Maryland Oyster Population Status Report
2019 Fall Survey

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and the Staff of the Shellfish Division and
Cooperative Oxford Laboratory
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Cover Photo*: "Thar they are!" John Hess sounding for oysters. *(Photo: R. Bussell)

In Memoriam
John Hess
(1942-2019)

Photo: C. McCollough

John Hess, former Field Operations Supervisor for the DNR Shellfish Division and manager of the Deal Island facility, passed away on May 6, 2019. John came to DNR in 1983 after decades of working the water as a crabber and oysterman (he started at age 13), bringing with him valuable experience and knowledge. Born in Spring Hills, MD in December 1942 he was a graduate of Marion High School class of 1960 and the Nashville Auto & Diesel College. John served in the US Army Reserves as well.

John's career in the Shellfish Division focused on the Repletion Program and spanned 25 years, during which time he helped coordinate the planting of over 60 million of bushels of shells and about 4 million bushels of seed oysters to enhance the habitat and population. This represents a personal commitment to about 10,000 acres of oyster bottom. John surveyed oyster bars for the plantings, set buoys, coordinated efforts with the local county oyster committees, worked with numerous shucking houses and runboat captains to acquire and plant fresh shells in local waters, and coordinated with DNR's dredging contractor to plant dredged shells each summer on over 300 acres of oyster bars. John also provided key assistance on the annual DNR Fall Oyster Survey aboard the R/V *Miss Kay*, keeping the data sheets for many years and overseeing the samples as they were examined for oysters and spat. The boat crew often heard John call out "There they are!" as he tested the bottom with a 20' sounding pole to signal when the bar had been reached and the dredge could be deployed. When GPS units and color fathometers became available the oyster bars were located easily, but John kept sounding the bottom and training others to do the same. A humorous event occurred one day close to the shore of St. Mary's College during the Fall Survey when John called out his trademark "There they are": two students holding hands while relaxing at the shore scurried off like flushed quail thinking John was talking about them and they had been discovered. John was well known and appreciated by many at DNR. Colleagues at the Cooperative Oxford Laboratory, where the oyster samples are analyzed for diseases, remember John as conservative, careful, hardworking, and that he expected the same of his coworkers. He exhibited these traits as he selected sites to plant shells and seed oysters, as he kept detailed records of the program's activities, and as he expertly maintained the heavy equipment used by the Repletion Program each season. He is remembered with affection.

John retired in 2008 and he and his wife Peggy enjoyed many years together, taking trips with their Model-T vintage car. In 2016 they traveled cross country to visit three additional states to give him a total of 48 states visited. They also enjoyed their friends and family around their home in Shelltown, Maryland. John and Peggy were seen every year at the Watermen's Trade Show in Ocean City, where John caught up with watermen and coworkers on the latest news about oysters.

John was dedicated to improving the oyster population throughout their full extent in tidewater Maryland from Pooles Island in the upper bay to Smith Island near the Virginia state line and from the upriver bars of the Potomac River near the industrial setting of the Morgantown generating station to the far reaches of the bucolic Chester River on the Eastern Shore. The Repletion Program was complicated, with a lot of moving parts and numerous individuals to deal with, yet he could always be relied on to get the job done, and with the utmost professionalism.

-Christopher Judy

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DNR Shellfish Director Chris Judy (l) and Field Operations Supervisor John Hess inspect a sample during the Fall Oyster Survey. ***(Photo: C. McCollough)***

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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 2019 Fall Oyster Survey was conducted from 15 October to 25 November throughout the Maryland portion of Chesapeake Bay and its tributaries, including the Potomac River. A total of 339 samples were collected from 286 oyster bars. Sites monitored included natural oyster bars, oyster seed production areas, seed and shell plantings, and sanctuaries.

Following the record high freshwater streamflows of 2018, elevated flows continued into the first half of 2019, depressing salinities, which in turn affected spatset, diseases, mortality and growth of oysters. By mid-year the above average flows had subsided and salinities returned to normal by the fall.

The Spatfall Intensity Index of 23.0 equaled the 35-year median value. Spatset intensity increased 53% from the previous year, with slightly more than twice as many 2019 index bars having increased spatfall when compared with 2018. The highest spatset was restricted to areas much further downbay, primarily in lower Tangier Sound and adjacent mainstem of the bay across to the Western Shore, and to a lesser extent the Manokin River and Pocomoke Sound. The normally productive Choptank/Little Choptank region had unusually low counts, and spat were absent from large swaths of the bay. No spat were found along the Western Shore upbay from mid-Calvert County, the upriver two-thirds of the Potomac oyster growing region, the upper Choptank River, parts of Eastern Bay and its tributaries, and the entire Chester River and bay north of the Bay Bridge. The highest spatset on an individual bar (388 spat/bu) was observed on Point Lookout Lot B on the lower Western Shore.

Disease levels were the lowest on record for the 30-year time series. Although dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, being found on 88% of the sentinel bars, the percentage of infected oysters was much lower than in 2018. The 2019 mean prevalence (27%) decreased from the previous record low 40% of 2018, and was substantially below the 30-year average of 64.5%. The mean infection intensity for dermo disease (1.0) was half of the long-term average, breaking the record of the previous year for the lowest average intensity. MSX disease mean prevalence (0.1%) tied the previous year for the Disease Index bars. In contrast to 2018, the disease was not evident on the supplemental disease sites. Thus 2019, with only one diseased oyster detected, had the smallest number of sampled oysters infected with *H. nelsoni* in Fall Oyster Survey records from the past 30 years.

The Observed Mortality Index of 13% was slightly lower than in 2018, remaining below the long-term mean for the sixteenth consecutive year. However, elevated freshwater-related mortalities of up to 100% were observed on several of the uppermost bars of the Potomac River and to a lesser extent in the upper bay, along with the Chester and upper Choptank rivers. Aside from these areas, regional average observed mortalities were generally low to moderate. Tangier Sound, typically a higher mortality area, averaged a remarkably low observed mortality of 4.2%.

The 2019 Oyster Biomass Index of 1.72 represents a slight drop of this index from the previous year, ranking it sixth highest in the 27-year time series. The size distribution of index bar oysters shifted to more market oysters relative to sublegal oysters, reflecting the increase in average size. Although the sizes increased, the index population abundance declined, accounting for the dip in the Biomass Index.

The 2019 Cultch Index of 0.89 bu/100 ft. was similar to the 15-year average of 0.90 bu/100 ft. However, some individual bars showed steep declines. Of the 52 bars used in this analysis, 37% had standardized volumes that were more than 25% below their respective 15-year averages. The three-year rolling averages of cultch indices have been stable over the past five years. 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 2019 Fall Survey. Trends in recruitment, disease, and mortality were in keeping with the baywide results and well below their respective Key/Disease Bar long-term averages. Recruitment within the five restoration sanctuaries - Harris Creek, Tred Avon, Little Choptank, Manokin, and St. Marys - was lower than during the previous year, as it was in most of the adjacent harvest areas. This was unanticipated considering that the 2019 spat index was about 50% higher than in 2018, and reflects the limited geographic range for good spatset this year. A comparison of spatset in these sanctuaries with adjacent harvest areas showed similar results, with the exception of higher counts in mid-Tangier Sound (the center of higher spatsets). Oysters from monitoring sites in the restoration sanctuaries showed no evidence of MSX disease. Dermo disease prevalences and intensities were well below long-term averages, although they trended somewhat higher in the sanctuaries than in adjacent harvest areas, probably because the sanctuaries had a higher proportion of larger, older oysters which can accumulate higher burdens of the parasites. Despite the slightly higher dermo levels, observed mortality rates in the sanctuaries were comparable to those of harvest areas and continued to be markedly lower than the long-term average. The average biomass per index bar in 2019 was substantially higher in the sanctuaries than in the open harvest areas. Most of this difference was in the larger market size classes.

With reported harvests of 145,000 bushels with a dockside value of $6.6 million during the 2018-19 season, commercial oyster landings dropped 24% with a loss of $2.1 million from the previous season, extending a declining trend to five years. Power dredging accounted for 44% of the landings, primarily from the lower Eastern Shore and Choptank regions. Hand tongs were the second dominant gear type, harvesting 25% of the total. The Choptank region was the leading production area with 39% of the Maryland landings, with Broad Creek alone accounting for 22% of the total landings, followed by the Tangier Sound region with 28%.

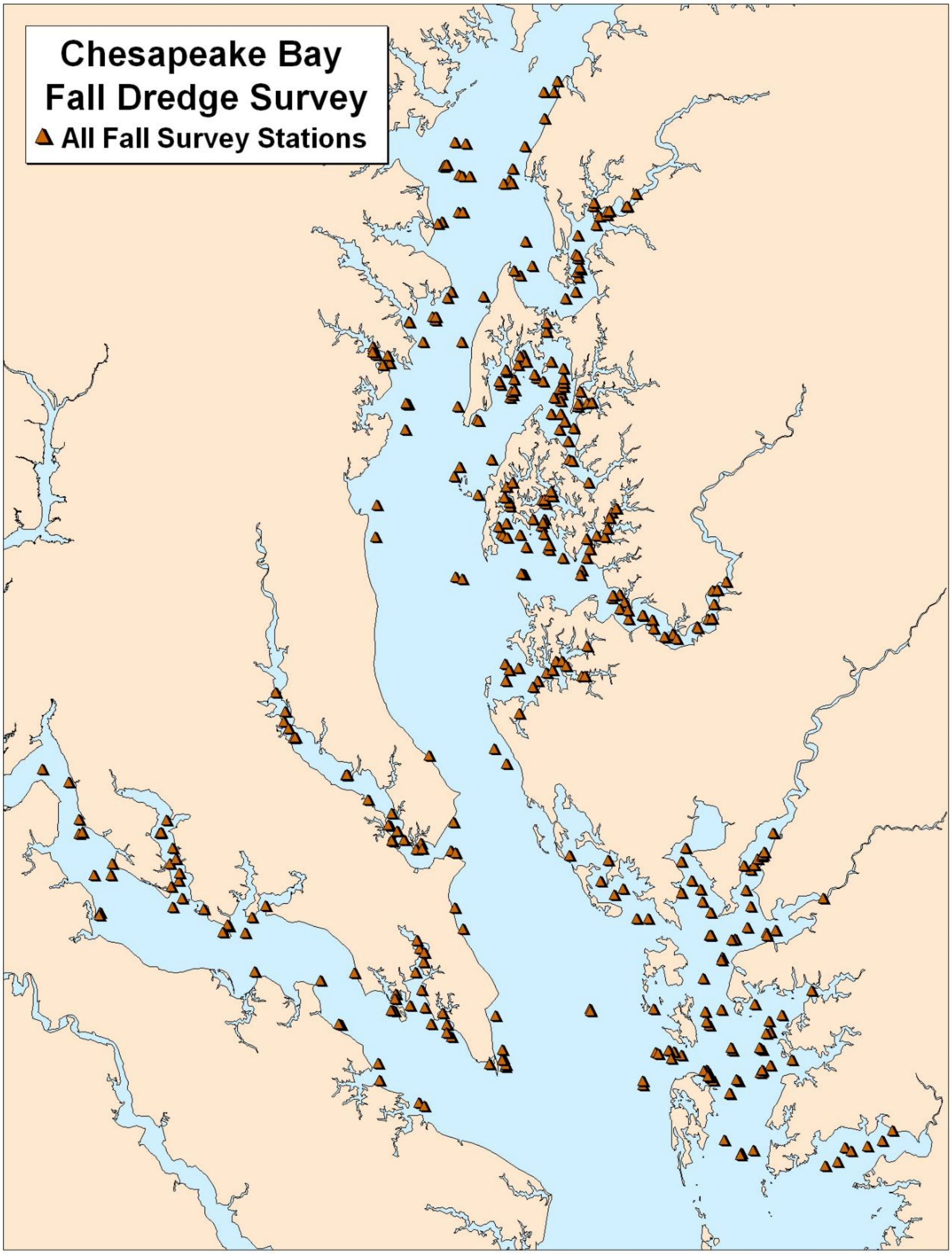

Figure 1a. 2019 Maryland Fall Oyster Survey station locations, all bar types (standard, Key, Disease, seed) included.

