries with adjacent harvest areas showed mixed results, but none of the differences were statistically significant as determined by t-tests ($P > 0.05$)[4]. For example, Harris Creek sanctuary stations averaged 30 spat/bu., somewhat lower than the harvest portion of that tributary, while the open and closed areas of the Tred Avon River had similarly poor spatfall averages. Broad Creek open harvest area, historically a higher recruitment tributary located between Harris Creek and the Tred Avon River, averaged 54 spat/bu, the highest in the Choptank region. Recruitment in the open harvest area of the Little Choptank River averaged 7 spat/bu compared with 14 spat /bu inside the sanctuary, and the St. Marys River spatfall averaged 9 spat/bu in the open area and 4 spat/bu in the sanctuary; both of these tributaries had roughly an order of magnitude lower spatfalls than their long-term Key Bar averages. Lastly, the open harvest area of mid-Tangier Sound averaged 65 spat/bu with a high count of 208 spat/bu (Terrapin Sands bar), while spatfall in the Manokin sanctuary averaged 107 spat/bu with a high count of 190 spat/bu on Mine Creek bar. Another sanctuary in the mid-Tangier Sound region, Somerset Sanctuary, had the highest spatset of any sample observed during the 2018 survey – 288 spat/bu – with an average of 147 spat/bu for the three samples taken there.

[4] The exception was a statistically significant difference between the Tred Avon sanctuary and Broad Creek ($P < 0.01$), but this is an inappropriate comparison since recruitment in Broad Creek has historically outperformed the Tred Avon River by almost sevenfold. The consistently higher spatset in Broad Creek is due to differences in the hydrodynamics between the two tributaries (Seliger et al. 1982, Kennedy 1996).

Table A. 2018 regional spat per bushel and long-term Key Bar averages for restoration sanctuaries and nearby harvest areas. The Manokin Sanctuary has two Key Bars, hence two values for the 34-year average. There were no statistically significant differences within pairings of open and closed areas within regions or between Broad Creek and the Harris Creek sanctuary (t-test, *P* > 0.05).

Region	**Status**	**Regional 2018 Spat**	***Key Bar 34-Yr Avg.***
Harris Cr.	Sanc.	30	*40*
Harris Cr.	Open	41	*66*
Broad Cr.	Open	54	*118*
Tred Avon R.	Sanc.	0.2	*18*
Tred Avon R.	Open	1	*18*
L.Choptank R.	Sanc.	14	*90*
L.Choptank R	Open	7	*58*
Manokin R.	Sanc.	107	*69/97*
Mid-Tangier S.	Open	65	*99*
St. Marys R.	Sanc.	4	*170*
St. Marys R.	Open	9	*82*

Oyster disease samples were obtained from 20 sanctuaries. The average dermo disease levels in these sanctuaries were considerably lower than the previous year (average prevalences of 51.2% in 2018 vs. 83.9% in 2017; mean intensities of 1.5 in 2018 vs. 3.3 in 2017). Of the 13 sentinel Disease Bars within oyster sanctuaries, dermo disease prevalences and intensities were below the 29-year site averages at 11 bars, compared with just two bars below their long-term averages in 2017. Dermo disease levels were lower on Disease Bars in the open harvest areas, averaging 36.9% prevalence and 1.1 mean intensity (Table B). The higher dermo disease levels in the sanctuaries can be attributed to the fact that they had a greater proportion of older, larger oysters than the harvest bars (Figure 18); parasite burdens tend to build up as oysters age (Ford & Tripp 1996).

The average MSX disease prevalence declined 80% from 2017. The disease was not detected at any of the 13 Disease Index Bars within sanctuaries (Table 4), and only at two of the six non-Index bars in sanctuaries at low prevalences (3%, or one oyster at each location). Monitoring sites in the five restoration sanctuaries showed no evidence of MSX disease (Table B). MSX disease was found at a low prevalence (3%) on one of the nearby harvest areas - Piney Island East Disease Bar outside of the Manokin sanctuary (Table 4).

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 34-year individual bar average. Despite anecdotal reports of high oyster mortalities in the Manokin River sanctuary, the measured average observed mortality was only 16%, lower than the Tangier open harvest bars (20%) and well below the long-term index mean. For all Mortality Index bars, observed mortalities were virtually identical between sanctuary bars (14.6%) and open harvest bars (14.4%), despite the higher overall mean dermo disease levels at the sanctuary sites (Table B).

Table B. 2018 Dermo disease levels and observed mortality estimate on restoration sanctuaries and nearby harvest areas. MSX disease was not detected at any of these sites except for Piney Island East (3% prevalence). There were no statistically significant differences between the averages of all sanctuary and harvest disease index bars (t-test, $P > 0.05$).

Region	Disease Bar	Status	Dermo		Observed Mortality	
			Prevalence	Intensity	Disease Bar	Regional
Harris Cr.	Mill Pt.	Sanc.	67%	1.9	3%	5%
Harris Cr.	Tilghman Wharf	Open	47%	1.2	7%	7%
Tred Avon R.	Double Mills	Sanc.	67%	2.1	11%	6%
Broad Cr.	Deep Neck	Open	57%	1.3	3%	3%
L. Choptank R.	Cason	Sanc.	77%	2.2	8%	5%
L. Choptank R.	Ragged Pt.	Open	67%	1.7	6%	7%
Manokin R.	Georges	Sanc.	77%	2.7	9%	16%
Mid-Tangier S.	Piney Island East	Open	27%	1.1	38%	20%
St. Marys R.	Pagan	Sanc.	63%	1.4	4%	7%
St. Marys R.	Chicken Cock	Open	63%	2.1	17%	8%
Average of all Sanctuary Disease Index Bars			47.2%	1.4	14.6%	
Average of all Harvest Disease Index Bars			36.9%	1.1	14.4%	

