Maryland Oyster Population Status Report
2024 Fall Survey

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Maryland Department of Natural Resources
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Cover Photo: S. Ridgley (L) and R. Bussell dumping the sample onto the sorting table. (Photo: C. McCollough)

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EXECUTIVE SUMMARY

Since 1939, the Maryland Department of Natural Resources and its predecessor agencies have monitored the state's oyster population by means of annual field surveys – one of the longest running programs of this kind in the world. 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 2024 Fall Survey was conducted from 8 October to 25 November throughout the Maryland portion of Chesapeake Bay and its tributaries, including the Potomac River. A total of 357 samples were collected from 286 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, condition, and growth of oysters. For 2024, the annual average freshwater flow was slightly above the long-term average, indicating a normal year. However, average monthly flows were above average for the first four months of the year, breaking the drought that had persisted through 2023. Consequently, salinities fell precipitously during the spring. Following the spring freshets, flows fell back to well below average for seven of the remaining months and salinities slowly rebounded. By October the salinities had risen sharply to the extent that 15 ppt, a critical threshold above which MSX disease can cause extensive mortalities in oyster populations, was exceeded in the mainstem as far upbay as the Bay Bridge.

The timing of the reduced flows was such that it enabled another good spatset. Although not as strong as the 2023 recruitment event, the 2024 spat index of 40.7 spat/bu was above the long-term median for the fifth year in a row and was widespread in some areas. A small number of spat were even observed in the bay north of the Bay Bridge – a rare occurrence. An experimental crushed concrete planting in Pocomoke Sound produced the highest natural spatset of the survey – 616 spat/bu. Unfortunately, following the exceptional previous year, recruitment in the Potomac River reverted to its previous pattern of modest spatsets in the lower third of the river and no spat were found above that portion of the river.

There was an abundance of 2023 year class oysters in many areas, boding well for both the fishery in the near term and ecologically for the sanctuaries. The once in a generation spatset on the upper bars of the Potomac River appear to have survived the high freshwater flows of the winter and spring. Little mortality was observed although their growth was stunted by the lower salinities.

A total of 1,589 oysters were analyzed for diseases in 2024 – 1,289 from the 43 Disease Bars (sentinel bars) and 300 from ten supplemental sites. Disease levels largely receded due to the drop in salinities. Both indexes of dermo disease – prevalence and intensity – declined substantially both in degree and distribution. But the even more encouraging news was the retreat of MSX disease. Of the 53 Disease Bar and supplemental samples, 44 had no sign of MSX disease (0% prevalence), while the highest detected prevalence was 7%. Although drought conditions once again returned during the latter half of 2024, MSX disease did not strengthen and spread. As a consequence, the observed mortalities declined by 25% from the previous year to 11.6%, which is in the low to moderate range, remaining below the 40-year average for the twenty-first year in a row.

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 Biomass Index has been trending upward since 2011, following an eight-year recovery period after the devastating millennial epizootics. The 2024 Biomass Index was the third highest of the 32-year record. This was a 5% increase from the 2023 index and represents a gain of 62% over the long-term average.

The Cultch Index is a relative measure of oyster habitat. The three-year rolling average for the 2024 Cultch Index was the second highest in the 20-year time series and a 28% increase from the previous year. 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 2024 Fall Survey. The priority large-scale restoration sanctuaries were compared with adjacent open areas. Recruitment within the priority sanctuaries was generally below their respective Key Bar 20-year averages. The exception was the St. Marys River sanctuary, which had an above average spatset. In contrast, spatsets in most of the adjacent open harvest areas was at or above the long-term averages, particularly in the St. Marys River open area, which experienced a ten-fold increase. It should be noted that the Broad Creek recruitment average is about five times as high as the Harris Creek Sanctuary over the 20-year time series, including prior to the creation of the sanctuary in 2010.

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). Broad Creek, historically one of the highest oyster producing regions in Maryland, had the greatest average number of adult oysters of any area in this comparison, thanks to the extraordinary spatset in 2020 and a strong set in 2023. The St. Marys sanctuary averaged the second highest number of adults.