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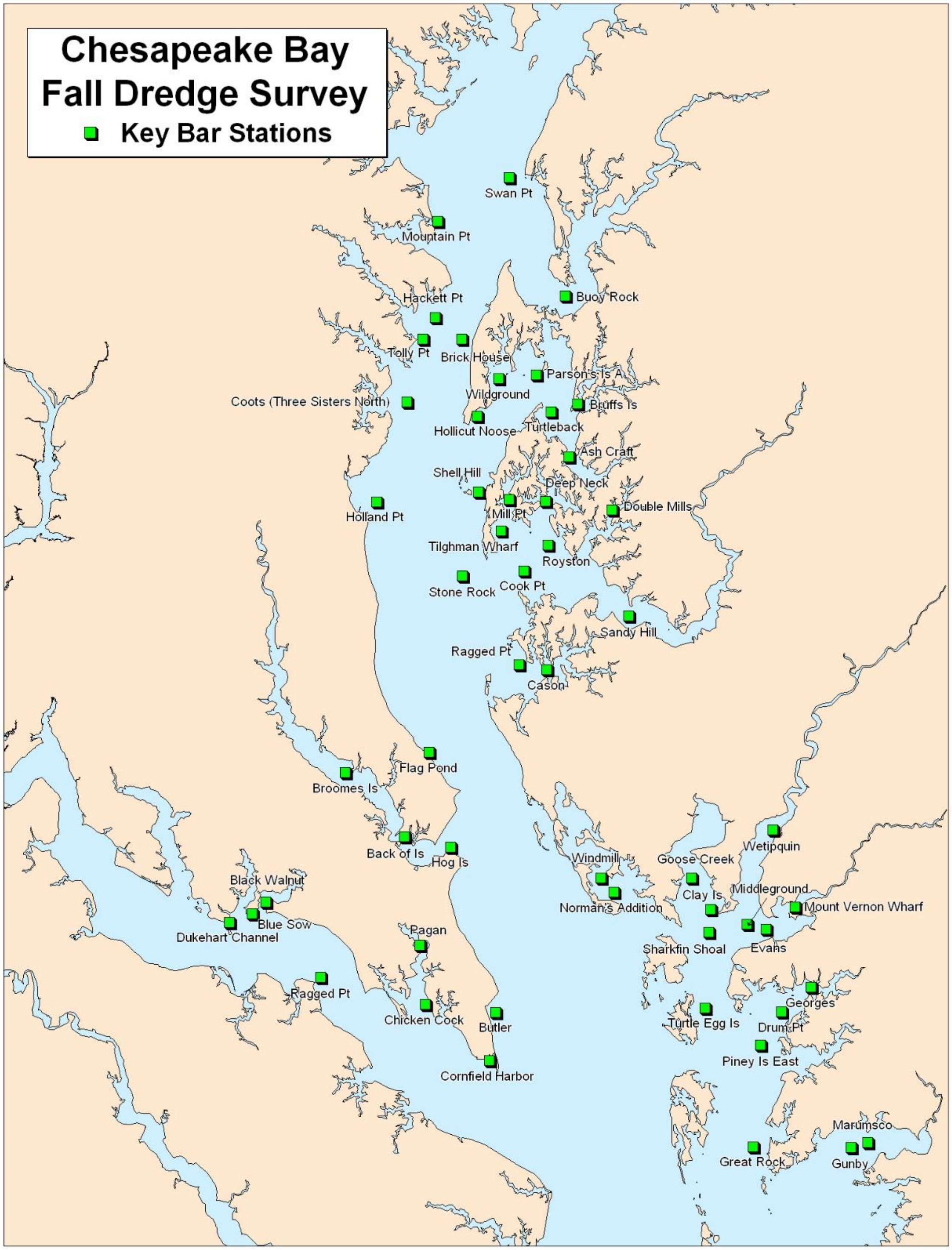

Figure 1b. Maryland Fall Oyster Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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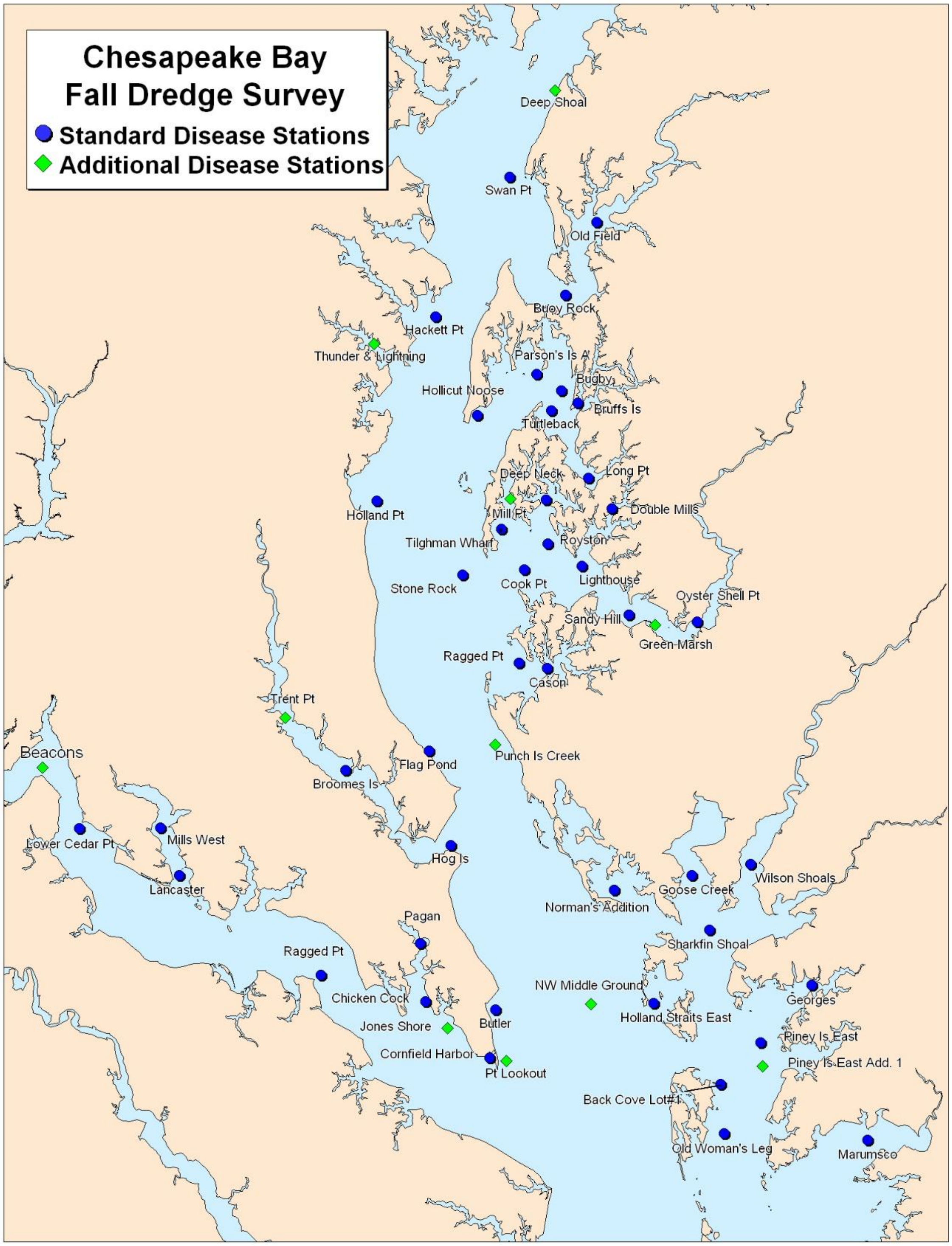

Figure 1c. Maryland Fall Oyster Survey standard Disease Bar monitoring locations and additional disease sample stations. Disease samples could not be obtained from Lower Cedar Point, and the supplemental sites at Deep Shoal and Beacons, in 2019.

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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, parasitic infections and habitat in the Maryland waters of 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 2019, 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 multi-year collaborative study on contaminants of emerging concern in the Chesapeake Bay. 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 was 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 and will continue to be used in future stock assessments. Disease data collected during the survey are now shared annually in a Rutgers University database intended to facilitate oyster aquaculture along the east coast of the United States.

METHODS

Field Collection

The 2019 Annual Fall Oyster Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources Fishing and Boating Services from 15 October to 25 November. A total of 339 samples was collected during surveys on 286 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:

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 42 Disease Bar sites. A sample could not be collected at Lower Cedar Point due to the total absence of live oysters on that bar. Also, the scarcity of oysters at Old Woman's Leg resulted in a smaller sample ($n = 20$) obtained there. Additional samples for disease diagnostics were collected from supplemental sites, sanctuaries, and other areas of special interest. Oyster parasite diagnostic tests were performed by 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 2019 biomass index is derived from the 2019 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. $\sum$ dmw per size class = total dmw per 1 bu station sample

For **all** monitoring stations:

3. ($\sum$ 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 for 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 reports. 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 temporally and spatially 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.

Annual Streamflow
Following the record high freshwater streamflows of 2018 (Tarnowski 2019), elevated flows continued into the first half of 2019, depressing salinities, which in turn affected spatset, disease, mortality and growth of oysters. By mid-year the above average flows had abated and salinities returned to normal by the fall. Nevertheless, the annual streamflow into the Maryland portion of the Bay (Sec. "C" in Bue 1968) in 2019 exceeded the 83-year average by 27% (Figure 2a).

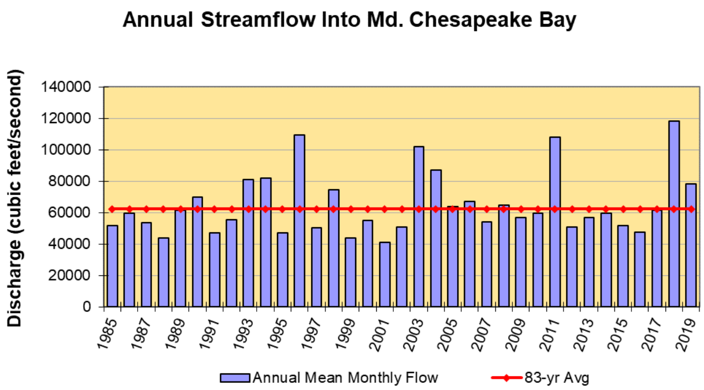

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2019. USGS Section C: all Maryland tributaries and the Potomac River.

Note that the United States Geological Survey (USGS) account of 2019 as the record high flow year refers to a *water* year, which runs from 1 October of the previous year (2018) to 30 September of the reporting year (2019) (USGS 2020). In contrast, this report refers to the *calendar* year, which results in 2018 being the record-high flow year. In this case the difference between the two methods of reporting is considerable – the annual average monthly streamflow for Section C during the 2019 water year was 101,170 cu ft/sec compared with 78,058 cu ft/sec for the 2019 calendar year.

Monthly Streamflow

The discrepancy between the two methods can be explained by the monthly streamflow patterns (Figure 2b).

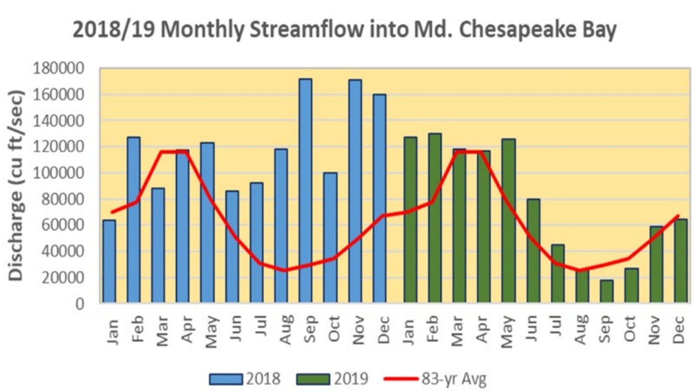

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2018-19, including the 83-yr monthly average.

The highest streamflows in 2018 were during the latter part of that year – especially the last three months, which are counted in the 2019 water year. It was the extraordinary streamflows during the last quarter of 2018 that set both the record for calendar year 2018 and water year 2019. Those elevated flows persisted through the winter and spring of 2019. But in contrast to 2018, the flows declined steeply beginning in May 2019. By September flows had reached their lowest point of 2019 - only 61% of the long-term average and a full order of magnitude lower than the same time in 2018.

Salinities

Elevated freshwater flows during 2018 lowered salinities over an extended time period well into 2019, impacting spatset, disease, mortality and growth of oysters.

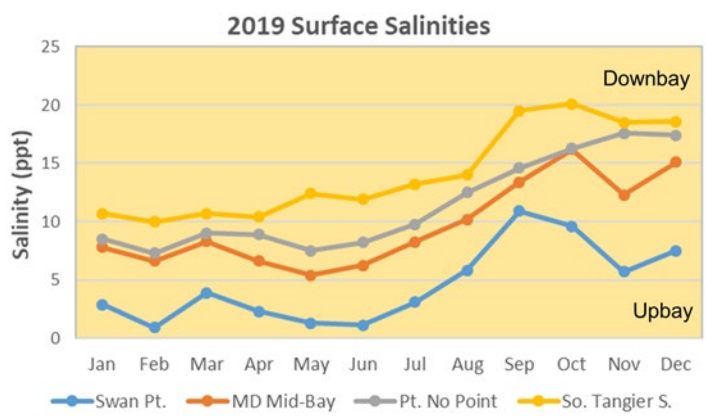

Figure 2c. Monthly surface salinities during 2019 at four monitoring stations along a salinity gradient in Chesapeake Bay. Swan Pt. (CB3.2) is in the upper bay, the mid-bay station (CB4.2C) is off the mouth of the Choptank R., Pt. No Point (CB5.2) is in the lower mainstem, and the southern Tangier Sound station (EE3.2) is near the Virginia state line.

Monthly surface salinities for four regions of the Chesapeake Bay in Maryland during 2019 are shown in Figure 2c (Chesapeake Bay Program 2019). These examples demonstrate the influence of streamflow to varying degrees depending on distance from the Susquehanna River, the largest source of freshwater discharge into the bay. Salinities remained depressed through the first half of the year. As streamflows slacked off at mid-year, salinities started to climb, roughly doubling by September/October. The most dramatic increase occurred at Swan Point in the upper bay, where surface salinities jumped from 1.1 ppt in June to 10.9 ppt in September. These increases returned salinities to close to their respective long-term averages at all four locations for that time of year.

A critical threshold for a number of biological processes in oysters is 5 ppt (Tarnowski 2019). Swan Point in the upper bay had surface salinities below 5 ppt for 14 continuous months from June 2018 through July 2019. None of the other locations had salinities below 5 ppt reported in 2019, and the salinity in southern Tangier Sound never fell below 10 ppt (Figure 2c).

SPATFALL INTENSITY

The Spatfall Intensity Index, a measure of recruitment success and potential increase in the population, was 23.0 spat/bu, almost identical to the 35-year median value (Figure 3a).

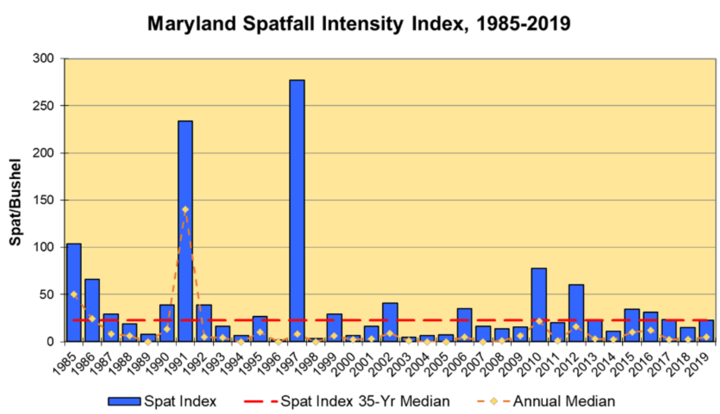

Figure 3a. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including annual median values.