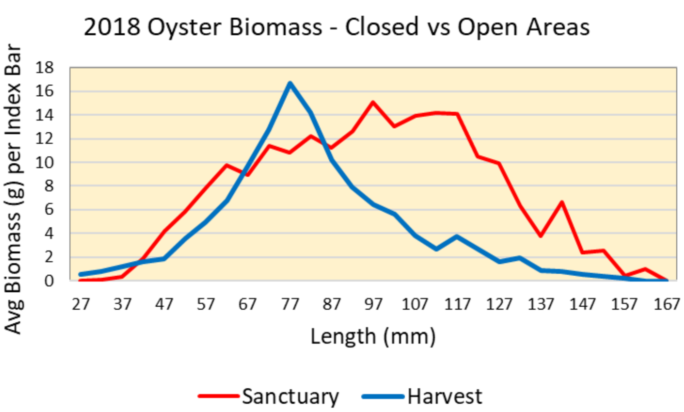

Figure 18. Average oyster biomass by 5 mm size classes on Biomass Index bars in harvest areas and sanctuaries.

Of the 43 Biomass Index bars, 13 bars are within sanctuaries (Table 8). From 2017 to 2018, the biomass cumulatively increased by 52% on these 13 bars, compared with a 14% rise on the 30 harvest bars (Figure 13b). The average biomass per index bar in 2018 was substantially higher in the sanctuaries (211.0 g/bar) than in the open harvest areas (124.2 g/bar) (Figure 13b). Most of this difference was in the larger market size classes (Figure 18), where the average market biomass per bar in the sanctuaries (160.8 g/bar) was twice as high as in the open harvest areas (80.4 g/bar). In contrast, the average biomass of sublegal oysters was relatively close between the two management categories (50.2 g/bar in the sanctuaries vs. 43.9 g/bar in the harvest areas).

DISCUSSION

The Consequences of Record Streamflows

One of the most critical physical factors influencing oyster populations, both directly and indirectly, is salinity. Salinity, as a function of freshwater flow, varies seasonally, annually, and spatially depending on weather patterns such as rainfall and snow pack. Changes in freshwater discharges into the Bay can alter salinity regimes sufficiently to affect recruitment patterns, predation, disease pressure, and mortality rates. Depressed salinities can inhibit reproduction and recruitment, arrest feeding, slow growth, and elevate mortalities in marginally viable areas, but reduce disease-related mortalities by lowering disease levels. Even slight shifts in salinities can have profound consequences for oysters in a given area.

The effect of extremely elevated freshwater discharge on oyster populations and consequent oyster survivorship in

Chesapeake Bay was again demonstrated in 2018, which had the highest monthly average streamflows in the 82-year record. As a result, the 2018 spat intensity index was subpar, a large pool of sublegal oysters did not grow to marketable size, oyster disease levels fell to their lowest since systematic monitoring began in 1990 (comparable to 2011), and oyster plantings suffered elevated mortalities in the upper bay and were nearly wiped out on the uppermost Potomac River bars.

Reproduction and Recruitment
Suboptimal salinities can adversely impact all phases of oyster reproduction from gametogenesis through settlement and metamorphosis. Gametogenesis is reduced or suppressed during periods of low salinity. Oysters may not be able to feed sufficiently, in which case they must draw on their glycogen reserves, inhibiting the development of gametes (Thompson et al. 1996). Gonadal development is abnormal at salinities of 5 ppt (Loosanoff 1953). Should oysters with near-ripe gonads gape open when salinity conditions are unfavorable their eggs may disintegrate (Loosanoff 1953).

The earlier developmental stages are more sensitive to low salinities; eggs and trocophore larvae cannot survive in salinities below about 10 to 12.5 ppt (Calabrese & Davis 1970). Once the swimming veliger larvae produce shells, larvae can tolerate salinities down to 7.5 ppt from the straight hinge stage through metamorphosis, although at salinities below 10 ppt development is retarded and survivorship lower (Davis 1958, Loosanoff 1965). This is a primary reason why recruitment is so low and sporadic in the low salinity regions of the upper bay and tributaries. Recruitment in these locations (<10 ppt) is likely from late-stage larvae migrating from more favorable areas when conditions are right (Davis 1958). High freshwater flow conditions can contribute to the loss of larvae in upstream regions by physically transporting oyster larvae further down the estuary, essentially flushing them out of an area well beyond the point to which the incoming tide would ordinarily return them.

Feeding and Growth
Freshets can disrupt oyster feeding behavior in different ways. Oysters may simply shut tight in response to freshwater inundation and may remain so for extended periods of time, depending on temperature (Loosanoff 1953, Andrews et al. 1959). Ciliary activity – the mechanism by which oysters feed – slows at about 5 ppt and ceases at 3 ppt (Loosanoff 1953). The food supply itself may also be affected by high streamflows and depressed salinities. Although little is known about phytoplankton population dynamics during freshets, one scenario is that the phytoplankton on which oysters feed are lost to the impacted area, either from intolerance to the lower salinities or by flushing down bay. These may be replaced by species that oysters cannot utilize. Excessive nutrients carried into the waters by runoff may result in noxious algal blooms (Heisler et al. 2008), further inhibiting feeding by adults and larvae.

