Maryland Oyster Population Status Report
2023 Fall Survey

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Cover Photo: Oyster diseases on the rise, Choptank River, October 2023. (Photo: R. Bussell)

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EXECUTIVE SUMMARY

Since 1939, the Maryland Department of Natural Resources and its predecessor agencies have monitored the state's oyster population by means of annual field surveys – one of the longest running programs of this kind in the world. Currently over 250 bars are sampled annually. Integral to the Fall Survey are five types of indices intended to assess the status and trends of 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 Disease Bar 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 2023 Fall Survey was conducted from 3 October to 15 November throughout the Maryland portion of Chesapeake Bay and its tributaries, including the Potomac River. A total of 352 samples was collected from 281 oyster bars. Locations monitored included natural oyster bars, oyster seed production areas, seed and shell planting sites, and sanctuaries.

Among the environmental factors affecting oyster populations, freshwater streamflow is critical as it controls the salinity regime of the bay, which in turn influences spatset, diseases, mortality and growth of oysters. For 2023, the annual average freshwater flow was below the 25th percentile of the long-term normal range, indicating a drought year. As a consequence, salinities were higher than normal throughout 2023. Salinities reached 15 ppt at least as far upbay as the mid-bay station off the mouth of the Choptank River, a critical threshold above which MSX disease can cause extensive mortalities in oyster populations.

The elevated salinities contributed to a strong recruitment cohort in 2023. The Spatfall Intensity Index was 86.8 spat/bu, a 270% increase from the previous year and the fifth highest of the time series, surpassing the 39-year median for the fourth consecutive year. Equally important to the high index was the widespread nature of the spatset. Spat were observed on 50 of the 53 Key Bars, the most bars with spat since 1985. Spat were even observed in the upper reaches of oyster bars in tributaries that are normally too brackish to receive a spatset. Notably, the Potomac River and some of its Maryland tributaries received a once in a generation spatfall. A supplemental survey in the Potomac found numerous spat well above the Route 301 bridge, an area which rarely receives a spatset and where oysters had been extirpated by the devastating freshwater deluges of 2018-19. The north shore of the lower Potomac River had the highest spat count of all regions, averaging 288 spat/bu, followed closely by the lower mainstem east of the channel with 285 spat/bu. The only regions where no spat were found were the upper bay north of the Bay Bridge and the Chester River.

A total of 1,558 oysters were analyzed for diseases in 2023 – 1,288 from the 43 Disease Bars (sentinel bars) and 270 from nine supplemental sites. Dermo disease has increased appreciably since the record low levels in 2019. The disease was detected in oysters on 98% of the Disease Bars and supplemental sites. The percentage of individual infected oysters grew considerably over the last two years to 67% in 2023, compared to 36% in 2021; this was the highest average prevalence in the last six years. The trend in the mean infection intensity for dermo disease also continued to increase in 2023. The mean infection intensity (2.3 on a 0-7 scale) was 31% higher than in 2022 (1.7). This marks the fourth time in the last 21 years since the record high epizootics at the turn of the millennium that both dermo disease metrics - mean prevalence and intensity - have been above the long-term averages. The majority of the highest intensities were detected in southern Maryland as far north as the Choptank River and noticeably in several of the tributaries.

Both the prevalence and geographic range of MSX disease increased substantially in 2023. The mean prevalence of infected oysters rose from 1.9% in 2022 to 17.6%, and was higher than the previous infection peak in 2016 (11.1%). This is the first year prevalences surpassed the long-term average since 2016, ending the trend of below average prevalences for the last six years, three of which were record lows. The prevalences ranged from 3% to 93% on the Disease Bars where MSX was detected. The latter was found on Lighthouse bar in the Choptank River and was the highest recorded prevalence for an individual bar in the 34-year time series. When considering both the Disease Bars and supplemental sites, the geographic extent of MSX disease expanded throughout the mainstem up to the Bay Bridge and into several of the tributaries. In only one year, the frequency of positive Disease Bars increased from 19% (eight bars) in 2022 to 65% (28 bars) in 2023, surpassing the most recent peak in 2016 of 56% (24 bars).

At 15.3%, the 2023 Observed Mortality Index was nearly double that of 2022 (which was the fifth lowest of the 39-year time series), and was the highest mortality index since 2016. Nevertheless, the 2023 mortality index marks the 20th consecutive year that mortalities were below the long-term mean of 21.2%, largely as a consequence of low to moderate disease pressure during that time period. From 2010 to 2023, the average observed mortality of 11.3% approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics. The highest Index-bar mortality was observed on Cooks Point (56.5%) in the Choptank River, followed by Ragged Point (53.2%) in the Little Choptank River.

The Oyster 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. The 2023 Biomass Index was 2.21, the third highest index of the 31-year record. Although this was a 7% decline from the 2022 index, it represents a gain of 58% over the long-term average. The modest decline is attributed to the increase in landings during the previous season. Ten of the last twelve years have had biomass indexes above the 31-year mean.

The Cultch Index is a relative measure of oyster habitat. The three-year rolling average for the 2023 Cultch Index of 0.92 bu/100 ft. was a modest increase over the 2020-22 average of 0.87 bu/100 ft. and similar to the 19-year average of 0.91 bu/100 ft. Strong regional differences in cultch mean volumes were evident. The areas with the lowest standardized cultch averages included the mainstem of the bay, followed by the combined Chester River/Eastern Bay region. The highest cultch indexes were in areas with more favorable recruitment and consequent additions to cultch, specifically the Tangier Sound and Choptank River tributaries, as well as the Patuxent River.

A total of 95 oyster bars within 38 sanctuaries were sampled during the 2023 Fall Survey, including one sanctuary and two bars that were newly added to the survey. Recruitment within three priority sanctuaries (those that have received large-scale restoration) and adjacent open harvest areas was generally well above their respective Key Bar 19-year averages, while Harris Creek sanctuary had a below average spatset and the Little Choptank sanctuary had an about average spatset. Increasing trends in disease and mortality were in keeping with the baywide results. Of the thirteen sentinel Disease Bars within oyster sanctuaries, eleven bars had dermo disease prevalences and eight of those had intensities above their 34-year site averages. The average dermo disease levels in these sanctuaries this past year rose to 85.5% prevalence and 2.9 intensity. Average dermo disease levels in the comparison harvest areas also increased to 61.5% prevalence and 2.1 intensity. MSX disease was detected at two of the five priority sanctuaries and eight of sixteen other sanctuaries. In addition, MSX disease was found at twenty-one of thirty Disease Bars in open harvest areas, as well as one of two supplemental monitoring sites. The average MSX disease prevalence for all sanctuary disease samples was 11.6%, while it was higher at 19.0% for all harvest area disease samples. Regional observed mortalities in sanctuary bars were similar to their proximal open harvest bars. The distributions of oyster biomass between the two management areas were distinctly different. Oyster biomass in the sanctuaries continues to outpace that of the open harvest areas. The Biomass Index bars in the sanctuaries had higher biomass in the larger size classes and a higher total overall, while the open areas had greater biomass in the sublegal and smaller market size classes. The 2023 average biomass index in the sanctuaries was considerably higher (+88%) than the baywide 31-year average, indicating population growth over time.

The priority restoration sanctuaries were compared with adjacent open areas. The sanctuaries had higher recruitment to varying degrees, except for the Tred Avon sanctuary and Broad Creek harvest areas. The highest spat counts of any of the comparison areas was in St. Marys sanctuary, which averaged 399 spat/100 ft. tow and was more than twice as high as the open area. Aside from the Tred Avon River, the number of adult (small and market) oysters per 100 ft tow in the priority sanctuaries was consistently higher than in adjacent harvest areas, collectively averaging over twice as many adult oysters in the sanctuaries as their respective open areas (not including Broad Creek). The St. Marys sanctuary had the greatest average number of adult oysters of any area in this comparison, with 1,128/100 ft. tow. Broad Creek, historically one of the highest oyster producing regions in Maryland, averaged the second highest number of adults, thanks to the extraordinary spatset in 2020. There was little difference in the average regional mortality between the restoration sanctuaries and the corresponding harvest areas. Excluding Deep Neck bar in Broad Creek, which had the highest biomass of these areas, the biomass on the sanctuary Index bars was more than twice as high as their respective open area Index bars. Cultch, the substrate required for spatset, was at higher densities in all of the restoration sanctuaries but the Tred Avon compared to their adjacent open harvest areas.

Commercial oyster landings during the 2022-23 season were the highest in 36 years (1986/87 season). With reported harvests of 720,000 bushels, oyster landings were 31.3% higher than the previous harvest season (546,000 bushels), the fourth year in a row of increased harvests, and were well above the 38-year average of 310,000 bu/yr. The average reported price also rose 8.9% to $43.22/bu from $39.68/bu in 2022. This combination of larger harvest and higher price per bushel resulted in a 43% increase in the total dockside value from $21.8 million in 2022 to $31.1 million in 2022. Power dredging accounted for 48% of the landings, mainly from the lower Eastern Shore and Choptank regions. Patent tongs were the second dominant gear type, harvesting 32% of the total. The Tangier Sound region was by far the leading production area with 67% of the Maryland landings. The Choptank region followed with 13% of the landings, primarily from Broad Creek. The Patuxent River also produced well above average harvests, accounting for 11% of the total landings.

An ancillary spring dredge survey was conducted in 2024 to address four questions related to the findings of the 2023 Fall Survey: 1. Compare spat counts between the fall and the following spring to determine whether spat were underreported in the fall due to a late set just before or even after the survey. 2. Determine whether there was an increase in observed mortalities post-Fall Survey. 3. Investigate the persistence of MSX disease in response to falling salinities over the winter. 4. Compare adult (>1-year old) oyster densities at the beginning of the harvest season in the fall and after the season closes in the spring.

The survey took place between 25 April and 2 May 2024. A total of 33 locations were sampled from three major harvest regions: Tangier region, lower Patuxent River, and Choptank region. Samples for MSX disease analyses were obtained from three disease sentinel sites.

Spat counts were similar between the fall and spring surveys and does not justify adding a spring survey component in the future solely to assess spatfall. The Fall Survey spat counts are an appropriate reflection of recruitment and are consistent with the existing 39-year data set.

The prevalence of MSX disease dropped by varying amounts between the fall and spring surveys at the three sentinel sites, depending on the degree of decline in salinity during the winter and spring of 2024. With salinities marginal for MSX at Piney Island East in Tangier Sound, the prevalence declined somewhat by the spring, from 40% down to 26%. In contrast, salinities fell well below the tolerance limit of the pathogen at the two Choptank region sentinel sites. Consequently, Royston experienced a huge drop in MSX prevalence between the fall and spring, from 67% to 7%. But the most dramatic change was on Lighthouse, where prevalences plummeted from a record-high 93% to 0% in the spring.

Average observed mortalities increased considerably after the Fall Survey in the Patuxent River (22% to 37%) and Choptank region (21% to 40%), but were actually lower in the Tangier region (26% to 19%). Two hypotheses have been offered to explain the generally lower observed mortalities in the Maryland oyster populations over the past two decades – the development of resistance/tolerance to the disease or favorable salinities which inhibited *H. nelsoni*. These findings suggest that both are correct, depending on the salinity regime and frequency of exposure to MSX disease pathogens.

Market oysters showed steep losses in numbers/bu between the fall and spring surveys in all three areas, ranging from 31.7% in the Tangier region to 67.2% in the Choptank region. Thus, the ratio of sublegal oysters to market oysters increased between the fall and spring as the number of small oysters became more abundant relative to the market oysters. The declines are attributable to harvesting and disease-related mortalities.

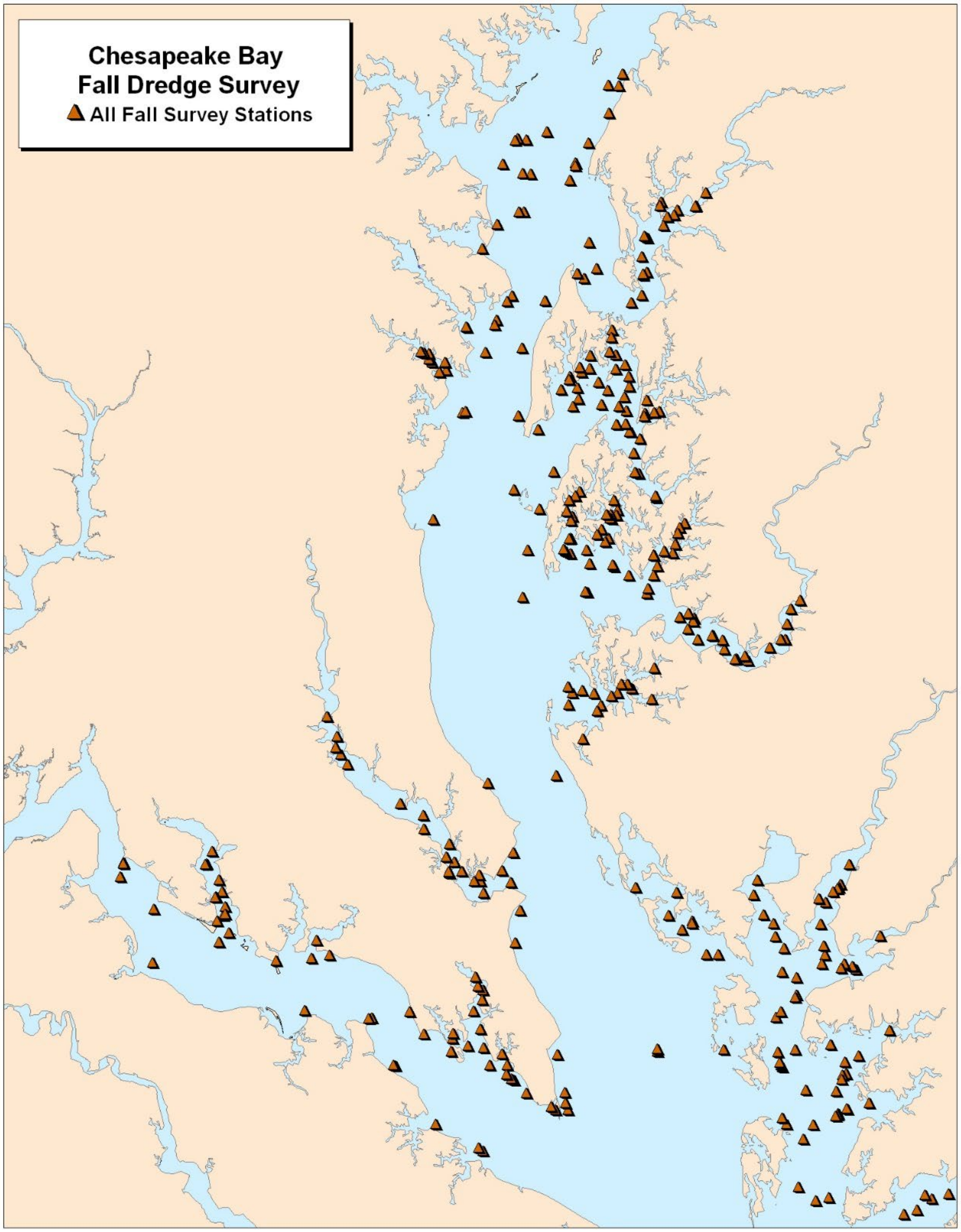

Figure 1a. 2023 Maryland Fall Survey station locations, all bar types included (Standard, Key, Disease, Seed).

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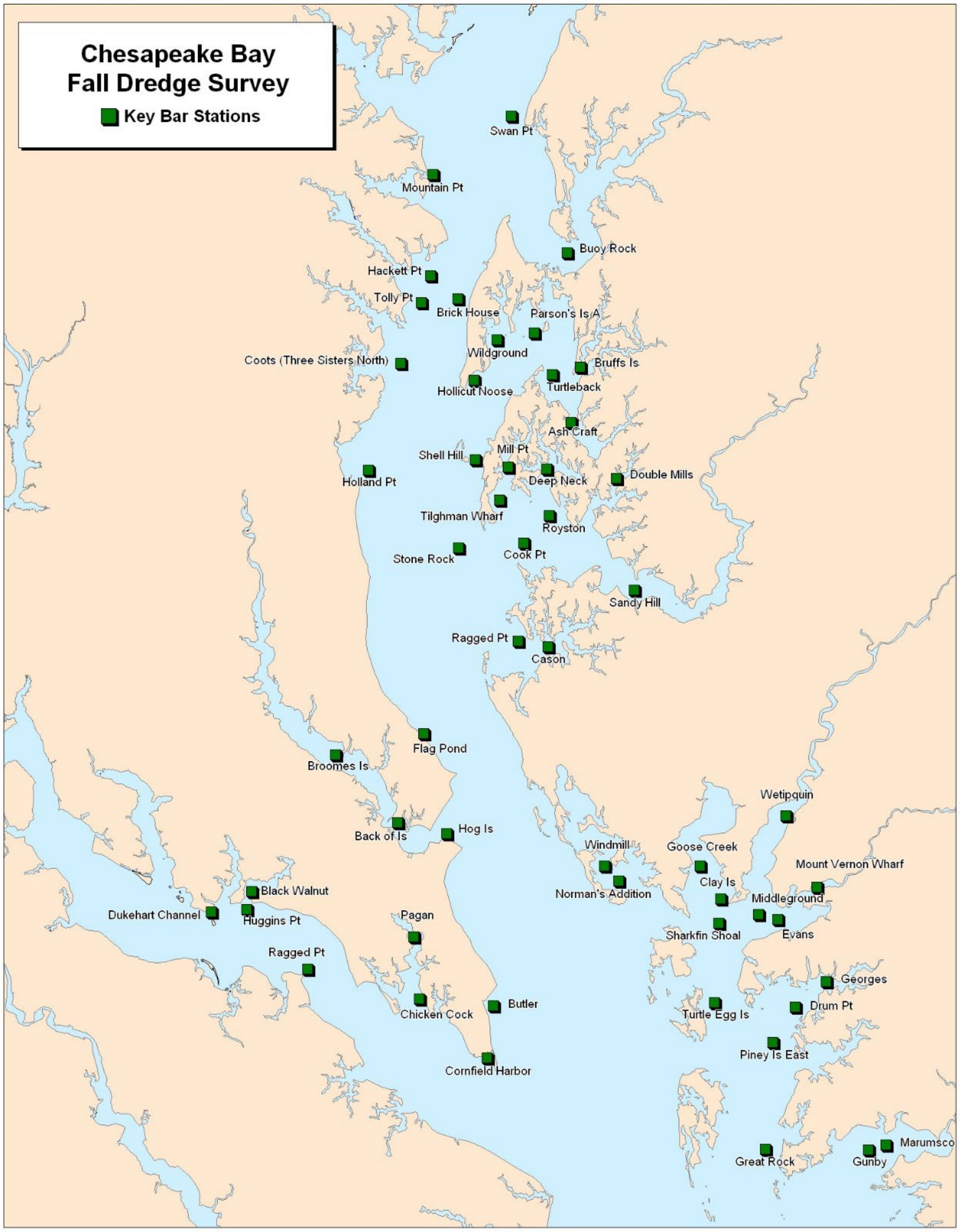

Figure 1b. Maryland Fall Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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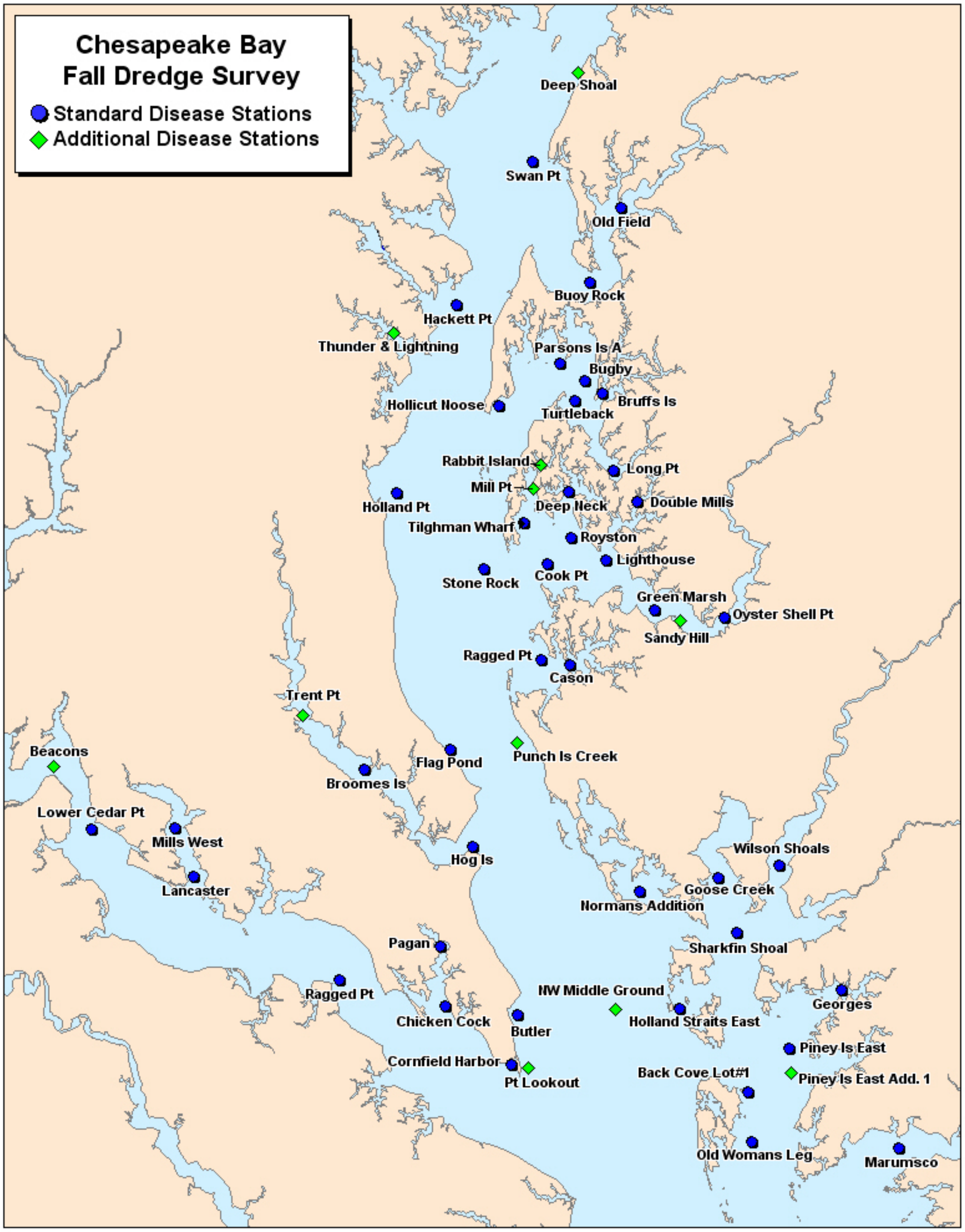

Figure 1c. Maryland Fall Survey standard Disease Bar monitoring locations and additional disease sample stations. Disease samples could not be obtained from the supplemental sites at Deep Shoal and Beacons in 2023.

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INTRODUCTION

Since 1939, a succession of Maryland state agencies have conducted annual dredge-based surveys of oyster bars. These oyster population assessments have provided biologists and managers with information on spatfall intensity, observed mortality, and more recently on parasitic infections, biomass, 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 (Appendix 1), dredged and fresh shell plantings, and sanctuaries.

Since this survey began, several changes and additions have been made to develop structured indexes and statistical frameworks while preserving the uninterrupted integrity 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 & 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 disease indexes were developed using standardized parasite prevalence and intensity data from a fixed 43-bar subset (Disease Bar set) (Appendix 2). Thirty-one of the Disease Bars are among the 53 spatfall index oyster bars (Key Bars). Mortality and Biomass Indexes are derived from the Disease Bar set, while a Cultch Index is based on the 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. The Fall Survey continued 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 Program under the 2014 Chesapeake Bay Watershed Agreement, as well as 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, updated in 2021, and is currently being updated again. Disease data collected during the survey are now shared annually in a regional database of molluscan shellfish health hosted by Rutgers University that is intended to facilitate oyster aquaculture along the east coast of the United States. Two direct larval set trials conducted by the Queen Anne's Watermen Association were also examined. A graduate student from IMET accompanied the survey to collect research samples from the Chester River.

METHODS

Field Collection

The 2023 Annual Fall Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources Fishing and Boating Services from 3 October to 15 November. A total of 352 samples were collected during surveys on 281 natural oyster bars (Figure 1a), including Key Bar (Figure 1b) and Disease Bar (Figure 1c) fixed sentinel sites as well as management areas such 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 = 1.3 U.S. standard bu; Appendix 3).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 volume of dredged material per tow was 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 Survey Indices

Integral to the Fall 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. The 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 total number of dead oysters (boxes and gapers) divided by the sum of live and dead oysters (Appendix 3). Although keyed to the Disease Index subset established in 1990, the 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.

Spatfall Intensity Index

The annual Spatfall Intensity Index is the arithmetic mean of spat counts per bushel of cultch from the 53 fixed Key Bars. As such, it does not take into account geographic distribution (i.e., how widespread or concentrated the spatfall is around the bay), whereas the discontinued statistical tiers method did (see Tarnowski 2019, p.14 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%. 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. Medians are generally higher 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 2021. 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), resulting in a poor median:spat index ratio. Understanding the geographic distribution of recruitment in these terms provides a clearer picture of this component of oyster population dynamics.

Oyster Disease Analyses

Representative samples of 30 oysters that were at least one year old were taken at each of 43 Disease Bar sites. An additional nine samples for disease diagnostics were collected from supplemental sites, sanctuaries, and other areas of special interest. Oyster parasite diagnostic tests were performed by Shellfish Health Project 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. A measure of infection intensity that weights the mean intensity by removing uninfected oysters from the computation (zeroes) is also calculated. 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 of oysters 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 1.0 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 2023 Biomass Index is derived from the 2023 Fall Survey data.

Biomass Equations
For **each** monitoring station:
(# post-spat oysters per size class) x (avg. dmw per size class) = total dmw per size class
∑ dmw per size class = total dmw per 1.0 bu station sample

For **all** monitoring stations:
(∑ dmw per 1.0 bu station sample)/43 = annual average biomass value
(annual average biomass value)/(1993 average biomass value) = Biomass Index

Cultch Index
The collection of quantitative cultch data was initiated during the 2005 Fall Survey. During a sampling tow, the distance covered by the dredge while sampling on the bottom is measured using a handheld 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 the total cultch volume by the actual tow distance, which yields the volume per foot of tow distance, and multiplying the result by 100. 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.

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. 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 two-dollar tax on each bushel purchased and an additional one-dollar tax on each bushel exported out of state. These funds are used to plant substrate and oysters back on public fishery bars. 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 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 determines salinity, provides a more synoptic view of baywide conditions and is therefore used as a surrogate for salinity.

Annual Streamflow

According to the U.S. Geological Survey (USGS 2024), the annual average freshwater flow into the Maryland portion of the bay (Sec. "C" in Bue 1968) in 2023 was below the 25th percentile of the long-term normal range (Figure 2a), indicating a drought year.

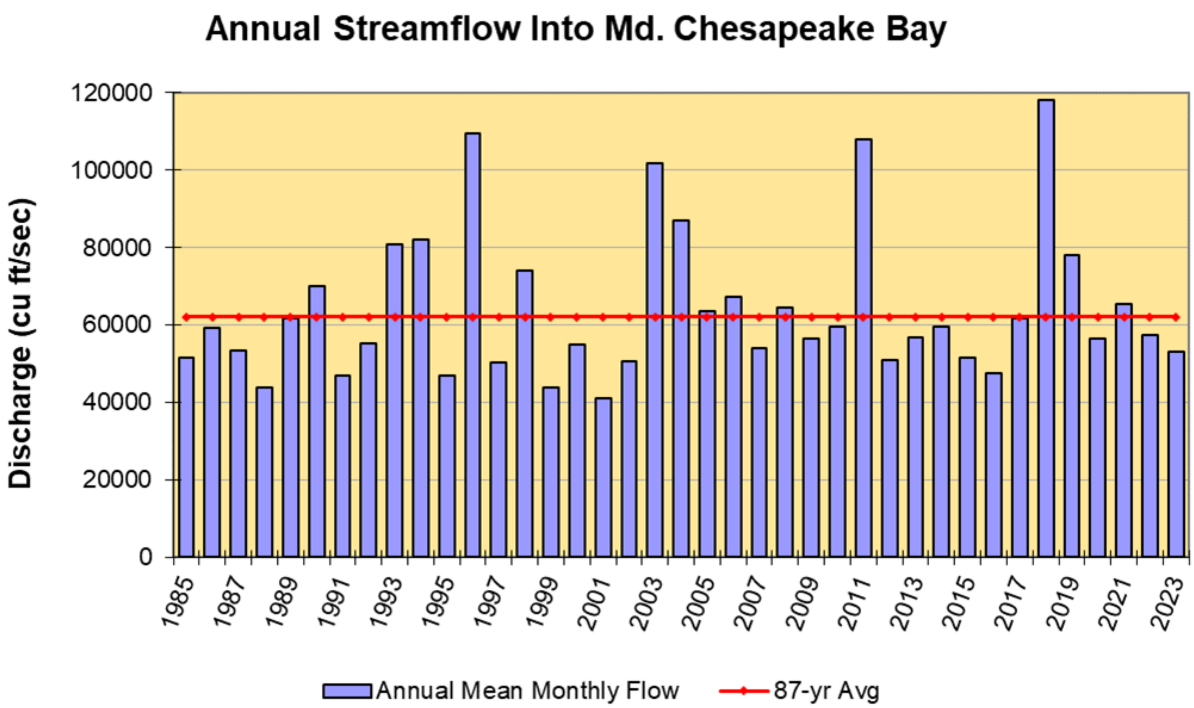

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2023. USGS Section C: all Maryland tributaries and the Potomac River. *Data courtesy of USGS.*

Note that the USGS reports refer to *water* years, which run from 1 October of the previous year to 30 September of the reporting year (USGS 2024). In contrast, this report refers to the *calendar* year.

Monthly Streamflow

Monthly freshwater flows were well below their respective 87-year averages during the winter through the spring and again during the fall, averaging 67% of the long-term mean for those months (Figure 2b). Although streamflows during the three summer months were at or above the long-term mean, they were still relatively low and contributed little to reduce salinities.