As in the general population, disease levels in the sanctuaries fell substantially from 2023. Although dermo disease was present in all thirteen sentinel Disease Bars and seven supplemental stations within oyster sanctuaries, prevalence declined from 85% in 2023 to 55% in 2024 and intensities fell from 2.9 to 1.6. Dermo disease levels in the comparison harvest areas also dropped from the previous year in prevalence (61% to 42%) and intensity (2.1 to 1.3). The somewhat 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; parasite burdens tend to build up as oysters age. MSX disease was detected at none of the five priority sanctuaries but at two of the associated harvest bars. Outside of the restoration sanctuaries/adjacent harvest areas, MSX disease was found at only three of fourteen other examined sanctuaries and four of twenty-six bars in open harvest areas. The highest MSX prevalence observed in 2024 was 7%. In contrast, 2023 saw the highest MSX disease record of the 35-year time series with 93% on Lighthouse open harvest bar in the Choptank River.

The lower disease levels in the sanctuaries were accompanied by a drop in observed mortalities. Regional observed mortalities in sanctuary bars were similar to their proximal open harvest bars. In the restoration sanctuaries, the average regional mortality was 13.2%, while in the corresponding harvest areas the average mortality was 11.2% in 2024.

Oyster biomass in the sanctuaries continues to outpace that of the open harvest areas. The average biomass per index bar in the sanctuaries was 235.3 g/bu, a slight increase from 222.6 g/bu in 2023, and substantially higher (30%) than in the harvest areas. In the open harvest areas, the average biomass per index bar has decreased in the past three years, from the high point in 2021 of 232.1 g/bu to 180.4 g/bu in 2024. Over the longer term, trends in biomass generally have been positive both in sanctuaries and harvest areas, with the results from 2024 exceeding their long-term averages by 54% and 59% 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. The recent decline of biomass in the harvest areas was driven by the cropping down of the larger legal-sized oysters combined with the influx of small oysters from the strong recruitment events over the past four years. There was a strong difference between the two management types in the proportion of sublegal oysters in each. Sublegal oysters comprised 47.6% of the adult oysters in the sanctuaries, little changed from 2023, while in the open area it was 69.1%, a large increase from 51.5% in 2023.

Cultch, primarily the shell and oyster substrate required for spatset, was at higher densities in all but one of the restoration sanctuaries compared to their adjacent open harvest areas. The exception was in the Tred Avon River, where cultch volumes were higher in the harvest area. For the paired comparison regions (i.e.

not including Broad Creek), 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 highest overall in three-year average cultch density, boosted by the tremendous 2020 spatset and a strong follow-up set in 2023. 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 the Harris Creek sanctuary was about double that of the harvest area in that river.

Commercial oyster landings fell sharply from the exceptional 2022-23 season, which had the highest harvest in 36 years. With reported harvests of 438,000 bushels, oyster landings during the 2023-24 season were 39% lower than the previous season total of 720,000 bushels. Although substantially below the previous season, the 2023-24 landings were the third highest since the 1986/87 season and remained well above the 39-year average of 313,000 bu/yr. The average reported price also dropped to $35.69/bu from $43.00/bu in 2023. This combination of smaller harvest and lower price per bushel resulted in a 50% decrease in the total dockside value from $31.1 million in 2023 to $15.6 million in 2024 - nevertheless a not insubstantial sum. The Tangier Sound region was the dominant harvest area, accounting for 51% of the 2023-24 landings in Maryland. The Choptank region was second, providing 28% of the total harvest, with the majority coming out of Broad Creek (17% of the Maryland harvest). Power dredging was the predominant method of harvesting, accounting for 54% of the total landings. This activity was mainly in the lower Eastern Shore and Choptank regions. Although patent tonging was second, producing 18% of the total harvests, this was a drop from 34% in 2023. Meanwhile, hand tonging almost doubled to 17% of the landings, primarily from Broad Creek.