Regardless of mechanism, it naturally follows that if oyster feeding is negatively impacted, growth would be slowed. Loosanoff (1953) found that growth was stunted at 7.5 ppt and limited or almost absent at 5 ppt. However, the impact of the extended 2018 freshet on oyster growth outside of the upstream areas is unclear. Anecdotally, in 2018 a sizable portion of sublegal oysters presumably failed to attain market size, but the majority of the harvest generally occurs from the Choptank region south, where salinities remained above 7.5 ppt for most of the year (Chesapeake Bay Program Data Hub). In fact, 49.1% of the oysters on the 30 Biomass Index bars were sublegals, with a peak biomass at 77 mm - barely legal (Figure 18). This had obvious implications for 2018-19 season's harvests, but this pool of sublegal oysters should be available for harvest during the following season, mitigating the downward trend in landings over the past few years. Nevertheless, baywide oyster growth in terms of biomass did not seem to be attenuated to any great extent. The Biomass Index bars within sanctuaries actually showed a robust increase in biomass, and even oysters on the harvest bars grew, albeit more modestly.

Freshet-Related Mortality

Having evolved for existence in the highly variable estuarine environment, oysters can tolerate a wide range of salinities from about 5 to 40 ppt, although the optimum range is considered to be about 14 to 28 ppt (Galtsoff 1964). Salinity tolerance values from different studies vary somewhat depending on temperature and the salinity regimes in which the experimental oysters were acclimated and lived. Because oysters can tightly close their valves (shell), they can remain alive during unfavorable salinity events for varying lengths of time depending on the ambient temperature. Oysters can survive freshets for months during the winter when they are in hibernation and can remain in a state of dormancy as late as June (Andrews et al. 1959). Even at temperatures a few degrees above quiescence, oysters have been shown to survive as long as 70 days in freshwater and 117 days at 3 ppt (Loosanoff 1953). However, if oysters have already started pumping when waters warm during the spring and summer, physiological activity increases, leaving oysters more vulnerable to adverse salinity conditions even if they consequently close up (Andrews et al. 1959). Survivorship is reduced to only a couple of weeks during the highest summer temperatures.

Devastating freshets have occurred in Maryland periodically throughout the 20th and into the 21st centuries, causing mass mortalities on vulnerable bars. During this time span ten major mortality events were documented in this region – in 1908/9, 1916, 1928, 1936, 1943, 1945/46, 1972, 1996, 2011, and now 2018 (Beaven 1947, Engle 1947, CRC 1976, Homer & Scott 2001, Tarnowski 2012).

The previous freshwater year, 2011, was marked by a wet spring, a tropical storm, and a late-summer hurricane. However, mortalities were largely confined to the upper bay. Among the unfortunate casualties of this mortality event were the young oysters of the 2010 spatset. Although this spatset was light in the upper bay, it was widespread and was important to help sustain these populations, which receive a set once about every decade (the previous set was in 2002). Spatsets in this region usually have good survivorship, but they are vulnerable to freshets. On Man-O-War Shoal, a bar outside the mouth of the Patapsco River, 100% of the oysters had died by the time of the 2011 Fall Survey. A portion of the bar has been subsequently replanted with seed oysters in recent years. Somewhat surprisingly, mortalities were lower in 2018 (averaging 42.5%) despite the record streamflows, although they may rise if depressed salinities persist into the spring.

The Eastern Shore side of the upper bay tends to have lower mortalities during freshets due to water circulation patterns. In 2011, elevated mortalities were observed much further down bay on the western side. Although the uppermost Eastern Shore bars had a cumulative mortality of 79% that year, Swan Point oysters had much lower mortalities, averaging 17% as compared to the 74% found on the Western Shore bars at the same latitude. The same pattern held true in 2018, when observed mortalities on Swan Point averaged only 8%. In part this is because this is a deeper bar than Man-O-War Shoal (salinity tends to increase with depth). In addition, flow from the Susquehanna River at the head of the bay, the major source of freshwater input, tends to veer towards the Western Shore due to the Coriolis effect. Furthermore, the Eastern Shore bars are adjacent to the deeper shipping channel, which serves as a conduit for higher salinity water during flood tide. As an example, Deep Shoal bar, the uppermost bar sampled during the 2011 Fall Survey, had a surface salinity of 0.9 ppt but a bottom reading of 5.1 ppt. As a consequence, the observed mortality was 53%, about half that of Man-O-War Shoals located several miles down bay.

In contrast to the upper bay, in 2011 the Potomac River did not experience extraordinary oyster mortalities. Unfortunately, this was not the case in 2018, when mortalities were considerably more severe. Observed mortalities ranged from 88% to 100%, a substantial loss to the fishery since several of these bars had been planted with seed oysters. Even the unique low-salinity adapted oyster population on Beacon bar, which had survived several freshets during the 1990s and 2000s, suffered nearly total mortalities. One concept to restore that bar is to reseed it with hatchery-reared progeny of the surviving broodstock, but a source of funding must be secured to carry out the project.

Disease and Disease-Related Mortality
The influence of salinity on oyster diseases is well documented (Ford & Tripp 1996; Tarnowski 2010, 2012). Oyster parasites are salinity sensitive, particularly *H. nelson*i. This parasite can exist in salinities as low as 10 ppt, below which it is purged from oysters. However, MSX disease becomes substantially more pathogenic in salinities greater than 15 ppt and temperatures higher than 20°C (Ford 1985).

This vulnerability of *H. nelson*i to lower salinities was dramatically illustrated in 2004, when persistently-high freshwater runoff pushed back MSX disease from its record high prevalences and extended range throughout much of Maryland waters during 2002 to relatively small areas in Tangier Sound and the lower mainstem (Tarnowski 2005). This pattern was repeated in the freshet years of 2011 and again in 2018. In 2017, the disease was found as far up bay as Hacketts bar near Annapolis. By 2018 its range had contracted to two lower Eastern Shore locations; only three out of the 1,499 oysters examined were found to have the disease.