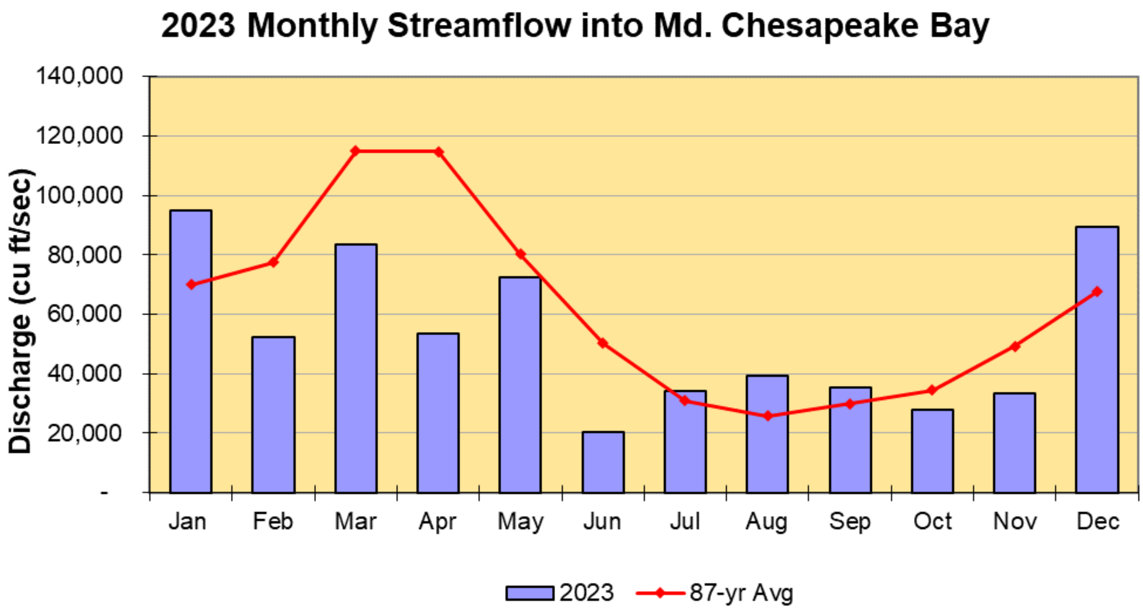

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2023, including the 87-yr monthly average. *Data courtesy of USGS.*

Salinities

Monthly surface salinities for four regions of the Chesapeake Bay in Maryland and one location in the Potomac River during 2023 are shown in Figure 2c (Chesapeake Bay Program). As a consequence of below average streamflows during the first half of the year, salinities were mostly higher than normal throughout 2023. In particular, salinities were more than double the average for April and were 31% higher than the long-term average for the entire year at the Route 301 bridge across the Potomac River. Long-term maximum salinity records at the four representative Chesapeake Bay sites were broken in five of the months. Swan Point in the usually low-salinity upper bay showed some large deviations from the long-term mean, with salinities more than double the means in March and June, surpassing the maximum records for both months. In addition, at this location all of the monthly long-term salinity averages are below 10 ppt but were exceeded during three months of 2023. In addition, each of the other three Chesapeake regions had a record-breaking maximum salinity either in June or July (the South Tangier Sound station was not sampled for salinity in July 2023).

Salinities reached 15 ppt at least as far upbay as the mid-bay station off the mouth of the Choptank River (Figure 2c), a critical threshold above which MSX disease can cause extensive mortalities in oyster populations. All but one of the months in the two representative lower bay stations had surface salinities higher than 15 ppt. Note that surface salinity tends to be lower than bottom salinity, depending on water depth, freshwater input, and water column stratification. The upper bay oyster grounds tend to have larger differences between surface and bottom salinities due to freshwater input at the surface and the tidal intrusion of saltier water at the bottom.

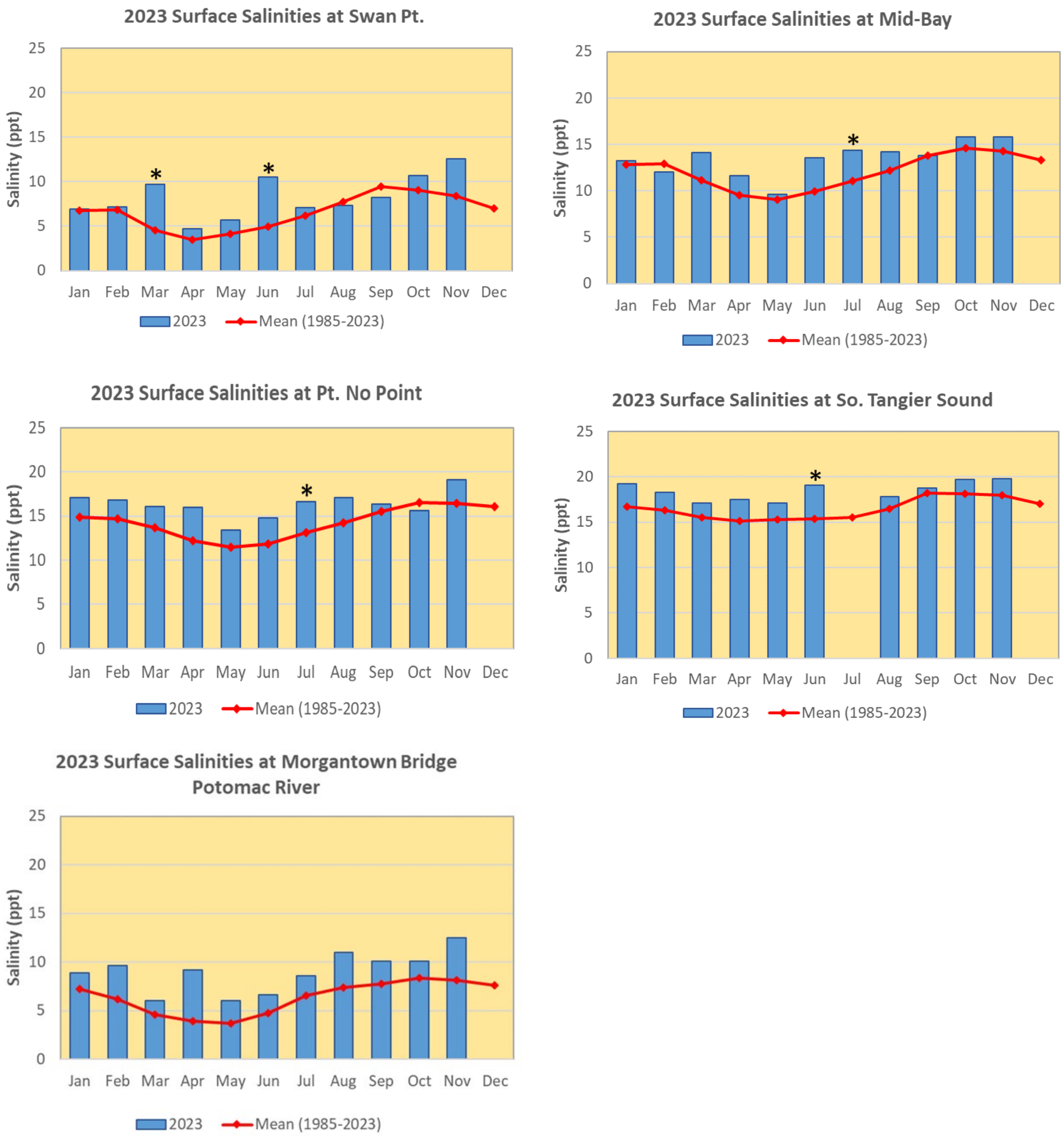

Figure 2c. Monthly surface salinities during 2023 at four monitoring stations along a salinity gradient in Chesapeake Bay and one station in the Potomac River. *Swan Pt. (CB3.2) is in the upper bay, the mid-bay station (CB4.2C) is off the mouth of the Choptank R., Pt. No Point (CB5.2) is in the lower mainstem, and the southern Tangier Sound station (EE3.2) is near the Virginia state line. The Potomac River station (RET2.4) is located at the Route 301 bridge crossing. Sampling was not conducted in December and at EE3.2 in July.* * Record maximum monthly salinity.

SPATFALL INTENSITY

The Spatfall Intensity Index, a measure of recruitment success and potential increase in the population, was 86.8 spat/bu, a 270% increase from the previous year. This was nearly four times the 39-year median of 23.6 spat/bushel and the fifth highest of the time series (Figure 3a). The increase in the overall Spatfall Intensity Index is reflected in the 85% of index bars showing increases from the previous year vs. decreases at 9% of the bars, with the balance showing no change (Table 2). This was the fourth consecutive year the index was above the long-term median, more than tripling that measure in 2023. Eight of the last 14 years have had above-median spat indexes, four of which can be considered exceptional (i.e., about three to five times higher than the long-term median), while only two years during this period were substantially (>25%) below the long-term median (Figure 3b).

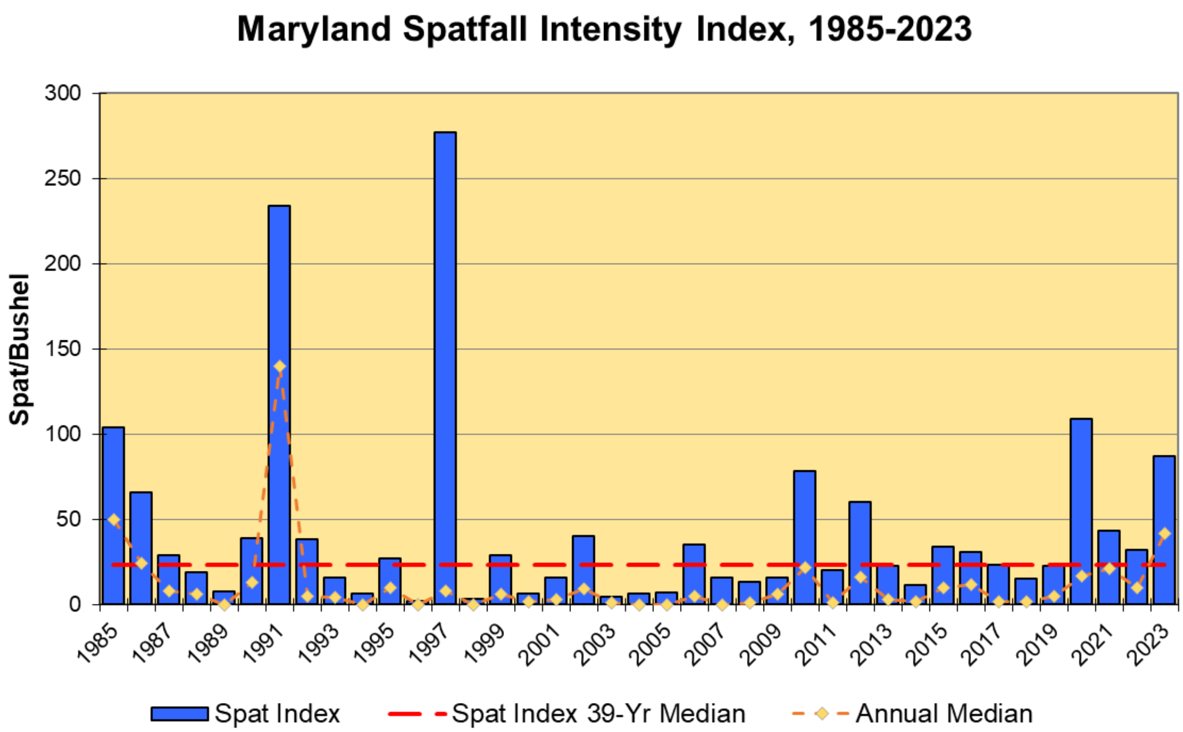

Figure 3a. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including annual median values.

Equally important to the high index was the extensive nature of the spatset. The median of the spatset is an indicator of the distribution of spat – the larger the median, the more widely distributed is the spatset. The median spatset of the Index bars in 2023 was 42 spat/bushel, compared with the long-term average of the medians of 11.9 spat/bushel. In contrast, while the Spat Index in 1997 was the highest in the time series at 277 spat/bushel, the median was only 8 spat/bushel, reflecting the narrow distribution of high spat counts.

Spat were observed on 50 of the 53 Key Bars, the most bars with spat since 1985 (Table 2). As indicated by the annual spatfall median:spat index ratio, the numerical distribution in 2023 was the third highest of the time series, meaning the number of spat were more evenly distributed and widespread among the index bars (Figure 3c). The spat total from ten bars accounted for 50% of the index (the highest since 1985), compared with three bars in 2022; while in 2023, 34 bars contributed to 95% of the spat index, an increase from 25 bars in 2022. The remaining 19 bars comprised just 5% of the Spat Intensity Index, but even so averaged 11.1 spat/bu, a respectable number in areas that ordinarily don't receive much if any spat. Deep Neck bar in Broad Creek had the highest count of the Index bars with 371 spat/bu, or 8% of the entire 2023 Spat Index, another indication of the more evenly distributed numbers, compared with Pagan bar the previous year, which dominated the 2022 Spat Index with 28% of the counts.

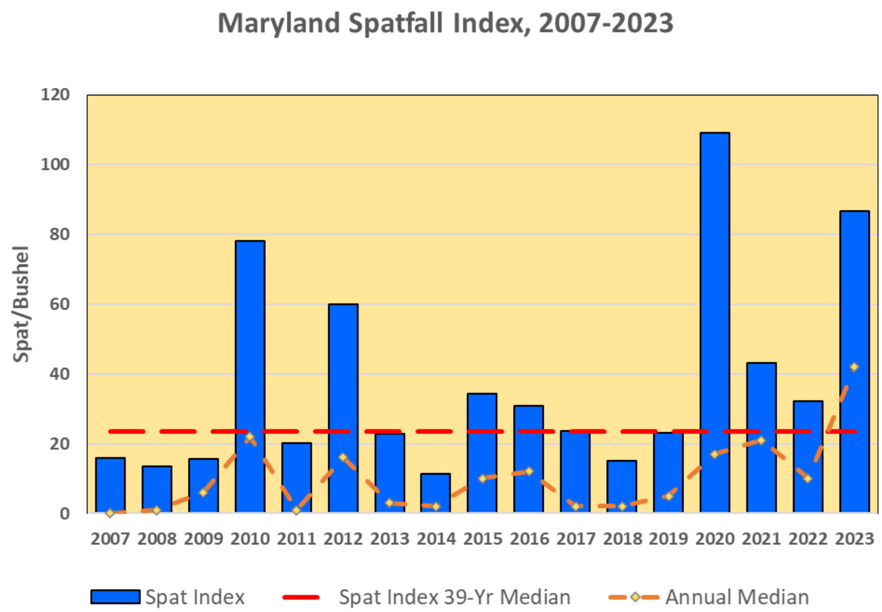

Figure 3b. Recent Maryland spatfall indices, 2007-2023, including annual median values.

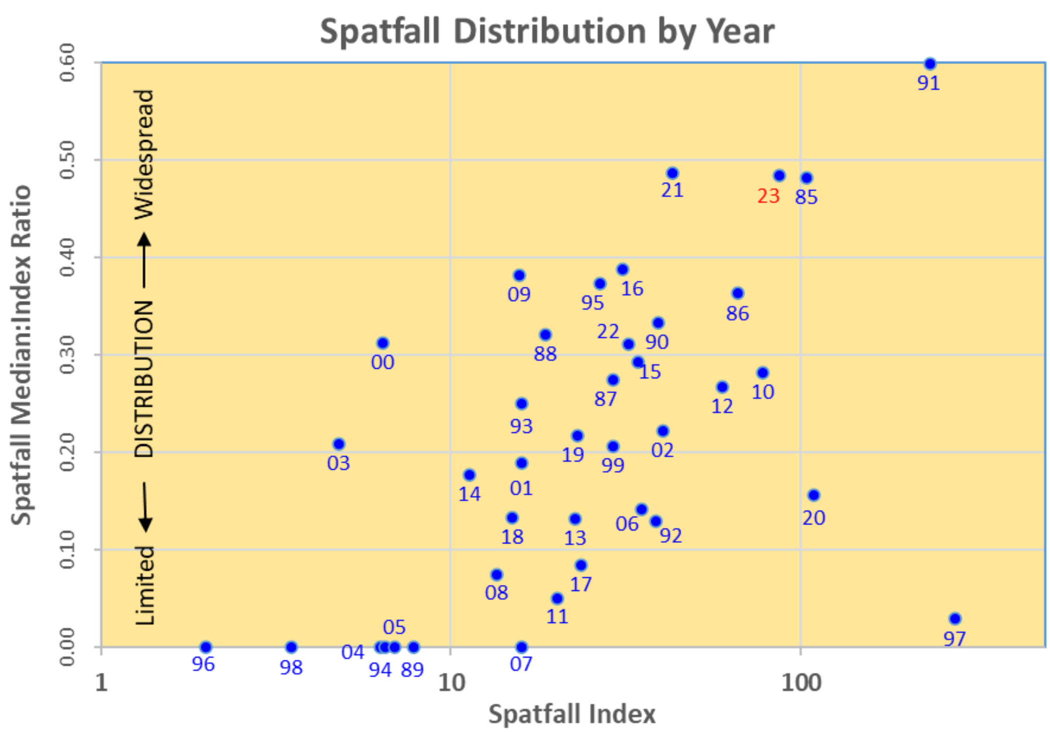

Figure 3c. Spatfall median:index ratios for the years 1985 to 2023 as denoted by "85" to "23" on the chart. The ratio measures the geographic distribution of spat counts for a given year. A lower ratio indicates that the spat counts are concentrated on fewer index bars, while a higher ratio indicates the numerical distribution of spat is more evenly spread among the index bars.

When considering all bars surveyed in addition to the Key Bars, the highest recruitment was observed throughout southern Maryland (Figure 4). Notably, the Potomac River and some of its Maryland tributaries received a once in a generation spatfall. A supplemental survey in the Potomac (not shown on map) found numerous spat well above the Route 301 bridge, an area which rarely receives a spatset and where oysters had been extirpated by the devastating freshwater deluges of 2018-19. The north shore of the lower Potomac River led all regions, averaging 288 spat/bu, followed closely by the lower mainstem east of the channel with 285 spat/bu. Twelve other regions had recruitment averages greater than 100 spat/bu including the Honga River (227 spat/bu), Tangier Sound (214 spat/bu), lower Patuxent River (213 spat/bu), Manokin River (180 spat/bu), lower Choptank River (164 spat/bu), Fishing Bay (157 spat/bu), lower south shore of the Potomac River (143 spat/bu), Tred Avon River (135 spat/bu), Broad Creek (131 spat/bu), and the St. Marys River (118 spat/bu). Moderate spatsets were observed in the upper reaches of several tributaries where recruitment tends to be much lower and more sporadic, including the Patuxent, Nanticoke, Potomac, western Wicomico, and Choptank rivers, and Breton Bay. The only regions where no spat were found were the upper bay north of the Bay Bridge and the Chester River.

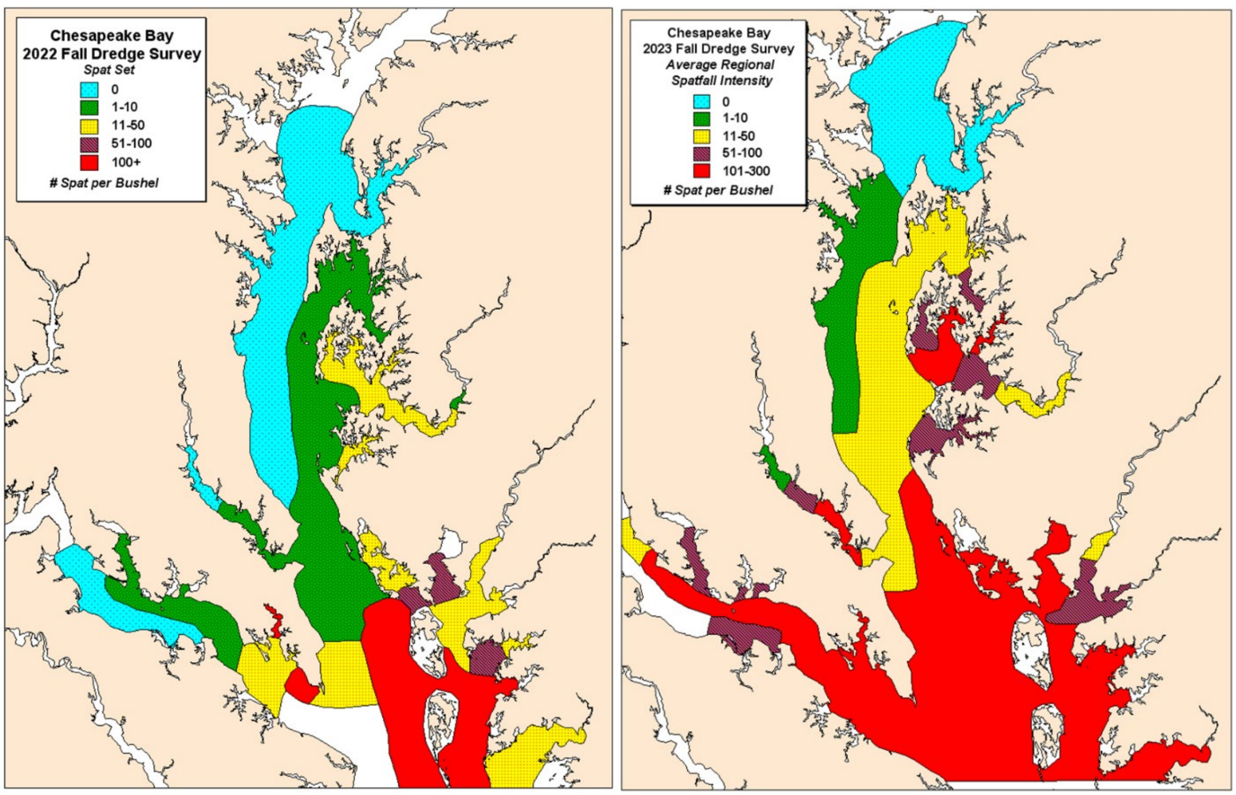

Figure 4. Oyster spatfall intensity and distribution in Maryland, 2022 vs. 2023. Intensity ranges represent regional averages.

OYSTER DISEASES

A total of 1,558 oysters were analyzed for diseases in 2023 – 1,288 from the 43 Disease Bars (sentinel bars) and 270 from nine supplemental sites.

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 from the disease. 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 and has remained widespread throughout Maryland ever since.

Dermo disease increased in 2023 from the preceding year (Figure 5). The disease was found throughout most of the bay and tributaries, being detected in oysters on 98% of the Disease Bars and supplemental sites (Figure 6). This is in contrast to 2020 when it was found at 84% of the bars, the lowest frequency since the 43-bar subset was standardized in 1990 (Table 3). From 2019 to 2021, the percentage of individual infected oysters have been the lowest on record, but since 2022 the overall mean **infection prevalence** in oysters sampled on the Disease Bars has increased substantially to 67% in 2023, compared to 36% in 2021; this was the highest average prevalence in the last six years (Figure 5). This marks the fourth of the last 21 years that dermo disease mean prevalences have exceeded the long-term average since the record high epizootics at the turn of the millennium.

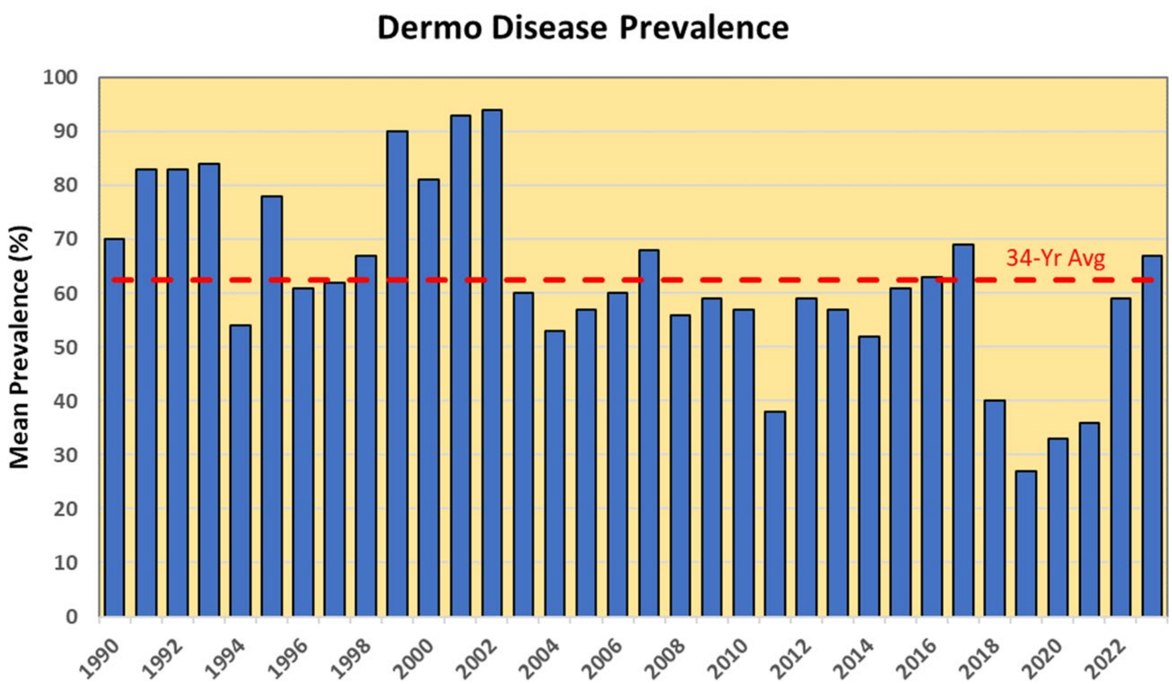

Figure 5. Annual mean *P. marinus* prevalences from Maryland disease monitoring bars.

The number of samples exhibiting high prevalences (>60%) has increased substantially over the last four years from 19% of the Disease Bars in 2020 to 53% 2022, and was even higher in 2023 at 67%. (Table 3, Figure 6).

Outside of the regular disease monitoring sites, dermo disease was found at all nine of the supplemental sites, with prevalences greater than 60% at eight of the bars, compared to seven bars in 2022 and four bars in 2021. The two supplemental bars furthest upstream, Deep Shoal in the mainstem and Beacon bar in the Potomac River (Figure 1c), once again were not sampled for disease in 2023 because of the absence or low densities of oysters due to freshet-related mortalities in 2018/19.

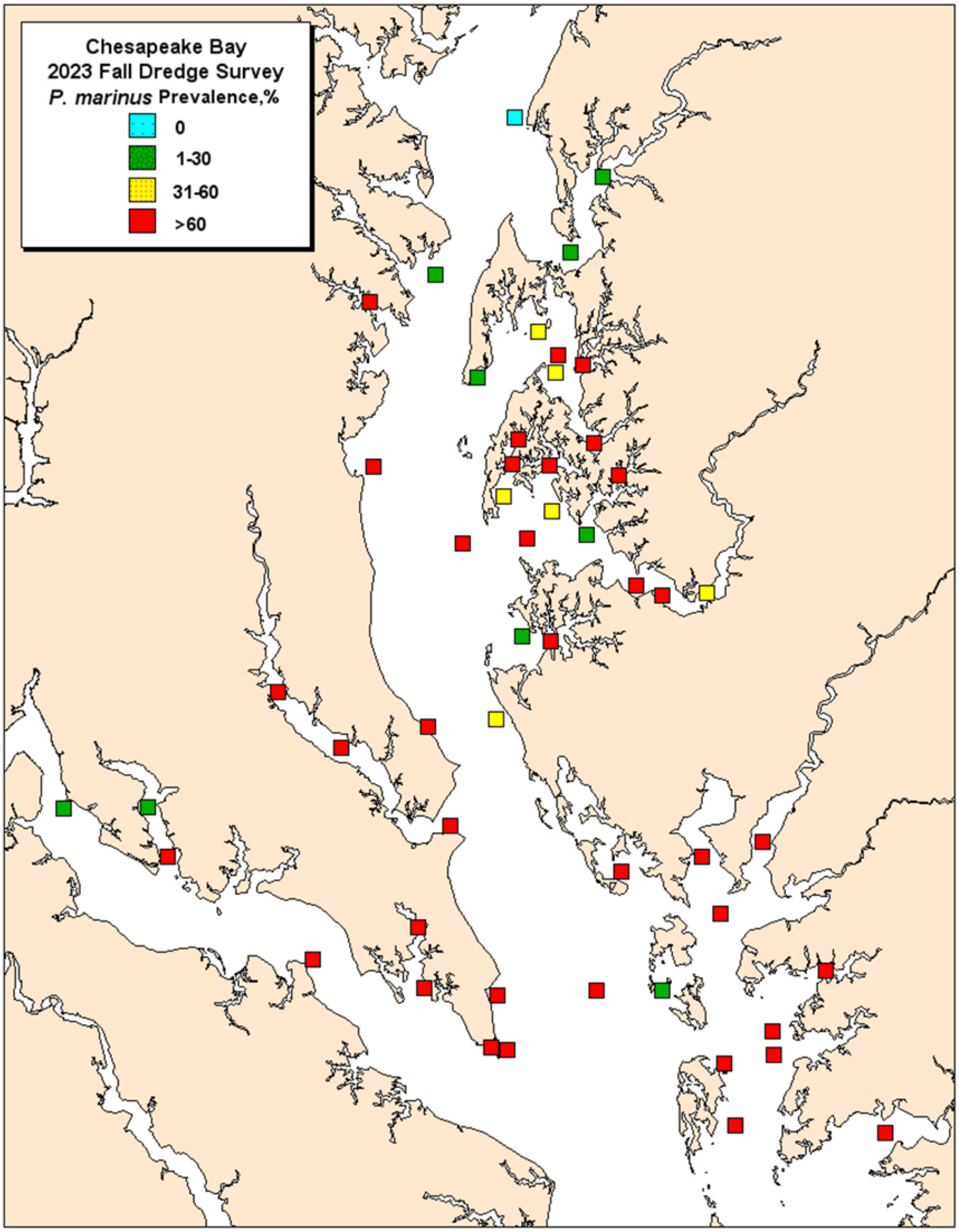

Figure 6. Geographic extent and prevalence of dermo disease in all disease samples, 2023.

The trend in the mean **infection intensity** for dermo disease also increased in 2023, exceeding the long-term average for the first time since 2016 and the fourth time in 21 years following the millennial epizootic (Figure 7). The 2023 mean infection intensity (2.28 on a 0-7 scale) was

31% higher than in 2022 (1.74) (Table 3). The average infection intensity over the 21 years since the end of the 1999-2002 drought is 1.8. In comparison, the annual infection intensities during this drought period averaged 3.4, which contributed to historically high mortalities.