As described in the 2023 Fall Survey report, an ancillary spring dredge survey was conducted in 2024. The results are included again in this report as they serve as a bridge to understanding the changes between the two very different fall survey outcomes. The purpose of the Spring Survey was 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 start 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 2023 and spring 2024 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 2023 and spring 2024 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 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.
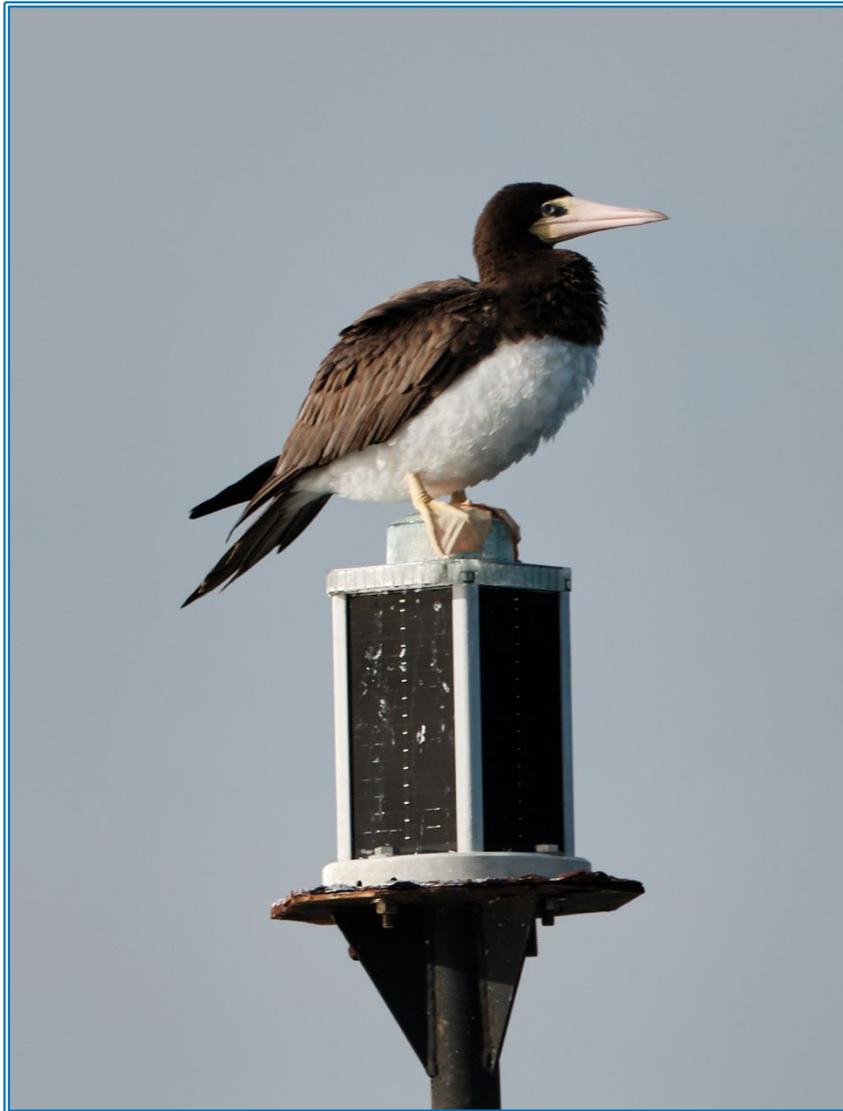
A visitor from the tropics, a brown booby roosts on a buoy in the upper bay. (Photo: R. Bussell)
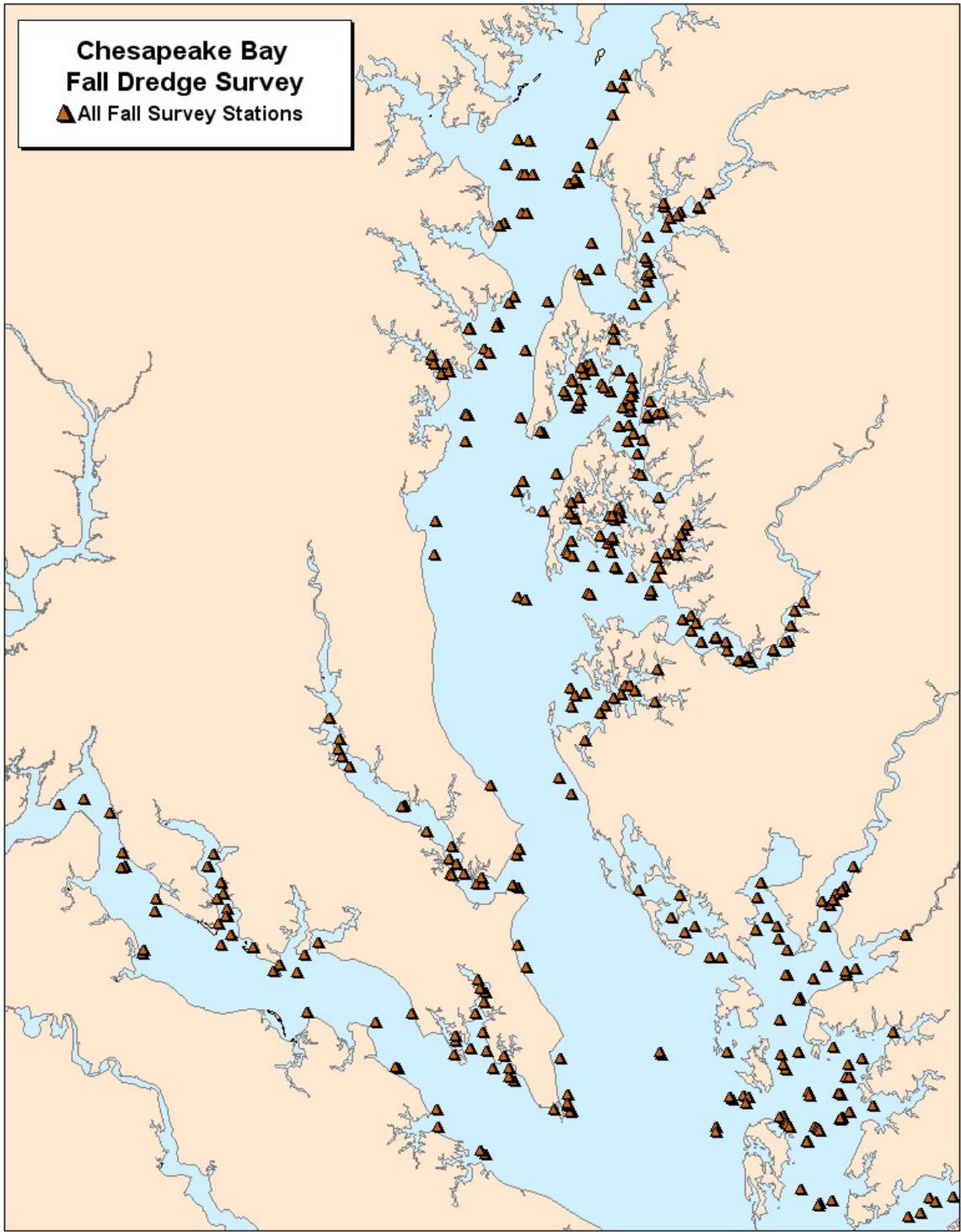
Figure 1a. 2024 Maryland Fall Survey station locations, all bar types included (Standard, Key, Disease, Seed).