Likewise, dermo disease, although still widespread, was at levels near or at their lowest point in 29 years, matching the record low levels of 2011. However, the host-parasite relationship as affected by salinity between oysters and *P. marinus* is considerably more involved than that described for MSX. Until the late 1980s - early 1990s, dermo disease epizootics would occur in the higher salinity bay regions and penetrate up bay only during low freshwater flow periods. Since the early 1990s, however, this disease has entrenched itself in the bay's oyster population; it is now an enzootic condition found almost everywhere oysters are present. Salinity patterns and resultant infection status observed prior to the onset of chronic dermo disease no longer apply to oyster populations. As described here, 2018 has seen a remarkable abatement of dermo disease on a baywide basis, measured by both prevalence and intensity. While environmental conditions can adequately account for what has been observed in recent years, the perceived evolving relationship, most likely still strongly influenced by salinity, between oyster and *P. marinus* populations is not fully understood.

As a consequence of reduced disease pressure, the 2018 mortality index was stable despite the freshet-related losses in the upper bay and Potomac River. Nonetheless, the index was almost double that of the previous freshet year of 2011, suggesting that some disease-related mortalities occurred in the earlier part of the year before salinities began to decline. The highest MSX disease prevalences of 2017 were detected in Tangier Sound and the adjacent lower mainstem, coinciding with the highest regional mortalities of 2018. Since the surface salinity in southern Tangier Sound remained intermittently above 15 ppt into September, it is possible that these mortalities were MSX-related. The only residual pockets of *H. nelson*i were found in this region, including at one of the deepest stations adjacent to the main channel in southern Maryland, the one most likely to maintain the higher salinities conducive to MSX disease.

LITERATURE CITED

Andrews, J.D., D. Haven, and D.B. Quayle. 1959. Freshwater kill of oysters (*Crassostrea virginica*) in James River, Virginia, 1958. Proc. Natl. Shellfish. Assoc. 49: 29-49.

Beaven, G.F. 1947. Effect of the Susquehanna River flow on Chesapeake Bay salinities and history of past oyster mortalities on upper Bay bars. Proc. Natl. Shellfish. Assoc. 1946: 38-41.

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

Calabrese, A. and H.C. Davis. 1970. Tolerances and requirements of embryos and larvae of bivalve mollusks. Helgolander Wiss. Meersunters. 20: 553-564.

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

Chesapeake Research Consortium, Inc. 1976. The Effects of Tropical Storm Agnes on the Chesapeake Bay Estuarine System. CRC Publ. No. 54. The Johns Hopkins Univ. Press, Baltimore, Md. 639 pp.

Davis, H.C. 1958. Survival and growth of clam and oyster larvae at different salinities. Biol. Bull. 114: 296-307.

Engle, J.B. 1947. Commercial aspects of the upper Chesapeake Bay oyster bars in the light of recent oyster mortalities. Proc. Natl. Shell. Assoc. (1946): 42-46.

Ford, S.E. 1985. Effects of salinity on survival of the MSX parasite *Haplosporidium nelsoni* (Haskin, Stauber, and Mackin) in oysters. J. Shellfish Res. 5: 85-90.

Ford, S. and M.R. Tripp. 1996. Chapter 17. Diseases and defense mechanisms. *In:* V.S. Kennedy, R.I.E. Newell, and A.F. Eble (eds.). The Eastern Oyster, *Crassostrea virginica*, p. 581-660. Md. Sea Grant Publ. UM-SG-TS-96-01. College Park, Md.

Galtsoff, P.S. 1964. The American oyster *Crassostrea virginica* Gmelin. Fish. Bull. 64: 1-480.

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

Heisler, J., Glibert, P. M., Burkholder, J. M., Anderson, D. M., Cochlan, W., Dennison, W. C., Dortch, Q., Gobler, .C. J., Heil, C.A., Humphries, E., Lewitus, A., Magnien, R., Marshall, H.G., Sellner, K., Stockwell, D.A., Stoecker, D.K., Suddleson, M. 2008. Eutrophication and harmful algal blooms: A scientific consensus. Harmful Algae, 8: 3–13.

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. Ch. 10. Biology of larvae and spat. *In:* V.S. Kennedy, R.I.E. Newell, and A.F. Eble (eds.). The Eastern Oyster, *Crassostrea virginica*, p. 371-421. Md. Sea Grant Publ. UM-SG-TS-96-01. College Park, Md.

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.

Loosanoff, V.L. 1953. Behavior of oysters in water of low salinities. Proc. Natl. Shellfish. Assoc. 43: 135-151.

Loosanoff, V.L. 1965. The American or eastern oyster. United States Dept. of the Interior Circular 205: 1-36.

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

Seliger, H.H., J.A. Boggs, R.B. Rivkin, W.H. Biggley, and K.R.H. Aspden. 1982. The transport of oyster larvae in an estuary. Mar. Biol. 71: 57-72.

Tarnowski, M. 2005. Maryland Oyster Population Status Report – 2003 and 2004 Fall Surveys. MDNR Publ. No. 17-1072005-62. Annapolis, Md. 33 pp.

Tarnowski, M. 2010. Maryland Oyster Population Status Report – 2009 Fall Survey. MDNR Publ. No. 17-8172010-471. Annapolis, Md. 43 pp.