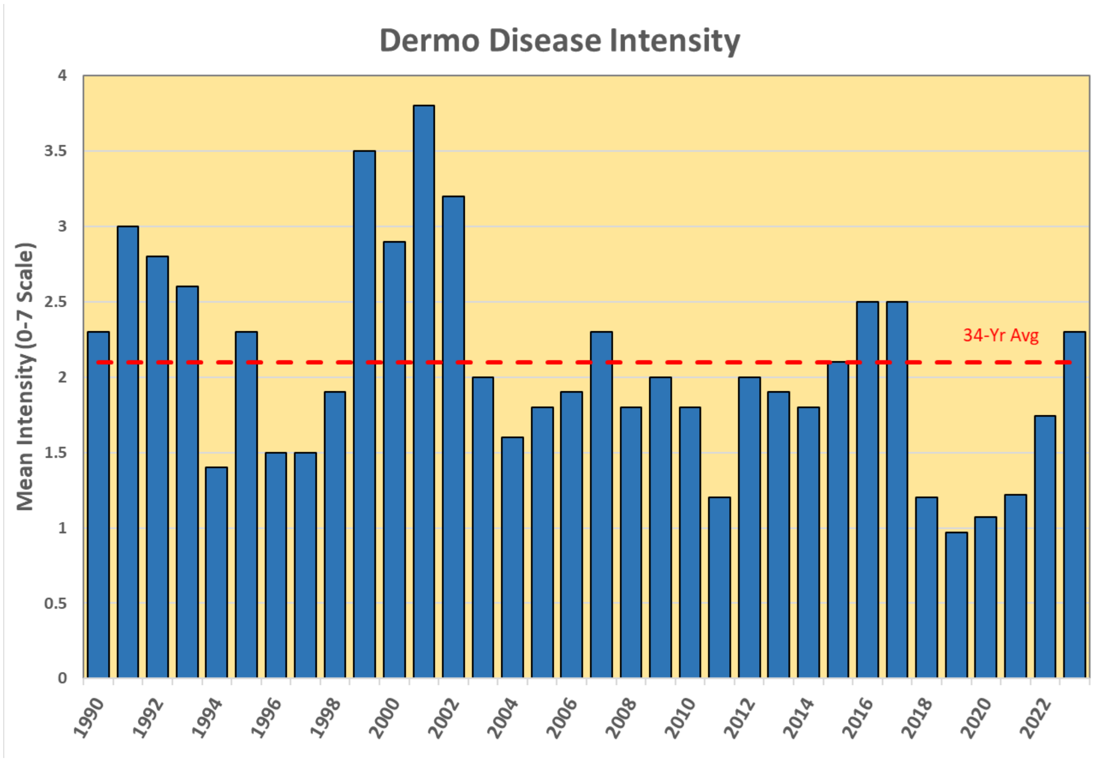

Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars.

The 2023 frequency distributions of sample mean infection intensities on the Disease Bars shifted substantially to the high range (Figure 8). In 2023, 17 of the sentinel bars (40%) had a mean intensity in the high range (3.0 or greater), compared to 21% in 2022 and only one bar (2%) in 2021. Consequently, the proportion of bars that were in the lowest intensity categories of zero and less than 1.0 dropped to 28% in 2023, compared to 35% in 2022. Meanwhile, the proportion of bars in the moderate intensity (1.0 to <3.0) range also decreased, from 44% in 2022 to 33% in 2023. However, for perspective, dermo disease intensities for the entire population remain much lower than during the millennial epizootic. 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. Four of the nine supplemental bars had mean infection intensities of greater than 3.0 in 2023 compared to two in 2022.

The geographic distribution of intensity ranges for both Disease Bars and supplemental sites are shown in Figure 9. The majority of the highest intensities were detected in southern Maryland as far north as the Choptank River and noticeably in several of the tributaries. On the Western Shore in particular, high intensities reached all the way up to the mid-Patuxent River and the Potomac River to the western Wicomico River. The occasional juxtaposition of high intensity samples with nearby low intensity samples is noteworthy, especially in the Choptank River.

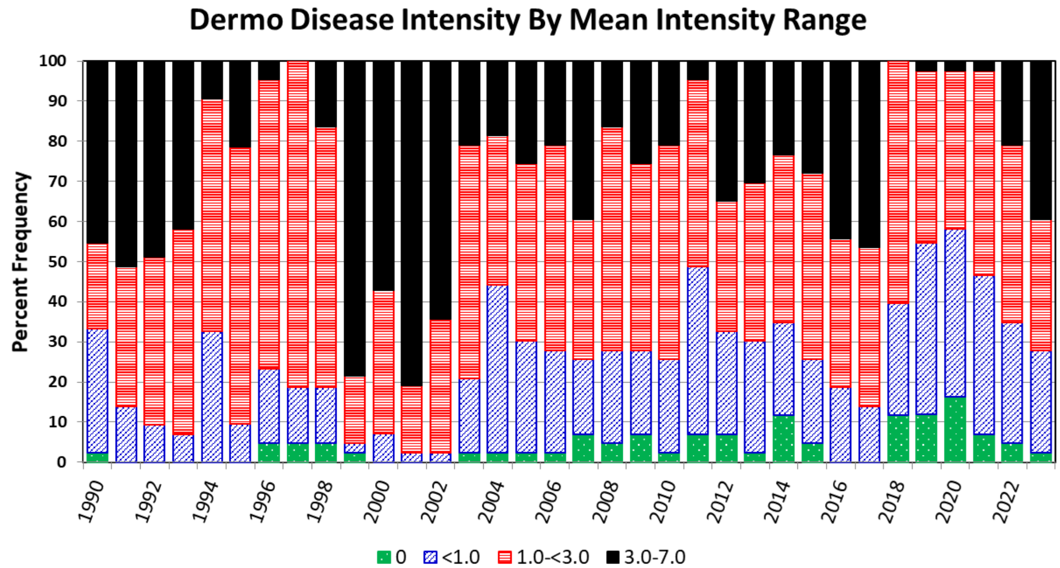

Figure 8. ***Perkinsus marinus*** **infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.**

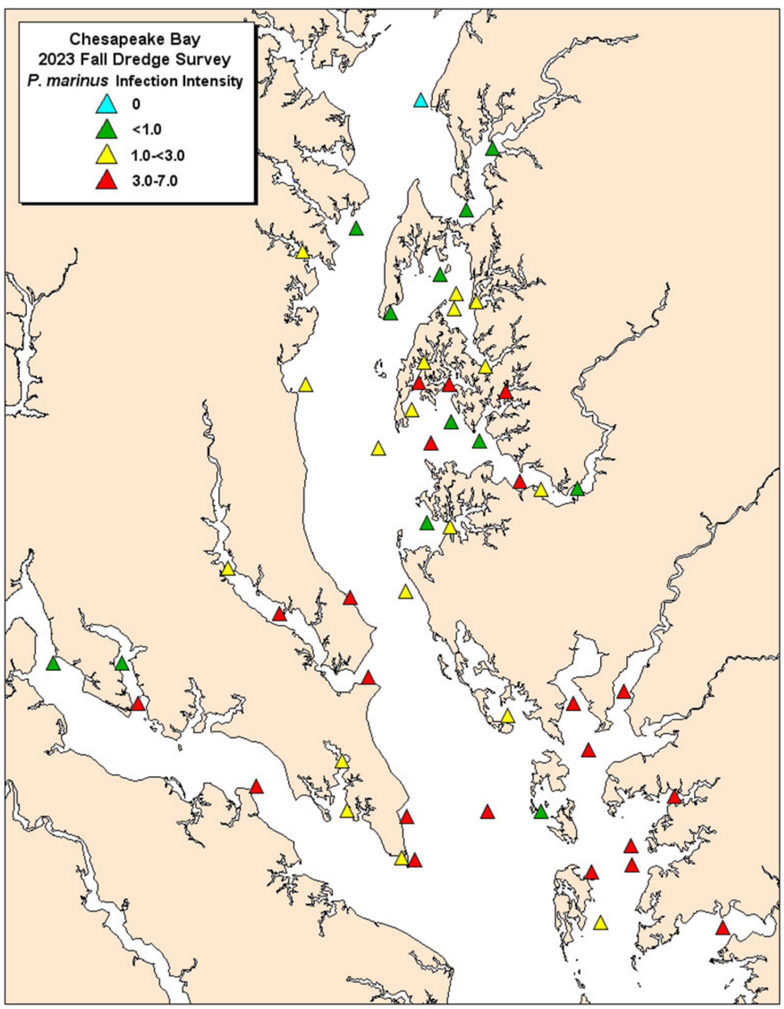

Figure 9. Geographic distribution of ***P. marinus*** **infection intensity ranges in all disease samples, 2023.**

Infection intensities in individual oysters that are ≥5.0 on a 0–7 scale are considered lethal; such infection intensities were found at 86% of the sentinel sites in 2023, an increase from 74% in 2022. However, as a percentage of all oysters sampled from sentinel and supplemental bars, lethal infections were detected in 25% of individual oysters in 2023, double the 12% lethal prevalence in 2022.

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 extremely high, as seen in 2001 and 2002. In Chesapeake Bay, MSX disease is most active in higher salinity waters (>15 ppt) (Appendix 2).

Both the prevalence and geographic range of MSX disease increased substantially on the Disease Bars in 2023. The mean prevalence of infected oysters rose from 1.9% to 17.6%, and was higher than the previous infection peak in 2016 (11.1%). This is the first year prevalences surpassed the long-term average since 2016, ending the trend of below average prevalences at six years, three of which were record lows (Table 4, Figure 9). The prevalences ranged from 3% to 93% on the Disease Bars where MSX was detected. The latter was found on Lighthouse bar in the Choptank River and was the highest recorded prevalence for an individual bar in the 34-year time series.

When considering both the Disease Bars and supplemental sites, the geographic extent of MSX disease expanded throughout the mainstem up to the Bay Bridge and into several of the tributaries (Figure 10). In only one year, the percent frequency of positive Disease Bars increased from 19% (eight bars) in 2022 to 65% (28 bars) in 2023, surpassing the most recent peak in 2016 of 56% (24 bars) (Table 4). MSX was also detected on four of the nine supplemental disease sites, with a high prevalence of 43% on Punch Island Creek in the eastern mainstem. For reference, at its greatest extent the parasite occurred on 90% of the examined bars in 2002.

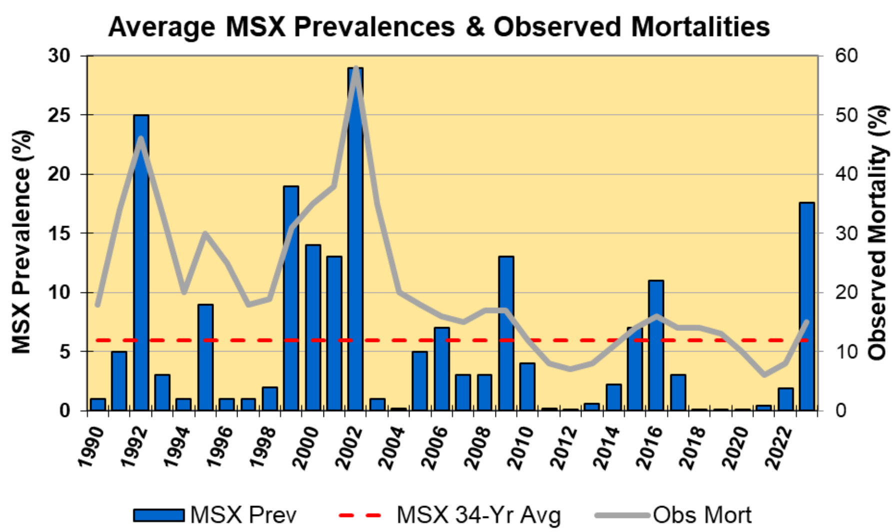

Figure 9. Annual percentage of Maryland oysters with MSX disease compared to 34-year mean and the correlation with observed mortalities on the disease monitoring bars from 1990-2023.

Historically, the abatement of MSX disease in 2003-2004 due to two consecutive years of greatly elevated 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 in conjunction with dermo disease. Since 1990, there have been six *H. nelsoni* epizootics: 1992, 1995, 1999-2002, 2009, 2015-16, and 2023. The first three were associated with prominent spikes in observed mortalities (Figure 9), while the 2009 and 2016 outbreaks were accompanied by modest mortality increases that were ameliorated by timely freshwater flows (Tarnowski 2011). All of these epizootics coincided with dry years (Figure 2a) and consequent elevated salinities. These were followed closely by periods of unusually high freshwater inputs into parts of Chesapeake Bay, which purged *H. nelsoni* infections from most Maryland oyster populations (Homer & Scott 2001; Tarnowski 2005, 2011). The recent six-year period of greatly diminished *H. nelsoni* infections is associated with the extraordinarily high streamflows of 2018 and 2019, followed by a return to normal flows (Figure 2a).

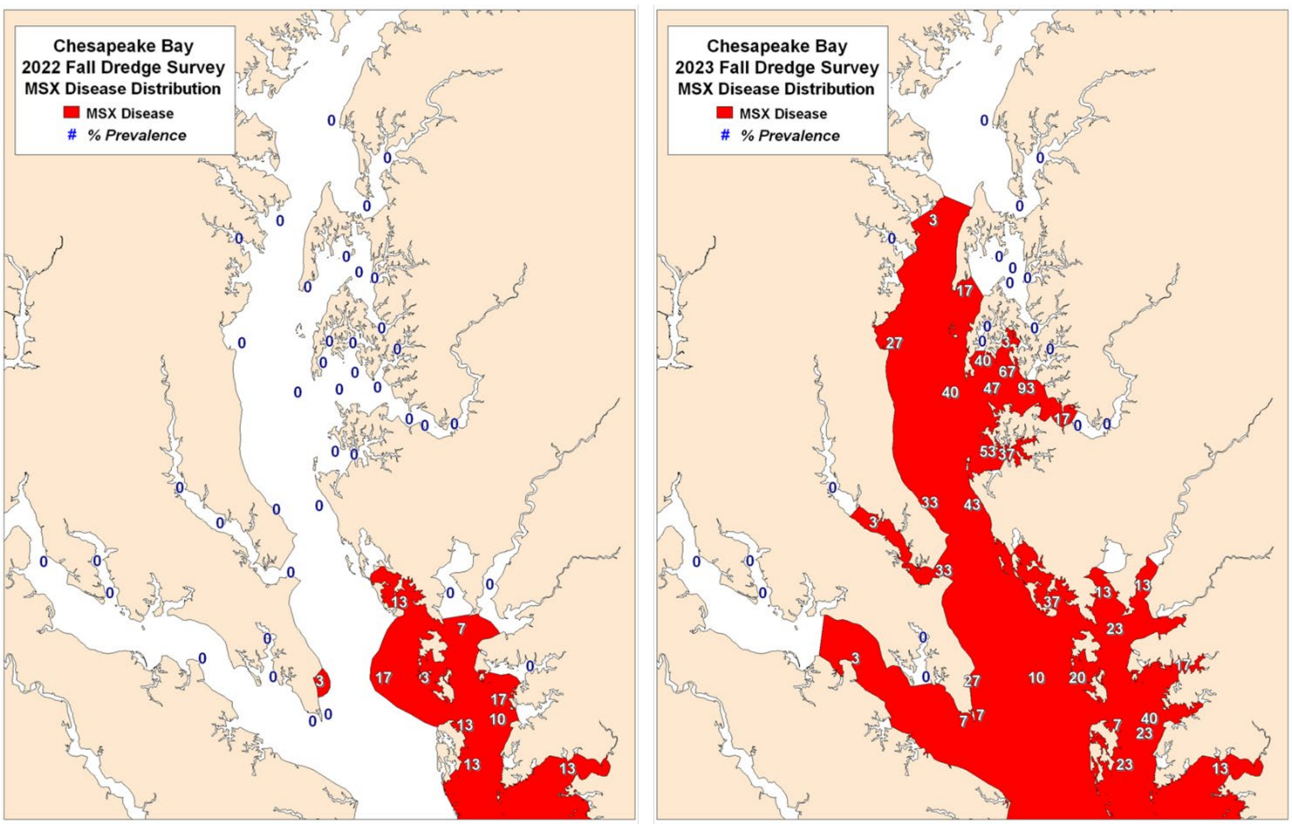

Figure 10. Geographic distribution and prevalence of MSX disease in Maryland waters in 2023 compared with 2022, illustrating how extensively the disease has spread in one year of favorable salinities.

OBSERVED MORTALITY

At 15.3%, the 2023 Observed Mortality Index was nearly double that of 2022 (which was the fifth lowest of the 39-year time series), and was the highest mortality index since 2016 (Table 5). Nevertheless, the 2023 mortality index marks the 20th consecutive year that mortalities were substantially below the long-term mean of 21.2% (Figure 11), largely as a consequence of low to moderate disease pressure during that time period. From 2010 to 2023, the average observed mortality of 11.3% approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (MDNR, unpubl. data). This is in remarkable contrast to 2002 when record-high disease levels devastated Maryland populations, resulting in a 58% observed mortality rate.

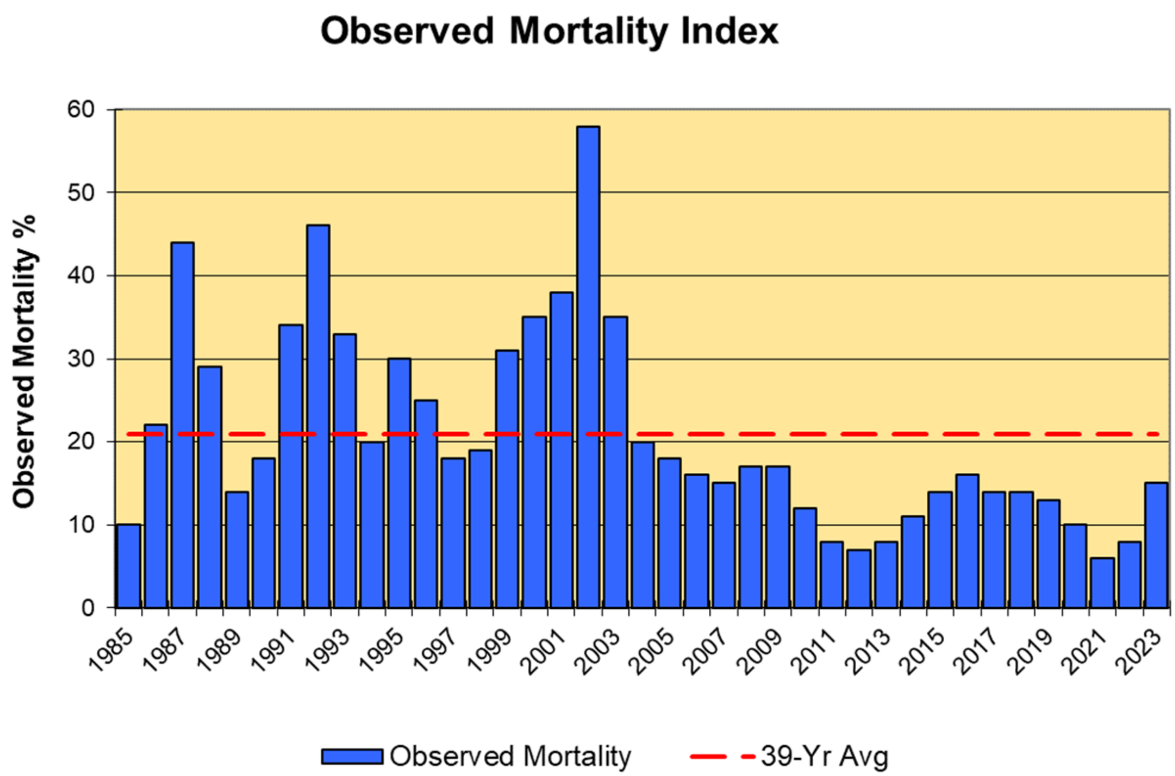

Figure 11. Mean annual observed mortality, small and market oysters combined.

Looking at all Fall Survey sites, observed mortalities were generally moderate over the lower half of the bay. There was a stark break between low mortality and high moderate mortality zones in several areas, especially in some of the tributaries, with little if any low moderate zones transitioning between the two (Figure 12). Tangier Sound, typically a higher mortality area, averaged 24.8%, a sharp increase following notably low observed mortalities for four years in a row, averaging 9.7% in 2022. Nevertheless, this was half of the mortalities in 1999 at the start of the millennial epizootic, when the average Tangier Sound observed mortalities climbed to 48.0%. The highest Index-bar mortality on bars with 40 or more small and market oysters was observed on Cooks Point (56.5%) in the Choptank River, followed by Ragged Point (53.2%) in the Little Choptank River (Table 5). For non-index bars with 40 or more oysters older than one year, the highest observed mortalities were on Evans (48.2%) in the eastern Wicomico River, Susquehanna (43.1%) in the Little Choptank River, and Ware Rock (43.1%) in Pocomoke Sound.

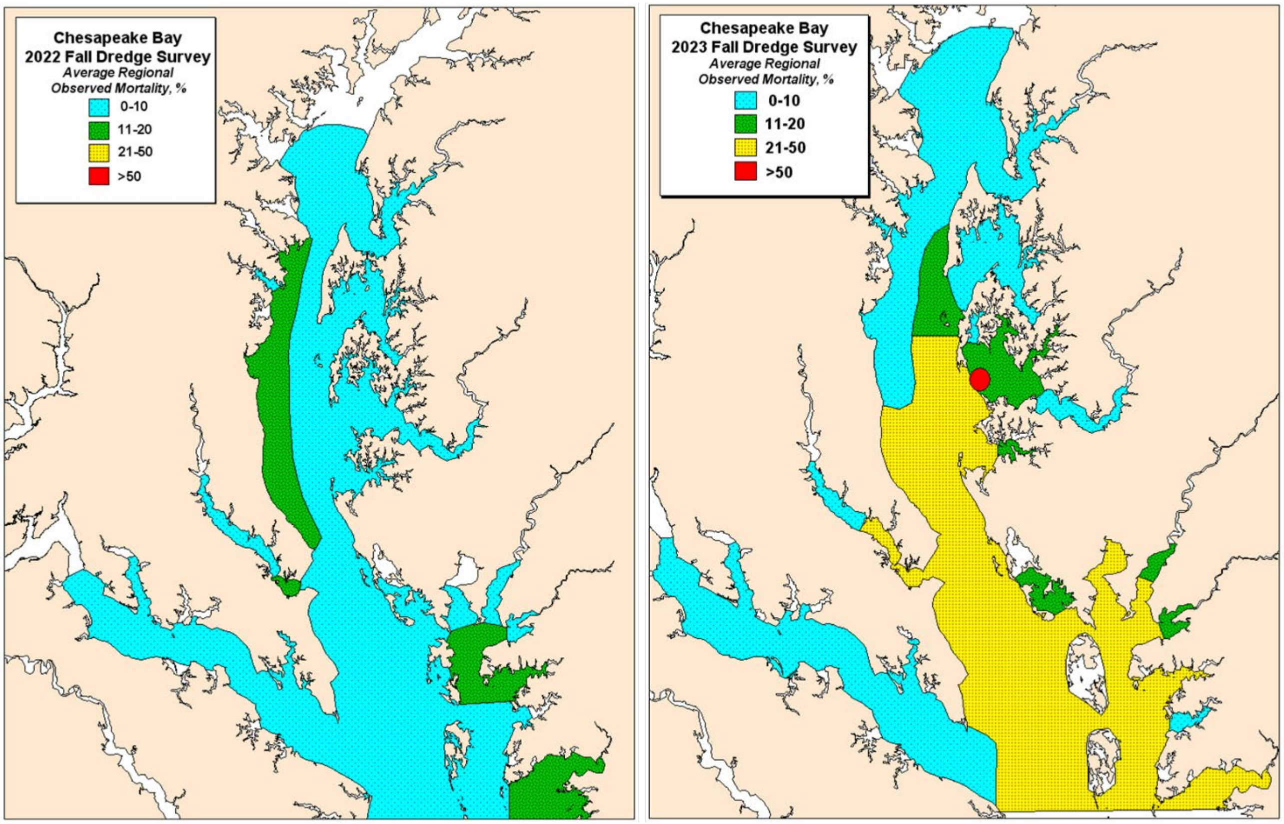

Figure 12. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2022 vs. 2023. Mortality ranges represent regional averages; individual bars may vary substantially.

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 2023 Maryland Oyster Biomass Index was 2.21, the third highest index of the 31-year record (Figure 13). Although this was a modest 7% decline from the 2022 index, it represents a gain of 58% over the long-term average. While the index has trended downward slightly from the peak index in 2021, the last three indexes have been the highest in the time-series. Ten of the last twelve years have had biomass indexes above the 31-year mean.

The size distribution of index bars had about equal numbers of small and market oysters at a ratio of 0.98 sublegals to one market oyster, compared with the sublegal to market ratio of 1.07 in 2022 and 1.13 in 2021. This can also be expressed as the percentage of sublegal oysters: 49.5% in 2023, slightly down from 51.7% in 2022 and 53.0% in 2021. This shift is reflected in the slight increases in average size of index bar oysters, from 74.6 mm in 2021 and 75.9 mm in 2022 to 76.8 mm in 2023. As expected, the slight increase in the average oyster size should 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 per sample dropped from 163.8/bu in 2021 to 137.7/bu, then to 125.7 in 2023, a 23.3% drop over two years. The large influx in the number of small oysters in the recent years and the slight increase in average size in 2023 was outweighed by the large increase in harvest (as related in a following section), which accounts for the decrease in the Biomass Index over the last two years.

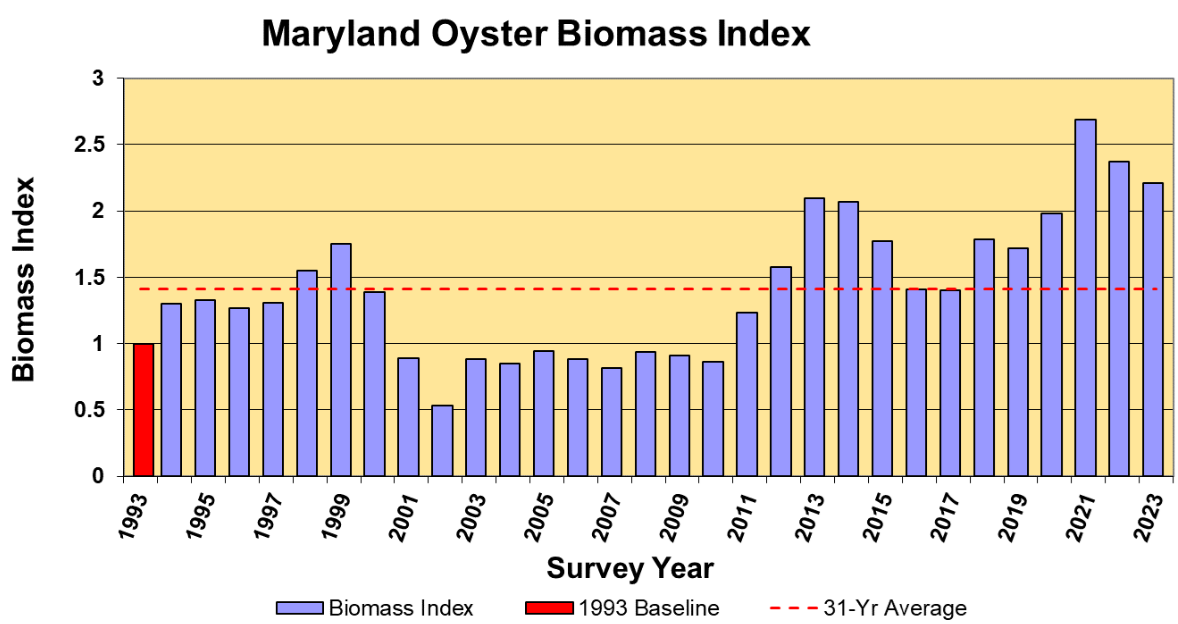

Figure 13. Maryland oyster Biomass Index. The year 1993 represents the baseline index of 1.0.

The oyster population had been slow to recover in the decade after its nadir in 2002, the last year of the devastating four-year disease epizootic. The Biomass Index remained below 1.0 for eight consecutive years despite low disease pressure and high oyster survivorship over this period.[1] 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. Since then, the Biomass Index has been at or above the long-term average in each of the last twelve years. With the strong spatsets of the last four years and ongoing restoration efforts in the sanctuaries, the index should continue to improve in the near future, depending on disease-related mortality remaining low, populations in the sanctuaries continuing to grow both in numbers and shell height, and the number of oysters removed by harvesting as these cohorts attain legal size.

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

CULTCH INDEX

The Cultch Index is a relative measure of oyster habitat; because the dredge is less than 100% efficient, the index is not an absolute measure of cultch. 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 Survey, cultch is defined as primarily both live and dead oysters plus loose shell combined. The collection of quantitative cultch data was initiated during the 2005 Fall Survey. 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) and assist in following trends.

The three-year rolling average for the 2023 Cultch Index of 0.92 bu/100 ft. was a modest increase over the 2020-22 average of 0.87 bu/100 ft. and similar to the 19-year average of 0.91 bu/100 ft. (Figure 14). However, some individual bars showed steep declines. Of the 53 bars used in this analysis, 13 had standardized volumes that were less than 75% of their respective 19-year averages (Figure 15).

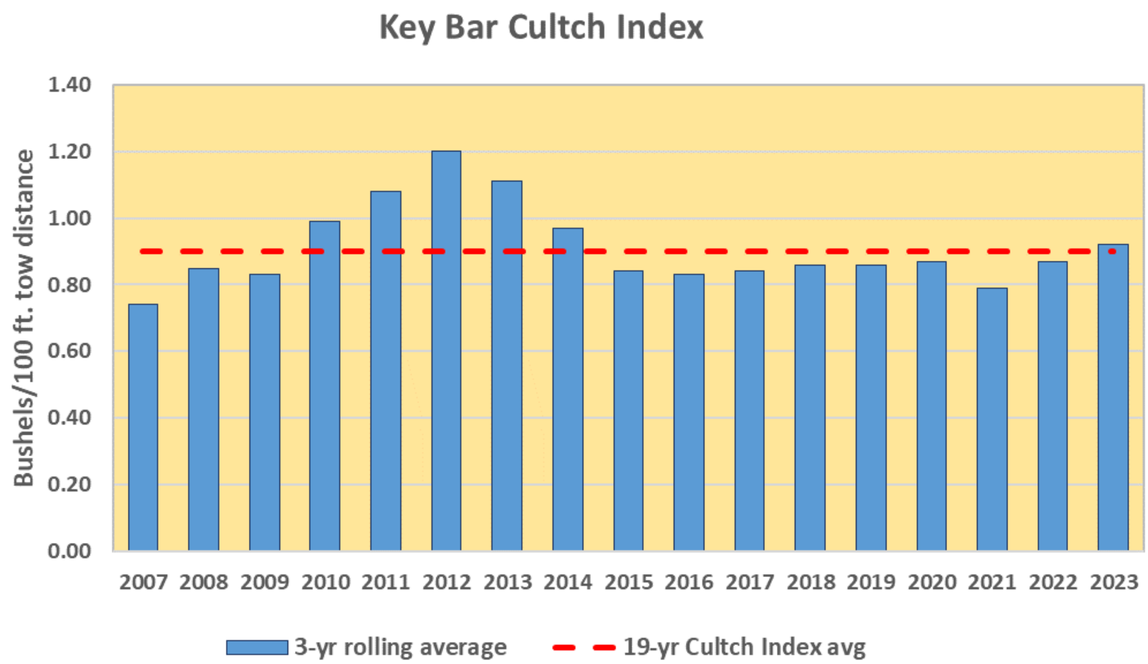

Figure 14. Three-year rolling average of annual means for the Key Bar Cultch Index, 2005-2023. The average is represented by the third year of the grouping (e.g., the 2005-07 average is graphed as 2007).