Spatset intensity increased 53% from the previous year, with almost half of the 2019 index bars having increased spatfall when compared with 2018 (Table 2). However, it is somewhat unexpected that in 2019 almost a quarter of the Key Index Bars had lower spat counts than in 2018, primarily in the Choptank, Little Choptank, and upper Tangier regions, and about one-third showed no change (albeit these were almost all zeroes), given the low salinity conditions and lower overall spat index in 2018. Two of the previous nine years (2010, 2012) had strong year classes (Figure 3b), which boosted the population and increased commercial landings.

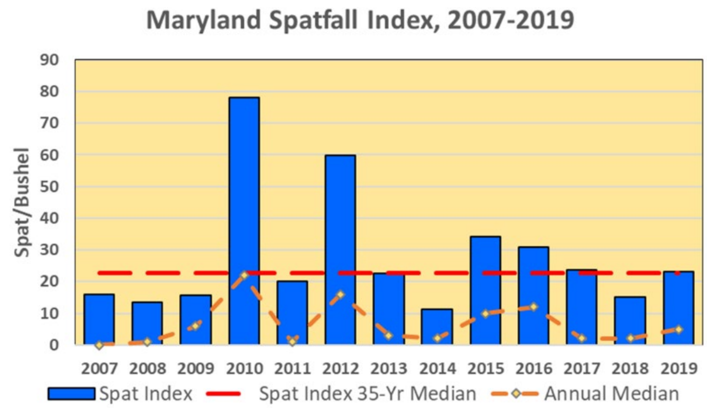

Figure 3b. Recent Maryland spatfall indices, 2007-2019, including annual median values.

However, the relatively unexceptional spatsets over the past seven years have had implications for population abundance, leading to declining harvests in the most recent years until the somewhat more favorable 2015 and 2016 year classes enter the fishery. Although only at the median of the index, the 2019 spatfall may help sustain harvest levels in the upcoming years, particularly in the Tangier Sound region.

Spatfall distribution among the Key Bars in 2019 expanded somewhat from the previous year. Spat were observed on 37 of the 53 Key Bars, whereas 32 Key Bars had spat in 2018 (Table 2). Only five bars accounted for 53% of the index, similar to 2018/2017 and compared with nine bars in 2016. In 2019, nine bars contributed 75% of the spat index (same as 2018/2017; 15 bars in 2016), while 21 bars were needed to reach 95% of the spat index; the remaining 32 bars made up only 5% of the 2019 index. In other words, 60% of the index bars were unproductive in 2019. Only four Key Bars reached triple-digit spat counts: 160 spat/bu on Drum Point in the Manokin Sanctuary, 151 spat/bu on Great Rock and 138 spat/bu on Middleground, both in the Tangier Sound region, and 110 spat/bu on Cornfield Harbor in the Potomac River. Of these, only Drum Point bars has ranked consistently near the top of Key Bar spat counts over the 35-year time series (Table 2). The 2019 spat count on Great Rock was four times its long-term average.

When considering all bars surveyed in addition to the Key Bars, the highest spatsets were observed downbay - primarily in middle and lower Tangier Sound and adjacent mainstem of the bay across to the Western Shore, and to a lesser extent the Manokin River and Pocomoke Sound (Figure 4). A modest spatset (11-50 spat/bu) occurred in the mid-bay, upper Tangier Sound and associated tributaries, and the lower Patuxent and lower Potomac rivers. Spatset was disappointingly light in the normally productive Harris and Broad creeks, Little Choptank and St. Marys rivers, as well as areas in Eastern Bay. Spat were absent from samples in large swaths of the bay - no spat were found along the Western Shore upbay from mid-Calvert County, the upriver two-thirds of the Potomac oyster growing region, the upper Choptank River, parts of Eastern Bay and its tributaries, and the entire Chester River and bay north of the Bay Bridge. The highest spatset on an individual bar (388 spat/bu) was observed on Point Lookout Lot B on the lower Western Shore.

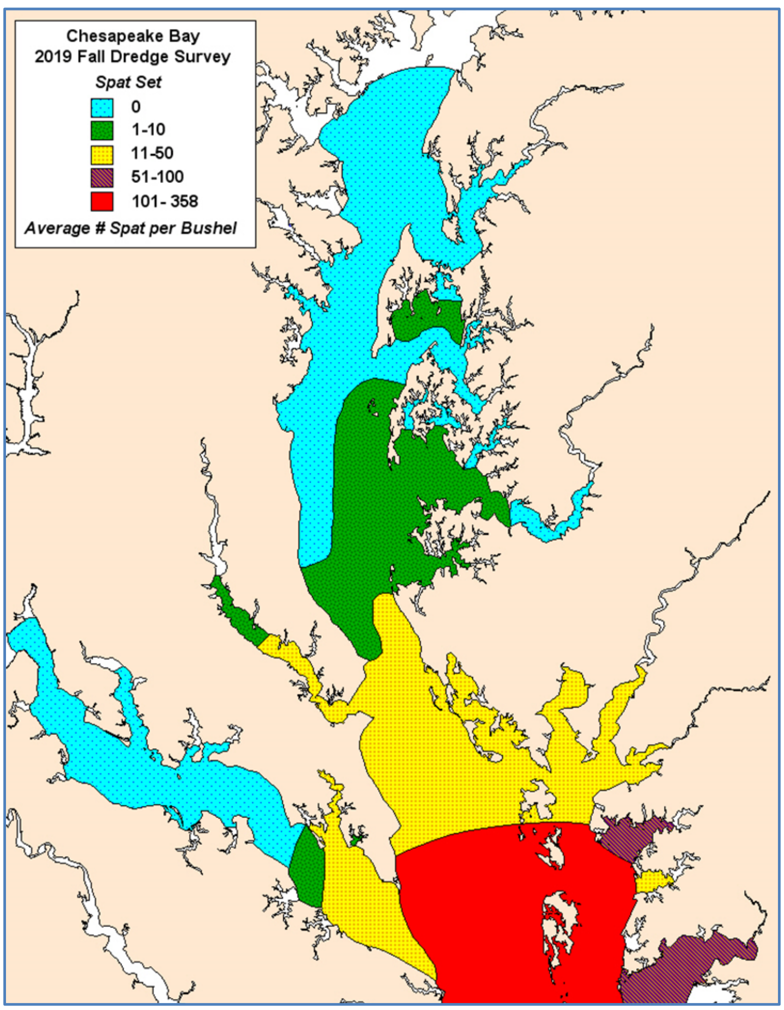

Figure 4. Oyster spatfall intensity and distribution in Maryland, 2019. Intensity ranges represent regional averages.

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 ranking tier (of six) 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 top statistical ranking notwithstanding having a lower spatfall index than 1997.

Another approach to understanding these skewed spatfall distributions examines the annual medians of the index (Figure 3a). Medians are generally higher in proportion to their index (mean or average) when there is a more uniform geographic distribution and are lower when the geographic distribution is limited in extent or skewed. In cases such as in 2019, where 60% of the Key Bars accounted for only 5% of the spat index, the median was low even though the index was moderate, 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 (e.g. 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 88% of the Disease Bars (Table 3) during 2019, the lowest frequency since the 43-bar subset[1] was standardized in 1990. Previously, the lowest frequency had been 91% in 2018. Although dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, the percentage of infected oysters has declined considerably over the past two years. The overall mean infection prevalence in oysters sampled on the Disease Bars was 27%, compared to 40% in 2018 and 69% in 2017, and was the lowest in the 30-year time series (2011 had the previous record-low mean prevalence of 38%) (Figure 5). This marks the 15th of the past 17 years when dermo disease mean prevalences were below the long-term average of 64.5%. The mean infection intensity for dermo disease (1.0)

[1] Samples were obtained from only 42 Disease Bars in 2019. Lower Cedar Point in the Potomac River had experienced 100% mortality from the freshets; no oysters were available for analysis.

was slightly lower than in 2018 (1.2) but half of the 2017 average, and well below the long-term average, establishing a new record for the lowest average intensity.

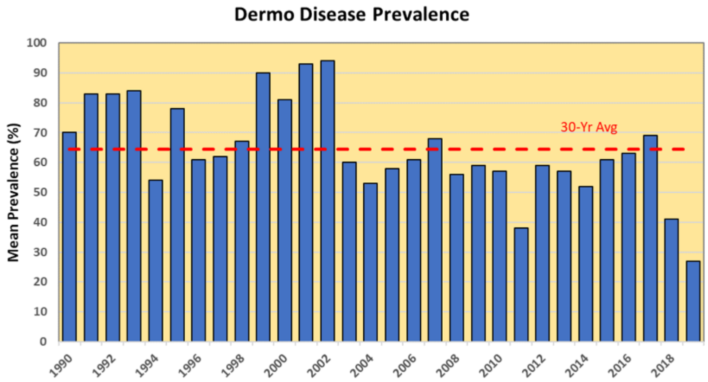

Figure 5. Annual mean *P. marinus* prevalences from Maryland disease monitoring bars.

The geographic distribution of high prevalences (>60%) contracted substantially over the past three years from 60% of the Disease Bars in 2017, to 37% in 2018, and down to 12% this year, retreating to the lower main stem but remaining in many of the tributaries, including the Miles and Wye rivers, Harris Creek, upper Tangier Sound, and Manokin River on the Eastern Shore. (Figure 6). Overall, prevalences were relatively low throughout the remainder of the survey sites and dermo disease was not even detected at five locations, notably in portions of Tangier Sound. Outside of the regular disease monitoring sites, dermo disease was found at all nine 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 2019 because of the absence or low densities of oysters due to freshet-related mortalities. Dermo disease was undetected at these locations in 2011 when streamflows were also elevated.

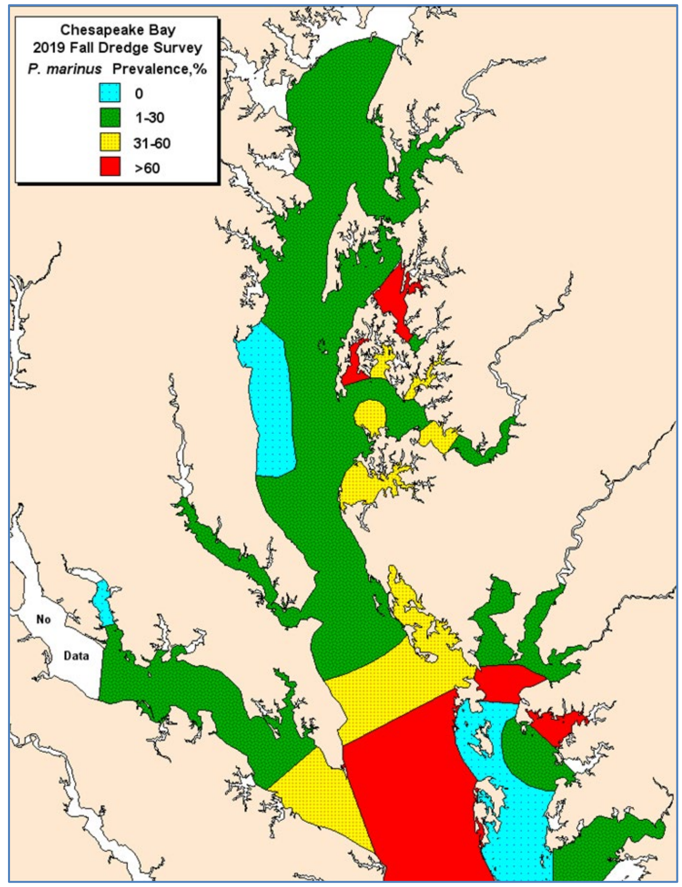

Figure 6. Geographic extent and prevalence of dermo disease in Maryland, 2019.

The 2019 annual mean infection intensity of 1.0 (on a 0-7 scale) was slightly lower than in 2018 (1.2) and less than half that of 2017 (2.5), establishing a new record low for the 30-year time series (Table 3). This is the 14th year of the past 17 that the infection intensity index has been at or below the long-term average (Figure 7). The average infection intensity over the 17 years since the end of the 1999-2002 drought is 1.8, similar to another 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.

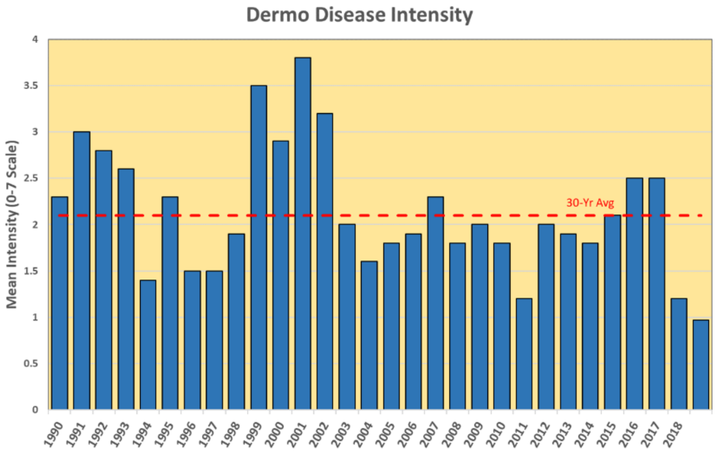

Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars.

The 2019 frequency distributions of sample mean infection intensities was similar to the previous year (Figure 8).

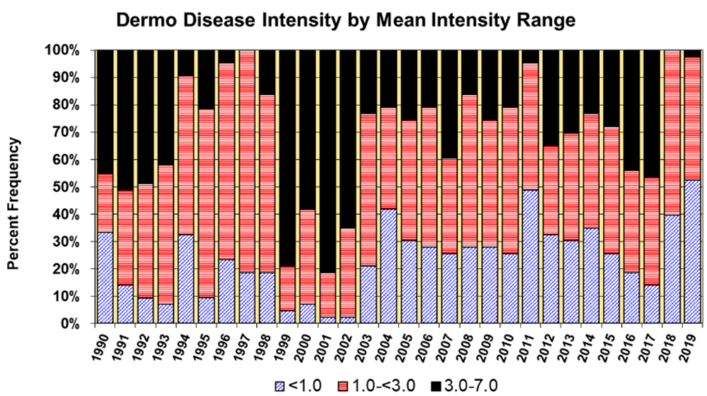

Figure 8. *Perkinsus marinus* infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.