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

Tarnowski, M. 2018. Maryland Oyster Population Status Report – 2017 Fall Survey. MDNR Publ. No. 17-080218-87. Annapolis, Md. 51 pp. http://dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

Thompson, R.J., R.I.E. Newell, V.S. Kennedy, and R. Mann. 1996. Reproductive processes and early development, pp 335-370 *in:* The Eastern Oyster- *Crassostrea virginica*, V.S. Kennedy, R.I.E. Newell, and A.F. Eble. Maryland Sea Grant College Program, College Park.

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

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 common fouling (mussels, barnacles, tunicates, etc.) 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 contained in digital files. Fouling and oyster condition data are in paper files; the more recent fouling data have also been digitized.

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Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 “Key” spat monitoring bars, 1985-2018. (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	2018	*34-Yr Avg*
Mountain Point	0	0	0	0	*0.3*
Swan Point	0	0	0	0	*0.4*
Brick House	0	0	0	0	*6.4*
Hackett Point	0	0	0	0	*0.7*
Tolly Point	0	2	0	0	*0.8*
Three Sisters	0	0	0	0	*0.7*
Holland Point (S)	0	0	0	0	*0.5*
Stone Rock	2	17	0	4	*24.4*
Flag Pond (S)	10	12	28	0	*23.2*
Hog Island	9	22	1	0	*17.7*
Butler	68	90	2	1	*39.7*
Buoy Rock	0	0	0	0	*1.4*
Parsons Island	8	0	0	0	*109.5*
Wild Ground	15	0	0	0	*41.0*
Hollicutt Noose	1	0	0	0	*4.9*
Bruffs Island (S)	0	0	0	0	*26.8*
Ash Craft	0	0	0	0	*71.3*
Turtle Back	13	4	0	0	*131.3*
Shell Hill	4	2	1	5	*7.3*
Sandy Hill (S)	0	3	1	0	*11.7*
Royston	21	13	23	22	*51.6*
Cook Point (S)	1	21	2	4	*17.0*
Eagle Pt./Mill Pt. (S)	34	68	55	28	*40.0*
Tilghman Wharf	45	58	13	40	*66.4*
Deep Neck	83	91	205	119	*118.1*
Double Mills (S)	9	12	3	1	*18.1*
Ragged Point	19	125	35	2	*57.8*
Cason (S)	11	60	67	9	*90.2*
Windmill	16	9	9	4	*51.4*
Norman Addition	34	60	44	13	*78.9*
Goose Creek	11	44	27	23	*31.5*
Clay Island	43	68	41	43	*47.9*
Wetipquin (S)	2	6	0	21	*4.8*
Middleground	12	32	66	49	*25.9*
Evans	14	18	1	7	*11.6*
Mt. Vernon Wharf	1	3	1	10	*2.8*
Georges (S)	29	61	137	40	*68.9*
Drum Point (S)	59	172	78	110	*96.7*
Sharkfin Shoal	57	53	32	23	*28.6*
Turtle Egg Island	64	57	15	69	*89.4*
Piney Island East	3	0	2	0	*98.6*
Great Rock	13	4	14	93	*33.1*
Gunby	95	73	34	25	*58.8*
Marumsco	141	69	31	8	*40.1*
Broome Island	6	21	6	1	*6.6*
Back of Island	18	42	5	5	*14.2*
Chicken Cock	712	33	19	5	*81.9*
Pagan (S)	24	91	247	7	*169.8*
Black Walnut (S)	3	4	0	0	*1.6*
Blue Sow (S)	0	10	0	0	*4.6*
Dukehart Channel	0	3	0	0	*1.7*
Ragged Point	1	11	2	2	*5.5*
Cornfield Harbor	100	92	6	6	*72.3*
Spat Index	**34.2**	**30.9**	**23.6**	**15.0**	***39.8***

(Return to Text)