Although 19 years is a comparatively short time frame for discerning long-term trends in the Cultch Index, a distinctive pattern emerged over this period (Figure 14). The increase in the Cultch Index during the early 2010s reflects improvements in recruitment and survivorship during that period, especially the strong spatsets in 2010 and 2012 (Figure 3b). The growth and high survivorship of these year classes contributed substantially to the index. The subsequent decline may be due to harvesting and inconsistent recruitment, as well as ongoing taphonomic processes such as shell burial and degradation. The more recent rise in spatsets have been sufficient to maintain but not increase the index to date.

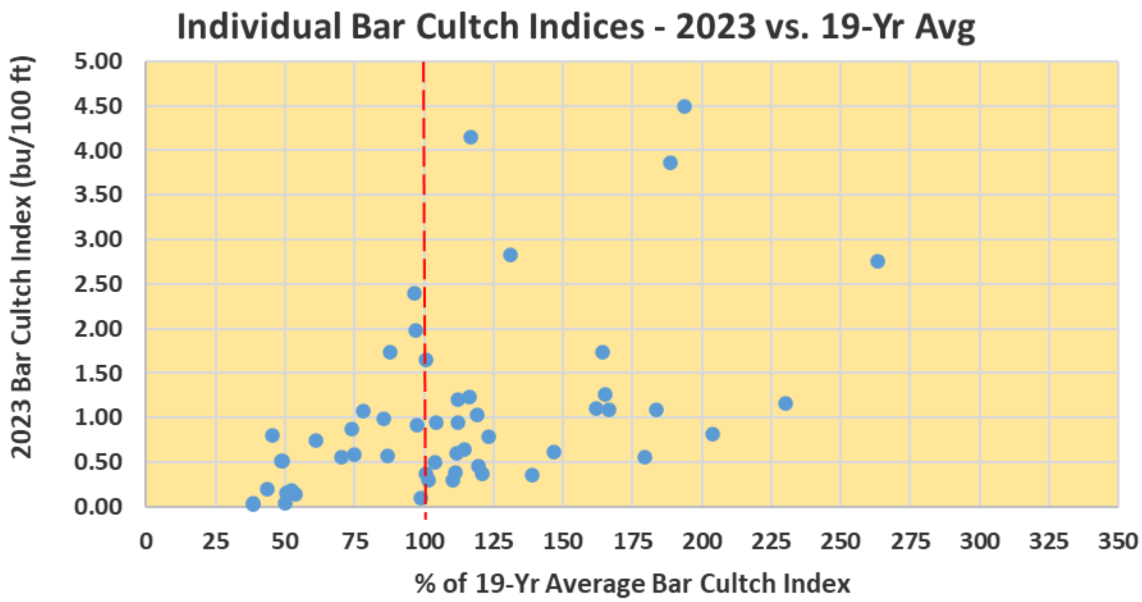

Figure 15. Range of cultch index values for individual Key bars in 2023 and the percent difference from their respective 19-year averages. The red dashed line represents the 19-year average.

Strong regional differences in cultch mean volumes were evident (Figure 16). The areas with the lowest standardized cultch averages included the mainstem of the bay, followed by the combined Chester River/Eastern Bay region. The highest cultch indexes were in areas with more favorable recruitment and consequent additions to cultch, specifically the Tangier Sound and Choptank River tributaries, as well as the Patuxent River. All regions but Tangier Sound had indices above their 19-year average (Figure 16). The Potomac region index is somewhat deceptive since it is largely driven by Pagan bar, whose 3-year average is nearly four times as high as the three-year average of the other six bars in this region; if not for Pagan the Potomac region index would be 29% lower. Removing Pagan would reduce the 19-year average for the Potomac region by 29%.

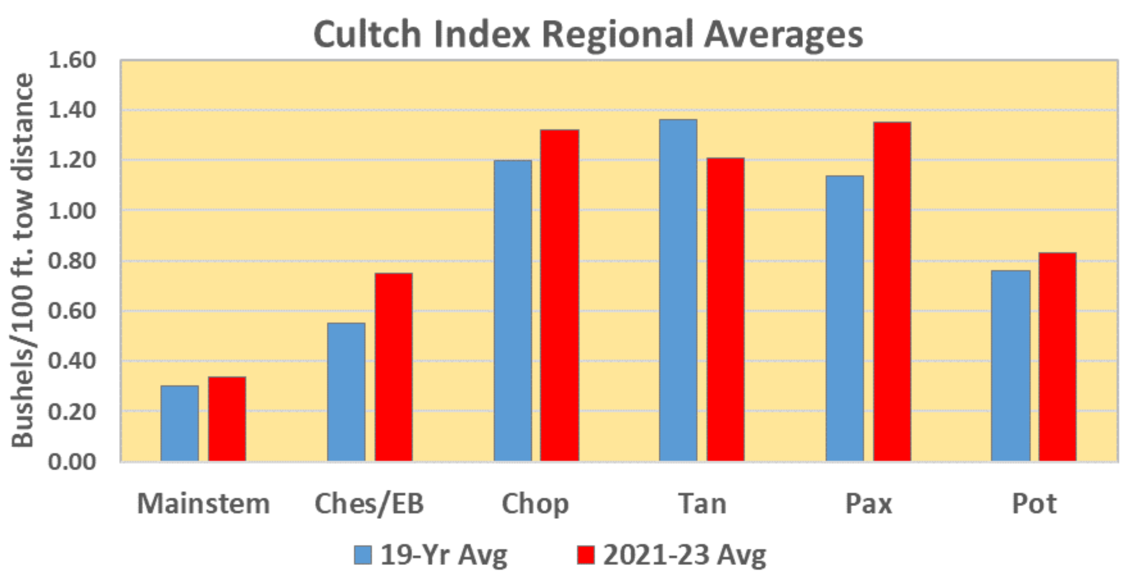

Figure 16. Regional cultch index averages for the 19-year time series and most recent three years. *Main=bay mainstem; Ch/EB=Chester River/Eastern Bay region; Chop=Choptank River region; Tan=Tangier Sound region; Pax=Patuxent River; Pot=Potomac River tributaries*

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 (Figure 16a). In 2023, the three-year average of the index stations of the five subregional tributaries was 1.11 bu/100 ft. tow distance while the Tangier Sound proper stations averaged 0.88 bu/100 ft. The average cultch indices for the individual tributaries were substantially higher in the Nanticoke River (1.46 bu/100 ft) and the Manokin River (1.45 bu/100 ft) sanctuaries (Figure 16a).

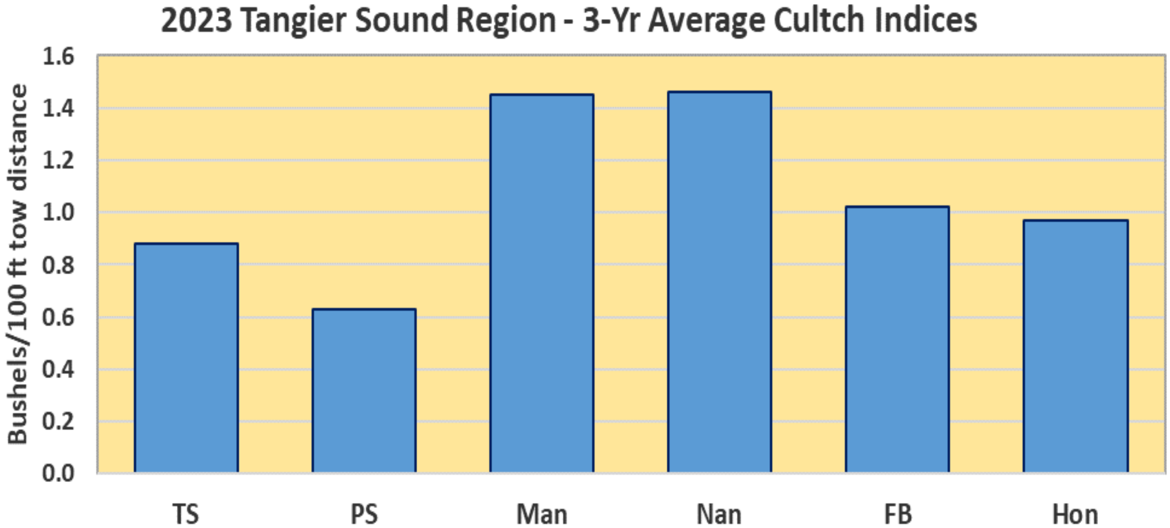

Figure 16a. Three-year averages (2021-2023) of bushels of cultch per 100 ft. tow distance for index stations by subregion within the Tangier Sound region. *TS=Tangier Sound; PS=Pocomoke Sound; Man=Manokin River; Nan=Nanticoke River; FB=Fishing Bay; Hon=Honga River*

COMMERCIAL HARVEST

Commercial oyster landings during the 2022-23 season were the highest in 36 years (1986/87 season). With reported harvests of 720,000 bushels, oyster landings were 31.3% higher than the previous harvest season (546,000 bushels), the fourth year in a row of increased harvests (Table 6, Figure 17a), and were well above the 38-year average of 310,000 bu/yr. The average reported price also rose 8.9% to $43.22/bu from $39.68/bu in 2022. This combination of larger harvest and higher price per bushel resulted in a 43% increase in the total dockside value from $21.8 million in 2022 to $31.1 million in 2023 (Table 7a.).

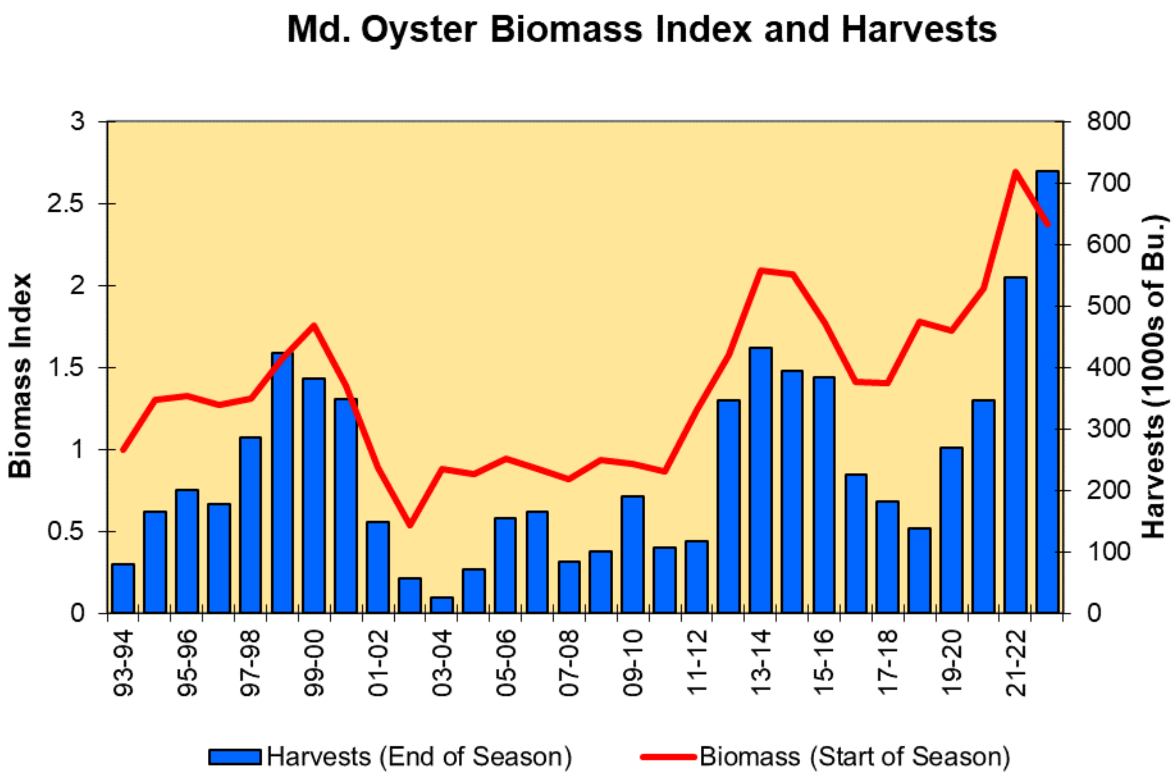

Figure 17a. Maryland oyster landings over the past 30 seasons and the relationship between the Biomass Index calculated at the start of the harvest season and total landings reported at the end of that same season. Note lag between the two metrics when abundant sublegal oysters add to the Biomass Index but have not yet entered the fishery.

Commercial oyster landings generally follow a similar pattern as the Biomass Index (Figure 17a). However, in some years there is a lag between the two metrics when abundant sublegal oysters add to the Biomass Index but have not yet entered the fishery (e.g., 2003-04, 2011-12, 2018-19). The dip in the 2023 index is likely due to increased harvest activity during the previous season.

During the ten years prior to the 2012-13 season, the fishery struggled to rebound from the devastating oyster blight that concluded in 2002. The Biomass Index reached its nadir that year, followed by the record low of 26,000 bu taken in 2003-04. The sizeable harvest increases of 2012-2016 (Figure 17a), following the below-average landings of the decade 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, as reflected in the Biomass Index, 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 in the 2016-17 to 2018-19 seasons. The Biomass Index did not parallel this harvest decline, but actually increased in 2019 because of above-median spatfalls in 2015 and 2016. As these two year classes of sublegal-size oysters accumulated, their subsequent growth as well as continued growth of oysters protected in sanctuaries contributed to maintaining the Biomass Index despite the drop in landings. Furthermore, the high streamflows in 2018/19 inhibited the growth of these sublegal oysters, delaying their reaching market size (Tarnowski 2020). As these year classes have entered the fishery, the general correlation between harvests and Biomass Index resumed in the 2019-20 season, with the landings increase over the last four years reflected in the rise of the index.

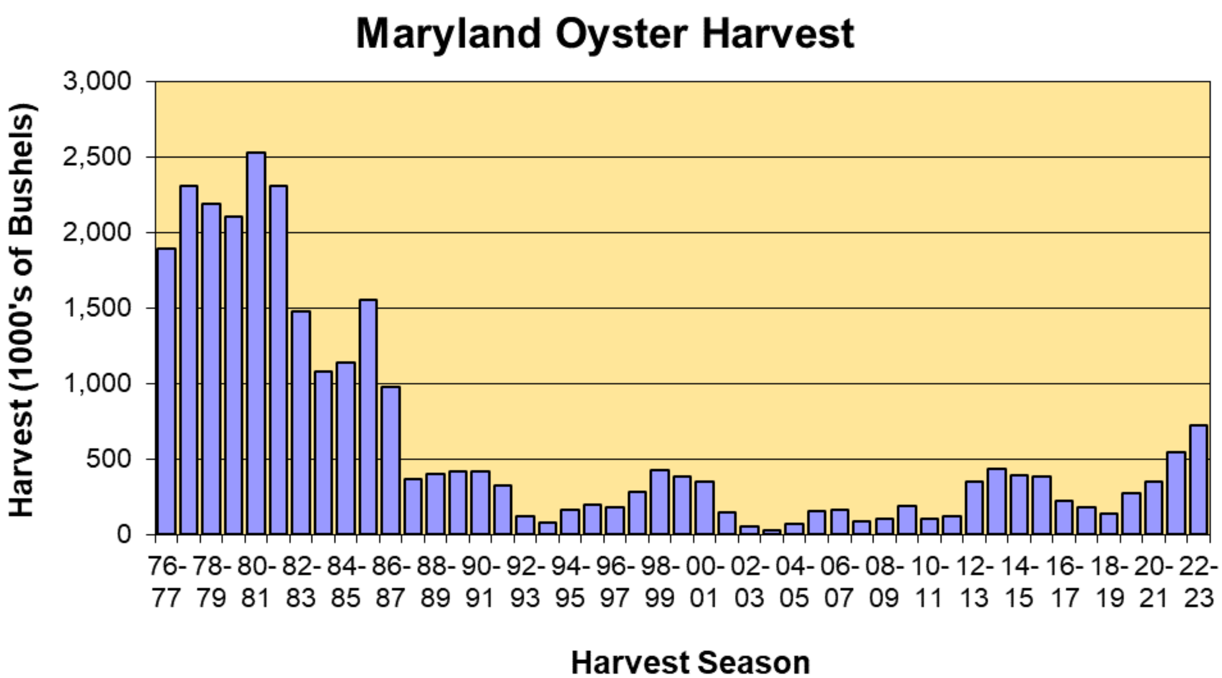

Figure 17b. Maryland seasonal oyster landings, 1976-77 to 2022-23.

Taken in the longer historical context, the average landings over the last several years remain a fraction of the harvests prior to the disease epizootics of the mid-1980s, when harvests ranged between one to two million bushels (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 30 years (and four of these in the most recent 21 years) following the onset of a series of disease epizootics beginning in the mid-1980s.

The Tangier Sound region, with landings of 480,000 bu, was the dominant harvest area, accounting for 67% of the 2022-23 landings in Maryland. The greatest proportion of these landings came from lower Tangier Sound (219,000 bu or 30% of the Maryland harvest) (Table 6). Upper Tangier Sound was second with 148,000 bu, providing 20% of the total harvest despite a 31% loss from the previous year. Other regions that exhibited declines to varying degrees included the upper bay, Chester River, Eastern Bay, western Wicomico River, Fishing Bay, and the Nanticoke and Manokin rivers. The most substantial changes (>5,000 bu) in Maryland regional landings between the 2021-22 and 2022-23 seasons are listed in Table A.

Table A. Changes of more than 5,000 bu in landings between 2022 and 2023.

Region	2023 Landings (bu)	Change from 2022 (bu)	% Change
Lower Tangier Sound	218,643	+137,956	+171%
Patuxent River	78,470	+39,670	+102%
Honga River	47,403	+22,406	+90%
Broad Creek	57,017	+19,576	+53%
Lower Bay	29,312	+11,729	+67%
Harris Creek	18,969	+11,077	+140%
Lower Choptank River	13,012	+6,290	+94%
Pocomoke Sound	10,847	+6,026	+125%
Upper Tangier Sound	147,541	-67,560	-31%
Nanticoke River	9,061	-12,982	-59%
Upper Bay	146	-7,205	-98%

The combined harvests in the entire Tangier Sound region increased by 85,654 bu or 21% from the 2021-22 season. The combined Choptank River region, the second most-productive area, also showed a substantial increase of 40,503 bu (+74%). Despite the recent gains, many regions remained below their long-term harvest averages. The exceptions were the most productive areas, including Tangier Sound and most of its tributaries, Broad and Harris creeks, the Little Choptank, Patuxent, and St. Marys rivers, and the lower bay mainstem (Table 6).

Generally, the northern portion of the bay and tributaries continued to perform poorly due to a lack of recruitment and large-scale repletion activity. The combined percentage of landings from the upper bay and Chester River, which in some seasons in the 1990s and early 2000s accounted for over half of Maryland's total landings, has been negligible in recent years (Table 6). For reference, the 38-year harvest average for these two regions was 31,000 bu/year, primarily sustained by numerous seed plantings from the historic MDNR Repletion Program. Similarly, in 2023 the once-productive Eastern Bay region produced only 7% of its 38-year average landings.

Not surprisingly, all gear types showing gains in harvests from the previous season (Table 7a). For the 16th consecutive season, power dredging was the predominant method of harvesting, accounting for 47% of the total landings (Table 7b). This activity was mainly in the lower Eastern Shore and Choptank regions. Patent tonging was second, producing 34% of the total harvests. Meanwhile, hand tonging increased slightly to 9% of the landings, primarily from Broad Creek - well below 74% of the landings during the 1996-97 season when power dredging was largely prohibited. Skipjacks (7%) and divers (2%) made up the remainder of the landings.

OYSTER SANCTUARIES

An in-depth analysis of the performance of Maryland's oyster sanctuary system is beyond the scope of this report but is provided in a stand-alone document examining longer-term trends (dnr.maryland.gov/fisheries/Pages/oysters/5-Year-Oyster-Review-Report.aspx). However, this report provides some important points and a concise view of the sanctuary oyster populations, focusing primarily on the priority (i.e., large-scale restoration) sanctuaries: Harris Creek, and the Tred Avon, Little Choptank, Manokin, and St. Marys rivers.

A total of 95 oyster bars within 38 sanctuaries were sampled during the 2023 Fall Survey, including one sanctuary and two bars that were newly added to the survey (Table 8). For comparison among areas, oyster counts were standardized to 100 ft tows, as the number per bushel count does not take into account varying tow lengths. Recruitment within the priority sanctuaries and adjacent open harvest areas was generally well above their respective Key Bar 19-year averages (Table S-1). The main exceptions were the Harris Creek sanctuary, which had a below average spatset, and the Little Choptank sanctuary with an about average spatset. Broad Creek without Royston had the highest regional recruitment, but including Royston placed Broad Creek behind the St. Marys sanctuary (Table S-1). It should be noted that the Broad Creek recruitment average is about five times as high as the Harris Creek Sanctuary over the 19-year time series, including prior to the creation of the sanctuary in 2010. For this comparison, Royston bar at the mouth of Broad Creek was omitted. This bar has substantially different characteristics from the remainder of the Broad Creek bars further upstream, with longer tow distances, fewer small and market oysters, and lower recruitment. Broad Creek averages with and without Royston are presented in Table S-1.

Table S-1. 2023 average number of oysters/100 ft tow by region and size/age class (Sm=smalls, Ma=markets) and average Key Bar (KB) spat/100 ft tow since 2005 (when tow distances were first measured) for priority restoration sanctuaries and nearby harvest areas. Broad Creek averages are presented both with and without Royston bar. n/a = There is no Key Bar in the Tred Avon River open area.

Region	Status	Regional 2023 Sm+Ma (#/100 ft tow)	Regional 2023 Spat (#/100 ft tow)	***KB Spat*** *19-yr Avg* (#/100 ft tow)	2023 Regional Avg. Tow Dist. (ft)
Harris Cr.	Sanc.	337	30	45.9	73
Harris Cr.	Open	183	39	10.7	215
Broad Cr.	Open	818	357	53.7	60
Broad Cr.[a]	Open	940	413	259.7	41
Tred Avon R.	Sanc.	185	205	31.4	81
Tred Avon R.	Open	239	196	*n/a*	79
L.Choptank R.	Sanc.	418	60	58.9	69
L.Choptank R	Open	83	57	6.2	156
Manokin R.	Sanc.	184	191	169.5	88
Mid-Tangier S.	Open	107	160	65.1	151
St. Marys R.	Sanc.	1,128	399	239.7	40
St. Marys R.	Open	298	158	26.9	99

[a] Not including Royston bar. [b] Average of two Key Bars.

Aside from the Tred Avon River, the number of adult (small and market) oysters per 100 ft tow in the priority sanctuaries was consistently higher than in adjacent harvest areas (Table S-1), collectively averaging over twice as many adult oysters in the sanctuaries as their respective open areas (not including Broad Creek). The St. Marys sanctuary had the greatest average number of adult oysters of any area in this comparison. Broad Creek, historically one of the highest oyster producing regions in Maryland (Table 6), averaged the second highest number of adults, thanks to the extraordinary spatset in 2020.

Twenty oyster disease samples from both Disease Bars and supplemental stations were obtained from 19 priority and non-priority sanctuaries (Table S-2). Of the thirteen sentinel Disease Bars within oyster sanctuaries, eleven bars had dermo disease prevalences and eight of those had intensities above their 34-year site averages (Table 3). Dermo disease levels in the comparison harvest areas also rose substantially, averaging 61.5% prevalence, up from 55.9% in 2022 and 32.8% in 2021, and 2.1 mean intensity, a gain from 1.6 in 2022 and 1.1 in 2021 (Table S-2). The higher dermo disease levels in the sanctuaries can be attributed to the fact that they had a greater proportion of larger, older oysters than the harvest bars (Figure 18); parasite burdens tend to build up as oysters age (Ford & Tripp 1996).

MSX disease was detected at two of the five priority sanctuaries and eight of sixteen other sanctuaries. In addition, MSX disease was found at twenty-one of thirty Disease Bars in open harvest areas, including all but one bar (Chicken Cock) in this comparison (Table S-2), as well as one of two supplemental monitoring sites. The average MSX disease prevalence for all sanctuary disease samples was 11.6%, while it was substantially higher at 19.0% for all harvest area disease samples. The highest MSX disease record of the 34-year time series was 93% on Lighthouse open harvest bar in the Choptank River (Table 4).

Table S-2. 2023 Dermo disease levels and observed mortality estimates for disease bars and regional averages on priority restoration sanctuaries and nearby harvest areas. Dermo disease and mortality averages for combined Disease Bars and Supplemental sites both within and outside sanctuaries are also presented.

Region	Disease Bar	Status	Dermo		MSX	Observed Mortality %	
			Prev.%	Int.	Prev.%	Disease Bar	Regional
Harris Cr.	Mill Pt.[a] /Rabbit Is.[a]	Sanc.	93/82	3.5/2.7	0/0	9.6/9.1	8.2
Harris Cr.	Tilghman Wharf	Open	60	1.5	40	8.4	10.4
Tred Avon R.	Double Mills	Sanc.	97	3.1	0	17.2	12.2
Mid-Choptank R	Lighthouse	Open	3	0.03	93	20.9	12.1
Broad Cr.	Deep Neck	Open	100	3.9	3	9.3	10.8
L. Choptank R.	Cason	Sanc.	87	2.6	37	11.9	11.4
L. Choptank R.	Ragged Pt.	Open	97	3.1	53	53.2	38.9
Manokin R.	Georges	Sanc.	100	4.3	17	26.6	28.5
Mid-Tangier S.	Piney Is. E./Back Cove	Open	100/97	3.3/4.7	40/7	18.9/41.4	24.9
St. Marys R.	Pagan	Sanc.	87	2.7	0	3.7	3.7
St. Marys R.	Chicken Cock	Open	77	2.2	0	5.8	5.8
Average of all Sanctuary Disease Samples[b]			85.5	2.9	11.6	16.0	
Average of all Harvest Disease Samples[b]			61.5	2.1	19.0	15.0	

[a] Supplemental bars; not part of the Disease Index set. [b] Including both Disease Bars and Supplemental sites.

The higher disease levels in the sanctuaries may have contributed to the doubling of observed mortalities on the Mortality Index bars from 8.1% in 2022 to 18.2% in 2023. Nevertheless, this remained lower than the long-term sanctuary index bar average of 20.5%; eight of eleven Mortality Index bars within sanctuaries had observed mortalities below their respective 39-year individual bar averages (Table 5). Holland Point and Old Field were not included in this evaluation as they had fewer than 40 oysters, which could skew the averages. Regional observed mortalities in sanctuary bars were similar to their proximal open harvest bars (Table S-2). The average regional mortality in the restoration sanctuaries rose from 5.8% in 2021 to 8.1% in 2022 and 16.0% in 2023, while in the corresponding harvest areas the average mortality went from 4.0% to 6.5% to 15.0% in 2023.

Oyster biomass in the sanctuaries continues to outpace that of the open harvest areas. Of the 43 Biomass Index bars, 13 bars are within sanctuaries (Table 8). The average biomass in the sanctuaries was substantially higher (32%) than in the harvest areas, ranging from 214.1 g/bu in 2021 to 222.6 g/bu in 2023. In the open harvest areas, the average biomass per index bar has slipped over the past two years, from 232.1 g/bu in 2021 to 192.6 g/bu in 2022 to 168.4 g/bu in 2023.Over the longer term, trends in biomass, as measured in grams/bushel (g/bu), generally have been positive both in sanctuaries and harvest areas, with the results from 2023 exceeding their long-term averages by 66% and 53% respectively.

The distributions of oyster biomass between the two management areas were distinctly different. The Biomass Index bars in the sanctuaries had higher biomass in the larger size classes, while the open areas had greater biomass in the sublegal and smaller market size classes (Figure 18). Biomass in the harvest areas quickly drops off above the minimum legal harvest size. The average biomass of sublegal oysters decreased to 43.6 g/bu (-16.2%) in the sanctuaries, and fell to 49.4 g/bu (-13.6%) in the harvest areas as the strong 2020 cohort attained market size. The average market oyster biomass in the sanctuaries increased to 179.1 g/bu (+8.3%), while the open harvest areas showed a loss to 119.0 g/bu (-12.1%), likely attributable to the substantial increase in harvests.

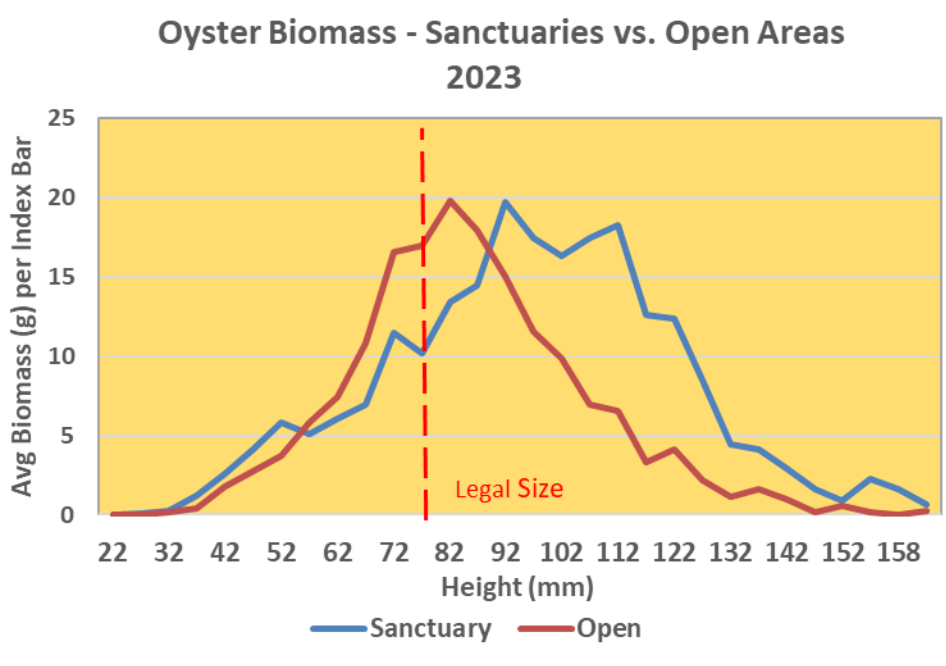

Figure 18. Average oyster biomass by 5 mm size classes on Biomass Index bars in harvest areas and sanctuaries. Dashed line indicates minimum legal harvest size.