In 2019, 2% of the sentinel bars (1 bar) had a mean intensity of 3.0 or greater, compared to 0% in 2018 47% (20 bars) 2017. For perspective, during the peak infection intensity year of 2001, 81% of the sentinel bars had dermo disease mean intensities equal to or greater than 3.0 and 51% had intensities equal to or greater than 4.0. The proportion of bars that were in the lowest intensity range of less than 1.0 was 52% in 2019, compared to 40% in 2018 and only14% in 2017. In addition, none of the nine supplemental bars had mean infection intensities of 3.0 or greater in 2019.

Infection intensities in individual oysters that are ≥5 on a 0–7 scale are considered lethal; such infection intensities were detected in 8% of oysters sampled in 2019, slightly up from 7% in 2018 but substantially lower than the 21% in 2017.

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 2019, MSX disease mean prevalence (0.1%) of infected oysters on Disease Bars was identical to 2018 and a two-fold order of magnitude lower than the most recent peak in 2016 (11.1%). This reprises 2018 as having the lowest number of infected sentinel Disease Bars and the lowest average prevalence recorded in the time series. When considering both the Disease Bars and supplemental sites, the geographic range of MSX disease diminished slightly in 2019 and shifted to Pocomoke Sound (Figure 9). While in 2019 *Haplosporidium nelsoni* was detected in only one oyster on one (2%) of the Disease Bars (Marumsco) and from none of the supplemental sites, in 2018 it was found in two oysters from two supplemental bars in addition to the one oyster from the Disease Bar. Thus, 2019 had the smallest number of sampled oysters infected with *H. nelsoni* in Fall Oyster Survey records from the past 30 years. This compares with 14 Disease Bars (33%) with infected oysters in 2017 and 24 (56%) in 2016 (Table 4, Figure 9). For reference, at its greatest extent the parasite occurred on 90% of the bars in 2002.

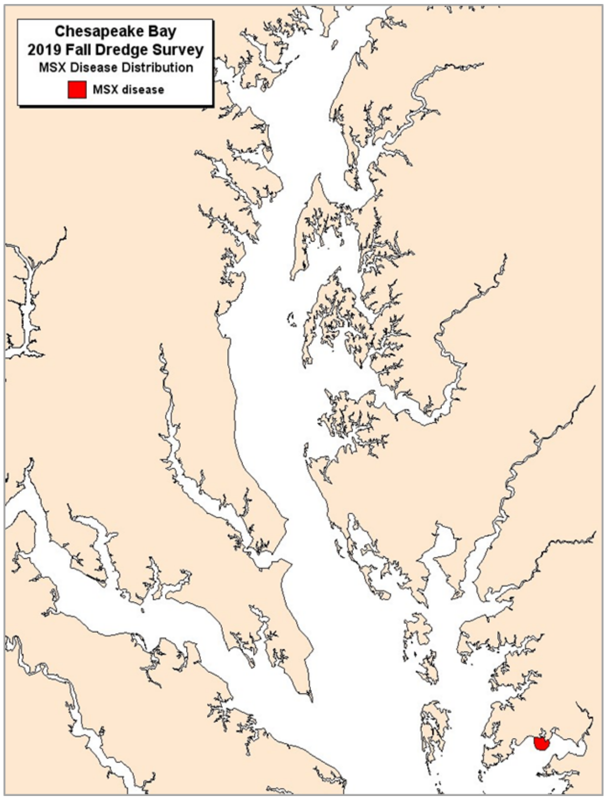

Figure 9. Geographic distribution of MSX disease in Maryland waters, 2019.

Historically, 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 five *H. nelsoni* epizootics: 1991-92, 1995, 1999-2002, 2009, and 2015-16. The first three were associated with prominent spikes in observed mortalities (Figure 10), while the 2009 and 2016 outbreaks were accompanied by a modest mortality increase that were ameliorated by timely freshwater flows (Tarnowski 2011).

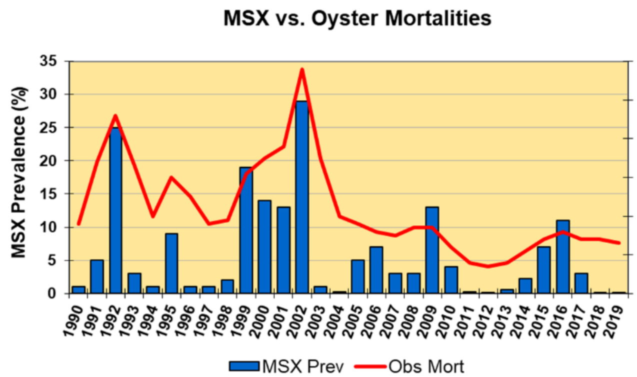

Figure 10. Percentage of Maryland oysters with MSX disease compared to annual means for observed mortalities on the disease monitoring bars from 1990-2019.

All 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 purging *H. nelsoni* infections from most Maryland oyster populations (Homer & Scott 2001; Tarnowski 2005, 2011). The current decrease in *H. nelsoni* infections is associated with the record high streamflows of 2018 which remained elevated into 2019 (Figure 2b).

OBSERVED MORTALITY

Despite locally devastating freshets at some upstream locations (see below), the Maryland-wide Observed Mortality Index was slightly lower than the previous year (Table 5). At 13%, the 2019 index was well below the 35-year mean of 22.2%, continuing a 16-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 16 years approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (DNR, unpubl. data). This is in remarkable contrast to 2002 when record-high disease levels devastated Maryland populations, resulting in a 58% observed mortality rate.

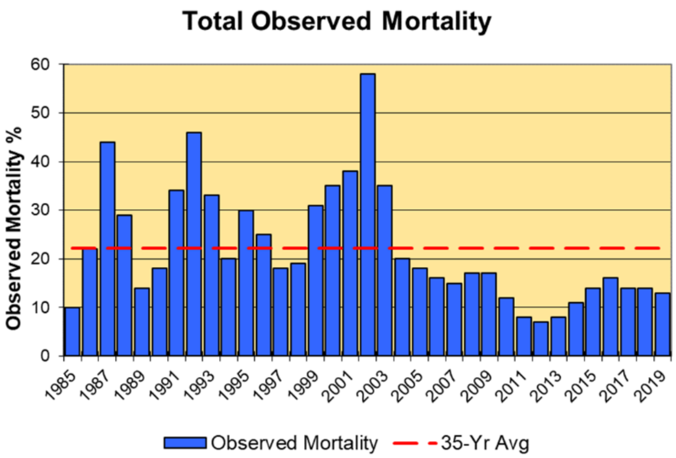

Figure 11. Mean annual observed mortality, small and market oysters combined.

Looking at all Survey sites, observed mortalities were generally low to moderate. Aside from the upper Potomac River and the upper bay, the highest mortality observed on an individual bar with more than 50 live oysters/bushel[2] was 32.7% on Cabin Creek bar in the upper Choptank River.

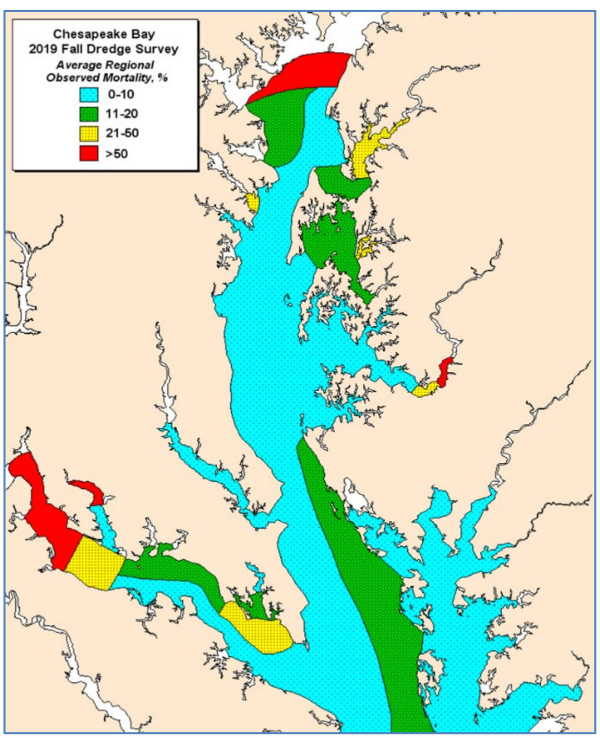

Figure 12a. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2019. Mortality ranges represent regional averages; individual bars may vary substantially.

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

The north-south gradient in observed mortalities evident in most years was not apparent in 2019, with strikingly low average mortalities throughout most of the mainstem including the lower Western Shore, and the entire Tangier Sound region (Figure 12a). Tangier Sound itself, typically a higher mortality area, averaged a remarkably low observed mortality of 4.2%, in contrast to 1999 at the start of the millennial epizootic when the average observed mortalities climbed to 48.0%. Aside from the extreme mortalities observed in the upper Potomac River and upper bay, higher regional mortalities were observed in the Chester and upper Choptank rivers, typically lower salinity areas that may suffer from freshet effects. The highest Index-bar mortality was observed on Lower Cedar Point in the upper Potomac River, where 100% of the oysters were dead (Table 5).

Freshet-Related Mortalities

The prolonged period of elevated streamflows that began in 2018 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, all of the surveyed bars above Swan Point were devoid of live oysters (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 early on at Bluff Point bar, where in 2018 a one bushel sample had 226 dead oysters and no live oysters. This was a prelude to what would befall the other upper Potomac bars. While a few oysters remained alive on the upper river bars in the fall of 2018, no live oysters were found in samples taken in 2019. There were also more subtle consequences from the freshet. The oysters on Beacon bar, 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 100% mortality in 2019.

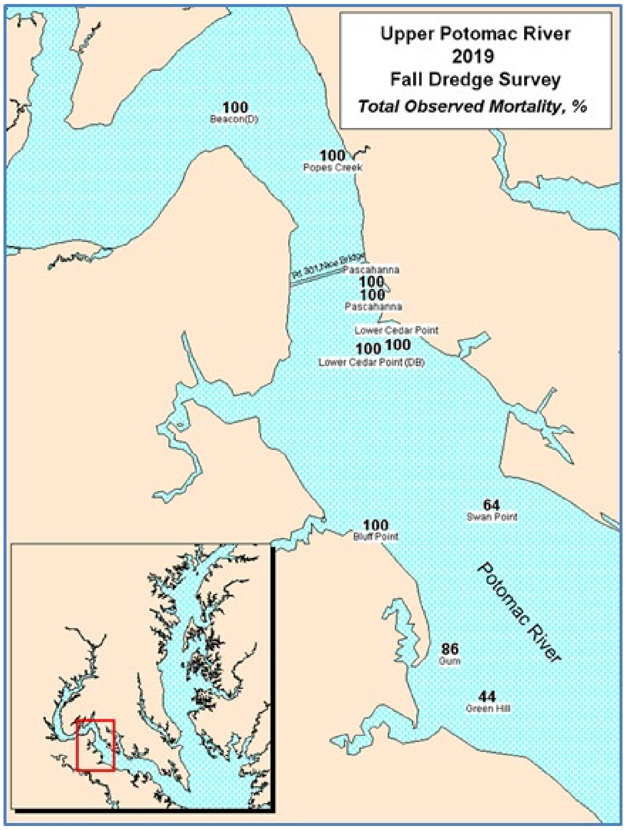

Figure 12b. Observed mortalities on the upper oyster bars of the Potomac River sampled in October 2019.

Compared to the upper Potomac bars, the upper bay oyster populations fared somewhat better. On the Eastern Shore side, the highest observed mortalities ranged from 62% to 100% on the three uppermost surveyed bars, but unlike in the Potomac, these were bars with extremely low numbers of live or dead oysters – less than 10 oysters/bu. For the remainder of the Eastern Shore bars in the upper bay, the observed mortality averaged 4.3%.

Mortalities on the Western Shore bars of the upper bay were somewhat higher. Only one bar with more than 50 live oysters had elevated mortalities - two oyster seed plantings on Man-O-War Shoals had mortalities of 37% and 50%, while a third sample site had only four dead but no live oysters, resulting in an exaggerated observed mortality for that sample. Surprisingly, these are almost identical to mortalities observed in 2018, despite the continued high streamflows that extended through the spring of 2019. The combined observed mortality on Man-O-War Shoals was 41.9%, in contrast with the 2011 freshet, when 100% of the oysters died on this bar. Aside from Man-O-War Shoals, the observed mortality on the other Western Shore bars in the upper bay averaged 13.9%.

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 2019 Maryland Oyster Biomass Index of 1.72 represents a slight decline in this index from the previous year (Figure 13a), ranking it sixth highest in the 27-year time series. The size distribution shifted to more market oysters relative to sublegal oysters at a ratio of 0.80 sublegals to one market oyster, compared with the sublegal to market ratio of 1.32 in 2018. This can also be expressed as the percentage of sublegal oysters: 44.5% in 2019, down from 56.6% in the previous year. This shift is reflected in the increase in average size of index bar oysters, from 72.7 mm in 2018 to 78.1 mm in 2019. It might be expected that an increase in oyster size would result in a corresponding increase in biomass. However, the second component of the

Biomass Index, oyster abundance, showed a decline. For all index bars, the average number of oysters dropped from 114.4/bu in 2018 down to 97.8/bu in 2019. This difference was sufficient to counter the increase in average size, resulting in the slight dip in the Biomass Index.

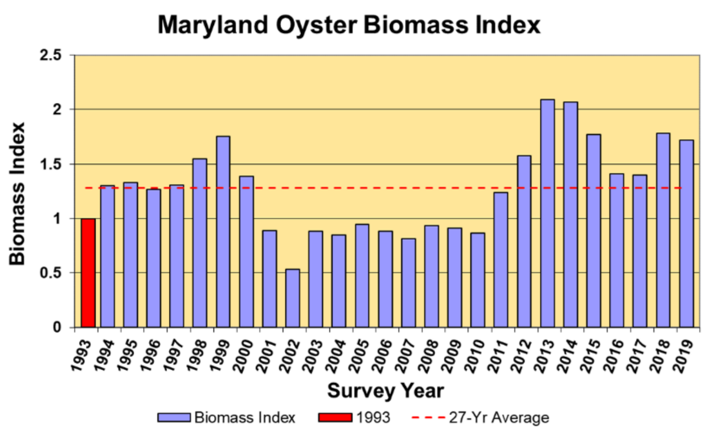

Figure 13. Maryland oyster Biomass Index. The year 1993 represents the baseline index of (1).