Table 3. *Perkinsus marinus* prevalence and mean intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2018. 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		2018		*29-Yr Avg*	
	%	I	%	I	%	I	%	I	%	I	%	I	*%*	*I*
Swan Point	27	0.4	3	0.0	33	0.3	3	0.0	3	0	0	0.0	*27.8*	*0.7*
Hackett Point	13	0.6	0	0.0	10	0.3	40	1.2	56	1.6	27	0.9	*50.4*	*1.5*
Holland Point (S)	5	0.1	0	0.0	0	0.0	27	0.6	47	1.2	7	0.07	*41.0*	*1.2*
Stone Rock	67	2.0	100	4.0	93	4.5	97	4.4	83	3.4	53	1.7	*72.9*	*2.4*
Flag Pond (S)	23	0.8	10	0.3	18	0.5	50	1.9	52	1.6	27	0.6	*47.3*	*1.5*
Hog Island	27	0.9	43	1.2	87	3.0	97	4.3	100	4.5	63	2.1	*74.0*	*2.7*
Butler	70	2.4	73	2.4	60	2.0	37	1.5	63	2.2	73	2.1	*67.2*	*2.1*
Buoy Rock	27	0.6	13	0.4	17	0.2	20	0.7	30	0.8	0	0.0	*52.0*	*1.6*
Old Field (S)	57	1.5	47	1.5	57	1.7	63	2.1	60	2.1	27	0.7	*58.2*	*1.8*
Bugby	73	2.5	83	2.8	87	3.3	90	3.3	97	3.3	43	1.1	*80.7*	*2.7*
Parsons Island	30	0.9	15	0.4	53	1.3	77	2.2	83	2.9	43	1.3	*72.8*	*2.4*
Hollicutt Noose	13	0.4	23	0.6	33	0.7	50	1.5	57	1.8	17	0.5	*61.0*	*1.9*
Bruffs Island (S)	37	1.2	23	0.7	77	2.0	100	4.2	97	4.3	63	1.9	*73.1*	*2.3*
Turtle Back	63	2.2	80	2.5	100	4.2	83	3.5	83	3.2	70	2.1	*84.4*	*2.9*
Long Point (S)	37	1.2	10	0.4	20	0.5	73	2.6	36	1.1	7	0.3	*65.4*	*2.2*
Cook Point (S)	97	3.2	80	3.1	90	3.3	100	4.6	90	3.5	63	1.6	*59.0*	*2.0*
Royston	60	2.0	60	2.0	63	2.1	47	1.5	43	1.5	17	0.5	*55.4*	*2.0*
Lighthouse	10	0.3	10	0.3	23	0.5	10	0.4	17	0.4	7	0.2	*45.3*	*1.5*
Sandy Hill (S)	93	2.8	77	2.4	93	3.3	93	4.0	96	3.9	53	1.4	*75.4*	*2.8*
Oyster Shell Pt. (S)	7	0.2	3	0.0	40	1.0	80	2.6	77	2.8	57	1.8	*41.4*	*1.2*
Tilghman Wharf	10	0.2	7	0.1	20	0.6	47	1.5	70	2.2	47	1.2	*53.0*	*1.5*
Deep Neck	80	3.1	67	1.8	93	2.9	80	3.1	77	2.4	57	1.3	*80.1*	*2.8*
Double Mills (S)	83	3.1	73	2.6	70	2.9	87	3.6	97	3.9	67	2.1	*80.0*	*2.9*
Cason (S)	80	2.8	90	2.8	93	2.8	100	4.2	97	3.3	77	2.2	*79.8*	*2.6*
Ragged Point	97	3.0	83	2.3	100	3.2	93	4.0	97	3.7	67	1.7	*80.3*	*2.7*
Norman Addition	80	3.1	87	3.7	77	2.7	93	3.6	93	3.2	63	2.0	*79.4*	*2.8*
Goose Creek	80	2.6	83	2.5	100	3.4	93	4.3	80	3	70	2.7	*67.5*	*2.3*
Wilson Shoals (S)	93	3.0	90	3.4	80	2.8	90	3.2	87	3.2	73	2.1	*84.4*	*2.6*
Georges (S)	83	3.4	97	3.9	93	3.9	83	3.4	97	3.9	77	2.7	*81.5*	*2.9*
Holland Straits	90	3.7	80	3.6	83	3.0	13	0.3	30	0.6	7	0.2	*64.9*	*2.1*
Sharkfin Shoal	93	3.5	90	3.4	77	2.8	90	4.1	93	4.1	57	2.1	*82.7*	*2.9*
Back Cove	93	3.9	80	3.1	77	3.2	30	0.9	30	0.9	3	0.07	*80.1*	*2.9*
Piney Island East	63	2.0	40	1.4	53	1.8	60	2.4	70	2.3	27	1.1	*77.8*	*2.6*
Old Woman's Leg	52	1.3	60	2.6	67	2.1	11	0.2	50	1.6	6	0.06	*73.3*	*2.6*
Marumsco	100	4.4	80	3.5	90	3.6	93	3.7	100	3.9	63	1.6	*82.9*	*2.9*
Broome Island	93	3.2	70	1.9	80	2.6	90	3.8	93	4	50	1.3	*76.6*	*2.6*
Chicken Cock	50	1.2	67	1.9	67	2.1	73	2.4	97	3.1	63	2.1	*73.3*	*2.4*
Pagan (S)	77	2.4	83	2.1	83	2.9	83	3.1	80	3.1	63	1.4	*80.6*	*2.5*
Lancaster	30	1.2	20	0.8	3	0.2	37	1.6	47	1.8	10	0.1	*57.7*	*1.7*
Mills West	70	2.1	53	1.8	57	1.7	40	1.8	60	2	3	0.07	*57.5*	*1.8*
Cornfield Harbor	90	3.1	80	3.1	57	1.8	63	2.6	97	3.6	63	1.9	*79.3*	*2.5*
Ragged Point	0	0.0	3	0.0	0	0.0	3	0.0	7	0.1	0	0	*20.0*	*0.6*
Lower Cedar Point	20	0.4	3	0.1	55	1.6	33	1.1	50	1.6	0	0	*22.3*	*0.6*
Annual Means	**57**	**1.9**	**52**	**1.8**	**61**	**2.1**	**63**	**2.5**	**69**	**2.5**	**40**	**1.2**	***66.8***	***2.2***
Bar Freq. (%)	**98**		**95**		**95**		**100**		**100**		**91**		***97.1***	