A similar picture emerges when comparing the Biomass Index bars in the large-scale restoration sanctuaries with their corresponding adjacent open areas. The average biomass standardized to a 100 ft tow distance for these five sanctuary bars was 697.0 g/bu, compared to the average biomass/100 ft tow on the seven Biomass Index bars in adjacent open harvest areas of 445.0 g/bu. Aside from Deep Neck bar in Broad Creek, the biomass on the sanctuary Index bars was substantially higher than their respective open area Index bars (Figure 19). This was a function of higher oyster densities in the sanctuaries as reflected by the shorter average tow distance required to obtain a sample (57.8 ft for the five sanctuary bars versus 164.1 ft for the seven open area bars). The dominating biomass value for Deep Neck bar is the product of the exceptional 2020 recruitment event (Tarnowski 2022) following three years of growth and low natural mortalities.

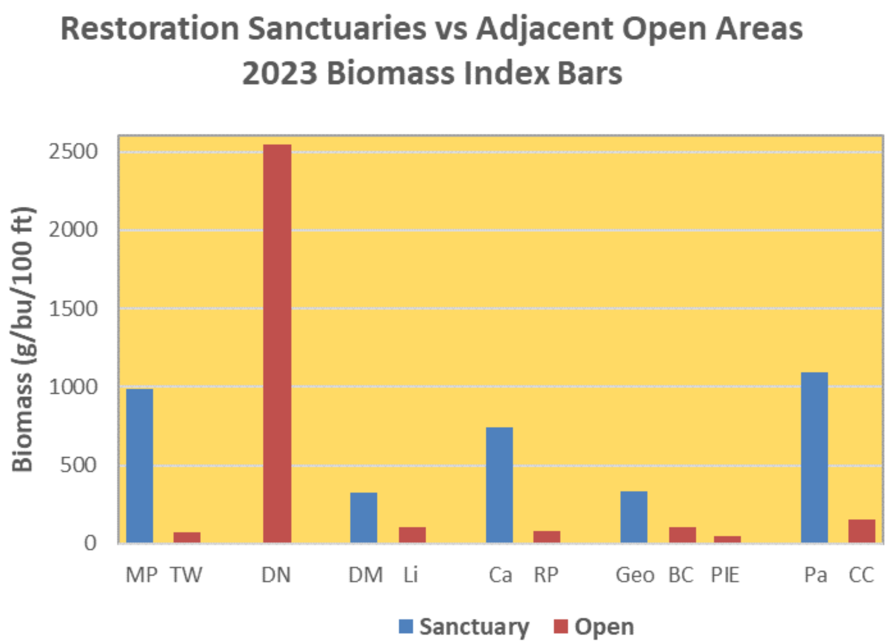

Figure 19. Comparison of biomass/100 ft tow between Biomass Index bars in the large-scale restoration sanctuaries and adjacent open areas. See Table S-2 for the regional locations of these bars. *MP=Mill Point (not a Biomass Index bar), TW=Tilghman Wharf, DN=Deep Neck, DM=Double Mills, Li=Lighthouse, Ca=Cason, RP=Ragged Point, Geo=Georges, BC =Back Cove, PIE=Piney Island East, Pa=Pagan, CC=Chicken Cock*

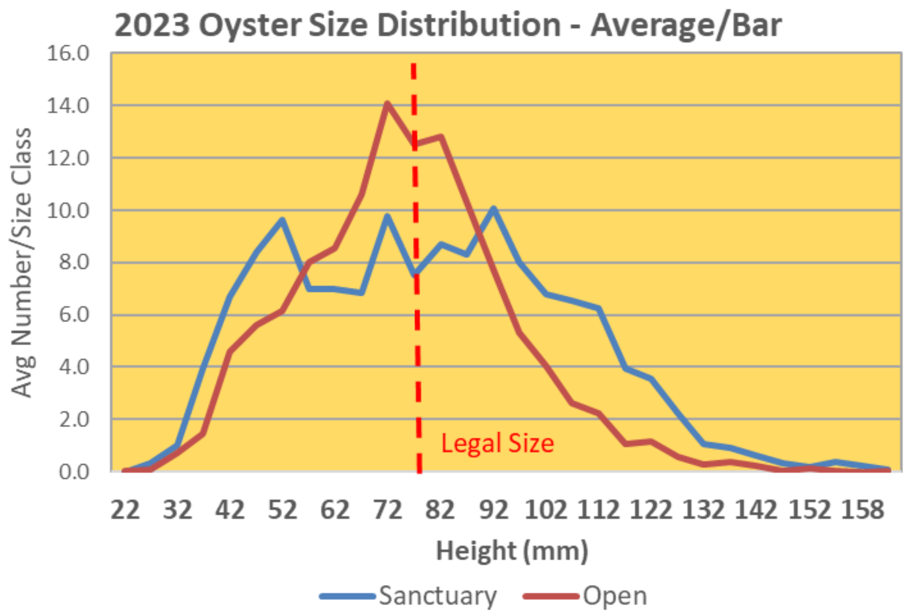

Figure 20. Size-frequency distributions of oysters in the sanctuaries and open harvest bars in 2023. The open harvest area peak between 72 mm and 82 mm is due to the strong 2020 year class.

The size distribution of oysters is a reflection of the strong recruitment events in recent The dominant size classes of the sanctuary oysters were spread across a broad range of sizes, with peaks at 52 mm, 72 mm, and 92 mm, whereas the modal height in the adjacent open areas was a more defined peak between 72 mm and 82 mm (Figure 20). The average size of adult oysters (equal to or greater than one-year old) on the Biomass Index bars in the sanctuaries decreased over the last three years (79.8 mm in 2023 vs. 86.4 mm in 2020), while the harvest bars grew in average size (75.3 mm in 2023 vs. 72.4 mm in 2021). These changes were driven by the influx of small oysters from the strong recruitment events over the past three years - the earlier spatsets and subsequent growth in the harvest areas and more recently in the sanctuaries (Figure 20). There was some difference between the two management types in the proportion of sublegal oysters in each. Sublegal oysters comprised 45.6% of the adult oysters in the sanctuaries, down from 51.2% in 2022, and 51.5% in the open areas, little changed from 52.0% in 2022.

Cultch, the substrate required for spatset, was at higher densities in all but one of the restoration sanctuaries compared to their adjacent open harvest areas (Figure 21). The exception was in the Tred Avon River, where cultch volumes were higher in the harvest area. The St. Marys sanctuary had the highest average cultch volume per sample, standardized to 100 ft. tows, over the last three-year period. For reference, Broad Creek was second in three-year average cultch density, boosted by the tremendous 2020 spatset. The lowest cultch volume was found in the Little Choptank harvest area, which was less than half of that in the sanctuary. Likewise, cultch volume in St. Marys sanctuary was almost double that of the harvest area in that river.

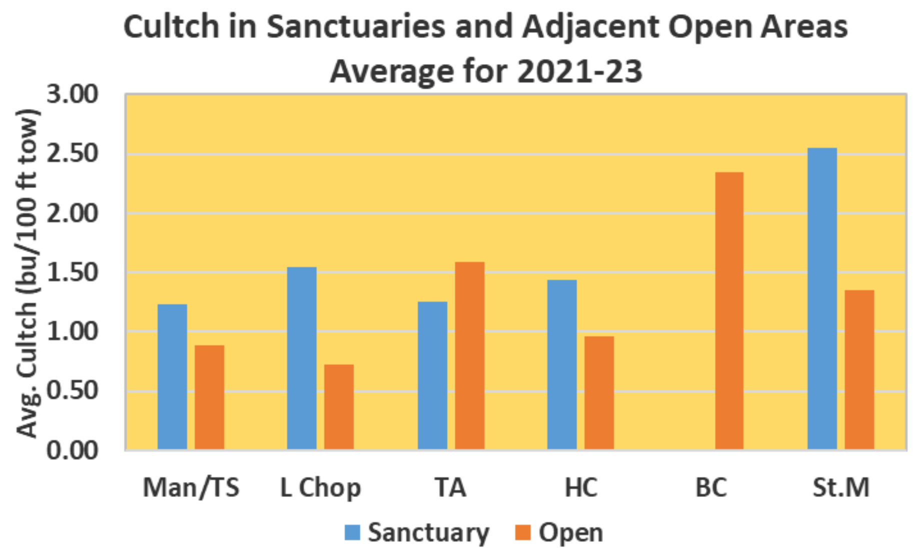

Figure 21. Comparison of cultch volumes between sanctuaries and adjacent open areas averaged for 2021-23. All stations with sufficient data within an area were included in the averages, standardized to 100 ft. tow distances. *Man=Manokin River; TS=mid-Tangier Sound; L Chop=Little Choptank River; TA=Tred Avon River; HC=Harris Creek; BC=Broad Creek; St.M=St. Marys River*

DISCUSSION

The findings of the 2023 Fall Oyster Survey and two ancillary surveys illustrated the profound influence salinity has on oyster population dynamics. An extended drought and consequent elevated salinities enabled an exceptional spatset while allowing for the rapid and extensive spread of MSX disease. A dramatic reversal in salinity levels during the late winter and spring of 2024 resulted in a sharp decline and even disappearance of MSX at selected sites.

This Discussion deals with these two opposing factors: population growth through recruitment and regression through disease-mediated mortality. The first section describes the strong and widespread recruitment that occurred in 2023, focusing on the Potomac River as an example of how important this event was for repopulating depleted, normally low-recruitment areas. The second section incorporates the results of a directed spring survey in 2024 that was conducted in large part as a follow-up to the fall MSX disease and observed mortality findings. The Spring Dredge Survey results are presented in Appendix 1 of this report.

An Outstanding Spatset

The 2023 Spatfall Intensity Index, a measure of reproductive success and potential population growth, was the fifth highest of the 39-year time series and nearly four times the index median over that time period. It also marks the fourth consecutive year of above-median recruitment, rebounding from the extended freshets of 2018-19.

Equally important, and what made this recruitment year exceptional, was the widespread distribution of the spatset. Spat were even observed in the upper reaches of tributaries that are normally too brackish to receive a spatset. Fifty of the 53 Key (Spat Index) Bars had spat, the most bars since 1985 - the first year of this time series. The only regions where spat were not found were the upper bay above the Bay Bridge and the Chester River. Spat numbers were well distributed within the Key Bar data set, with ten stations accounting for 50% of the spat index. No one station dominated the 2023 index, in contrast to 2020, which had a higher spat index but was heavily skewed by the extraordinary spatset on one bar – Deep Neck in Broad Creek – which alone accounted for 32% of that year's index.

Salinity is a primary environmental driver of oyster recruitment. Adequate salinity is necessary for gametogenesis, spawning, larval survivorship, and settlement (Loosanoff 1953, Davis 1958, Calabrese & Davis 1970, Thompson et al. 1996, Kimmel & Newell 2007, Tarnowski 2019). Salinity is regulated by freshwater streamflow into the bay. When the Chesapeake watershed entered a drought period beginning towards the latter portion of 2022 and throughout 2023, the reduction in streamflows caused salinities to rise to suitable levels for spatset in most corners of Maryland's oyster grounds.

Suitable salinity for spatset is influenced by this streamflow-salinity dynamic in two ways: dilution and tidal transport (Pritchard 1952, 1967). Higher salinity originates from the Atlantic Ocean, which is carried up the estuary by tidal currents and is increasingly diluted by freshwater input along the way. With lower streamflow entering the bay such as in 2023, there was less fresh water mixing with the incoming tidal flow, raising salinities further upstream. But in addition to dilution there is a second factor influencing salinity. Lower streamflows mean less volume and force of freshwater to push against the tidal surge, allowing saltier water to penetrate further up the estuary. This transport mechanism also allows the pelagic oyster larvae to be carried further into the upper reaches of tributaries where broodstock might be limited or nonexistent. Flushing time is also regulated by streamflow. Lower freshwater flows mean longer flushing times and longer retention of larvae, enhancing the possibility of settlement in a given area (Gaines and Bertness 1992).

Adequate salinity is necessary but not always sufficient for a strong recruitment event. A combination of other physical parameters including temperature, dissolved oxygen, water chemistry, wind-driven currents, ill-timed storms, siltation, and suitable substrate to set on interplay with biological factors such as sufficient broodstock, predation, competition for space and food with other epibenthic organisms, adequate and appropriate phytoplankton food, harmful algal blooms, and likely other unknown factors to determine whether an outstanding recruitment event occurs. Oftentimes these are dependent on extremely localized conditions, such as the 2020 Broad Creek spatset. So, to have such an extensive recruitment event as in 2023 is rare, given the host of variables that can negatively impact spatset even under optimal salinity conditions. The significance of this event is illustrated by a case study of the Potomac region, which experienced a once in a generation spatset.

The Potomac Region

The Potomac oyster populations have been struggling ever since Tropical Storm Agnes inundated the river with freshwater and silt in 1972, causing extensive mortalities (Krantz and Carpenter 1981, Haven et al. 1976). This was followed by high MSX disease-related mortalities that periodically ravaged the populations in the lower portion of the river beginning in the mid-1980s through the millennial epizootics which ended after 2002 (Tables 4, 5). Oysters further up the river, at least as far as Lower Cedar Point and the western Wicomico River, were not spared from disease, succumbing to high levels of dermo disease (Tables 3, 5). Even Beacon bar, the furthermost bar upriver to be surveyed in a normally low salinity regime, had a dermo prevalence of 43% in 2002 (MDNR, unpubl. data). Compounding the problem on these uppermost bars were three killing freshets during the mid-1990s (Homer and Scott 2001).

Coincident with these events was the collapse of recruitment, possibly a consequence of the loss of broodstock coupled with often unfavorable environmental conditions. There was a brief reversal in this trend during the early 1980s when a series of strong recruitment years lasting through 1986 occurred in the lower portion of the Potomac, though not on the upper bars. This was followed by decades of persistently poor spatsets, save for an occasional modest event in the lower north shore (Figure 22). The Potomac's Maryland tributaries of the Wicomico River and Breton Bay also endured long-term recruitment failures. The only bright spot in this region was the St. Marys River, which has produced above average spatsets fairly consistently through the years.

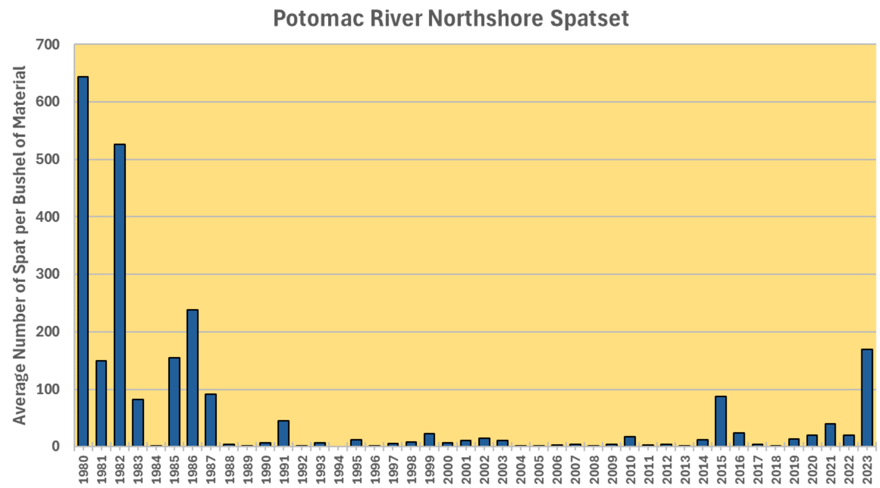

Figure 22. Average annual natural spatset in the north shore of the Potomac River.

In more recent years, the latest freshet event persisted for an extended period overlapping 2018 into 2019, and was the most devastating. The freshet completely extirpated oyster populations over a distance of approximately 15 km, from Beacon bar, at the first bend in the river, all the way below the Route 301 bridge to Colonial Beach, where mortalities began to ease somewhat. Gum bar, directly in front of Colonial Beach, had an observed mortality rate of 86%, while across the river, 64% of the oysters were dead on Swan Point (Tarnowski 2019). Thus, there was an extensive stretch of the upper oyster grounds, normally an extremely poor recruitment region to begin with, that had lost the entirety of its broodstock (Figure 23). In particular, Beacon bar oysters were unique in that they were adapted to living in lower salinities and had withstood the mid-1990s freshets. Being so far upriver with no immediate source of broodstock, the likelihood of a recovery seemed remote without management actions such as oyster seed plantings, but this area above the bridge has a history of low harvest activity. Given the logistical and monetary constraints, as well as the high-risk factor of such an option with marginal returns for the funds-limited Potomac River Fisheries Commission (PRFC), this seemed unlikely to happen. The area would probably remain one of relict shell bars without living oysters.

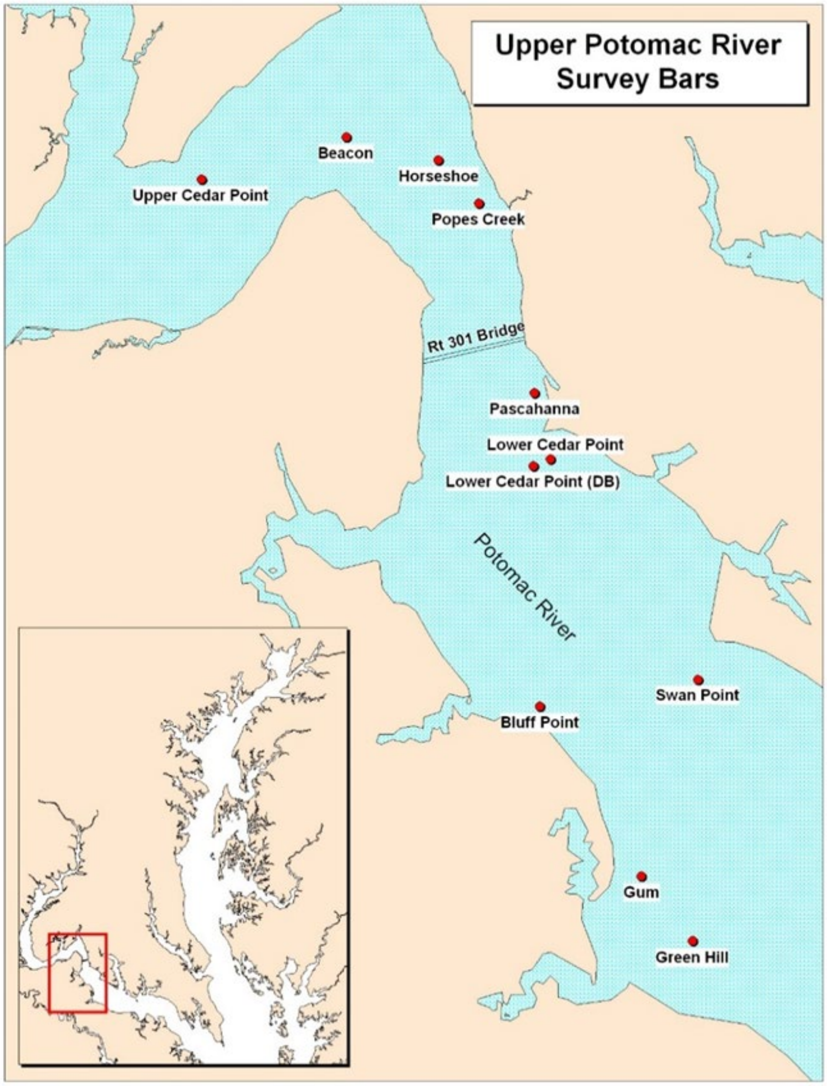

Figure 23. Location of upper Potomac bars referred to in the text.

Because of the absence of oysters on the bars above the Route 301 bridge and the considerable additional travel time to get to those bars, this area had not been included in the Fall survey since 2020. However, in 2023 spat were found throughout the Potomac as far upriver as Pascahanna bar, just below the bridge. The Wicomico River and Breton Bay also had welcome spatsets after three decades of recruitment failures (Figure 24). Notably, the north shore of the Potomac River experienced the highest average spat count of any region in Maryland – the best recruitment in the river in almost 40 years. It was a salient event for a river that had faired so poorly for so many years. But the tantalizing question remained: What if any spatset occurred above the bridge?

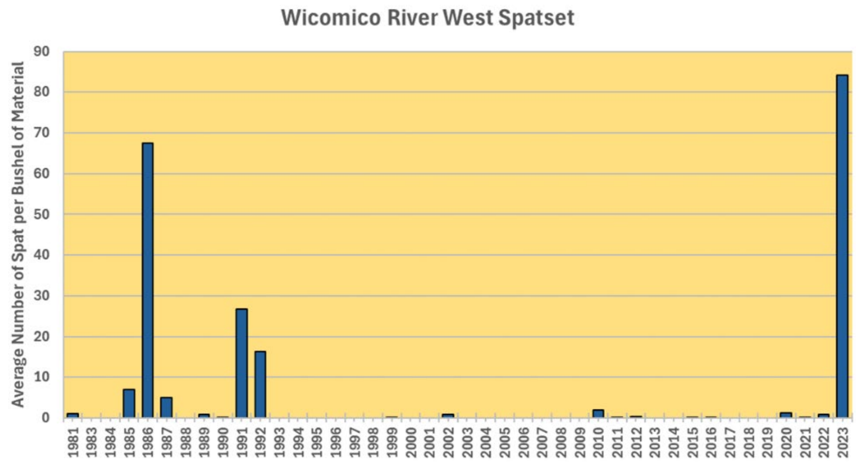

Figure 24. Average annual natural spatset in the western Wicomico River.

On 25 November 2023, an informal survey of four bars in this area using a local waterman's boat found excellent spatsets not only on Beacon bar (250 spat/bu) but even about 6.5 km further upstream on Upper Cedar Point (115 spat/bu), which has never been sampled on the Fall Survey. Lesser, but still important, spat counts were observed on Horseshoe and Popes Creek bars. The significance of this spatset in repopulating this area cannot be understated - recruitment had essentially ceased in this upper zone since 1969 (Krantz and Abbe 1981; MDNR, unpubl. data). The only spatset of importance on Beacon bar since then had been 46 spat/bu in 1986 (MDNR, unpubl. data). Given the rarity of such occurrences and absence of oysters in this region, the 2023 spatset was a serendipitous event.

Adequate broodstock is a primary biological consideration for successful recruitment. The source of the oyster larvae that settled on the upper Potomac bars is a matter of conjecture. A larval transport model specific to the Potomac River projected a median dispersal distance of 12 km, with a range of estimates from 2 km at the 25th percentile and 22 km at the 75th percentile (North et al. 2008). The nearest known broodstock reservoir was on Lower Cedar Point bar, approximately 8.4 km downriver from Beacon bar and 15 km from Upper Cedar Point bar. The population on Lower Cedar Point bar had suffered 100% mortality during the latest freshet. Despite the losses, under ordinary conditions this bar is notable for the growth rates and quality of its oysters. Consequently, PRFC has been planting seed oysters for eventual harvest every year since 2020, while unintentionally providing a concentration of broodstock waiting for proper conditions to reproduce.

Larvae could possibly have travelled from further down river but this does not seem as likely. The next closest bar is Swan Point, about 15 km below Beacon bar. But the freshet mortality on this bar was heavy, leaving a relatively sparse population of oysters (34/bu scattered over a 304 ft tow). On the south shore, the nearest known location with oysters was on Green Hill, some 20 km from Beacon bar, but oysters were extremely scarce (6/bu) when the bar was last sampled in 2022. The paucity of oysters and distance from the bridge would seem to preclude these areas as sources of larvae. There are also some bars in the deeper portion of the river where oysters may have survived the freshet, but these are in the firing range of Dahlgren Naval Station and have not been surveyed since an artillery shell was dredged up several years ago.

An increase in broodstock through management actions involving planting and harvesting on a rotational basis among bars may have benefitted the western Wicomico River, a tributary of the Potomac River. Recruitment in this river has basically been non-existent since 1986, but in 2023 there was a fair spatset, averaging 67 spat/bu. Numerous seed oyster plantings for eventual harvest have been made here in recent years, which could have contributed to this spatset. There may have even been some spillover effect from the Wicomico River into the Breton Bay area, which averaged 92 spat/bu despite a paucity of broodstock oysters there.

As described previously, reduced streamflows in 2023 allowed for the strong recruitment event on the upper Potomac bars in two ways. First was the dilution factor, where there was less freshwater to dilute the incoming tidal flow, raising salinities to suitable levels for recruitment. The surface salinity during the Beacon bar sampling was 13 ppt, more than adequate for recruitment and survival (Davis 1958, Calabrese and Davis 1970). Second was the transport mechanism. Lower freshwater flow means the saltier flood tide can penetrate further upstream, carrying oyster larvae along with it. The high spat count on Beacon bar may also be attributable to its location at the first sharp bend in the river (Figure 23), with the tidal current running into and over the shoal bar. Similarly, larvae travelled against the net downstream flow even further upriver to Upper Cedar Point.

Cultch is oyster habitat consisting of hard substrate, usually oyster shell, and is crucial for larval oysters to set or attach to (Tarnowski 2018). Field notes from the November 2023 upper bars survey reported that there was an abundance of brown surface shell on these sites. Previous Fall Surveys needed only short tow distances to obtain a sample on Beacon bar, indicating abundant cultch. With good habitat and suitable salinity, Beacon bar was primed and ready to receive the oyster larvae in 2023.

Beacon bar also provides an example that adequate salinity is not always sufficient for successful spatsets. Being so far upriver, Beacon was thought to be a refuge from oyster diseases. In fact, dermo disease was not detected in 1999 downstream on Lower Cedar Point bar, the closest disease monitoring bar prior to 2002. But by 2002, the fourth year of drought-level streamflows, the dermo prevalence was 97% on Lower Cedar Point, and a supplemental sample taken on Beacon bar found 43% prevalence. The point is that *Perkinsis marinus*, the organism that causes dermo disease, could travel upstream and infect remote oyster bars in normally low-salinity areas during elevated salinity periods, likely utilizing the same transport mechanism as oyster larvae. Fall Survey salinities over this drought period ranged from 8.7 to 11.0 ppt, sufficient for a spat set. Yet Beacon bar received no spat during this time span.

In conclusion, elevated salinities enabled a once in a generation spatfall, perhaps assisted by management actions that boosted broodstock numbers, in a region that desperately needed it. This epic recruitment event bodes well for the Potomac oyster populations, along with the ecological benefits they afford and watermen they help support. As they grow, the oysters will provide additional habitat and reproduction potential in a positive feedback loop, allowing the possibility for the population to expand even further. But as always with oysters, there is a caveat: providing they survive in this hostile environment. They must grow and reproduce without facing freshwater deluges and the ravages of diseases on either end of the historically notorious Potomac.

Spring Survey Observed Mortalities and MSX Disease

The effect of streamflow and consequent salinity on *Haplosporidium nelsoni* - the causative agent of MSX disease - and associated oyster mortalities was graphically demonstrated in the half-year span separating the Fall and Spring (Appendix 1) surveys. As discussed in the 2022 Fall Survey report (Tarnowski 2023):

> *Persistent elevated salinities over the next year or so may allow for an unintended and perhaps unwelcome experiment. MSX becomes lethal at salinities above about 15 ppt (Appendix 3). A prolonged period of higher salinities could test the hypothesis that the lower observed mortalities of the last two decades are the result of disease resistance/tolerance in oysters (Appendix 4). A counter hypothesis is that oyster survival is due to favorable salinities, not genetic improvements.*

With elevated salinities continuing throughout 2023, the spread of MSX disease was anticipated, but not to the geographic extent or extraordinary prevalence levels acquired by oyster populations on certain bars. MSX range and prevalences were already expanding in 2022, increasing from one oyster at each of two locations in 2020 to eight sites throughout much of the waters of the lower Eastern Shore and establishing a toehold on the Western Shore. Thus, the system was primed for the 2023 MSX epizootic, as streamflows remained reduced and salinities increased. By the 2023 Fall Survey, MSX disease was found at 27 disease sentinel sites (65% of total) as far upbay as Hacketts bar outside of Annapolis. The Patuxent River is not included in the following discussion since the nearest disease sentinel bar was outside of the study area and had a lower MSX prevalence than the other sites.

As the MSX pathogens infiltrated the middle reaches of the bay, they encountered oyster populations that were relatively naïve to them. Prior to 2023, the two Choptank region disease bars in this study had experienced *H. nelsoni* infections only a limited number of times in the 21 years since the millennial epizootics: Lighthouse – three years; Royston – two years. With so few challenges combined with light mortalities, there was little opportunity for these populations to develop resistance or tolerance to the disease, with little selection taking place. Consequently, the results in the fall of 2023 were a hefty 67% prevalence on Royston and an astonishing 93% prevalence on Lighthouse. In contrast, the Piney Island East oysters were challenged by MSX disease in 16 of the past 21 years. Considering that the salinity regime in Tangier Sound is the highest in Maryland, and by extension has the greatest disease prospects, the highest fall *H. nelsoni* prevalence in that region was only 40% (at Piney Island East), well below the lower Choptank bars – a strong indication that this population has evolved a tolerance or resistance to MSX infection.

Another feature of the *H. nelsoni* prevalences during the fall 2023 was the patchy distribution. It appears there was a sharp demarcation between high and low disease levels. While Lighthouse bar, just outside of the mouth of the Tred Avon River, established a record high MSX prevalence, the pathogens were not detected about 10 km away on Double Mills within the Tred

Avon oyster sanctuary. Also, the next Choptank disease bar upstream from Lighthouse (also about 10 km) – Sandy Hill – had a much lower prevalence (17%). This pattern was observed in other tributaries as well, such as Harris Creek, Little Choptank River, and Manokin River (Table 4).

Observed mortalities in the fall were not as accordant with disease levels as might been expected. Regionally, the Tangier area had the highest observed mortality averaging 26%, although it was somewhat lower on Piney Island East (18.9%). Observed mortalities in the naïve Choptank populations were even lower, averaging 21%. Despite their extremely high *H. nelsoni* prevalences, observed mortalities were only slightly elevated at Royston (17.5%) and Lighthouse (20.9%).