The oyster population had been slow to recover since its nadir in 2002, the last year of the devastating four-year disease epizootic. The Biomass Index remained below one[3] (1.0) 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. However, the index seems to have plateaued with the series of unexceptional spatsets over the past few years.

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 oysters (live and dead) and shell (combined). The collection of quantitative cultch data was initiated during the 2005 Fall Oyster Survey.

The 2019 Cultch Index of 0.89 bu/100 ft. was similar to the 15-year average of 0.90 bu/100 ft. However, some individual bars showed much steeper declines. Of the 52 bars used in this analysis, 37% had standardized volumes that were less than 75% of their respective 15-year averages (Figure 14).

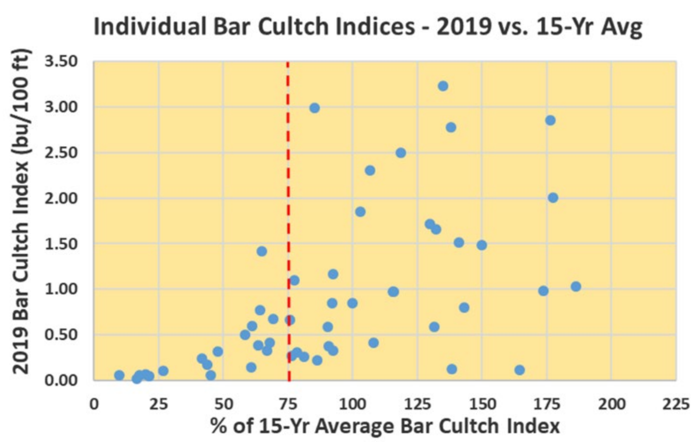

Figure 14. Range of cultch index values for individual Key bars in 2019 and the percent difference from their 15-year averages. The red dashed line indicates 75% of the 15-year average.

Although 15 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). The increase in the Cultch Index during the early 2010s reflects improvements in recruitment and survivorship during that period, especially

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[3] The baseline (Biomass Index = 1) year of 1993 was chosen because it had the lowest harvest on record when the index was established.

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.

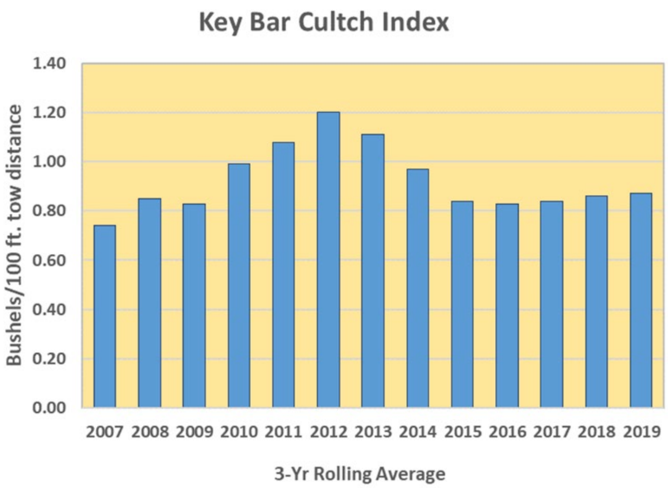

Figure 15. Three-year rolling average of annual means for the Key Bar Cultch Index, 2005-2019. The average is represented by the third year of the grouping (e.g. the 2005-07 average is graphed as 2007).

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, and to a lesser extent the Patuxent River. Three of the six regions had indices below the 15-year average (Figure 16a). The largest decline in regional indices occurred in the Chester River/Eastern Bay region. The Tangier Sound region saw improvement in its index, as did the Choptank region and Patuxent River. The Potomac region index is somewhat deceptive since it is largely driven by Pagan bar, whose 3-year average is six times as high as the 3-year average of the other six bars in this region; if not for Pagan the Potomac region index would be 46% lower. Removing Pagan would also lower the 15-yr average for the Potomac region by 21 percentage points.

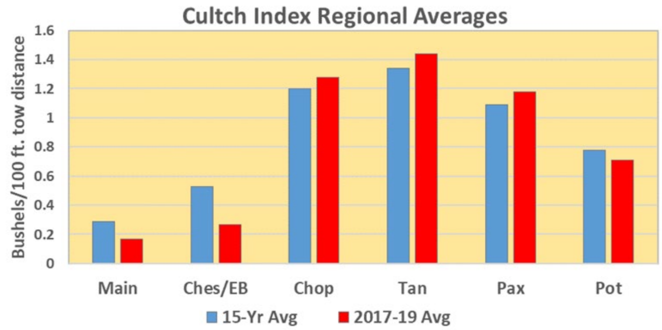

Figure 16a. Regional cultch index averages for the 15-year time series and most recent three years. *Main=bay mainstem; Ch/EB=Chester River/Eastern Bay region; Chop=Choptank River region; Tan=Tangier Sound region; Pax=Patuxent River; Pot=Potomac River tributaries*

Cultch volumes among subregions of the broader regions can be highly variable. The greater part of the Tangier Sound region cultch index is contributed by the tributaries and not Tangier Sound proper. This disparity is even more apparent when all bars in addition to the index bars are taken into account (Figure 16b). In this case, the stations of the six regional tributaries averaged 1.33 bu/100 ft. tow distance while the Tangier Sound proper stations averaged 0.60 bu/100 ft.

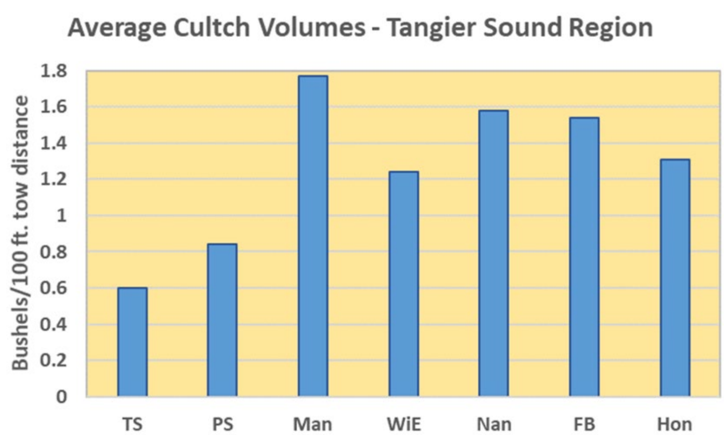

Figure 16b. Average bushels of cultch per 100 ft. tow distance for all stations by subregion within the Tangier Sound region. *TS=Tangier Sound; PS=Pocomoke Sound; Man=Manokin River; WiE=Wicomico River East; Nan=Nanticoke River; FB=Fishing Bay; Hon=Honga River*

COMMERCIAL HARVEST

Commercial oyster landings continued to slump during the 2018-19 season. With reported harvests of 145,000 bushels, oyster landings were 20% lower than the previous harvest season, extending a declining trend to five years (Table 6, Figure 17a). This was the lowest harvest total since the 2011-12 season and was a 65% drop from the most recent landings peak in the 2013-14 season. From the long term perspective, landings during the 2018-19 season were only half of the 34-yr average of 291,000 bu/yr. At an average reported price of $45.52 per bushel, the dockside value of $6.6 million was a decrease of $2.1 million (-24%) from the previous year (Table 7a.).

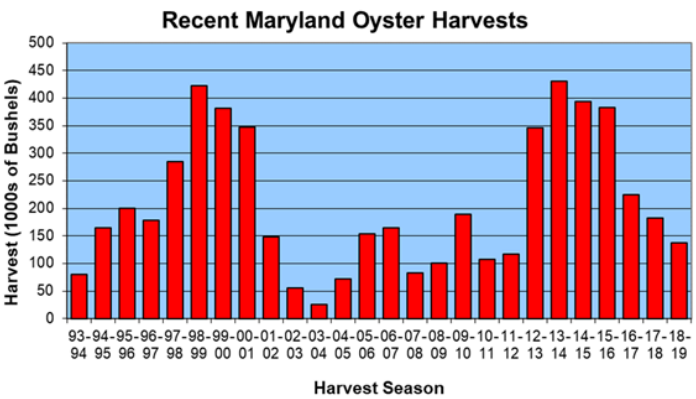

Figure 17a. Maryland oyster landings over the past 27 seasons.

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 26 years (and four of these in the most recent 17 years) following the onset of a series of disease epizootics beginning in the mid-1980s.

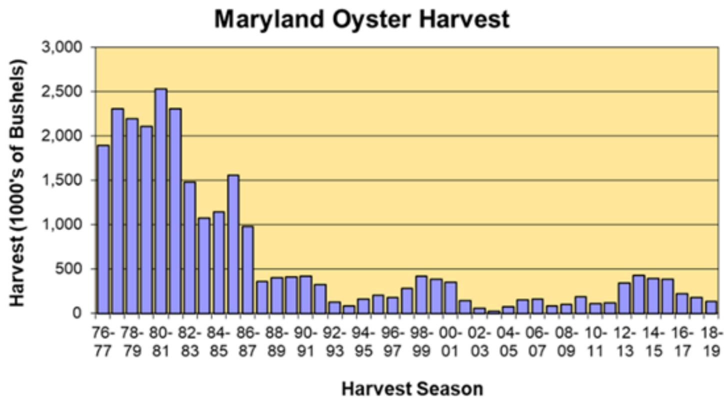

Figure 17b. Maryland seasonal oyster landings, 1976-77 to 2018-19.

In the 15 years before the 2016-17 season, commercial oyster landings followed a similar pattern as the Biomass Index (Figure 18). 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, unexceptional spat sets in 2011, 2013, and 2014 were insufficient to sustain harvests, leading to the substantial drop in landings during the last three seasons. The Biomass Index did not track this harvest decline but actually increased because of above-median spatfalls in 2015 and 2016. The subsequent growth of the sublegal-size oysters as well as continued growth of oysters protected in sanctuaries contributed to maintaining the Biomass Index despite the drop in landings.

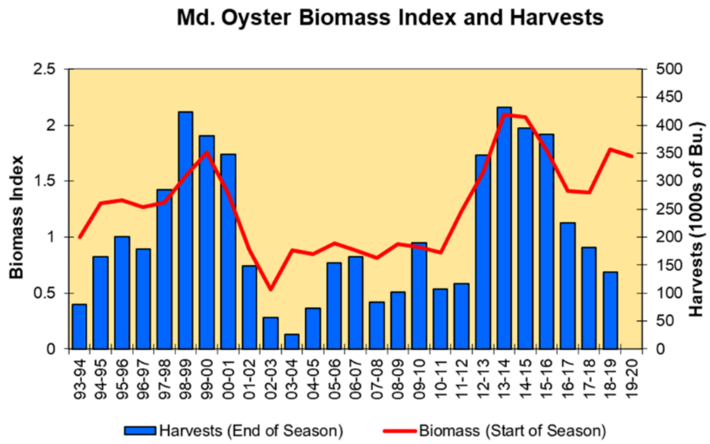

Figure 18. Relationship between the Biomass Index calculated at the start of the harvest season and total landings reported at the end of that same season. Note lag between the two metrics when abundant sublegal oysters add to the Biomass Index but have not yet entered the fishery (e.g. 2018-19).

Oyster growth was stunted by the low salinity conditions prevalent in 2018, with many small oysters (likely 2015/16 year classes) failing to reach market size (Figure 19).

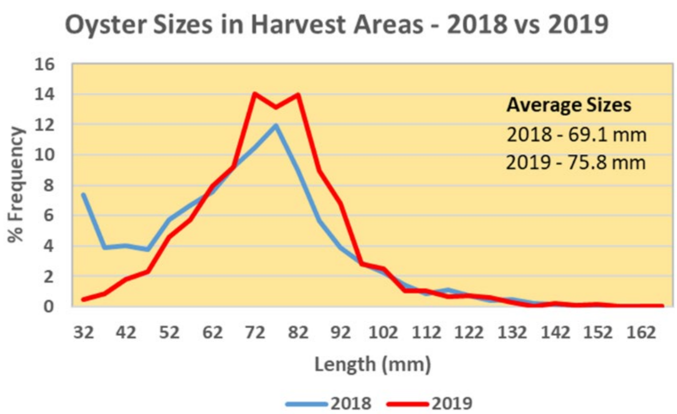

Figure 19. Size distribution and growth of oysters from the Biomass Index bars in open harvest areas between 2018 and 2019.

In fact, the average size of oysters on Biomass Index bars in harvest areas increased a mere 2.4 mm between 2017 and 2018, despite the fact that the average size of oysters in 2017 was heavily weighted with small oysters (70% of the index bar oysters were sublegals). Along with underperforming spatsets and the reduced number of market oysters, this could help account for the steep decline in harvests during the 2018-19 season. As salinities returned to normal, the average size of oysters on the Biomass Index bars within harvest areas increased from 69.1 mm in 2018 to 75.8 mm in 2019, illustrated by the shift of the mode of the size-frequency distribution to the right. With the sustained low mortality rates over the past few years, these younger oysters continued to grow and are beginning to recruit to the fishery, which should provide a boost to the landings in the 2019-20 harvest season.

The Choptank was the dominant harvest area, accounting for 39% of the 2018-19 landings, the majority of which came from Broad Creek (22% of the Maryland harvest) (Table 6). The Tangier Sound region, including the Nanticoke, Wicomico and Honga rivers, Pocomoke Sound and Fishing Bay, slipped into second place with 28% of the landings after dominating for years. With the exceptions of the Choptank region and lower bay, almost all of the regions experienced declines in landings. The most substantial changes (>4,000 bu) in Maryland landings between the 2017-18 and 2018-19 seasons are listed below.