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2018. 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	2018	*29-Yr Avg*
Swan Point	0	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	*0.7*
Holland Point (S)	0	0	3	0	0	0	0	0	0	3	0	*2.5*
Stone Rock	10	23	3	0	0	0	0	7	13	10	0	*9.0*
Flag Pond (S)	3	13	7	0	0	0	0	12	10	0	0	*5.6*
Hog Island	7	17	0	0	0	0	0	10	40	3	0	*9.2*
Butler	7	37	17	0	0	0	3	13	48	0	0	*11.7*
Buoy Rock	0	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	*0.0*
Bugby	0	0	0	0	0	0	0	3	3	0	0	*1.5*
Parsons Island	0	0	0	0	0	0	0	0	7	0	0	*1.2*
Hollicutt Noose	0	13	0	0	0	0	0	0	10	0	0	*3.8*
Bruffs Island (S)	0	3	0	0	0	0	0	0	3	0	0	*0.9*
Turtle Back	0	0	0	0	0	0	0	3	7	0	0	*2.5*
Long Point (S)	0	0	3	0	0	0	0	0	0	0	0	*0.2*
Cook Point (S)	7	43	10	0	0	0	0	13	30	3	0	*10.2*
Royston	0	0	0	0	0	0	0	7	30	0	0	*5.0*
Lighthouse	0	13	3	0	0	0	0	0	37	0	0	*6.8*
Sandy Hill (S)	0	0	0	0	0	0	0	0	0	0	0	*2.7*
Oyster Shell Pt. (S)	0	0	0	0	0	0	0	0	0	0	0	*1.3*
Tilghman Wharf	0	3	0	0	0	0	0	7	27	0	0	*6.0*
Deep Neck	0	13	0	0	0	0	0	3	0	0	0	*4.1*
Double Mills (S)	0	0	0	0	0	0	0	0	0	0	0	*1.8*
Cason (S)	0	20	0	0	0	0	0	23	0	0	0	*7.3*
Ragged Point	0	13	10	0	0	0	0	20	17	3	0	*9.6*
Norman Addition	10	33	10	0	0	0	3	3	7	0	0	*11.3*
Goose Creek	7	27	0	0	0	0	0	13	7	0	0	*8.0*
Wilson Shoals (S)	0	7	0	0	0	0	0	3	0	0	0	*4.7*
Georges (S)	0	10	0	0	0	0	0	3	0	0	0	*6.8*
Holland Straits	7	33	23	0	0	0	3	10	13	0	0	*15.4*
Sharkfin Shoal	17	17	10	0	0	0	10	10	0	0	0	*13.5*
Back Cove	13	27	7	0	0	3	10	17	37	13	0	*13.6*
Piney Island East	0	33	7	0	0	10	27	33	10	13	3	*15.5*
Old Woman's Leg	0	27	20	7	3	3	20	23	17	25	0	*16.7*
Marumsco	0	17	3	0	3	0	10	10	0	3	0	*8.6*
Broome Island	0	3	0	0	0	0	0	0	7	7	0	*2.3*
Chicken Cock	13	57	10	0	0	0	0	23	60	7	0	*13.0*
Pagan (S)	0	30	0	0	0	0	0	0	0	0	0	*3.4*
Lancaster	0	0	0	0	0	0	0	0	0	0	0	*0.4*
Mills West	0	0	0	0	0	0	0	0	0	0	0	*1.6*
Cornfield Harbor	10	30	7	0	0	10	10	30	33	7	0	*13.9*
Ragged Point	0	0	0	0	0	0	0	0	3	10	0	*3.6*
Lower Cedar Point	0	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**	**11.1**	**2.6**	**0.1**	***6.0***
Pos. Bars (%)	**30**	**60**	**40**	**2**	**5**	**9**	**21**	**56**	**56**	**33**	**2**	***30.8***

(Return to Text)

Table 5. Oyster population mortality estimates from the 43 disease monitoring bars, 1985-2018. 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	2018	*34-yr Avg*
Swan Point	4	0	3	0	0	8	*10.7*
Hackett Point	0	0	0	3	19	3	*12.9*
Holland Point (S)	12	40	29	0	0	50	*23.8*
Stone Rock	2	5	31	36	30	9	*22.5*
Flag Pond (S)	15	13	5	6	50	3	*21.8*
Hog Island	2	2	12	38	27	18	*28.1*
Butler	7	7	10	11	4	5	*24.4*
Buoy Rock	5	9	3	12	4	12	*16.7*
Old Field (S)	0	3	0	5	33	10	*13.1*
Bugby	8	31	21	21	13	12	*25.5*
Parsons Island	2	4	15	2	10	14	*21.4*
Hollicutt Noose	1	9	6	7	29	30	*21.3*
Bruffs Island (S)	0	4	5	16	20	41	*22.8*
Turtle Back	0	8	14	18	3	15	*25.0*
Long Point (S)	20	0	0	17	0	0	*21.9*
Cook Point (S)	9	12	16	48	45	24	*26.7*
Royston	1	6	9	16	4	2	*17.7*
Lighthouse	1	1	2	9	7	0	*20.2*
Sandy Hill (S)	3	13	11	15	15	11	*25.3*
Oyster Shell Pt. (S)	2	5	2	11	11	18	*10.5*
Tilghman Wharf	5	1	5	11	1	7	*17.5*
Deep Neck	5	7	16	8	2	3	*21.1*
Double Mills (S)	11	12	10	20	13	11	*21.0*
Cason (S)	11	8	17	26	33	8	*26.0*
Ragged Point	15	13	21	45	14	6	*27.0*
Norman Addition	9	7	13	14	15	8	*25.4*
Goose Creek	5	15	22	27	6	10	*33.1*
Wilson Shoals (S)	5	4	7	17	6	4	*20.9*
Georges (S)	15	5	8	23	15	9	*29.0*
Holland Straits	9	48	71	18	4	17	*30.0*
Sharkfin Shoal	16	18	24	19	3	7	*31.8*
Back Cove	11	19	14	1	2	8	*23.1*
Piney Island East	7	10	9	21	25	38	*29.4*
Old Woman's Leg	50	75	15	0	50	25	*31.8*
Marumsco	13	13	17	13	20	34	*25.2*
Broome Island	7	8	14	21	3	4	*21.0*
Chicken Cock	1	7	16	32	20	17	*27.8*
Pagan (S)	4	13	22	28	6	4	*20.8*
Lancaster	13	0	3	1	1	10	*15.3*
Mills West	20	9	5	14	0	5	*14.6*
Cornfield Harbor	10	16	10	36	8	3	*28.8*
Ragged Point	0	0	50	10	8	4	*22.2*
Lower Cedar Point	0	0	6	8	27	96	*15.1*
Annual Means	**8**	**11**	**14**	**16**	**14**	**14**	***22.5***