Lower Choptank Region

In the Choptank oysters, two possibilities for this incongruity between MSX prevalence and mortality during the fall are that either they had only recently acquired the disease or environmental conditions had suppressed its impact. Although oysters usually become infected in May, parasite acquisition can occur as late as October (Ford and Tripp 1996). Given the distance of the Choptank bars from the presumed initial source of infection in the Tangier region, it would not be surprising for infections to have been acquired later in the year as the parasites expanded their range up the bay, but there is no way of knowing for sure.

Considering the second possibility, salinities at the Outer Choptank monitoring station were above 10-12 ppt for the entire year, allowing infection by the MSX pathogen without inflicting mortalities (Ford 1985, Sprague et al. 1969). During the period of potential infection, salinities did not exceed the 15 ppt threshold for increased MSX-related mortalities until in October 2023 and remained above it through December. Salinities fell below 15 ppt in January, concomitant with temperatures below 5°C, and continued to drop to 8 ppt by May.

It may be that either or both possibilities were at work. If *H. nelsoni* parasites were acquired earlier in the season, salinities appeared to be in the range to allow infections but not result in mortality. In both cases, there was still at least two months of suitable environmental conditions after the Fall Survey for the pathogens to proliferate before water temperatures below 5°C inhibited their activity (Ford and Haskin 1982). A second mortality period in late winter and spring can occur when water temperatures rise above the pathogen's activity threshold (Ford and Tripp 1996). Stressed oysters may continue to die as metabolic demands for host response remain high in the face of declining energy reserves and food availability. As it turned out, in the Choptank region the temperature dropped below the 5°C threshold only during January (Figure A1-3). This suggests that at least in the Choptank region the combination of low temperatures and dropping salinities caused pathogenic activity to be suppressed during the first half of 2024. By the time of the Spring Survey in late May the parasites had essentially been purged from the two study populations, with 7% prevalence on Royston and 0% prevalence on Lighthouse. This is consistent with findings that *H. nelsoni* was purged from oysters when salinities were 10 ppt or less (Haskin and Ford 1982, Andrews 1983).

Because of unsuitable environmental conditions for *H. nelsoni* in late winter/spring, it would be expected that the increased mortalities occurred soon after the Fall Survey. However, the Spring Survey results found the number of recently dead small oysters in the Choptank region was double that of older small boxes, indicating a spring mortality event. And although market boxes tended to be older, about a third of them were recent. We can only speculate that the oysters were so physiologically weakened in the spring that they eventually succumbed despite the absence of the parasite. The final result was that post-Fall Survey observed mortalities doubled regionally and more than doubled by the time of the Spring Survey at the two study bars with the highest fall *H. nelsoni* prevalences of the Choptank region.

Tangier Sound Region

Piney Island East presented a different situation from the Choptank region. Salinities remained above 15 ppt throughout 2023 into 2024 before falling below that mark in March (Figure A1-2) and temperatures never dropped below 5°C, presumably allowing the pathogens to remain active through the winter. With salinities hovering at the lower tolerance threshold for *H. nelsoni* (Figure A1-2), the prevalence declined in the spring, but was still a substantial 26%. Yet the mortalities were actually lower in the spring. This conundrum raises three questions: Why was the average MSX prevalence in the fall about half of the Choptank region? Why did observed mortalities not go up as they did in the Choptank region? Instead, why did mortalities go down?

Despite environmental conditions at Piney Island East that were conducive to MSX acquisition and pathogenic activity, prevalences and related mortalities were relatively moderate in the fall, and post-Fall Survey observed mortalities failed to rise as they did at the Choptank bars. Also, the Tangier region likely was the epicenter of the disease outbreak, as the oyster populations there were already infected from the previous year. Yet there was not a similar impact as seen in the Choptank region. The most parsimonious answer is that the Tangier region populations had developed resistance/tolerance to MSX disease after years of being challenged by it, as opposed to the infrequent exposure of the Choptank region to *H. nelsoni*. Resistance is suggested in the Tangier region oysters as prevalences never got very high, averaging 19.9% in the fall, compared to 50.7% in the more susceptible Choptank region populations.

The possibility of MSX disease tolerance and/or resistance among Maryland oyster populations in the Tangier Sound regions is supported by findings in neighboring localities. In higher salinity waters such as Delaware Bay and the Virginia portion of Chesapeake Bay, native oyster populations have demonstrated greater survivorship in the face of MSX disease (Ford & Tripp 1996, Burreson & Ford 2004). Furthermore, selective breeding has produced oyster strains with genetically enhanced resistance/tolerance to both MSX and dermo diseases (Ford & Tripp 1996, Ragone Calvo et al. 2003).

Observed mortalities did not increase by the spring, even though the prevalence on Piney Island East, for example, was still 26%, perhaps because the infected oysters were able to tolerate the pathogens, again because of the frequent MSX challenges over the decades that this population has endured. This idea might be confounded by the drop in salinities in March 2024 to below the 15 ppt lethal threshold, which would allow the parasites to exist without killing the oysters, and may have reduced the prevalence from the fall value. Nevertheless, salinities remained above 15 ppt for an extended period through the winter while water temperatures remained above 5°C, which should have allowed pathogenic activity to continue.

One possible explanation for the decline of observed mortalities in the Tangier region between fall and spring is the impact of heavy fishing activity on boxes. Most of the bars selected for the spring survey were in commercial areas and had the highest reported landings for each region. In the Tangier region, approximately 20% of the boxes were categorized as recent with the remainder as old. Old boxes could be anywhere from a few weeks to almost a year old, so there was no telling when the Tangier oysters died. In the Choptank region, about 40% of the boxes were considered recent in the fall. Added to that was the fresh wave of mortalities after the Fall Survey. Recent boxes would be much less likely to disarticulate from fishing activity than old boxes. So, although the Choptank region also experienced a good amount of harvesting, the large proportion of recent boxes likely remained intact through the harvest season, while there was a higher degree of disarticulation in the older Tangier boxes due to fishing and possibly other taphonomic processes associated with their age.

The unintended and unwelcome experiment mentioned in the quote at the beginning of this discussion came to pass in 2023. Which of the two hypotheses explaining the lower observed mortalities over the past two decades is correct – the development of resistance/tolerance to the disease or favorable salinities which inhibited *H. nelsoni*? The answer appears to be both are correct, depending on the salinity regime and frequency of exposure to MSX disease pathogens.

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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 mostly in paper files.

(Return to Text)

Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 “Key” spat monitoring bars, 1985-2023.
(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**
	Median	**50**	**24**	**8**	**6**	**0**	**13**

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**
Median	**140**	**5**	**4**	**0**	**10**	**0**	**8**	**0**

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**
Median	**6**	**2**	**3**	**9**	**1**	**0**	**0**	**5**

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**
Median	**0**	**1**	**6**	**22**	**1**	**16**	**3**	**2**

Table 2 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)									
	2015	2016	2017	2018	2019	2020	2021	2022	2023	*39-Yr Avg*
Mountain Point	0	0	0	0	0	0	0	0	0	*0.3*
Swan Point	0	0	0	0	0	0	0	0	0	*0.3*
Brick House	0	0	0	0	0	0	1	0	10	*5.9*
Hackett Point	0	0	0	0	0	0	0	0	7	*0.8*
Tolly Point	0	2	0	0	1	0	0	0	15	*1.1*
Three Sisters	0	0	0	0	1	0	1	0	10	*0.9*
Holland Point (S)	0	0	0	0	0	1	0	0	3	*0.5*
Stone Rock	2	17	0	4	6	7	1	0	19	*22.2*
Flag Pond (S)	10	12	28	0	2	0	0	0	25	*20.9*
Hog Island	9	22	1	0	19	8	14	7	32	*17.5*
Butler	68	90	2	1	42	34	65	28	55	*40.4*
Buoy Rock	0	0	0	0	0	0	0	0	0	*1.2*
Parsons Island	8	0	0	0	2	0	13	5	15	*96.4*
Wild Ground	15	0	0	0	1	2	9	2	7	*36.3*
Hollicutt Noose	1	0	0	0	0	2	7	4	17	*5.1*
Bruffs Island (S)	0	0	0	0	0	0	28	10	29	*25.1*
Ash Craft	0	0	0	0	0	1	14	0	9	*62.8*
Turtle Back	13	4	0	0	0	5	42	7	12	*116.1*
Shell Hill	4	2	1	5	2	0	7	9	30	*7.6*
Sandy Hill (S)	0	3	1	0	2	5	18	13	32	*12.0*
Royston	21	13	23	22	0	231	96	17	75	*55.7*
Cook Point (S)	1	21	2	4	7	68	28	10	202	*22.9*
Eagle Pt./Mill Pt. (S	34	68	55	28	0	187	51	7	8	*41.3*
Tilghman Wharf	45	58	13	40	5	247	134	22	91	*70.7*
Deep Neck	83	91	205	119	17	1838	162	75	371	*166.2*
Double Mills (S)	9	12	3	1	1	74	21	5	299	*26.0*
Ragged Point	19	125	35	2	1	18	6	0	27	*51.7*
Cason (S)	11	60	67	9	4	613	62	24	22	*97.3*
Windmill	16	9	9	4	12	62	66	8	203	*53.8*
Norman Addition	34	60	44	13	24	227	170	38	275	*87.6*
Goose Creek	11	44	27	23	18	448	44	65	137	*45.7*
Clay Island	43	68	41	43	14	43	35	79	167	*50.5*
Wetipquin (S)	2	6	0	21	33	15	13	17	6	*6.3*
Middleground	12	32	66	49	138	100	41	14	108	*32.9*
Evans	14	18	1	7	37	52	66	19	28	*15.3*
Mt. Vernon Wharf	1	3	1	10	7	42	4	11	34	*5.0*
Georges (S)	29	61	137	40	78	185	20	14	86	*69.9*
Drum Point (S)	59	172	78	110	160	445	61	58	105	*105.6*
Sharkfin Shoal	57	53	32	23	14	17	21	16	72	*28.5*
Turtle Egg Island	64	57	15	69	88	122	66	47	196	*91.3*
Piney Island East	3	0	2	0	68	196	103	95	206	*103.1*
Great Rock	13	4	14	93	151	258	44	288	120	*51.0*
Gunby	95	73	34	25	46	18	54	47	97	*58.0*
Marumsco	141	69	31	8	61	53	29	48	39	*40.8*
Broome Island	6	21	6	1	12	1	73	2	79	*10.1*
Back of Island	18	42	5	5	13	7	18	5	282	*20.7*
Chicken Cock	712	33	19	5	10	37	111	23	182	*80.7*
Pagan (S)	24	91	247	7	15	53	426	478	183	*177.6*
Black Walnut (S)	3	4	0	0	0	0	0	1	42	*2.5*
Blue Sow (S)	0	10	0	0	0	1	1	1	60	*5.6*
Dukehart Channel	0	3	0	0	0	0	0	2	175	*6.0*
Ragged Point	1	11	2	2	0	4	9	10	190	*10.3*
Cornfield Harbor	100	92	6	6	108	55	70	68	107	*73.5*
Spat Index	**34.2**	**30.9**	**23.6**	**15.0**	**23.0**	**109.1**	**43.9**	**32.1**	**86.81**	***42.3***
Median	**10**	**12**	**2**	**2**	**5**	**17**	**21**	**10**	**12**	***23.6***

Table 3. *Perkinsus marinus* prevalence and mean intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2023. 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	0.0
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	0.1
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	3.0	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	0.1
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	0.1
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	4.0	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	2.0	3	0.1
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	0.0
Lower Cedar Point	20	0.4	3	0.1	55	1.6	33	1.1	50	1.6	0	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		2020		2021		2022		2023		*34-Yr Avg*	
	%	I	%	I	%	I	%	I	%	I	*%*	*I*
Swan Point	3	0.1	0	0.0	0	0	13	0.2	0	0	*24.1*	*0.6*
Hackett Point	10	0.5	30	0.9	40	1.8	57	1.4	27	0.8	*47.8*	*1.4*
Holland Point (S)	0	0.0	0	0.0	3	0.1	3	0.1	90	2.1	*37.8*	*1.1*
Stone Rock	23	1.0	23	0.6	10	0.3	63	1.9	67	2	*67.6*	*2.2*
Flag Pond (S)	13	0.5	87	3.0	90	3.8	100	3.2	93	3.9	*52.0*	*1.7*
Hog Island	27	1.0	30	1.0	30	0.7	90	2.7	97	3.4	*71.2*	*2.6*
Butler	60	2.0	60	2.0	80	2.8	93	3.7	87	3.2	*68.5*	*2.2*
Buoy Rock	3	0.1	0	0.0	13	0.3	23	0.4	7	0.1	*45.7*	*1.4*
Old Field (S)	17	0.4	20	0.7	17	0.6	39	0.7	27	0.5	*53.2*	*1.6*
Bugby	90	2.8	57	1.6	67	2.2	90	2.5	93	2.3	*80.5*	*2.6*
Parsons Island	7	0.4	23	0.5	3	0.07	20	0.4	37	0.9	*64.7*	*2.1*
Hollicutt Noose	13	0.5	13	0.4	10	0.2	33	0.9	30	0.6	*55.0*	*1.7*
Bruffs Island (S)	70	2.3	33	0.8	57	2.3	13	0.3	63	1.2	*69.3*	*2.2*
Turtle Back	73	2.9	67	2.2	37	1	67	1.8	47	1.1	*80.6*	*2.7*
Long Point (S)	3	0.03	13	0.3	27	1	70	1.6	67	1.3	*61.1*	*2.0*
Cook Point (S)	37	1.2	80	2.6	57	2	90	2.2	100	4.3	*61.2*	*2.0*
Royston	20	0.6	60	1.5	13	0.5	27	0.5	33	0.9	*51.7*	*1.8*
Lighthouse	3	0.2	0	0.0	0	0	3	0	3	0.03	*38.9*	*1.3*
Sandy Hill (S)	53	2.4	67	2.1	27	0.7	70	1.5	97	3.6	*73.6*	*2.7*
Oyster Shell Pt. (S)	3	0.1	20	0.5	13	0.2	60	1.1	47	0.7	*39.5*	*1.1*
Tilghman Wharf	23	0.9	20	0.7	40	1.1	40	0.9	60	1.5	*50.6*	*1.5*
Deep Neck	33	1.2	30	0.9	57	1.4	93	2.7	100	3.9	*77.5*	*2.7*
Double Mills (S)	47	1.8	63	2.2	70	2.3	97	3	97	3.1	*79.3*	*2.8*
Cason (S)	60	2.0	50	1.7	57	1.7	90	2.6	87	2.6	*78.1*	*2.6*
Ragged Point	60	1.4	73	2.6	77	2.3	97	2.6	97	3.1	*80.4*	*2.6*
Norman Addition	37	1.5	23	0.8	7	0.3	67	1.9	67	2.4	*73.6*	*2.6*
Goose Creek	27	1.1	53	2.0	63	2.5	93	3.5	100	4.6	*67.5*	*2.4*
Wilson Shoals (S)	30	1.0	47	1.2	60	2	90	3	97	4.3	*81.5*	*2.6*
Georges (S)	77	3.1	77	2.9	73	2.6	90	4	100	4.3	*81.8*	*2.9*
Holland Straits	0	0.0	0	0.0	3	0.03	20	0.6	27	0.8	*56.8*	*1.9*
Sharkfin Shoal	63	2.4	67	2.7	57	2.8	93	4	100	3.6	*81.7*	*3.0*
Back Cove	3	0.2	10	0.3	83	2.6	93	4.1	97	4.7	*76.7*	*2.8*
Piney Island East	17	0.5	3	0.1	23	0.6	53	1.7	100	3.3	*72.1*	*2.4*
Old Woman's Leg	0	0.0	0	0.0	3	0.1	30	0.7	73	2.2	*65.6*	*2.3*
Marumsco	30	1.0	7	0.3	37	1.1	73	1.7	100	4.9	*78.0*	*2.8*
Broome Island	13	0.5	27	0.8	27	0.7	67	1.8	97	3.2	*72.1*	*2.5*
Chicken Cock	27	1.2	23	0.7	30	1.1	57	1.4	77	2.2	*68.8*	*2.2*
Pagan (S)	17	0.4	37	1.1	70	2.4	50	1.6	87	2.7	*76.4*	*2.4*
Lancaster	7	0.2	47	1.5	63	2	93	3.1	97	3.9	*58.2*	*1.8*
Mills West	0	0.0	3	0.2	3	0.2	3	0	7	0.1	*49.5*	*1.5*
Cornfield Harbor	40	1.3	53	2.0	43	1.6	90	2.3	83	2.3	*76.7*	*2.4*
Ragged Point	0	0.0	0	0.0	0	0	23	0.3	3	0.03	*17.9*	*0.5*
Lower Cedar Point	NA	NA	10	0.4	17	0.5	7	0.1	27	0.5	*21.5*	*0.5*
Annual Means	**27**	**1.0**	**33**	**1.1**	**36.2**	**1.2**	**58.9**	**1.7**	**67.3**	**2.28**	***62.5***	***2.1***
Bar Freq. (%)	**88**		**84**		**93**		**100**		**98**		***96.5***	

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2023. 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	2020	2021	2022	2023	*34-yr avg*
Swan Point	0	0	0	0	0	0.0
Hackett Point	0	0	0	0	3	0.6
Holland Point (S)	0	0	0	0	27	2.9
Stone Rock	0	0	0	0	40	8.9
Flag Pond (S)	0	0	0	0	33	5.7
Hog Island	0	0	0	0	33	8.9
Butler	0	0	0	3	27	10.8
Buoy Rock	0	0	0	0	0	0.0
Old Field (S)	0	0	0	0	0	0.0
Bugby	0	0	0	0	0	1.3
Parsons Island	0	0	0	0	0	1.0
Hollicutt Noose	0	0	0	0	17	3.8
Bruffs Island (S)	0	0	0	0	0	0.8
Turtle Back	0	0	0	0	0	2.1
Long Point (S)	0	0	0	0	0	0.2
Cook Point (S)	0	0	0	0	47	10.1
Royston	0	0	0	0	67	6.3
Lighthouse	0	0	0	0	93	8.5
Sandy Hill (S)	0	0	0	0	17	2.8
Oyster Shell Pt. (S)	0	0	0	0	0	1.1
Tilghman Wharf	0	0	0	0	40	6.3
Deep Neck	0	0	0	0	3	3.6
Double Mills (S)	0	0	0	0	0	1.6
Cason (S)	0	0	0	0	37	7.3
Ragged Point	0	0	0	0	53	9.7
Norman Addition	0	0	0	13	37	11.1
Goose Creek	0	0	3	0	13	7.3
Wilson Shoals (S)	0	0	0	0	13	4.4
Georges (S)	0	0	0	0	17	6.3
Holland Straits	0	0	0	3	20	13.8
Sharkfin Shoal	0	0	3	7	23	12.5
Back Cove	0	0	3	13	7	12.3
Piney Island East	0	3	3	17	40	15.1
Old Woman’s Leg	0	0	7	13	23	15.5
Marumsco	3	0	0	13	13	8.1
Broome Island	0	0	0	0	3	2.0
Chicken Cock	0	0	0	0	0	11.0
Pagan (S)	0	0	0	0	0	2.9
Lancaster	0	0	0	0	0	0.3
Mills West	0	0	0	0	0	1.4
Cornfield Harbor	0	0	0	0	7	12.1
Ragged Point	0	0	0	0	3	3.1
Lower Cedar Point	NA	0	0	0	0	0.0
Avg. Prev. (%)	**0.1**	**0.1**	**0.4**	**1.9**	**17.9**	5.7
Pos. Bars (%)	**2**	**2**	**12**	**19**	**65**	29.2

Table 5. Oyster population observed mortality estimates from the 43 disease monitoring bars, 1985-2023. 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	2020	2021	2022	2023	***39-yr Avg***
Swan Point	4	0	3	0	0	8	12	3	3	12	1	***10.2***
Hackett Point	0	0	0	3	19	3	5	21	23	4	4	***12.7***
Holland Point (S)	12	40	29	0	0	50	NA	NA	0	50	0	***23.2***
Stone Rock	2	5	31	36	30	9	5	4	3	6	24	***20.5***
Flag Pond (S)	15	13	5	6	50	3	1	7	17	17	37	***20.9***
Hog Island	2	2	12	38	27	18	0	5	3	3	31	***25.5***
Butler	7	7	10	11	4	5	7	14	8	14	30	***23.1***
Buoy Rock	5	9	3	12	4	12	9	13	5	0	3	***15.3***
Old Field (S)	0	3	0	5	33	10	31	33	7	33	18	***14.5***
Bugby	8	31	21	21	13	12	17	18	23	9	11	***24.3***
Parsons Island	2	4	15	2	10	14	0	5	0	0	1	***18.8***
Hollicutt Noose	1	9	6	7	29	30	8	2	10	4	3	***19.3***
Bruffs Island (S)	0	4	5	16	20	41	38	25	20	4	3	***22.2***
Turtle Back	0	8	14	18	3	15	8	3	0	7	2	***22.2***
Long Point (S)	20	0	0	17	0	0	37	NA	0	0	7	***20.7***
Cook Point (S)	9	12	16	48	45	24	13	12	5	8	56	***25.7***
Royston	1	6	9	16	4	2	4	3	2	0.3	18	***16.1***
Lighthouse	1	1	2	9	7	0	4	2	1	0	21	***18.4***
Sandy Hill (S)	3	13	11	15	15	11	11	4	4	7	10	***23.0***
Oyster Shell Pt. (S)	2	5	2	11	11	18	24	12	4	3	6	***10.4***
Tilghman Wharf	5	1	5	11	1	7	4	6	1	1	8	***15.8***
Deep Neck	5	7	16	8	2	3	3	2	1	6	9	***18.9***
Double Mills (S)	11	12	10	20	13	11	2	7	6	13	17	***19.5***
Cason (S)	11	8	17	26	33	8	4	2	2	2	12	***23.3***
Ragged Point	15	13	21	45	14	6	3	11	4	8	53	***25.6***
Norman Addition	9	7	13	14	15	8	2	2	1	2	18	***22.7***
Goose Creek	5	15	22	27	6	10	3	4	5	7	32	***30.2***
Wilson Shoals (S)	5	4	7	17	6	4	4	6	9	2	22	***19.3***
Georges (S)	15	5	8	23	15	9	5	7	9	26	27	***27.2***
Holland Straits	9	48	71	18	4	17	4	1	0	6	16	***26.9***
Sharkfin Shoal	16	18	24	19	3	7	4	5	13	20	29	***29.5***
Back Cove	11	19	14	1	2	8	1	1	4	22	41	***21.8***
Piney Island East	7	10	9	21	25	38	33	4	9	6	19	***27.5***
Old Woman's Leg	50	75	15	0	50	25	10	5	5	5	12	***28.6***
Marumsco	13	13	17	13	20	34	36	4	8	23	26	***24.4***
Broome Island	7	8	14	21	3	4	0	4	1	2	7	***18.7***
Chicken Cock	1	7	16	32	20	17	20	2	6	3	3	***25.1***
Pagan (S)	4	13	22	28	6	4	4	49	11	7	3	***20.1***
Lancaster	13	0	3	1	1	10	5	2	5	10	10	***14.1***
Mills West	20	9	5	14	0	5	15	21	5	0	0	***13.8***
Cornfield Harbor	10	16	10	36	8	3	5	2	3	4	6	***25.6***
Ragged Point	0	0	50	10	8	4	33	0	12	0	1	***20.3***
Lower Cedar Point	0	0	6	8	27	96	100	100	1	1	0	***18.4***
Annual Means	**8**	**11**	**14**	**16**	**14**	**14**	**13**	**10**	**6**	**8**	**15**	***21.0***

Table 6. Regional summary of oyster harvests (bu.) in Maryland from buy tickets, 1985-86 through 2022-23 seasons as reported by seafood dealer buy tickets.

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. Marys 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. Marys 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. Marys 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. Marys 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. Marys 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). Landing figures for the 2015-16 through 2021-22 seasons have been revised from previous tables to reflect the most accurate data presently available. Subtotals subject to rounding.

Region/Tributary	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
Upper Bay	3,634	4,657	2,603	794	48	0
Middle Bay	14,112	9,196	5,160	2,977	4,960	3,749
Middle Bay Tributaries	2,398	1,900	1,180	181	780	979
Lower Bay	4,285	4,314	9,204	11,347	13,506	8,797
Total Bay Mainstem	*24,428*	*20,067*	*18,146*	*15,298*	*19,294*	*13,525*
Chester R.	1,533	469	5,024	386	644	23
Eastern Bay	13,180	15,619	9,678	8,578	9,696	4,671
Miles R.	3,335	1,666	572	962	180	0
Wye R.	8	17	4	0	0	0
Total Eastern Bay Region	*16,523*	*17,302*	*10,254*	*9,540*	*9,876*	*4,671*
Upper Choptank R.	62	36	83	167	0	0
Middle Choptank R.	9,782	5,749	6,545	3,891	4,367	2,209
Lower Choptank R.	24,611	11,017	6,472	11,853	13,111	10,124
Tred Avon R.	3,901	2,431	889	2,730	631	375
Broad Cr.	68,039	32,075	32,581	32,359	39,984	33,970
Harris Cr.	7,028	2,663	3,631	5,220	6,508	3,248
Total Choptank R. Region	*113,423*	*53,970*	*50,200*	*56,220*	*64,600*	*49,926*
Little Choptank R.	2,481	2,361	445	222	9,864	8,588
Upper Tangier Sound	64,342	35,522	33,287	22,029	83,248	148,232
Lower Tangier Sound	28,491	9,481	7,277	2,790	7,522	29,462
Honga R.	13,285	11,188	2,122	916	2,788	7,678
Fishing Bay	20,258	13,637	7,508	5,828	23,329	33,621
Nanticoke R.	7,075	7,430	7,984	4,193	8,435	13,144
Wicomico R.	10,137	4,735	1,132	939	1,185	952
Manokin R.	1,409	1,054	1,843	1,029	407	0
Big Annemessex R.	4,076	473	90	74	24	37
Pocomoke Sound	10,261	6,131	5,269	2,166	2,178	3,705
Total Tangier Sound Region	*159,333*	*89,650*	*66,511*	*39,963*	*129,115*	*236,830*
Patuxent R.	51,451	23,623	9,973	9,395	24,525	17,001
Wicomico R., St. Clement and Breton bays	5,608	3,452	893	1,166	356	231
St. Marys R. and Smith Cr.	10,574	7,974	19,224	12,361	11,686	13,167
Total Potomac Md. Tribs.	*16,181*	*11,426*	*20,117*	*13,527*	*12,042*	*13,398*
Total Maryland (bu.)[1]	***388,381***	***223,616***	***182,639***	***145,208***	***272,143***	***345,479***

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued). Landing figures for the 2015-16 through 2021-22 seasons have been revised from previous tables to reflect the most accurate data presently available. Subtotals subject to rounding.

Region/Tributary	2021-22	2022-23	*38-yr Avg*
Upper Bay	7,351	146	*11,193*
Middle Bay	1,545	4,126	*13,898*
Middle Bay Tributaries	889	439	*1,093*
Lower Bay	17,583	29,312	*7,213*
Total Bay Mainstem	*27,368*	*34,022*	*32,155*
Chester R.	856	26	*18,865*
Eastern Bay	3,181	2,384	*26,051*
Miles R.	3	0	*4,607*
Wye R.	0	0	*1,632*
Total Eastern Bay Region	*3,184*	*2,384*	*32,289*
Upper Choptank R.	0	0	*8,260*
Middle Choptank R.	2,518	2,970	*16,407*
Lower Choptank R.	6,722	13,012	*14,539*
Tred Avon R.	553	3,663	*9,609*
Broad Cr.	37,441	57,017	*23,983*
Harris Cr.	7,892	18,969	*7,955*
Total Choptank R. Region	*55,127*	*95,630*	*80,752*
Little Choptank R.	12,882	12,032	*11,126*
Upper Tangier Sound	215,101	147,541	*31,519*
Lower Tangier Sound	80,687	218,643	*21,386*
Honga R.	24,997	47,403	*9,026*
Fishing Bay	46,032	42,056	*16,746*
Nanticoke R.	22,043	9,061	*7,868*
Wicomico R.	1,646	4,404	*1,450*
Manokin R.	1,037	20	*3,051*
Big Annemessex R.	0	44	*218*
Pocomoke Sound	4,821	10,847	*5,282*
Total Tangier Sound Region	*396,363*	*480,017*	*96,543*
Patuxent R.	38,800	78,470	*15,439*
Wicomico R., St. Clement and Breton bays	4,697	2,190	*9,151*
St. Marys R. and Smith Cr.	8,004	10,659	*8,976*
Total Potomac Md. Tribs.	*12,700*	*12,849*	*18,109*
Total Maryland (bu.)[1]	***548,155***	***719,716***	***310,210***

[1] Includes harvests from unidentified regions.

Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2022-23 seasons as reported by seafood dealer buy tickets. Dockside value is in millions of dollars. Landing figures for the 2015-16 through 2021-21 seasons have been revised to reflect the most accurate data presently available.

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	79,060	38,202	103,620	126,290	38,774	*388,381*	*$15.0 M*
2016-17	45,301	24,113	53,710	81,815	17,647	*223,616*	*$10.6 M*
2017-18	37,449	22,922	31,417	78,694	11,135	*182,369*	*$8.7 M*
2018-19	35,899	11,556	21,257	64,222	12,243	*145,208*	*$6.6 M*
2019-20	44,174	19,978	69,796	113,038	25,083	*272,143*	*$12.3 M*
2020-21	39,193	14,452	102,573	148,624	40,533	*345,479*	*$10.5 M*
2021-22	45,146	15,405	177,364	262,017	48,175	*548,155*	*$21.8 M*
2022-23	67,331	17,660	243,177	338,287	53,138	*719,716*	*$31.1M*

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

Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2022-23 seasons as reported by seafood dealer buy tickets. Some years may not total 100% due to incomplete data. Percentages for the 2015-16 through 2021-22 seasons have been revised to reflect the most accurate data presently available.

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	20	10	27	33	10
2016-17	20	11	24	37	8
2017-18	21	13	17	43	6
2018-19	25	8	15	44	8
2019-20	16	7	26	42	9
2020-21	11	4	30	43	12
2021-22	8	3	32	48	9
2022-23	9	2	34	47	7

Table 8. Oyster bars within sanctuaries sampled during the 2023 Fall Survey. Newly added sanctuaries/survey stations are in *italics*.