Chester River
-decreased 4,522 bu (-88%)
Upper Tangier Sound
-decreased 11,263 bu (-34%)
Lower Tangier Sound
-decreased 4,438 bu (-61%)
St. Marys River
-decreased 6,388 bu (-34%)
Lower Choptank River
-increased 5,391 bu (+84%)

The combined harvests in the entire Tangier Sound region decreased by 26,449 bushels or -40% from 2017-18, which itself had experienced a 26% loss from the previous year, and a staggering 196,461 bushels (-83%) from just five years earlier (the recent peak season of 2013-14). The St. Marys River showed the second largest decrease in harvest from the prior year, yet was still almost 50% above its long-term average, ranking it third highest in the percentage of total landings. Harvests in the Chester River fell to 613 bushels, a tributary whose long-term average is 21,000 bu/year. While the Choptank region as a whole went up in landings, the middle Choptank portion and Broad Creek had declines. 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 0.9% of the total harvest in 2018-19 (Table 6). The 34-year harvest average for these two regions was 33,000 bu/year, primarily sustained by numerous seed plantings from the DNR Repletion Program. Similarly, harvests from the once-productive Eastern Bay region are about a quarter of the 34-year average.

For the 12th consecutive season, power dredging was the predominant method of harvesting, accounting for 44% of the total landings (Table 7b). However, the actual landings from power dredging were about one-quarter of those during the peak 2013-14 season (Table 7a). This activity took place mainly in the lower Eastern Shore and Choptank regions. Hand tonging produced 25% 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 fell slightly to 15% of the total; sail dredging (skipjacks) and diving also experienced declines.

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 priority (i.e. large-scale restoration) sanctuaries.

A total of 88 oyster bars within 32 sanctuaries were sampled during the 2019 Fall Survey (Table 8). Recruitment within the priority sanctuaries and adjacent open harvest areas was actually lower than the previous year and well below their respective Key Bar long-term averages, with the exception of mid-Tangier Sound (Table S-1). This was unanticipated considering that the spat index was about 50% higher than the prior year (Table 2) and speaks to the limited extent of good spatset in 2019 (Figure 4). A comparison of spatset in sanctuaries with adjacent harvest areas showed similar results. Although the trend showed slightly higher spatsets in the open areas, the spat counts were so low that any differences were biologically meaningless. Tangier Sound and to a lesser extent the Manokin River, were within the locus of elevated spatsets in Maryland during 2019. The average spat count of the mid-Tangier Sound bars was significantly above that of the Manokin River (t-test, $P < 0.05$). This is the reverse of 2018, when the Manokin River had a higher average spatfall than mid-Tangier Sound.

The average number of adult (small and market) oysters per bushel in the priority sanctuaries was over twice as high as in adjacent harvest areas. The Manokin Sanctuary had the highest average number of adult oysters of any area in this comparison and was almost an order of magnitude above the nearby mid-Tangier Sound bars (Table S-1). The only region where there was little difference between the two management treatments was the Little Choptank River.

Table S-1. 2019 average regional oysters/bushel by size/age class and long-term Key Bar spat/bushel for priority restoration sanctuaries and nearby harvest areas.

Region	Status	Regional 2019 Sm + Mkt	Regional Spat 2019	Regional Spat 2018	*Key Bar 35-Yr Avg.*
Harris Cr.	Sanc.	133	0	30	*38.8*
Harris Cr.	Open	82	7	41	*64.6*
Broad Cr.	Open	116	6	54	*115.3*
Tred Avon R.	Sanc.	65	0.2	1	*17.6*
Tred Avon R.	Open	41	3	1	*17.6*
L.Choptank R.	Sanc.	119	5	14	*87.8*
L.Choptank R	Open	117	3	7	*56.2*
Manokin R.	Sanc.	332	85	107	*83.8**
Mid-Tangier S.	Open	39	184	81	*93.5**
St. Marys R.	Sanc.	162	8	4	*165.3*
St. Marys R.	Open	76	15	9	*79.9*

*Average of two Key Bars.

Twenty oyster disease samples were obtained from 18 sanctuaries. The average dermo disease levels in these sanctuaries were considerably lower than the previous year (average prevalences of 32.8% in 2019 vs. 51.2% in 2018; mean intensities of 1.2 in 2019 vs. 1.5 in 2018). Of the 13 sentinel Disease Bars within oyster sanctuaries, dermo disease prevalences were all below the 30-year site averages, and only Georges bar in the Manokin River sanctuary exceeded the long-term intensity average (Table 3). Dermo disease levels were somewhat lower on Disease Bars in the open harvest areas, averaging 24.4% prevalence and 0.9 mean intensity (Table S-2). 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 20); parasite burdens tend to build up as oysters age (Ford & Tripp 1996). MSX disease was not detected at any of the 13 Disease Index Bars (Table 4) and seven supplemental disease sites within sanctuaries.

Mortality rates on sanctuary bars generally continue to be well below their long-term averages (Table 5). Eight of the 12 Mortality Index bars within sanctuaries had observed mortalities below the 35-year individual bar averages. For all Mortality Index bars, observed mortalities were similar between sanctuary bars (5.6%) and open harvest bars (7.1%), despite the higher overall mean dermo disease levels at the sanctuary sites (Table S-2). The bars associated with the five priority sanctuaries and adjacent harvest areas showed extremely low observed mortalities – all were in single digits and were close to the regional estimates except for two open harvest Mortality Index bars. The 33% observed mortality on the Piney Island East harvest bar may be an overestimate, as only six oysters were found in the sample. On the other hand, Chicken Cock bar had a more representative sample of 90 live and dead oysters combined with an observed mortality of 20%.

Table S-2. 2019 Dermo disease levels and observed mortality estimates for disease bars and regional averages on priority restoration sanctuaries and nearby harvest areas. MSX disease was not detected at any of these sites. Averages for all Disease Bars both within and outside sanctuaries are also presented.

Region	Disease Bar	Status	Dermo Prevalence %	Dermo Intensity	Observed Mortality % Disease Bar	Observed Mortality % Regional
Harris Cr.	Mill Pt./Rabbit I.*	Sanc.	54	1.9	3	2.9
Harris Cr.	Tilghman Wharf	Open	23	1.5	4	1.8
Tred Avon R.	Double Mills	Sanc.	47	2.7	3	6.1
Mid-Choptank R.	Lighthouse	Open	3	0.2	4	2.8
Broad Cr.	Deep Neck	Open	33	2.8	2	1.2
L. Choptank R.	Cason	Sanc.	60	2.6	4	5.7
L. Choptank R.	Ragged Pt.	Open	60	2.6	3	3.9
Manokin R.	Georges	Sanc.	77	3.1	5	5.9
Mid-Tangier S.	Piney Island East	Open	17	2.5	33	5.2
St. Marys R.	Pagan	Sanc.	17	2.4	4	6.5
St. Marys R.	Chicken Cock	Open	27	2.4	20	10.8
Average of all Sanctuary Disease Index Bars			32.8	1.2	5.6	
Average of all Harvest Disease Index Bars			24.4	0.9	7.1	

*Dermo disease values are averages of the two bars. Both are supplemental bars and not part of the Disease Index set.

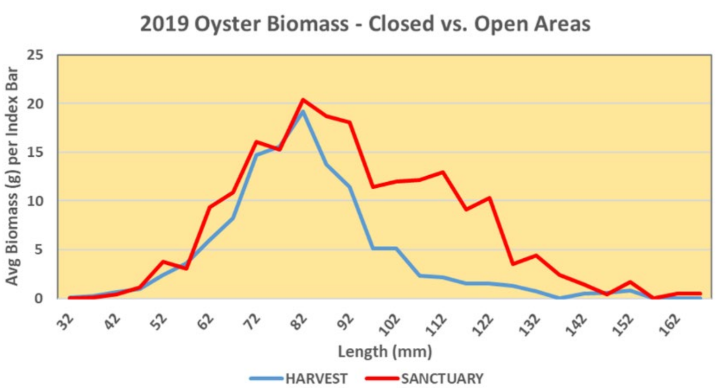

Figure 20. Average oyster biomass by 5 mm size classes on Biomass Index bars in harvest areas and sanctuaries.

Of the 43 Biomass Index bars, 13 bars are within sanctuaries (Table 8). The average biomass per index bar in 2019 was substantially higher in the sanctuaries (200.1 g/bar) than in the open harvest areas (118.4 g/bar). Most of this difference was in the larger market size classes (Figure 20), where the average market biomass per bar in the sanctuaries (155.3 g/bar) was almost twice as high as in the open harvest areas (81.5 g/bar). In contrast, the average biomass of sublegal oysters was relatively close between the two management categories (44.7 g/bar in the sanctuaries vs. 36.9 g/bar in the harvest areas). The average size of adult oysters was somewhat larger in the sanctuaries (81.7 mm) than on the harvest bars (75.8 mm).

DISCUSSION

Streamflow – Timing is Everything

The consequences of the elevated streamflows over the first half of 2019 and the timing of its return to normal during that summer were mixed. The most dramatic of the adverse effects were the catastrophic mortalities suffered by the oyster populations on the most upriver bars of the Potomac River. What few oysters remained during the 2018 Fall Survey succumbed to the continued onslaught of freshwater afterwards. Observed mortalities were 100% on the seven farthest upstream Potomac River sites surveyed in 2019.

Recruitment was also impacted throughout large swaths of Maryland waters. The abatement of streamflows and return to normal salinities occurred too late in many areas to allow for spawning and/or spatset, which ordinarily begins in June/early July, but can be inhibited by depressed salinities (see Tarnowski 2019 for a review of the effects of low salinities on oysters). The broodstock oysters may have been in poor condition due to sustained exposure to these low salinity conditions. Another possibility is the phytoplankton that they feed on may have been sparse or of a different community composition more suited to lower salinities, which the oysters were unable to fully utilize. Either situation would affect their ability to store the energy reserves needed for gametogenesis. Further exacerbating the problem, the inability to feed sufficiently also causes oysters to draw on whatever glycogen reserves they have remaining from overwintering (Thompson et al. 1996). This could account for the poor spatfall in normally productive areas such as Broad Creek. This tributary actually had higher recruitment in 2018, probably because of spring salinities favorable to oyster condition and gametogenesis before the summer deluge began.

Further downbay, the situation was quite different. The surface salinity in southern Tangier Sound remained at or above 10 ppt through the winter and into spring, sufficient to allow the initiation of the gametogenic process (Loosanoff 1953, Calabrese & Davis 1970), even though it was below average for that time of year in that region. The elevation in salinity during May and into mid-summer was well timed for successful spawning and spatfall (Thompson et al. 1996). The result was a geographic band of elevated spatfalls from middle and lower Tangier Sound across the bay to Pt. Lookout, with counts ranging from about 100 spat/bu to 350 spat/bu.

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. The below average spring/early summer salinities, coupled with low salinities of the previous year, suppressed the development of diseases to striking effect – disease levels were the lowest in the 30-year time series. Although MSX disease can exist in salinities as low as 10 ppt, below which it is purged from oysters, it becomes substantially more pathogenic in salinities greater than 15 ppt and temperatures higher than 20°C (Ford 1985). But by the time salinities returned to normal, it was too late in the year for diseases to progress to any great extent. As a consequence of reduced disease pressure, the 2019 observed mortality index remained below the long-term average despite the freshet-related losses in the upper bay and Potomac River.

The timing of the reduced freshwater flow also benefited oyster growth, which had been depressed from the prolonged freshet. With salinities returning to normal in the late summer and early fall, at least two year classes of sublegal oysters began attaining market size simultaneously, just in time for the 2019-20 harvest season.

The Status of Tangier Sound Oysters

Several notable metrics call attention to the current status of the oyster population in Tangier Sound. As one of the most productive regions in Maryland, Tangier Sound historically has been the center of the oyster industry in the state. Although this productivity is in part due to its higher salinity regime, for the same reason it is also an area that has been battered by diseases, and has been especially vulnerable to MSX disease. During the 2000-01 season, in the middle of the millennial epizootics, soaring mortalities as high as 61% were observed on some bars and harvests sank to a scant 1,550 bu, or only 4% of the total Maryland landings. And yet, despite this devastation, by the 2013-14 season landings had rebounded to 103,000 bu, the highest since the 1985-86 season and three times the 34-year average, which speaks to the resiliency of this population. Landings continued to be above the long-term average until this past (2018-19) season.

The disease results of the 2019 survey in Tangier Sound have turned long-term patterns of geographic distribution on its head. Expected increased levels of disease with increased salinity did not occur and were below the baywide average; despite the near ubiquity of dermo disease in Maryland oysters, it was not detected in three of the five disease monitoring stations within Tangier Sound (Holland Straits bar is included in this group). The average prevalence was 16% compared with the 2019 baywide average of 27% and the 30-year average in Tangier Sound of 73.8%. Likewise, the average infection intensity was 0.58 versus 0.97 baywide and 2.6 for the 30-year average. To give an idea of how exceptional the Tangier Sound dermo disease levels were, note that the 2019 baywide averages for both prevalence and intensity were the lowest in the long-term time series. Furthermore, MSX disease, a past scourge of Tangier Sound oysters, was not detected in oysters at any of the five standard monitoring sites.

The exceptionally low disease levels consequently inverted the spatial model for mortality. Observed mortality for all Tangier Sound bars was 4.2% and 3.3% for the subset of the five disease/mortality index bars, compared with 13% for the 2019 baywide mortality index and 28.7% for the long-term average of those five Tangier Sound bars. This is in contrast with the upper reaches of the bay and tributaries, where elevated 2019 observed mortalities ran as high as 100% at some locations due to prolonged high freshwater flows.

Equally noteworthy was the good spatset experienced in Tangier Sound, in particular the middle and lower portions of the sound. For example, Great Rock near the Virginia line had spat counts that were four times its long-term average. Bars in this region had the highest counts since the strong 2010 and 2012 year classes. This same portion of the sound also had an above average spatset in 2018, though the counts were not nearly as high as in 2019.