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland from buy tickets, 1985-86 through 2017-18 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	2017-18	*33-yr Avg*
Upper Bay	3,648	4,693	2580	*12,637*
Middle Bay	13,019	11,072	5,134	*15,501*
Lower Bay	4,285	4,314	9,112	*5,862*
Total Bay Mainstem	*20,952*	*20,079*	*16,826*	*33,564*
Chester R.	1,547	569	5,135	*21,671*
Eastern Bay	13,091	15,576	9,663	*29,129*
Miles R.	3,335	1,666	527	*5,269*
Wye R.	18	17	21	*1,880*
Total Eastern Bay Region	*16,444*	*17,259*	*10,211*	*36,277*
Upper Choptank R.	192	42	129	*9,512*
Middle Choptank R.	8,420	5,749	6,563	*18,368*
Lower Choptank R.	22,141	10,979	6,458	*15,004*
Tred Avon R.	4,007	2,403	889	*10,826*
Broad Cr.	67,375	32,063	32,516	*21,511*
Harris Cr.	7,072	2,704	3,901	*7,903*
Total Choptank R. Region	*109,207*	*53,940*	*50,456*	*83,124*
Little Choptank R.	2,027	2,048	453	*11,468*
Upper Tangier Sound	64,305	35,521	33,322	*17,623*
Lower Tangier Sound	28,269	9,471	7,244	*14,342*
Honga R.	13,241	11,114	2,051	*7,849*
Fishing Bay	20,195	13,608	7,441	*14,706*
Nanticoke R.	7,095	7,430	8,017	*7,339*
Wicomico R.	10,122	4,735	1,044	*1,390*
Manokin R.	1,431	1,128	1,914	*3,443*
Big Annemessex R.	4,037	473	90	*245*
Pocomoke Sound	10,261	6,131	5,269	*5,363*
Total Tangier Sound Region	*158,956*	*89,611*	*66,392*	*72,297*
Patuxent R.	50,048	22,669	9,446	*12,594*
Wicomico R., St. Clement and Breton bays	5,596	5,130	891	*10,326*
St. Mary's R. and Smith Cr.	10,537	8,716	18,759	*8,650*
Total Potomac Md. Tribs.	*16,133*	*13,846*	*19,650*	*18,955*
Total Maryland (bu.)[1]	**383,534**	**224,758**	**182,310**	***295,553***

[1] Includes harvests from unidentified regions.

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Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2017-18 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*
2017-18	35,717	14,787	26,673	61,882	19,161	*182,310*	*$8.7 M*

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

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Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2017-18 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
2017-18	23	9	17	39	12

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Table 8. Oyster bars within sanctuaries sampled during the 2018 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	Sandy Hill[1,2], Hambrooks
	Howell Point - Beacons	Beacons
	Upper Choptank River	Green Marsh, Shoal Creek, 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/Biomass Index Bar

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APPENDIX 1
OYSTER HOST & OYSTER PATHOGENS

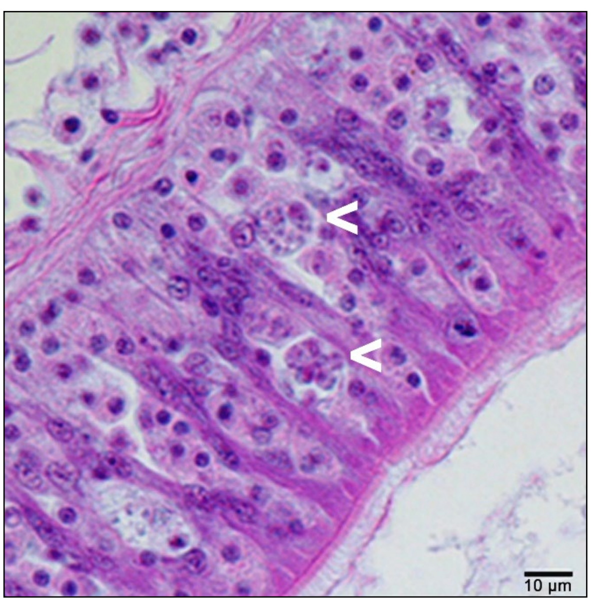
Chris Dungan, Maryland DNR, April 24, 2019

Oysters

The eastern oyster *Crassostrea virginica* is found in waters with temperatures of -2°C to 36°C and sustained salinities of 4 ‰ to 40 ‰, 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, salt contents of oyster tissues 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, oyster valves (shells) 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 those 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 91-100% 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 29-year average of 66%.

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 29-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 an extended drought of 1999-2002, 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 range for MSX disease also expanded widely during recent epizootics of 2009 and of 2014-2016. During 2003-2008, 2010-2012, and 2017-2018, 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 2018). During 2018, low water salinities reduced the distribution and the mean prevalence of MSX disease to historic minima.

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. 2018. Maryland Oyster Population Status Report: 2017 Fall Survey. Maryland Department of Natural Resources Publ. No. 17-080218-87. Annapolis, MD. 59 pp. http://dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

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).

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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 — Average of mean intensities for annual survey samples from constant **mean** 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 (76 mm) 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

spatfall intensity index, annual median The median of spatfall intensities from 53 fixed reference sites (Key Bars).

spatfall intensity index, long-term median The median of the spatfall intensity indices over the time series.

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