Region	Oyster Sanctuary	Surveyed Bars Within Sanctuary
Upper Bay	Man O War/Gales Lump	Man O War Shoals, Tea Table
Middle Bay	Poplar Island	Poplar I.
	Herring Bay	Holland Pt.[1,2]
	Tilghman Island	*Pone*
	Calvert Shore	Flag Pond[1,2]
Lower Bay	Lower Mainstem East	Northwest Middleground[3]
	Cedar Point Hollow	Cedar Point Hollow Addition 1
	Point Lookout	Pt. Lookout[3]
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
	Prospect Bay	Sawmill Creek
	Cox Creek	Ringold Middleground
	Eastern Bay	Tilghman Pt.
Wye River	Wye River	Bruffs I.[1,2], Mills, Race Horse, Whetstone, Wye River Middleground
Miles River	Miles River	Long Pt.[2], *Bazzles Hill*
Choptank River	Cook Point	Cook Pt.[1,2]
	Lower Choptank River	Chlora Pt.
	Sandy Hill	Sandy Hill[1,2]
	Howell Point - Beacons	Beacons
	Upper Choptank River	Green Marsh[3], 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, 3], Seths Pt., Walnut, Little Neck, Rabbit I.[3]
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[3]
Magothy River	Magothy River	Persimmon
Severn River	Severn River	Chinks Pt.
South River	South River	Almshouse
Patuxent River	Upper Patuxent	Thomas, Broad Neck, Trent Hall, Buzzard I., Holland Pt.
	Neal Addition	Neale
	Lower Patuxent	Millstone
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 [3] Supplemental Disease Bar

APPENDIX 1
2024 Spring Dredge Survey

PURPOSE

A spring dredge survey was conducted in 2024 to address four questions related to the findings of the 2023 Fall Survey, hence its inclusion in this report.

1. Compare spat counts between the fall and the following spring to determine whether spat were underreported in the fall due to a late set just before or even after the survey. A late set can yield very small spat that could potentially be undetectable during sample processing. The higher recruitment regions in southern Maryland are the first to be sampled in October to accommodate disease sample logistics when a secondary spatset may have occurred. In the spring the spat are larger and presumably easier to find. The strong spatset in 2023 presented an opportunity to examine this question.
2. Determine whether there was an increase in observed mortalities post-Fall Survey. MSX disease levels markedly increased during 2023, and while observed mortalities rose somewhat from the previous year, the increases were not to the degree expected considering the often high MSX prevalences. The timing of disease acquisition may be a factor - if occurring later in the season, there may not have been enough time to kill the infected oysters before the survey. Additionally, the pathogens would remain active after the survey until water temperatures reached the minimum threshold of 5ºC in December (Ford and Haskin 1982).
3. Investigate the persistence of MSX disease in response to falling salinities over the winter. *Haplosporidium nelsoni* is sensitive to lower salinities. The pathogens can tolerate salinities down to 10-12 ppt and become lethal at about 15 ppt and higher (Ford 1985, Sprague at al. 1969)). The extensive spread of the disease in 2023 was enabled by drought conditions which raised salinities. MSX disease was detected as far upbay as Hacketts bar, located just outside of Annapolis, and was sometimes found at astonishingly high prevalences – the 93% prevalence on Lighthouse bar in the Choptank River was the highest on record in Maryland. The drought broke during the winter/spring of 2024 and salinities plummeted throughout the bay. Dermo disease was not considered for this study because it is usually undetectable in the spring using standard analysis techniques.
4. Compare adult (>1-year old) oyster densities at the beginning of the harvest season in the fall and after the season closes in the spring. This was to provide information for the oyster stock assessment project currently being revised and updated. Sampling took place in three of the major harvest regions. Preliminary results are presented but analyses of these data are left to the benchmark stock assessment project, which is scheduled for completion later in 2024.

METHODS

The sampling methodology follows that of the Fall Survey described previously with the exception that two dredge tows were taken at every location to obtain two 0.5 bu subsamples. These were processed individually and the results combined to place them on a per bushel basis per location.

The survey was conducted between 25 April and 2 May 2024. A total of 33 locations were sampled from three major harvest regions: Tangier region – 13 samples, lower Patuxent River – 12 samples, and Choptank region - 8 samples (Figure A1-1). Samples for disease analyses were obtained from three disease sentinel sites: Piney Island East in Tangier Sound, Royston in Broad Creek, and Lighthouse in the Choptank River. These sites were selected because of their high MSX prevalences found during the Fall Survey. A disease sample was not taken from the Patuxent River because the nearest disease sentinel bar was outside of the study area and had a lower MSX prevalence than the other sites.

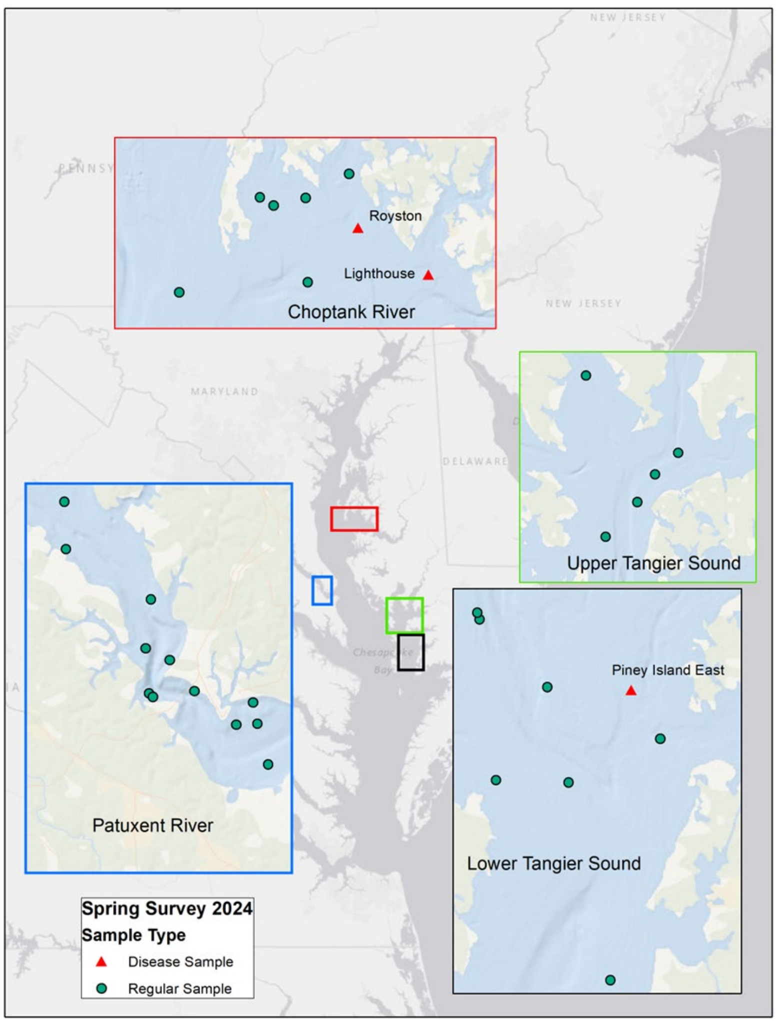

Figure A1-1. Location of 2024 Spring Dredge Survey sample locations and disease sentinel sites.

RESULTS

Salinity

Salinities in both south Tangier Sound and the outer Choptank River were above average throughout 2023 (Figure A1-2). Tangier Sound salinities remained above 15 ppt through February 2024, setting a record high for the 39-year time series of 19.1 ppt in June 2023, and reached a peak of 19.8 ppt in November 2023. They subsequently fell below the long-term mean in March 2024 and remained so into June. By May 2024, salinities had dropped to 12.4 ppt.

In the outer Choptank River, salinities were above 15 ppt for the first two months of the year, then dropped just below that mark through September. Salinities then climbed above 15 ppt for the remainder of the year, reaching a high of 17 ppt in November, before falling precipitously beginning in January 2024. In April, the salinity had fallen below 10 ppt and by May the salinity had collapsed by over half of the fall peak to 8.0 ppt.

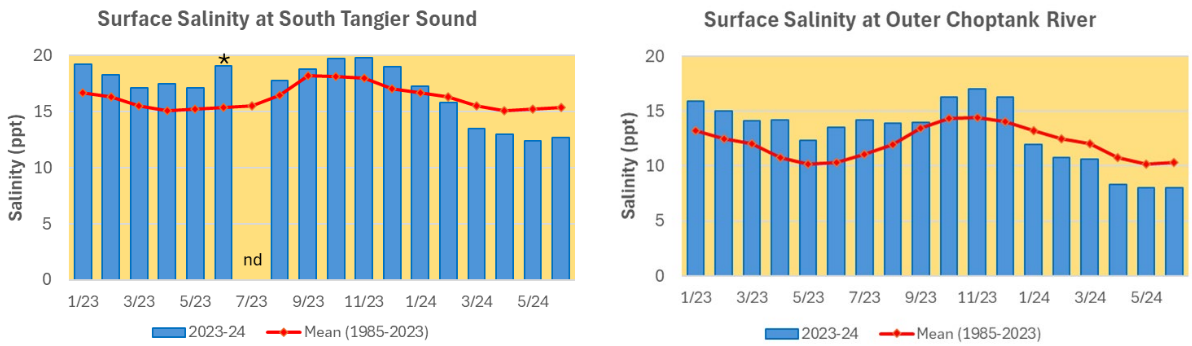

Figure A1-2. Monthly surface salinities during 2023 and the first half of 2024 at monitoring stations closest to sentinel sites for disease samples obtained during the Spring Dredge Survey. The average difference between surface salinity and at 5 m was 0.18 ppt at both locations. * Record maximum monthly salinity.

Surface water temperatures in south Tangier Sound and outer Choptank River closely mimicked each other save for January 2024, when it dropped below 5°C at the Choptank site, the only time to do so (Figure A1-3). This is the minimum temperature threshold for MSX activity.

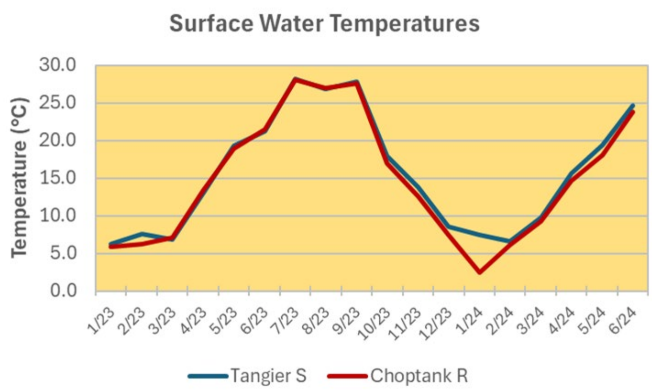

Figure A1-3. Monthly surface temperatures during 2023 and the first half of 2024 at monitoring stations closest to sentinel sites for disease samples obtained during the Spring Dredge Survey.

Spat Count Comparisons

Regional spat averages were somewhat lower during the spring compared to the fall, but there were no statistically significant differences between the two periods (t-tests, p=0.45 to 0.53) (Figure A1-4). The lower spring averages suggest that either spat were not overlooked during processing nor missed due to a secondary post-survey set or, if there was indeed a missed late set, it was balanced out by natural mortality. In either case the counts were similar between the fall and spring surveys and does not justify adding a spring survey component in the future solely to assess spatfall. The fall survey spat counts are an appropriate reflection of recruitment and are consistent with the existing 39-year data set.

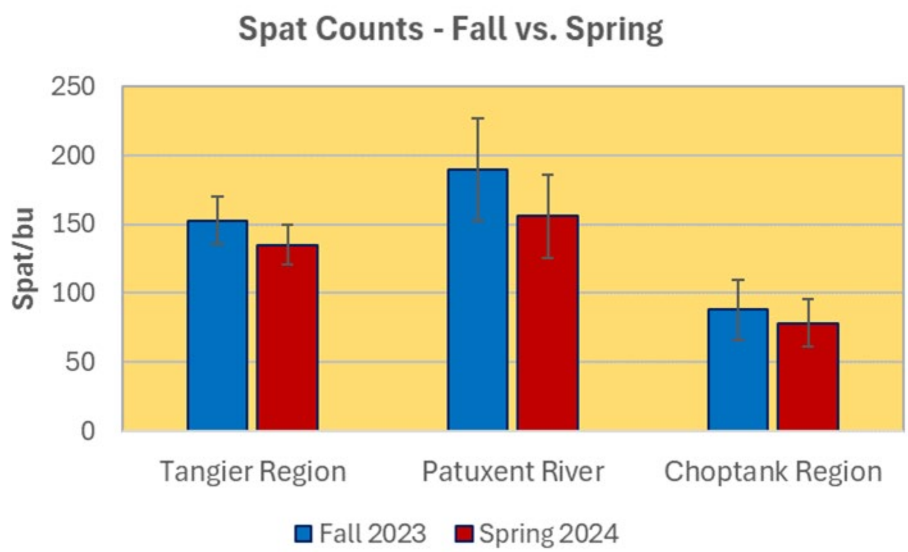

Figure A1-4. Mean ±SE spat counts comparing between fall and spring surveys in three recruitment regions.

Post-Fall Survey Observed Mortalities

Average observed mortalities increased considerably after the Fall Survey in the Patuxent River (from 22% to 37%) and Choptank region (from 21% to 40%) (Figure A1-5). Interestingly, spring observed mortalities were actually lower in the Tangier region (from 26% to 19%). The differences in all three regions were statistically significant (t-tests, $p<0.05$). The range of observed mortalities contracted in the Tangier region from 14-41% to 13-27% in the spring. In contrast, mortality ranges expanded post-Fall Survey in the Patuxent River (15-32% to 14-65%) and the Choptank region (8-56% to 15-68%).

The presence of recent boxes in May indicate that mortalities had resumed in the spring (Table A1-1). Also, box counts per bushel in the Choptank region were double that of the next highest numbers, suggesting that this was a more vulnerable population to MSX disease.

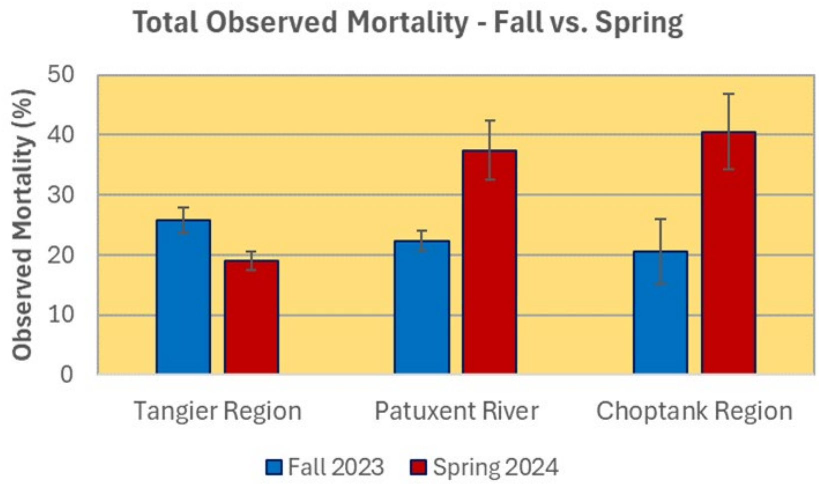

Figure A1-5. Mean ±SE of observed mortalities during the fall and spring surveys in three regions.

Table A1-1. Spring Survey box counts categorized by age.

Region	Dead Oysters per Bushel					
	Market Boxes		Small Boxes		Percent of Total Boxes	
	Old	Recent	Old	Recent	Old	Recent
Tangier Sound	10.6	1.8	11.9	4.7	77.6%	22.4%
Patuxent River	15.9	3.7	14.3	3.7	80.3%	19.7%
Choptank River	15.3	8.3	16.0	34.5	42.2%	57.8%

MSX Disease

The prevalence of MSX disease dropped by varying amounts between the fall and spring surveys at three sentinel sites (Figure A1-6), depending on the degree of decline in salinity during the winter and spring of 2024. Piney Island East in Tangier Sound had the highest MSX prevalence in the Tangier region (40%) during the fall. With marginal salinities for *H. nelsoni* in the spring (Figure A1-2), the prevalence fell somewhat, but at 26% was still considered high. In contrast, salinities fell well below the tolerance limit of the pathogen at the two Choptank region sentinel sites (Figure A1-2). Consequently, Royston experienced a huge drop in MSX prevalence between the fall and spring, from 67% to 7%. But the most dramatic change was on Lighthouse, where prevalences plummeted from a record-high 93% to 0% in the spring. Disease-related parameters for the three sentinel sites in this study are in Table A1-2. A spring sample was not taken at the nearest Patuxent disease monitoring site (Hog Island), as it was outside the survey area. Also, the Hog Island fall sample had lower MSX disease prevalence than the other sites selected for disease analysis and had a high prevalence and intensity of dermo disease (Table 3) which could confound mortality results.

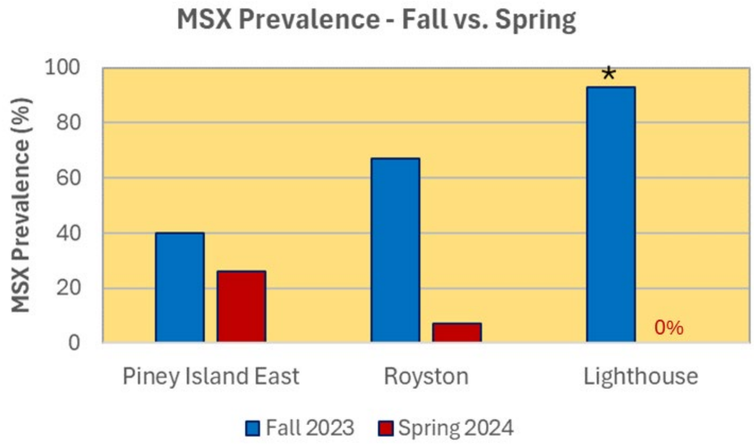

Figure A1-6. Changes in MSX disease between fall 2023 and spring 2024 surveys at three disease sentinel bars. *Highest MSX prevalence on a bar in the 34-year time series.

Table A1-2. Disease-related parameters for the fall 2023 and spring 2024 surveys at three sentinel bars. The time span for percent of years with MSX is from 2003 to 2023. * Highest MSX prevalence on a bar in the 34-year time series for Maryland.

Disease Sentinel Bar	Bottom Salinity, ppt		MSX Prevalence %		Observ. Mortality %		% Years w/MSX
	Fall	Spring	Fall	Spring	Fall	Spring	
Piney Island East	19.2	12.3	40	26	18.9	12.9	76.2
Royston	16.1	7.9	67	7	17.5	41.9	14.3
Lighthouse	16.3	8.0	93*	0	20.9	50.4	19.0

Harvest Season Changes in Oysters/Bu

The three regions examined in this study were first surveyed during the beginning of the harvest season in October, starting with the Tangier region. This month accounts for only about 15% of the total seasonal landings (MDNR, unpubl. data). In addition, power dredging, which was the leading gear type in the Tangier and Choptank regions and was responsible for 55% of the landings during the 2023-24 season, began on 1 November – after these areas had been surveyed. Therefore, the surveys can effectively be considered to have been conducted at the start of the 2023-24 harvest season.

Table A1-3. Comparisons of oyster counts per bushel of cultch at the beginning of the harvest season and after its conclusion. Statistically significant differences are highlighted in bold.

Region	Market Oysters/bu				Small Oysters/bu				Sm:Ma Ratio	
	Fall	Spring	Change	P-value	Fall	Spring	Change	P-value	Fall	Spring
Tangier S.	**50.1**	**34.2**	**-31.7%**	**0.042**	74.9	96.9	29.4%	0.178	1.50	2.83
Patuxent R.	45.6	25.9	-43.2%	0.146	38.6	31.2	-19.2%	0.266	0.85	1.20
Choptank R.	**93.8**	**30.8**	**-67.2%**	**0.001**	82	114.4	39.5%	0.459	0.87	3.72

Market oysters showed steep losses in numbers/bu in all three areas, ranging from 31.7% in the Tangier region to 67.2% in the Choptank region (Table A1-3, Figure A1-7). However, the declines were statistically significant (t-tests, $p<0.05$) only in the Choptank and Tangier regions; the decrease in market oysters in the lower Patuxent River was not statistically significant (t-test, $p=0.146$) (Table A1-3). The declines are attributable to harvesting and disease-related mortalities.

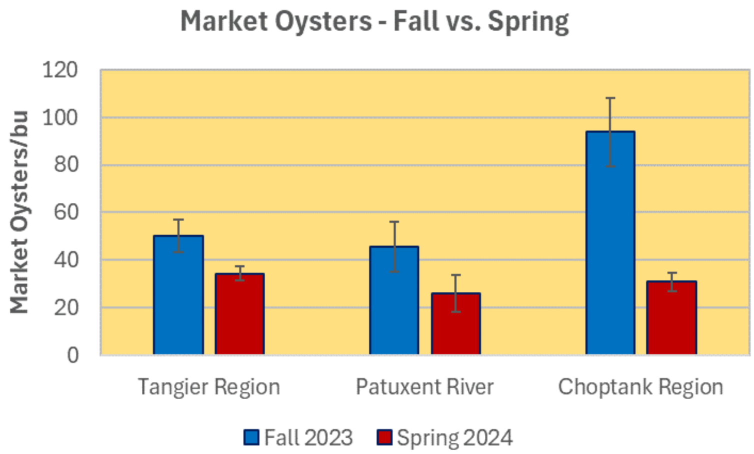

Figure A1-7. Changes in the mean ±SE number of market oysters per bushel of cultch in three harvest regions from the beginning of the 2023-24 season to after its conclusion.

In contrast, the average number of small oysters/bu increased in the Tangier and Choptank regions, while decreasing in the Patuxent River, though not to the degree as the market oysters in that river (Figure A1-8). None of these results were statistically significant (t-tests, $p>0.05$) (Table A1-3). These shifts in numbers of smalls and markets can be expressed as a ratio between the two size groupings. This ratio increased between the fall and spring as the number of small oysters became more abundant relative to the market oysters (Table A1-3).

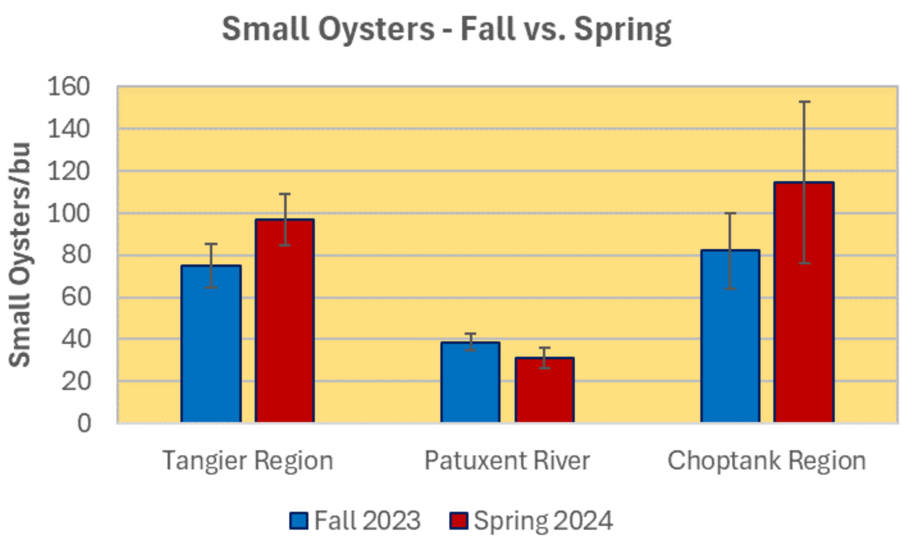

Figure A1-8. Changes in the mean ±SE number of small oysters per bushel of cultch in three harvest regions from the beginning of the 2023-24 season to after its conclusion.

APPENDIX 2
Hatchery Seed Plantings
Amy Larimer

Over 1.6 billion hatchery spat-on-shell were planted on 50 oyster bars in the Maryland portion of Chesapeake Bay (Table A2-1) during 2023. The Fall Survey sampled 15 of these plantings (Figure A2-1). Most were entirely new locations on bars with other Fall Survey samples. Approximately 1.7 billion hatchery seed were planted at sampled locations (Table A2-1), covering approximately 470 acres. The mean density of these plantings was 4.1 million spat per acre. All areas received diploid spat except Bugby and Well Cove in Eastern Bay, Tolly Point in Mid-Bay East, and Swan Point, in the Upper Bay, where triploid spat were planted.

Spat were counted and the number of spat per bushel was enumerated (Table A2-2). Approximately 50 spat were measured at each of six locations (Figure A2-1). For the rest (except for Bazzles Hill), size ranges, including a "typical" middle value, were determined. Growth rate for spat was calculated in mm/day by dividing the mean size by the maximum days since planting.

The number of spat per bushel on these sites ranged from 76 to 932, with a mean of 339 spat per bushel, lower than the past two years, but higher than in 2020 (Table A2-3). Spat counts are generally a function of both the initial planting density as well as elapsed time. Shorter elapsed time in 2022 resulted in higher numbers of spat per bushel. In 2023, the elapsed time was similar to 2020, ranging from 110 to 173 days, with a mean of 136 (Table A2-3). The mean density was 4.1 million spat per acre, compared to 2.5-3.5 for the past three years. The 1.7 billion spat planted was more than twice the total of the previous year and more than four times the total planted for 2020. Individual sites varied in the density of spat planted (Table A2-1), ranging from 0.82 million per acre to 12.38 million at Ringold Middleground in Eastern Bay. Nearly 75% of the spat planted was used in sanctuaries (Table A2-3), mainly in the Manokin River (700 million spat, Table A2-1) for ongoing restoration projects. Another 200 million spat were planted in sanctuaries in Eastern Bay for restoration work there.

Similar to 2020, spat at some locations were unusually large. Spat sizes ranged from 12 to 100 mm shell height, with a mean of 45 mm. The maximum sizes from all plantings averaged 65 mm, the largest of the time series (Table A2-3). The largest spat measured 100 mm, compared to 64 mm in 2022 (Table A2-2). Median size for measured spat was quite variable, from about 33 mm at bars planted with diploid spat, to 70 mm at Bruffs Island (Figure A2-2). Triploid spat were generally larger than diploid spat and growth rates were generally higher for triploid spat, except for Swan Point (Figure A2-3). Bruffs Island in the Wye River and Hood in Eastern Bay were not planted with triploid spat but were larger than average. Bruffs Island was the earliest planting, begun 173 days before sampling, which may account for some of the difference. The sample at Hood was a mix of 2022 and 2023 hatchery seed.

Because some hatchery planting sites were sampled repeatedly, we can follow them over time. Table A2-4 lists the results in counts per bushel as well as sizes of spat, small- and market-sized oysters. In general, at least some of these plantings persisted until the oysters reached market size (76 mm) by the third year for diploid oysters. For triploid oysters (at Well Cove and Nanticoke Middleground bars), that interval was generally two years. Some sites were planted in both 2020 and 2021 (Bald Eagle Add 2, Bugby, Howells Point, Man O War Shoals, Swan Point, and Thunder and Lightning). In most cases, an effort was made to separate the oysters from different plantings, but this was not always possible (Bugby).

Table A2-1. Hatchery plantings on Fall Survey bars. [1]Nanticoke Middleground was also planted with fresh shell at the same site. Plantings were sampled at locations in bold.

Region	Bar Name	Area (acres)	# Planted (millions)	Density (millions/ acre)
Chester River	Durdin	4.14	9.63	2.32
	Piney Point	3.94	9.45	2.40
Choptank River	Dickinson	4.37	9.99	2.28
	Irish Creek	6.35	6.75	1.06
	Lighthouse	11.00	9.73	0.88
Eastern Bay	Bald Eagle Add 2	6.30	11.35	1.80
	Bald Eagle Add 3	3.84	10.10	2.63
	Bugby	8.17	14.61	1.79
	Cedar Island	2.90	9.57	3.30
	Hood	2.78	10.01	3.60
	Mill Hill	7.56	91.59	12.12
	Ringold Middleground	6.05	74.87	12.38
	Saw Mill Creek	6.06	60.18	9.93
	Tilghmans Point	4.66	18.17	3.90
	Well Cove	2.63	10.50	3.99
Little Choptank R.	Susquehanna	42.29	111.42	2.63
Lower Bay West	Hog Island	6.09	11.75	1.93
	Simmons	3.01	4.31	1.43
Manokin River	Drum Point	71.77	315.43	4.39
	Georges	6.53	43.91	6.72
	Marshy Island	76.38	345.48	4.52
Mid-Bay West	Coots	6.33	14.35	2.27
	Holland Point	3.54	26.51	7.49
	Tolly Point	21.45	24.11	1.12
Miles River	**Bazzles Hill**	6.08	49.53	8.15
	Herring Island	1.79	6.03	3.37
Nanticoke River	Middleground[1]	5.89	22.20	3.77

Region	**Bar Name**	**Area (acres)**	**# Planted (millions)**	**Density (millions/ acre)**
Patuxent River	Back Of Island	1.63	6.00	3.67
	Bob Wise	4.35	9.89	2.27
	Hungerford Hollow	7.25	6.22	0.86
	Spencers	4.60	9.89	2.15
South River	Almshouse	1.77	13.28	7.50
	Hill Point East	3.69	11.01	2.99
	Saunders	4.13	14.44	3.50
Tred Avon River	Bachelor Point	2.61	10.86	4.16
	Double Mills	5.26	26.50	5.04
	Louis Cove	2.55	12.84	5.03
	Mares Point	1.66	20.25	12.17
	Orem	0.94	4.19	4.46
	Pecks Point	1.58	11.41	7.20
Upper Bay East	Swan Point	25.35	28.86	1.13
	Swan Point (Triploids)	11	9.02	0.82
Upper Bay West	Man O War Shoals	10.21	24.96	2.44
Wicomico River East	Evans	2.86	10.43	3.64
Wicomico River West	Wicomico Middleground	14.31	15.32	1.07
	Lancaster	6.03	13.95	2.31
	Manahowic Creek	4.07	8.56	2.10
	Mills East	9.47	12.31	1.30
	Rock Point	6.43	15.86	2.46
Wye River	**Bruffs Island**	6.08	59.15	9.73
Grand Total		470	1,687	4.1

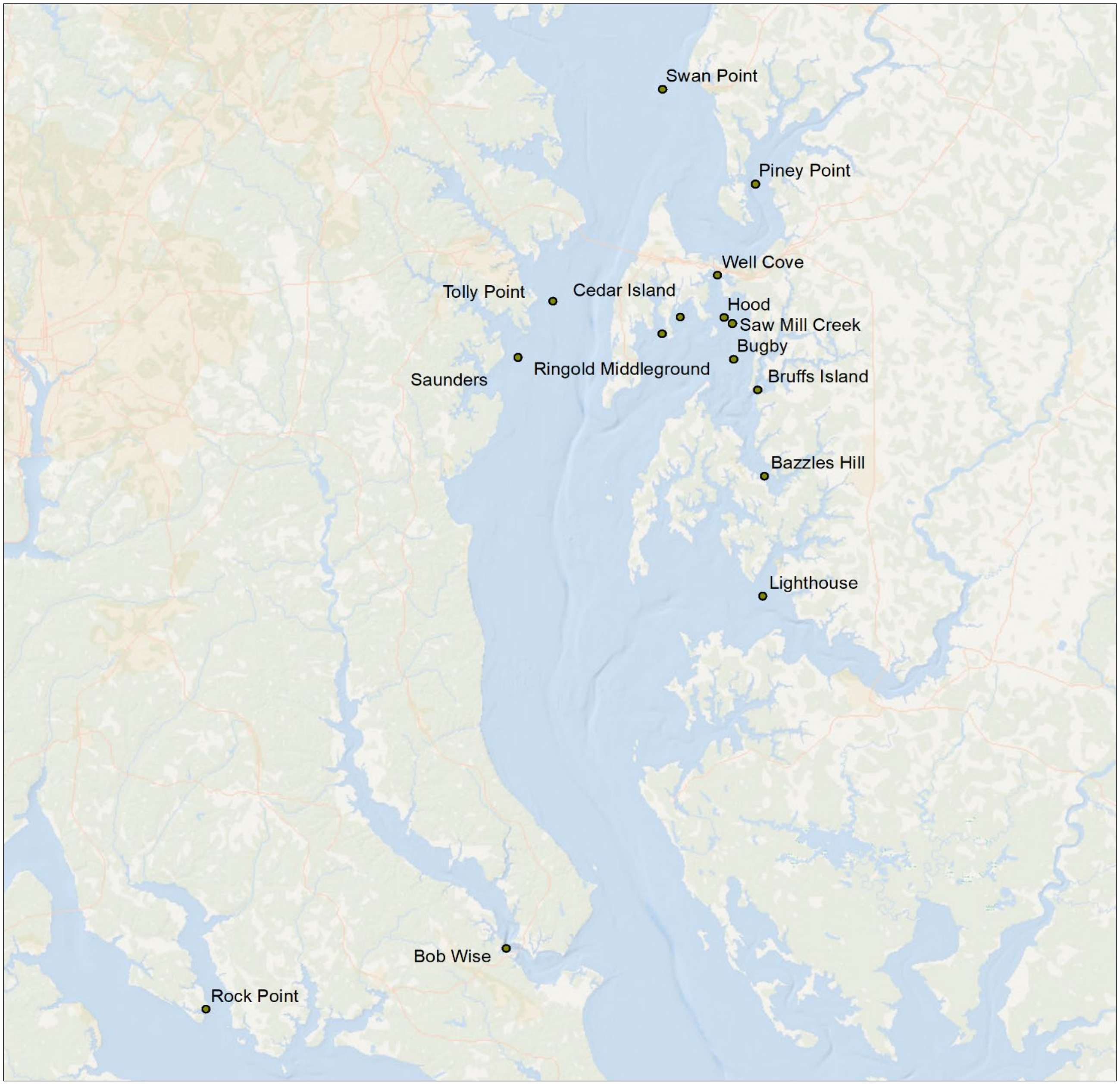

Figure A2-1. Map of Fall Survey stations on 2023 hatchery plantings.