This strong recruitment event brings to focus two issues in particular. First is the question of the source of the larvae that generated this spatset. Given the present state of scientific expertise, the source of these larvae is unknowable, so this topic is largely speculative. What brought attention to this issue was the low average density of oysters in Tangier Sound relative to nearby tributaries. Two of these tributaries, both with oyster sanctuaries within them, have substantial numbers of broodstock oysters that could very well have provided the larvae. As noted in Table S-1 of the Sanctuary section of this report, the Manokin Sanctuary averaged over eight times the number of broodstock oysters in a bushel sample as did the adjacent high recruitment area of mid-Tangier Sound. In addition, the Nanticoke River Sanctuary, with its substantial natural oyster population (averaging 172 adult oysters/bu sample), augmented by numerous oyster aquaculture operations, sits atop Tangier Sound. This difference is even starker when looking at oyster densities over a fixed tow distance, using the same methodology as was used to determine the Cultch Index. On average, a nearly threefold longer tow distance was required to obtain a sample in Tangier Sound than in these two tributaries. The mean number of adult oysters per 100 ft. tow distance in Tangier Sound was 17 oysters/100 ft., compared with 490 oysters/100 ft. in the Manokin Sanctuary and 271 oysters/100 ft. in the Nanticoke Sanctuary. Since oysters release their gametes into the water column when reproducing, the higher the oyster density the greater the probability of fertilization success (Thompson et al. 1996).

Other possible sources of larvae are suggested by the widespread nature of the southern Maryland recruitment event. This spatset, stretching from Tangier Sound across the bay to Point Lookout, may have resulted from a larval swarm from Virginia, riding saltier tidal currents upstream. Alternatively, there could have been two or more independent sources, benefitting from the mid-year increase in salinity. And, of course, the Tangier Sound oysters could have produced the larvae, but as noted, the broodstock/bu and densities/100 ft. in the sound proper were much lower than those of adjacent areas. But to repeat, the actual source of larvae producing the strong Tangier Sound spatset is unknown.

These findings lead to the second issue of concern. The longer tow distances required to obtain a sample in Tangier Sound compared to adjacent tributaries implies not only a lower density of oysters but also a lower quantity of cultch habitat. Although the Tangier Sound region ranked highest in the Cultch Index comparisons, the higher cultch densities were actually found in the surrounding tributaries. Combined, these tributaries (including the Manokin, Wicomico, Nanticoke, and Honga rivers, Pocomoke Sound, and Fishing Bay) averaged more than twice the quantity of cultch per 100 ft. tow distance than Tangier Sound proper (tributaries = 1.33 bu/100 ft. vs. Tangier Sound = 0.60 bu/100 ft.). Therefore, the high volumetrically assessed spatset (spat/bu) was actually found on a lower abundance of cultch scattered over a larger area, requiring a longer tow. Consequently, the density of spat (spat/area) was much lower than suggested by the volumetric measure. In other words, had the cultch density of Tangier Sound been as high as those in the surrounding tributaries, there likely would have been more spat.

The importance of cultch and maintaining a balance of shell for oyster habitat cannot be overemphasized. Larvae of *C. virginica* require a firm, sediment-free surface upon which to settle and attach, and their gregarious settlement response can produce dense aggregations of oysters. Additionally, oysters are unique among the species in Chesapeake Bay in that they create their own habitat. The shell cultch adds structure and firm substrate to the estuary, contributing habitat that is in stark contrast to the otherwise soft bottom environment of the bay. In addition to enhancing recruitment, the structural complexity the shell provides refuges from predation for the young oyster spat as well as other species. Therefore, rebuilding and maintaining oyster populations entails more than simply putting oysters in the water; it requires concomitantly rebuilding habitat as well (Mann and Powell 2007). Options include planting more shells, excavating buried shell in the region, and planting an alternate substrate suitable for harvest areas. **C**reative solutions may be required to effectively improve the availability of cultch.

In the near term, there is cause for optimism for the Tangier Sound fishery. Following the strong spatsets of 2010 and 2012 there was an uptick in harvests which lasted four years before winding down in the 2016-17 season. During this period landings averaged 88,000 bu/year; since then they have averaged about 36,000 bu/year. Meanwhile, a sizable proportion of the 2015/16 year classes have transitioned to market-size oysters, which could mean an increase in harvests in the upcoming season. The 2019 spatset, which was comparable in magnitude to that of 2012, should provide a further boost to the landings, supplemented by the 2018 set. This is contingent on whether nothing untoward happens during that time frame, such as a disease epizootic. However, disease levels and consequent mortalities have generally remained below average for the past 15 years. If this trend continues Tangier Sound could see respectable harvest levels in upcoming seasons. Given the poor recruitment in the Choptank region this past year, there may be a falling off of landings there, leaving Tangier Sound all the more important to sustaining the oyster fishery in Maryland over the next few years.

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TABLES

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

Physical Parameters

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

-Depth (ft.)

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

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

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

Biological Parameters

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

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

-Stage of oyster boxes (recent, old)

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

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

-Oyster condition index and meat quality

-Type and relative index of fouling and other associated organisms

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

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

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Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 “Key” spat monitoring bars, 1985-2019. (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	2019	*35-Yr Avg*
Mountain Point	0	0	0	0	0	*0.3*
Swan Point	0	0	0	0	0	*0.4*
Brick House	0	0	0	0	0	*6.2*
Hackett Point	0	0	0	0	0	*0.7*
Tolly Point	0	2	0	0	1	*0.8*
Three Sisters	0	0	0	0	1	*0.7*
Holland Point (S)	0	0	0	0	0	*0.5*
Stone Rock	2	17	0	4	6	*23.9*
Flag Pond (S)	10	12	28	0	2	*22.6*
Hog Island	9	22	1	0	19	*17.8*
Butler	68	90	2	1	42	*39.8*
Buoy Rock	0	0	0	0	0	*1.3*
Parsons Island	8	0	0	0	2	*106.5*
Wild Ground	15	0	0	0	1	*39.9*
Hollicutt Noose	1	0	0	0	0	*4.8*
Bruffs Island (S)	0	0	0	0	0	*26.0*
Ash Craft	0	0	0	0	0	*69.3*
Turtle Back	13	4	0	0	0	*127.5*
Shell Hill	4	2	1	5	2	*7.2*
Sandy Hill (S)	0	3	1	0	2	*11.5*
Royston	21	13	23	22	0	*50.1*
Cook Point (S)	1	21	2	4	7	*16.7*
Eagle Pt./Mill Pt. (S)	34	68	55	28	0	*38.8*
Tilghman Wharf	45	58	13	40	5	*64.6*
Deep Neck	83	91	205	119	17	*115.3*
Double Mills (S)	9	12	3	1	1	*17.6*
Ragged Point	19	125	35	2	1	*56.2*
Cason (S)	11	60	67	9	4	*87.8*
Windmill	16	9	9	4	12	*50.3*
Norman Addition	34	60	44	13	24	*77.3*
Goose Creek	11	44	27	23	18	*31.1*
Clay Island	43	68	41	43	14	*47.0*
Wetipquin (S)	2	6	0	21	33	*5.6*
Middleground	12	32	66	49	138	*29.1*
Evans	14	18	1	7	37	*12.3*
Mt. Vernon Wharf	1	3	1	10	7	*2.9*
Georges (S)	29	61	137	40	78	*69.1*
Drum Point (S)	59	172	78	110	160	*98.5*
Sharkfin Shoal	57	53	32	23	14	*28.1*
Turtle Egg Island	64	57	15	69	88	*89.4*
Piney Island East	3	0	2	0	68	*97.7*
Great Rock	13	4	14	93	151	*36.5*
Gunby	95	73	34	25	46	*58.5*
Marumsco	141	69	31	8	61	*40.7*
Broome Island	6	21	6	1	12	*6.8*
Back of Island	18	42	5	5	13	*14.1*
Chicken Cock	712	33	19	5	10	*79.9*
Pagan (S)	24	91	247	7	15	*165.3*
Black Walnut (S)	3	4	0	0	0	*1.5*
Blue Sow (S)	0	10	0	0	0	*4.5*
Dukehart Channel	0	3	0	0	0	*1.7*
Ragged Point	1	11	2	2	0	*5.3*
Cornfield Harbor	100	92	6	6	108	*73.3*
Spat Index	**34.2**	**30.9**	**23.6**	**15.0**	**23.0**	***39.3***

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Table 3. *Perkinsus marinus* prevalence and mean intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2019. 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	
	%	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
Hackett Point	13	0.6	0	0.0	10	0.3	40	1.2	56	1.6	27	0.9
Holland Point (S)	5	0.1	0	0.0	0	0.0	27	0.6	47	1.2	7	0.07
Stone Rock	67	2.0	100	4.0	93	4.5	97	4.4	83	3.4	53	1.7
Flag Pond (S)	23	0.8	10	0.3	18	0.5	50	1.9	52	1.6	27	0.6
Hog Island	27	0.9	43	1.2	87	3.0	97	4.3	100	4.5	63	2.1
Butler	70	2.4	73	2.4	60	2.0	37	1.5	63	2.2	73	2.1
Buoy Rock	27	0.6	13	0.4	17	0.2	20	0.7	30	0.8	0	0.0
Old Field (S)	57	1.5	47	1.5	57	1.7	63	2.1	60	2.1	27	0.7
Bugby	73	2.5	83	2.8	87	3.3	90	3.3	97	3.3	43	1.1
Parsons Island	30	0.9	15	0.4	53	1.3	77	2.2	83	2.9	43	1.3
Hollicutt Noose	13	0.4	23	0.6	33	0.7	50	1.5	57	1.8	17	0.5
Bruffs Island (S)	37	1.2	23	0.7	77	2.0	100	4.2	97	4.3	63	1.9
Turtle Back	63	2.2	80	2.5	100	4.2	83	3.5	83	3.2	70	2.1
Long Point (S)	37	1.2	10	0.4	20	0.5	73	2.6	36	1.1	7	0.3
Cook Point (S)	97	3.2	80	3.1	90	3.3	100	4.6	90	3.5	63	1.6
Royston	60	2.0	60	2.0	63	2.1	47	1.5	43	1.5	17	0.5
Lighthouse	10	0.3	10	0.3	23	0.5	10	0.4	17	0.4	7	0.2
Sandy Hill (S)	93	2.8	77	2.4	93	3.3	93	4.0	96	3.9	53	1.4
Oyster Shell Pt. (S)	7	0.2	3	0.0	40	1.0	80	2.6	77	2.8	57	1.8
Tilghman Wharf	10	0.2	7	0.1	20	0.6	47	1.5	70	2.2	47	1.2
Deep Neck	80	3.1	67	1.8	93	2.9	80	3.1	77	2.4	57	1.3
Double Mills (S)	83	3.1	73	2.6	70	2.9	87	3.6	97	3.9	67	2.1
Cason (S)	80	2.8	90	2.8	93	2.8	100	4.2	97	3.3	77	2.2
Ragged Point	97	3.0	83	2.3	100	3.2	93	4.0	97	3.7	67	1.7
Norman Addition	80	3.1	87	3.7	77	2.7	93	3.6	93	3.2	63	2.0
Goose Creek	80	2.6	83	2.5	100	3.4	93	4.3	80	3	70	2.7
Wilson Shoals (S)	93	3.0	90	3.4	80	2.8	90	3.2	87	3.2	73	2.1
Georges (S)	83	3.4	97	3.9	93	3.9	83	3.4	97	3.9	77	2.7
Holland Straits	90	3.7	80	3.6	83	3.0	13	0.3	30	0.6	7	0.2
Sharkfin Shoal	93	3.5	90	3.4	77	2.8	90	4.1	93	4.1	57	2.1
Back Cove	93	3.9	80	3.1	77	3.2	30	0.9	30	0.9	3	0.07
Piney Island East	63	2.0	40	1.4	53	1.8	60	2.4	70	2.3	27	1.1
Old Woman's Leg	52	1.3	60	2.6	67	2.1	11	0.2	50	1.6	6	0.06
Marumsco	100	4.4	80	3.5	90	3.6	93	3.7	100	3.9	63	1.6
Broome Island	93	3.2	70	1.9	80	2.6	90	3.8	93	4	50	1.3
Chicken Cock	50	1.2	67	1.9	67	2.1	73	2.4	97	3.1	63	2.1
Pagan (S)	77	2.4	83	2.1	83	2.9	83	3.1	80	3.1	63	1.4
Lancaster	30	1.2	20	0.8	3	0.2	37	1.6	47	1.8	10	0.1
Mills West	70	2.1	53	1.8	57	1.7	40	1.8	60	2	3	0.07
Cornfield Harbor	90	3.1	80	3.1	57	1.8	63	2.6	97	3.6	63	1.9
Ragged Point	0	0.0	3	0.0	0	0.0	3	0.0	7	0.1	0	0
Lower Cedar Point	20	0.4	3	0.1	55	1.6	33	1.1	50	1.6	0	0
Annual Means	**57**	**1.9**	**52**	**1.8**	**61**	**2.1**	**63**	**2.5**	**69**	**2.5**	**40**	**1.2**
Bar Freq. (%)	**98**		**95**		**95**		**100**		**100**		**91**	

Table 3 - Dermo (continued).

Oyster Bar	*Perkinsus marinus* Prevalence (%) and Mean Intensity (I)			
	2019		*30-Yr Avg*	
	%	I	*%*	*I*
Swan Point	3	0.1	*26.9*	*0.7*
Hackett Point	10	0.5	*49.1*	*1.5*
Holland Point (S)	0	0	*39.6*	*1.2*
Stone Rock	23	1	*71.2*	*2.4*
Flag Pond (S)	13	0.5	*46.0*	*1.5*
Hog Island	27	1	*72.4*	*2.7*
Butler	60	2	*66.9*	*2.1*
Buoy Rock	3	0.1	*50.4*	*1.6*
Old Field (S)	17	0.4	*56.8*	*1.7*
Bugby	90	2.8	*81.0*	*2.7*
Parsons Island	7	0.4	*70.6*	*2.4*
Hollicutt Noose	13	0.5	*59.4*	*1.9*
Bruffs Island (S)	70	2.3	*73.0*	*2.3*
Turtle Back	73	2.9	*84.1*	*2.9*
Long Point (S)	3	0.03	*63.3*	*2.1*
Cook Point (S)	37	1.2	*58.2*	*1.9*
Royston	20	0.6	*54.2*	*1.9*
Lighthouse	3	0.2	*43.9*	*1.4*
Sandy Hill (S)	53	2.4	*74.7*	*2.8*
Oyster Shell Pt. (S)	3	0.1	*40.1*	*1.2*
Tilghman Wharf	23	0.9	*52.0*	*1.5*
Deep Neck	33	1.2	*78.5*	*2.7*
Double Mills (S)	47	1.8	*78.9*	*2.8*
Cason (S)	60	2	*79.1*	*2.6*
Ragged Point	60	1.4	*79.7*	*2.6*
Norman Addition	37	1.5	*78.0*	*2.8*
Goose Creek	27	1.1	*66.2*	*2.3*
Wilson Shoals (S)	30	1	*82.6*	*2.6*
Georges (S)	77	3.1	*81.3*	*2.9*
Holland Straits	0	0	*62.7*	*2.1*
Sharkfin Shoal	63	2.4	*82.0*	*2.9*
Back Cove	0	0	*77.4*	*2.8*
Piney Island East	17	0.5	*75.7*	*2.5*
Old Woman's Leg	0	0	*70.9*	*2.5*
Marumsco	30	1	*81.1*	*2.9*
Broome Island	13	0.5	*74.5*	*2.6*
Chicken Cock	27	1.2	*71.7*	*2.4*
Pagan (S)	17	0.4	*78.5*	*2.4*
Lancaster	7	0.2	*56.0*	*1.7*
Mills West	0	0	*55.6*	*1.7*
Cornfield Harbor	40	1.3	*78.0*	*2.5*
Ragged Point	0	0	*19.4*	*0.5*
Lower Cedar Point	nd	nd	*22.3*	*0.6*
Annual Means	27	0.97	*64.5*	*2.1*
Bar Freq. (%)	**86**		***96.8***	

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2019. 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
Swan Point	0	0	0	0	0	0	0	0	0	0	0
Hackett Point	0	0	0	0	0	0	0	0	0	3	0
Holland Point (S)	0	0	3	0	0	0	0	0	0	3	0
Stone Rock	10	23	3	0	0	0	0	7	13	10	0
Flag Pond (S)	3	13	7	0	0	0	0	12	10	0	0
Hog Island	7	17	0	0	0	0	0	10	40	3	0
Butler	7	37	17	0	0	0	3	13	48	0	0
Buoy Rock	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
Bugby	0	0	0	0	0	0	0	3	3	0	0
Parsons Island	0	0	0	0	0	0	0	0	7	0	0
Hollicutt Noose	0	13	0	0	0	0	0	0	10	0	0
Bruffs Island (S)	0	3	0	0	0	0	0	0	3	0	0
Turtle Back	0	0	0	0	0	0	0	3	7	0	0
Long Point (S)	0	0	3	0	0	0	0	0	0	0	0
Cook Point (S)	7	43	10	0	0	0	0	13	30	3	0
Royston	0	0	0	0	0	0	0	7	30	0	0
Lighthouse	0	13	3	0	0	0	0	0	37	0	0
Sandy Hill (S)	0	0	0	0	0	0	0	0	0	0	0
Oyster Shell Pt. (S)	0	0	0	0	0	0	0	0	0	0	0
Tilghman Wharf	0	3	0	0	0	0	0	7	27	0	0
Deep Neck	0	13	0	0	0	0	0	3	0	0	0
Double Mills (S)	0	0	0	0	0	0	0	0	0	0	0
Cason (S)	0	20	0	0	0	0	0	23	0	0	0
Ragged Point	0	13	10	0	0	0	0	20	17	3	0
Norman Addition	10	33	10	0	0	0	3	3	7	0	0
Goose Creek	7	27	0	0	0	0	0	13	7	0	0
Wilson Shoals (S)	0	7	0	0	0	0	0	3	0	0	0
Georges (S)	0	10	0	0	0	0	0	3	0	0	0
Holland Straits	7	33	23	0	0	0	3	10	13	0	0
Sharkfin Shoal	17	17	10	0	0	0	10	10	0	0	0
Back Cove	13	27	7	0	0	3	10	17	37	13	0
Piney Island East	0	33	7	0	0	10	27	33	10	13	3
Old Woman's Leg	0	27	20	7	3	3	20	23	17	25	0
Marumsco	0	17	3	0	3	0	10	10	0	3	0
Broome Island	0	3	0	0	0	0	0	0	7	7	0
Chicken Cock	13	57	10	0	0	0	0	23	60	7	0
Pagan (S)	0	30	0	0	0	0	0	0	0	0	0
Lancaster	0	0	0	0	0	0	0	0	0	0	0
Mills West	0	0	0	0	0	0	0	0	0	0	0
Cornfield Harbor	10	30	7	0	0	10	10	30	33	7	0
Ragged Point	0	0	0	0	0	0	0	0	3	10	0
Lower Cedar Point	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**
Pos. Bars (%)	**30**	**60**	**40**	**2**	**5**	**9**	**21**	**56**	**56**	**33**	**2**

Table 4 - MSX (continued).

Oyster Bar	*Haplosporidium nelsoni* Prevalence (%)	
	2019	30-yr avg
Swan Point	0	0.0
Hackett Point	0	0.6
Holland Point (S)	0	2.4
Stone Rock	0	8.7
Flag Pond (S)	0	5.4
Hog Island	0	8.9
Butler	0	11.3
Buoy Rock	0	0.0
Old Field (S)	0	0.0
Bugby	0	1.4
Parsons Island	0	1.2
Hollicutt Noose	0	3.7
Bruffs Island (S)	0	0.9
Turtle Back	0	2.4
Long Point (S)	0	0.2
Cook Point (S)	0	9.8
Royston	0	4.8
Lighthouse	0	6.5
Sandy Hill (S)	0	2.6
Oyster Shell Pt. (S)	0	1.3
Tilghman Wharf	0	5.8
Deep Neck	0	4.0
Double Mills (S)	0	1.8
Cason (S)	0	7.1
Ragged Point	0	9.2
Norman Addition	0	11.0
Goose Creek	0	7.7
Wilson Shoals (S)	0	4.6
Georges (S)	0	6.5
Holland Straits	0	14.9
Sharkfin Shoal	0	13.0
Back Cove	0	13.1
Piney Island East	0	15.0
Old Woman's Leg	0	16.2
Marumsco	3	8.4
Broome Island	0	2.2
Chicken Cock	0	12.6
Pagan (S)	0	3.3
Lancaster	0	0.3
Mills West	0	1.6
Cornfield Harbor	0	13.5
Ragged Point	0	3.4
Lower Cedar Point	0	0.0
Avg. Prev. (%)	**0.1**	**29.8**
Pos. Bars (%)	**2**	**5.8**

(Return to Text)

Table 5. Oyster population mortality estimates from the 43 disease monitoring bars, 1985-2019.
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	2019	*35-yr Avg*
Swan Point	4	0	3	0	0	8	12	*10.8*
Hackett Point	0	0	0	3	19	3	5	*12.7*
Holland Point (S)	12	40	29	0	0	50	nd	*23.8*
Stone Rock	2	5	31	36	30	9	5	*22.0*
Flag Pond (S)	15	13	5	6	50	3	1	*21.1*
Hog Island	2	2	12	38	27	18	0	*27.3*
Butler	7	7	10	11	4	5	7	*23.9*
Buoy Rock	5	9	3	12	4	12	9	*16.5*
Old Field (S)	0	3	0	5	33	10	31	*13.6*
Bugby	8	31	21	21	13	12	17	*25.3*
Parsons Island	2	4	15	2	10	14	0	*20.8*
Hollicutt Noose	1	9	6	7	29	30	8	*20.9*
Bruffs Island (S)	0	4	5	16	20	41	38	*23.2*
Turtle Back	0	8	14	18	3	15	8	*24.5*
Long Point (S)	20	0	0	17	0	0	37	*22.3*
Cook Point (S)	9	12	16	48	45	24	13	*26.3*
Royston	1	6	9	16	4	2	4	*17.3*
Lighthouse	1	1	2	9	7	0	4	*19.8*
Sandy Hill (S)	3	13	11	15	15	11	11	*24.9*
Oyster Shell Pt. (S)	2	5	2	11	11	18	24	*10.9*
Tilghman Wharf	5	1	5	11	1	7	4	*17.1*
Deep Neck	5	7	16	8	2	3	3	*20.5*
Double Mills (S)	11	12	10	20	13	11	2	*20.5*
Cason (S)	11	8	17	26	33	8	4	*25.4*
Ragged Point	15	13	21	45	14	6	3	*26.3*
Norman Addition	9	7	13	14	15	8	2	*24.7*
Goose Creek	5	15	22	27	6	10	3	*32.3*
Wilson Shoals (S)	5	4	7	17	6	4	4	*20.4*
Georges (S)	15	5	8	23	15	9	5	*28.3*
Holland Straits	9	48	71	18	4	17	4	*29.3*
Sharkfin Shoal	16	18	24	19	3	7	4	*31.0*
Back Cove	11	19	14	1	2	8	1	*22.4*
Piney Island East	7	10	9	21	25	38	33	*29.5*
Old Woman’s Leg	50	75	15	0	50	25	10	*31.1*
Marumsco	13	13	17	13	20	34	36	*25.5*
Broome Island	7	8	14	21	3	4	0	*20.4*
Chicken Cock	1	7	16	32	20	17	20	*27.5*
Pagan (S)	4	13	22	28	6	4	4	*20.3*
Lancaster	13	0	3	1	1	10	5	*15.0*
Mills West	20	9	5	14	0	5	15	*14.7*
Cornfield Harbor	10	16	10	36	8	3	5	*28.1*
Ragged Point	0	0	50	10	8	4	33	*22.5*
Lower Cedar Point	0	0	6	8	27	96	100	*17.5*
Annual Means	**8**	**11**	**14**	**16**	**14**	**14**	**13**	***22.2***

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland from buy tickets, 1985-86 through 2018-19 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	2018-19	*34-yr Avg*
Upper Bay	3,648	4,693	2580	747	*12,288*
Middle Bay	13,019	11,072	5,134	3,005	*15,133*
Lower Bay	4,285	4,314	9,112	11,083	*6,015*
Total Bay Mainstem	*20,952*	*20,079*	*16,826*	*14,835*	*33,013*
Chester R.	1,547	569	5,135	613	*21,052*
Eastern Bay	13,091	15,576	9,663	8,566	*28,525*
Miles R.	3,335	1,666	527	962	*5,142*
Wye R.	18	17	21	0	*1,824*
Total Eastern Bay Region	*16,444*	*17,259*	*10,211*	*9,528*	*35,491*
Upper Choptank R.	192	42	129	183	*9,238*
Middle Choptank R.	8,420	5,749	6,563	3,930	*17,944*
Lower Choptank R.	22,141	10,979	6,458	11,849	*14,911*
Tred Avon R.	4,007	2,403	889	2,704	*10,587*
Broad Cr.	67,375	32,063	32,516	32,295	*21,828*
Harris Cr.	7,072	2,704	3,901	5,240	*7,825*
Total Choptank R. Region	*109,207*	*53,940*	*50,456*	*56,201*	*82,332*
Little Choptank R.	2,027	2,048	453	246	*11,138*
Upper Tangier Sound	64,305	35,521	33,322	22,060	*17,753*
Lower Tangier Sound	28,269	9,471	7,244	2,806	*14,003*
Honga R.	13,241	11,114	2,051	925	*7,646*
Fishing Bay	20,195	13,608	7,441	5,728	*14,442*
Nanticoke R.	7,095	7,430	8,017	4,201	*7,246*
Wicomico R.	10,122	4,735	1,044	939	*1,376*
Manokin R.	1,431	1,128	1,914	1,045	*3,372*
Big Annemessex R.	4,037	473	90	74	*240*
Pocomoke Sound	10,261	6,131	5,269	2,166	*5,269*
Total Tangier Sound Region	*158,956*	*89,611*	*66,392*	*39,943*	*71,345*
Patuxent R.	50,048	22,669	9,446	9,290	*12,497*
Wicomico R., St. Clement and Breton bays	5,596	5,130	891	1,160	*10,056*
St. Mary's R. and Smith Cr.	10,537	8,716	18,759	12,371	*8,760*
Total Potomac Md. Tribs.	*16,133*	*13,846*	*19,650*	*13,531*	*18,796*
Total Maryland (bu.)[1]	**383,534**	**224,758**	**182,310**	**145,161**	***291,130***

[1] Includes harvests from unidentified regions.

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Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2018-19 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*
2018-19	35,574	11,461	21,532	64,073	12,487	*145,161*	*$6.6 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 2018-19 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
2018-19	25	8	15	44	9

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Table 8. Oyster bars within sanctuaries sampled during the 2019 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

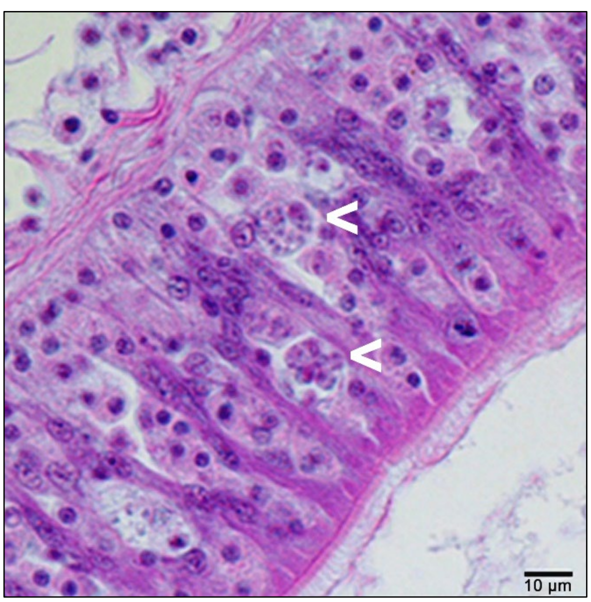
Chris Dungan, Maryland DNR, May 6, 2020

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 88-100% of all regularly tested Maryland populations have been infected. Annual mean prevalences for dermo disease have ranged at 27-94% of all tested oysters, with a 30-year average of 65%.

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 plasmodium (>) 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 30-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 2019). During 2018 and 2019, low water salinities reduced the distribution and the mean prevalence of MSX disease to historic minima.

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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, The number of spat per bushel of cultch. This is a relative measure of oyster spat

sample site 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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