Table A2-2. Hatchery plantings spat counts, sizes, elapsed time since planting, and growth rate. [1] Also had some natural spat (not included here). Triploid plantings in bold.

Region	Bar Name	# Spat (#/bu)	Min. Size (mm)	Max. Size (mm)	Avg. Size (mm)	Max. Days from Planting	Growth Rate (mm/day)
Chester River	Piney Point	348	32	62	43	140	0.30
Choptank River	Lighthouse	932	15	50	30	110	0.27
Eastern Bay	**Bugby**	86	37	60	45	124	0.36
	Cedar Island	737	26	60	40.78	131	0.31
	Hood	190	24	63	55	117	0.47
	Ringold Middleground	182	28	60	40	125	0.32
	Saw Mill Creek	76	15	50	40	117	0.34
	Well Cove	425	37	79	58.42	162	0.36
Mid-Bay West	**Tolly Point**	355	35	77	53.93	125	0.43
Miles River	Bazzles Hill	88	NA	NA	NA	154	NA
Patuxent River	Bob Wise	424	12	38	23.3	121	0.19
South River	Saunders	328	22	77	42.32	151	0.28
Upper Bay East	**Swan Point**	395	22	75	46.17	153	0.30
Wicomico River West	Rock Point[1]	214	17	60	45	139	0.32
Wye River	Bruffs Island	305	34	100	71.14	173	0.41
	Averages	339	25	65	45	136	0.33

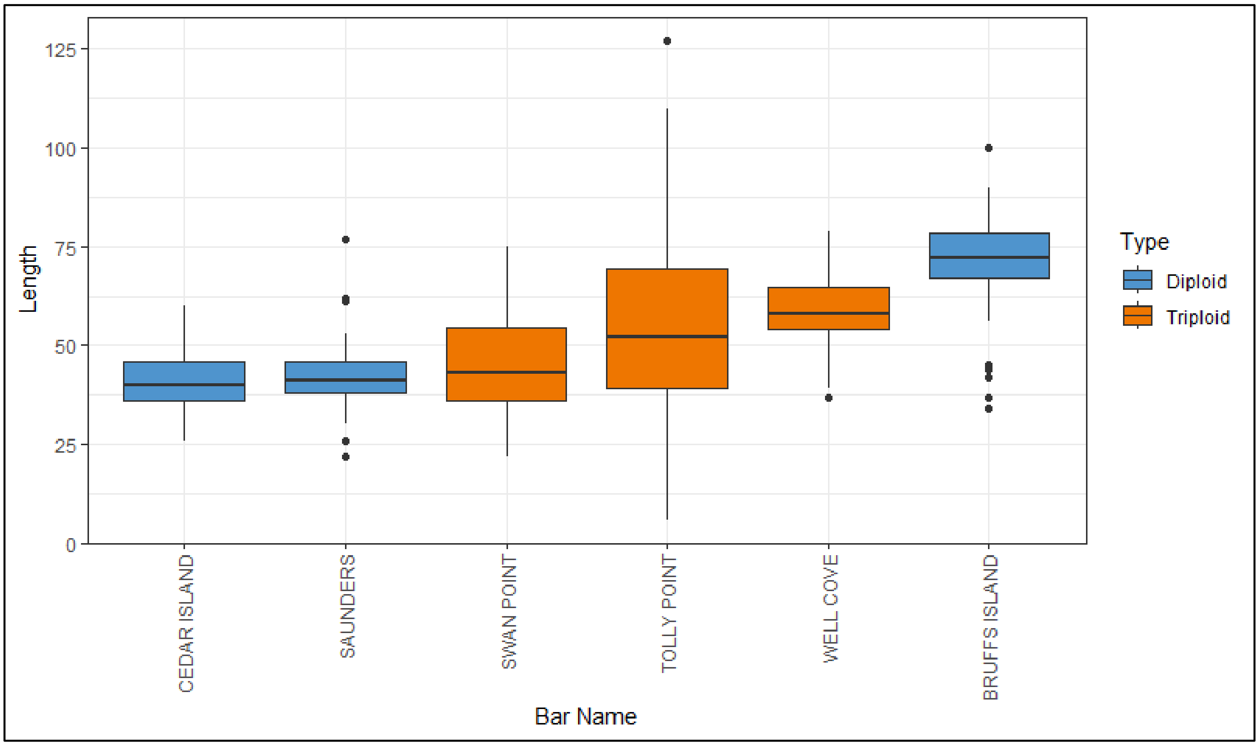

Figure A2-2. Size distribution of spat for Fall Survey planting sites, 2023. Stations in red were planted with triploid spat. Stations in blue were planted with diploid spat.

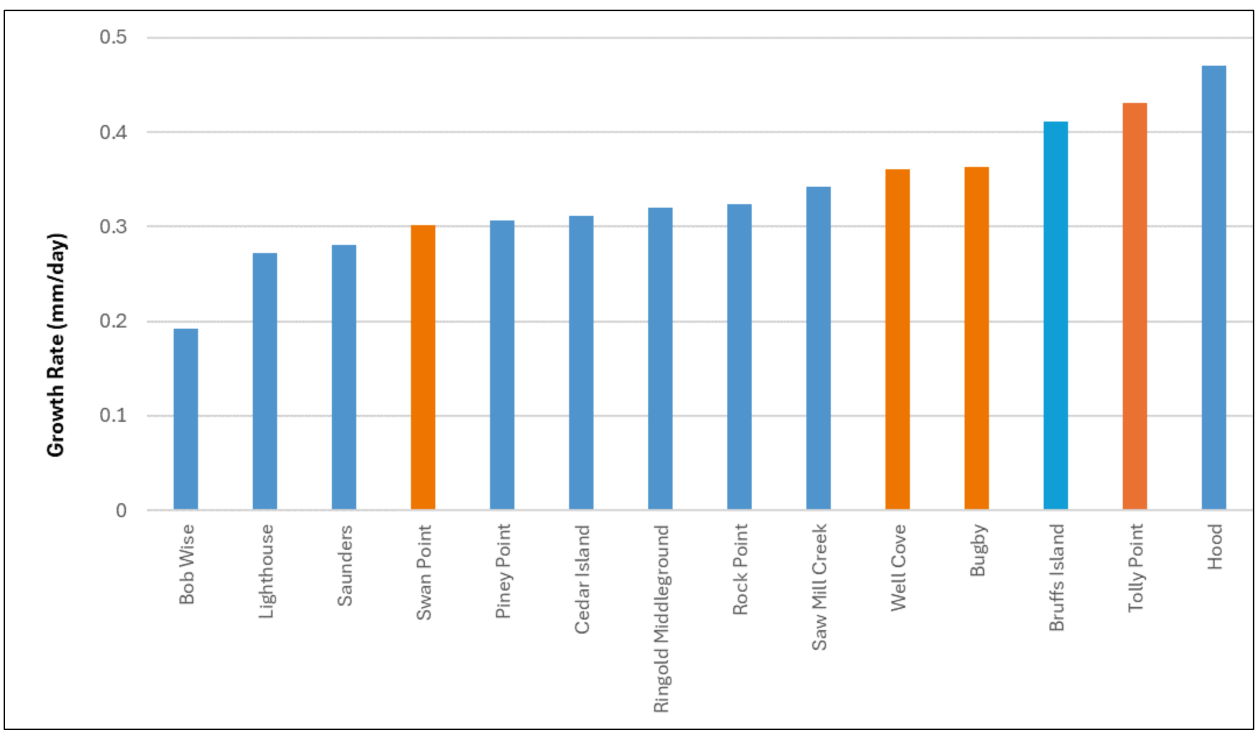

Figure A2-3. Growth rates of spat on hatchery plantings on Fall Survey in 2023. Locations in red received triploid spat, while those in blue received diploid spat.

Table A2-3. Table comparing sizes, elapsed time, spat counts and planting volumes for 2020-2023.

	2020	2021	2022	2023
Min. Size	22 mm	17 mm	16 mm	25 mm
Mean Size	41 mm	33 mm	32 mm	45 mm
Max. Size	60 mm	53 mm	49 mm	65 mm
Min. Days Since Planting	72	42	21	110
Mean Days Since Planting	132	108	83	136
Max Days Since Planting	181	161	129	173
Min. Spat per Bushel	26	32	268	76
Mean Spat per Bushel	299	680	874	339
Max. Spat per Bushel	1288	4068	2436	932
Volume (millions of spat)	387	712	725	1,686
Sanctuary	124	464	503	1,257
Non-Sanctuary	253	248	222	429
Acres Planted	209	220	258	470
Sanctuary	38	96	125	250
Non-Sanctuary	171	124	133	220
Average density (millions per acre)	2.5	3.5	2.8	4.1
Sanctuary	3.8	6.4	4.0	6.9
Non-Sanctuary	1.5	2.0	1.7	1.9

Table A2-4. Hatchery planting results for Fall Survey sites from 2020-2023. All counts are in number per bushel and the final three columns are minimum and maximum sizes with average or typical in parentheses. *A mix of spat planted in 2021 and smalls from the 2020 planting

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Spat (mm)	Small (mm)	Market (mm)
Chester River	Durdin	2020	52			17-63 (43)		
		2021		80	36		45-152 (113)	
		2022		4	38		44-53 (48.5)	85-152 (100)
		2023		102	46		40-71 (45)	85-108 (90)
	Piney Point	2020	54			31-70 (46)		
		2021		28	38		40-74 (63)	85-106(95)
		2022		4	4		62-73(67.5)	81-105(93)
		2023	348				32-62 (43)	
Choptank River	Dickinson	2020	290			22-52 (36)		
		2021		28	76		53-75 (63)	76-116 (90)
		2022		114	42		44-75 (60)	80-123 (93)
		2023		60	136		50-75 (67)	80-137 (95)
	Howells Point	2020	286			35-74 (51)		
		2021	186	122	30	16-57 (36)	39-72 (59)	76-105 (86)
		2022		122	76		35-75 (60)	76-132 (103)
	Howells Pt. Add 2	2020	358			17-58 (42)		
		2021		26	38		48-75 (57)	83-126 (93)
		2022		74	36		52-74 (63)	76-105 (90)
		2023		34	90		53-75 (67)	76-155 (103)

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Spat (mm)	Small (mm)	Market (mm)
Eastern Bay	Bald Eagle Add 2	2020	658			24-53 (43)		
		2021	524	12	24	31-88 (56)	50-68 (61)	76-102 (83)
	Bugby	2020	152			10-31 (27)		
		2021	318*			15-67 (52)		
		2022		36	76		46-70 (60)	80-120 (90)
		2023	86	162	42	37-60 (45)	44-75 (73)	76-125 (85)
	Crab Alley Lumps	2020	52			23-50 (43)		
		2021		202	18		40-75 (62)	76-84 (79)
		2022		58	14		35-75 (55)	76-95 (78)
		2023		20	30		55-73 (65)	76-95 (85)
	Well Cove	2020	110			38-85 (59)		
		2021		30	146		60-75 (70.5)	76-130 (92)
		2022			112			103-150 (105)
		2023			104			79-158 (110)
	Well Cove	2023	425			37-79 (58.4)		
Lower Bay East	Punch Island Creek	2020	1288			17-58 (36)		
		2021		160	120		52-74 (65)	76-123 (89)
		2022		16	108		55-75 (65)	76-125 (98)
Mid-Bay West	Coots	2020	226			28-63 (45)		
		2021		30	24		51-74 (65)	76-104 (90)
		2022	2436			11-44 (29.2)		
		2023		320			40-75 (65)	

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Spat (mm)	Small (mm)	Market (mm)
Mid-Bay West	Hackett Point	2020	856			16-53 (35)		
		2021		154	10		33-74 (60)	78-95 (86)
		2022		12	18		51-75 (69)	83-117 (97)
	Tolly Point	2020	368			15-55 (36)		
		2021		110			35-75 (57)	
Miles River	Herring Island	2022	750			15-46 (34.8)		
		2023		118	100		32-75 (66.2)	76-142 (86)
	Persimmon Tree	2022	1740			17-54 (30)		
		2023		54	98		33-75 (63.7)	77-109 (87.7)
Nanticoke River	Middleground	2020		282			22-75 (51)	
		2021			104			76-140 (95)
	Middleground 1	2021	626			4-39 (21)		
		2022		125	62		37-75 (72)	78-104 (91)
	Middleground 2	2021	4068			6-55 (38)		
		2022		90	58		42-75 (70)	78-117 (89)
		2023		22	18		43-70 (60)	76-132 (90)
	Middleground	2022	505			17-53 (38.5)		
		2023		36	54		36-75 (64)	76-105 (89)
Severn River	Chinks Point (2)	2022	1000			25-61 (42.1)		
		2023		76	116		44-75 (65.7)	76-123 (93)
South River	Outer Round Point	2020	550			18-60 (36)		
		2021		105	153		54-74 (66)	76-116 (87)

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Spat (mm)	Small (mm)	Market (mm)
South River		2022		44	168		60-75 (72)	76-137 (95)
	Thunder and Lightning	2021	852			23-52 (39)		
		2021	260					
		2022		404	64		45-75 (64)	76-148 (88)
		2023			182			76-127 (93.5)
Tred Avon River	Mares Point	2020	1150			21-65 (45)		
		2021		266	30		45-75 (65)	76-135 (88)
		2022		122	146		40-75 (70)	76-127 (105)
		2023			146			79-130 (95)
	Town Point/Ferry Bar	2020	194			20-66 (37)		
		2021		252	50		33-75 (60)	76-125 (85)
		2022		158	116		44-75 (70)	76-114 (85)
		2023			102			76-119 (90)
Upper Bay East	Swan Point North	2020	520			21-66 (45)		
		2021	406	236	40	17-42 (25)	28-75 (65)	79-131 (95)
		2022	324	138	32	8-42 (30)	40-75 (65)	76-120 (85)
		2023	80	66	80		40-75 (72)	82-154 (97)
	Swan Point North (Peach Orchard)	2020	254			21-64 (43)		
		2021	316	102	2	11-38 (27)	30-75 (52.5)	
		2022	374	32	92	11-40 (30)	33-75 (65)	77-117 (93)

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Spat (mm)	Small (mm)	Market (mm)
Upper Bay East	(Peach Orchard)	2023	32	142	60	16-46 (33)	52-75 (63)	76-145 (95)
	Swan Point KB/DB	2020	59			22-51 (38)		
		2021		17	83		44-75 (61)	76-146 (93)
		2022		8	51		50-74 (64.5)	76-148 (103)
		2023		5	107		67-71 (69)	76-144 (99)
	Swan Point/Peach Orchard S	2020	94			12-55 (33)		
		2021	410	70		19-40 (29)	42-70 (57)	
Upper Bay West	Man O War Shoals	2020	168			27-66 (40)		
		2021	100	70		17-40 (25)	29-75 (49)	
		2022		102	16		43-75 (65)	77-139 (88)
		2023		48	36		54-75 (68)	78-90 (83)
Wicomico River East	Evans	2020	70			26-65 (45)		
		2021		64	108		44-75 (70)	77-141 (90)
		2022		18	112		41-75 (70)	83-135 (107)
	Great Shoal	2022	1505			22-64 (35.8)		
		2023		54	50		41-75 (70)	77-104 (82)
Wicomico River West	Lancaster	2022	364			23-50 (35.4)		
		2023		186	12		36-75 (60)	90-95 (92.5)

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Spat (mm)	Small (mm)	Market (mm)
Wicomico River West	White Point	2020	226			22-44 (35)		
		2021		358	42		46-73 (59)	78-100 (89)
		2022		86	104		48-75 (67)	76-103 (84)
		2023			72			77-108 (89)
	Wicomico Middleground	2022	606			17-42 (27.4)		
		2023		30	102		34-75 (50)	79-154 (105)

Fresh Shell Plantings

The Fall Survey sampled fourteen locations where fresh oyster shells were planted as substrate to attract spat (Figure A2-4). Fresh shells are oyster shells that have been collected from shucking houses and other locations, allowed to dry for several weeks or months and then either placed back in the water as substrate or used in hatcheries for spat-on-shell production. Over 125,000 bushels were planted on 110 acres in 2023, with most of that on the fourteen fall survey sample locations. A small amount of fresh shell was planted in the Manokin River sanctuary as part of a study, but all other fresh shell plantings were on public fishery bars.

For most of the Fall Survey samples on fresh shell plantings, the spat counts per bushel exceeded the average of other sites in the area (Table A2-5) that were not planted with either fresh shell or hatchery spat-on-shell. Fresh shell plantings appear to attract spat at a greater rate than non-planted areas (Figure A2-5). In years with very good spat sets (2020 and 2023), the number of spat per bushel was approximately twice that of non-planted areas. The non-planted areas were very similar to the annual spat index. Mean, maximum and average shell height of spat in the fall survey samples taken on these sites are listed in Table 6. The shell heights of spat on fresh shell plantings were similar to shell heights of spat from non-planted bars, which ranged from 3 mm to 57 mm, with a mean of 25 mm.

Figure A2-4. Fall Survey samples on fresh shell plantings in 2023.

Table A2-5. Fall Survey samples on fresh shell plantings in 2023, showing the spat count per bushel. acres, volume and density. The average spat count in the area is the average spat count on nearby bars, not including those that were planted with hatchery seed.

Region	Bar Name	Spat (#/bu)	Acres Planted	Volume (Bu)	Density (Bu/Acre)	Avg. Spat Count in Area
Fishing Bay	Clay Island	220	24.37	5,487	225.15	146
Harris Creek	Great Marsh	276	4.63	10,788	2327.99	46
	Tilghman Wharf	134	3.60	8,929	2477.84	46
Honga River	Lakes Cove	44	3.58	5,626	1571.67	249
Little Choptank River	Ragged Point	368	2.84	930	327.95	64
	Susquehanna	352	0.96	1,000	1038.57	64
Lower Bay West	Butler	100	2.58	6,206	2407.14	117
	Rocky Beach	80	4.59	6,322	1376.88	117
Nanticoke River	Middleground	314	5.64	15,718	2786.98	68
Patuxent River	Hawks Nest	364	8.15	10,034	1231.63	131
Potomac River Northshore	Cornfield Harbor	336	11.55	6,452	558.59	182
Tangier Sound	Piney Island East Addition	184	1.47	2,400	1628.74	287
	Piney Island West	264	11.30	20,938	1853.66	287
Tred Avon River	Pecks Point	86	0.12	1,000	8529.66	155
	Totals	223	85.4	101,830	2024.46	144

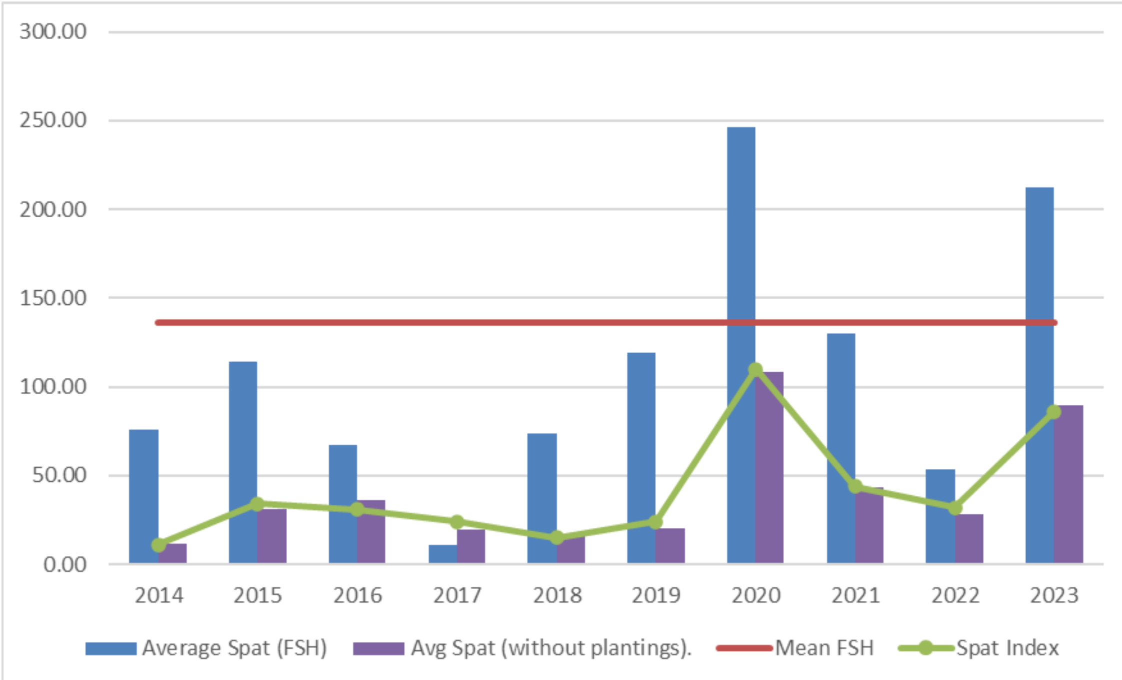

Figure A2-5. Average spat counts on fresh shell plantings (blue), average spat counts on areas without either shell or seed plantings (purple), mean fresh shell spat count for all years (red) and the annual spat index (green).

Table A2-4. Region, bar name and sizes of spat at samples taken from fresh shell plantings during the 2023 Fall Survey.

Region	Bar Name	Min. (mm)	Max. (mm)	Mean (mm)
Fishing Bay	Clay Island	5	44	30
Harris Creek	Great Marsh	16	55	40
	Tilghman Wharf	12	49	35
Honga River	Lakes Cove	9	32	26
Little Choptank River	Ragged Point	NA	NA	NA
	Susquehanna	8	40	24
Lower Bay West	Butler	11	47	33
	Rocky Beach	7	34	25
Nanticoke River	Middleground	15	54	30
Patuxent River	Hawks Nest	5	40	25
Potomac River Northshore	Cornfield Harbor	11	46	33
Tangier Sound	Piney Island East Addition	11	48	27
	Piney Island West	5	47	30
Tred Avon River	Pecks Point	NA	NA	NA

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APPENDIX 3

Oyster Host & Oyster Pathogens

Chris Dungan, revised by Carol McCullough 2 July 2021

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 salinity is 35‰. Oysters reproduce (spawn) when both sexes simultaneously release gametes. Spawning in Chesapeake Bay occurs from May-September, and peaks during June-July. Externally fertilized eggs develop into swimming planktonic larvae. These are transported by water currents for 2-3 weeks while feeding on phytoplankton as they grow and develop. Mature larvae attach to solid benthic substrates, preferably oyster shells, and metamorphose to become sessile juvenile oysters. Unlike fishes and other vertebrates, oysters do not regulate the salt content of their tissues. Instead, oyster tissues conform to the broad and variable range of salinities that are found in oyster habitats. Thus, oyster parasites with narrow salinity requirements may be exposed to adverse salinities, inhibiting their virulence and reducing prevalences to the point of being eliminated altogether. At death, oyster shells (valves) passively open, exposing the soft tissues to predators and scavengers. However, the resilient hinge ligament holds the articulated valves together for months after death. Empty, articulated oyster shells (boxes) in survey samples are interpreted to represent oysters that died during the previous year. In dredge samples the numbers of dead and dying (gaper) oysters are compared to those of live oysters to estimate natural mortalities.

Dermo Disease

Although the protozoan parasite that causes dermo disease is now known as *Perkinsus marinus*, it was first described in Gulf of Mexico oysters and named *Dermocystidium marinum* (Mackin, Owen & Collier 1950), colloquially abbreviated then as 'dermo'. Almost immediately, dermo disease was also reported in Chesapeake Bay (Mackin 1951). *Perkinsus marinus* is transmitted through the water to nearby uninfected oysters in as few as three days, and across distances as much as five kilometers from infected populations. Heavily infected oysters are emaciated; showing reduced growth and reproduction (Ray & Chandler 1955, McCollough et al. 2007). Although *P. marinus* survives low temperatures and low salinities, it multiplies most rapidly 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, Carnegie et al. 2021). Between 1990 and 2018, at least some oysters in 91-100% of all regularly tested Maryland populations have been infected. During 2019, the percentage of infected bars dropped to a 30-year low of 88%. Annual mean prevalences for dermo disease have ranged at 27-94% of all tested oysters, with a 30-year average of 64%.

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). It also infected oysters in lower Chesapeake Bay during 1959 (Andrews 1968). The common location of lightest *H. nelsoni* infections is in oyster gill tissues. Although this suggests waterborne transmission of infectious pathogen cells, the complete life cycle and actual infection mechanism of the MSX parasite remain unknown.

Despite numerous experimental attempts, MSX disease has rarely been transmitted to uninfected oysters in laboratories. However, captive experimental oysters reared in enzootic waters with salinity above 14‰ 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 0.07-28%, with a 30-year average of 5.8%.

Since MSX disease is rare in oysters from waters with salinity below 10‰, the distribution of *H. nelsoni* in Chesapeake Bay varies as salinity changes with variable freshwater inflow. During an extended drought of 1999-2002, consistently low freshwater inflows raised salinities of Chesapeake Bay waters, which fostered 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, and dramatically restricted the geographic range and effects of MSX disease (Tarnowski 2018). During 2018, low water salinities reduced the distribution and the mean prevalence of MSX disease to historic minima.

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APPENDIX 4
GLOSSARY

box oyster	Pairs of empty shells joined together by their hinge ligaments. These remain connected for months after the death of an oyster, providing a durable estimator of recent oyster mortality (see **gaper**). **Recent boxes** are those with no or little fouling or sedimentation inside the shells, generally considered to have died within the previous two to four weeks. **Old boxes** have heavier fouling or sedimentation inside the shells and the hinge ligament is generally weaker.
bushel	Unit of volume used to measure oyster catches. The official Maryland bushel is equal to 2,800.9 cu. in., or 1.0194 times the U.S. standard bushel (heaped) and 1.3025 times the U.S. standard bushel (level). (Return to Text)
cultch	Hard substrate, such as oyster shells, spread on oyster grounds or used in hatcheries for the attachment of spat.
dermo disease	The oyster disease caused by the protozoan pathogen *Perkinsus marinus.*
disease resistance/ tolerance	Disease **resistance** is the ability of the oyster to prevent infection. Disease **tolerance** is the maintenance of relatively normal function (growth, reproduction, survival) despite the presence of disease in the animal.
dredged shell	Oyster shell dredged from buried ancient (3000+ years old) shell deposits From 1960 to 2003 this shell had been the backbone of the Maryland shell planting efforts to produce seed oysters and restore/replenish oyster bars.
fresh shell	Oyster shells from shucked oysters. These shells are planted back on oyster bars.
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 a 0-7 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 within a short time.
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 have mean infection intensities of 3.0 or greater are predicted to have 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	Infection intensities averaged only for infected oysters: *sum of individual infection intensities(1-7) ÷ number of infected oysters*
intensity index, annual	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 bill (ventral margin).
Millennial years	The years 1998-2002, defined by drought, elevated salinities, severe disease epizootics, and high oyster mortalities.
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 counting 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 providing shell as a substrate for oyster larvae to settle on, either naturally or in a hatchery. The seed oysters are subsequently transplanted to growout (seed planting and sanctuary) areas.
small oyster	An oyster equal to or greater than one year old but less than 3 inches (see market oyster, spat).
spat	Oysters younger than one year old.

spatfall, spatset, set The process by which swimming oyster larvae attach to a hard substrate such as oyster shell. During this process the larvae undergo metamorphosis, adopting the adult form and habit.

spatfall intensity, sample site The number of spat per bushel of cultch. This is a relative measure of oyster spat density at a specific location, which may be used to calculate the annual spatfall intensity index.

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

sum of Key Bar spatfall intensities ÷ number of Key Bars

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

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

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