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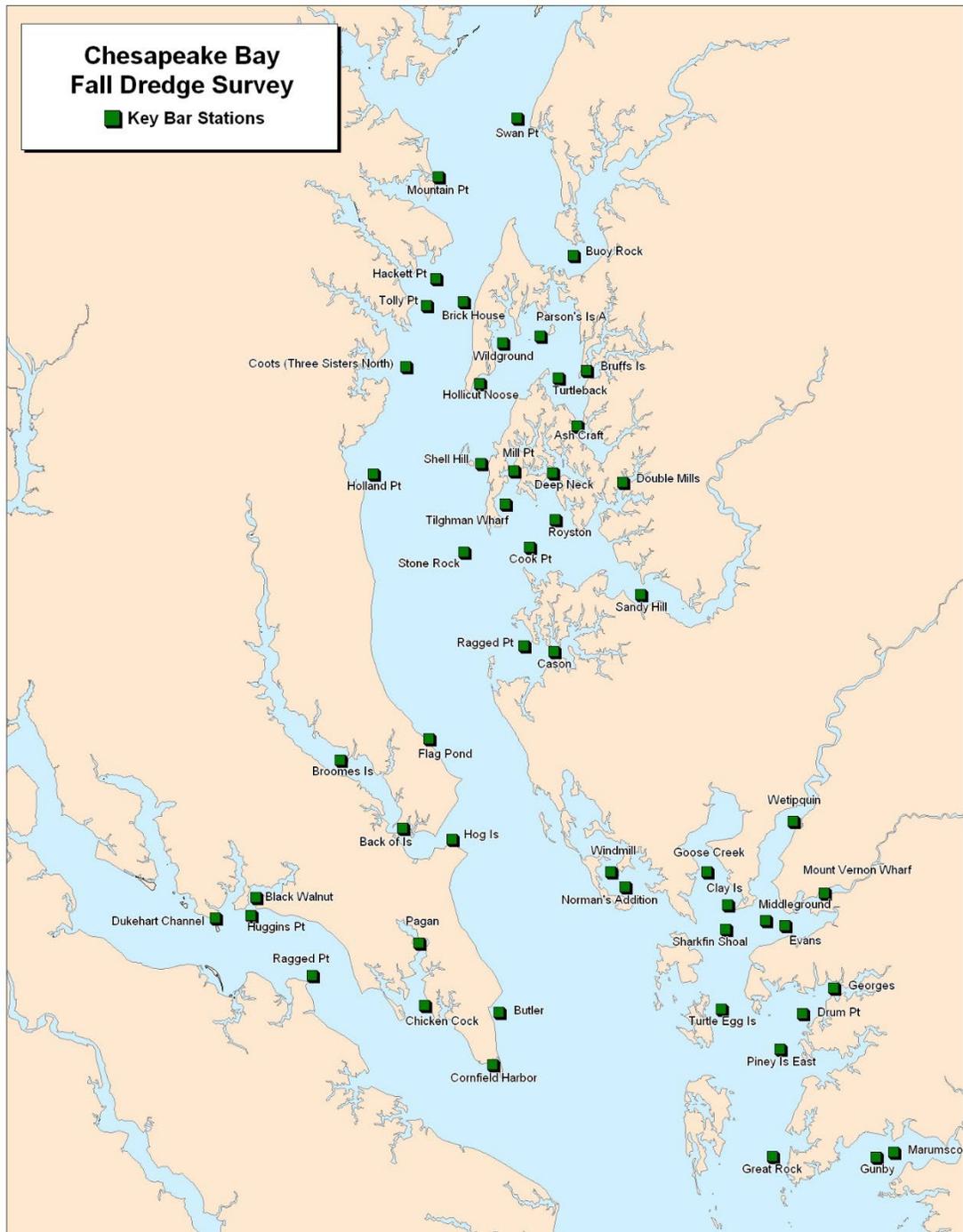
Figure 1b. Maryland Fall Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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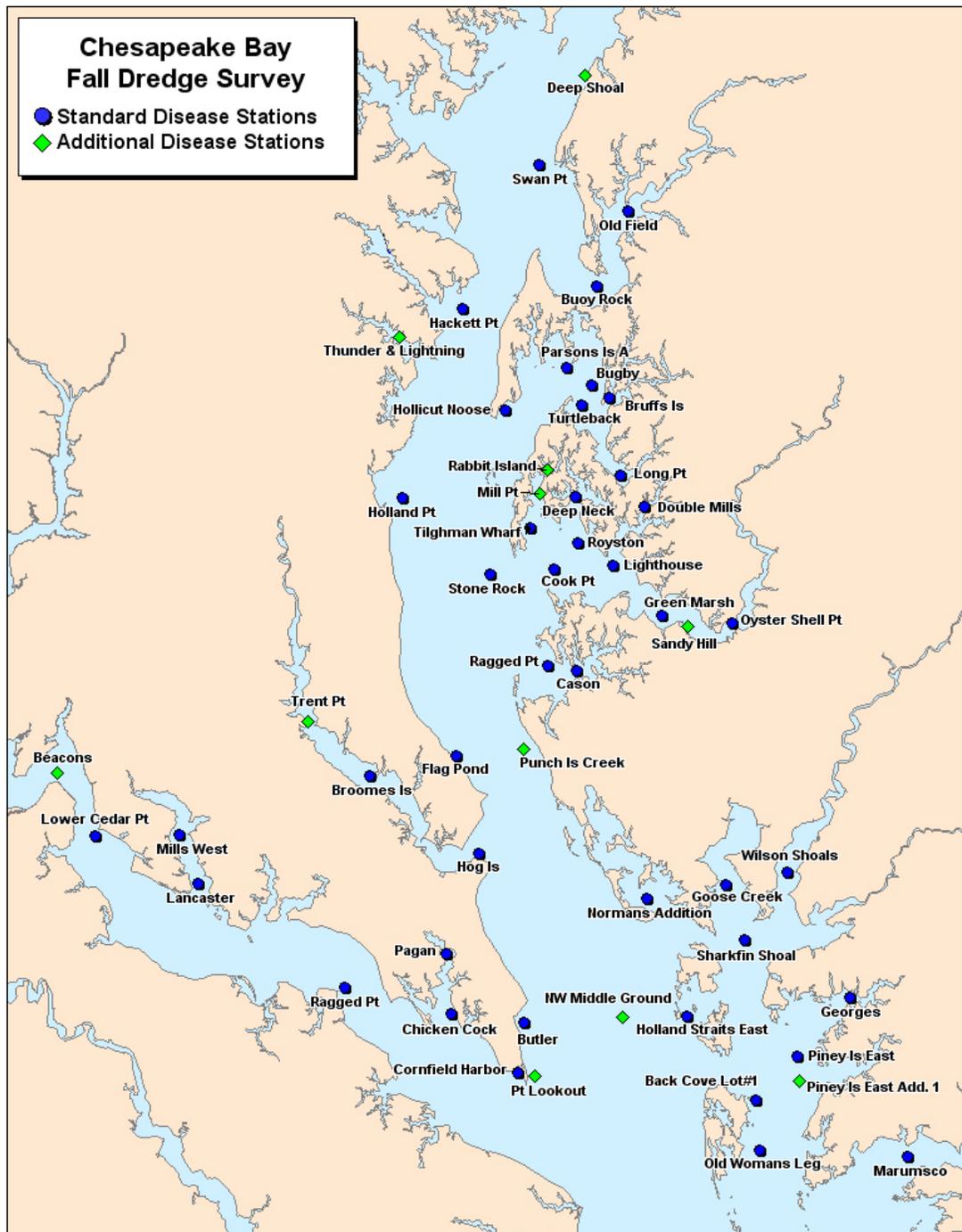
Figure 1c. Maryland Fall Survey standard Disease Bar monitoring locations and additional disease sample stations. Disease samples could not be obtained from the supplemental site at Deep Shoal in 2024.

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 (MDNR). The Fall Survey is a key data source for 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 2023, and is currently undergoing a benchmark assessment. In addition, data from the Fall Survey was used extensively by the multi-partner Oyster Restoration Program under the 2014 Chesapeake Bay Watershed Agreement. The Fall Survey continued to assist the Potomac River Fisheries Commission with their fishery management program, examining the exceptional 2023 cohort on the uppermost oyster grounds of the river and evaluating several rotational seed planting areas. 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. An experimental crushed concrete planting in Pocomoke Sound to enhance spatset made by the Somerset County Watermen Association was also examined. A graduate student from the University of Connecticut accompanied the survey to collect research samples from the Potomac River.

METHODS
Field Collection

The 2024 Annual Fall Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources Fishing and Boating Services from 8 October to 25 November. A total of 357 samples were collected during surveys on 286 natural oyster bars (Figure 1a), including Key Bar (Figure 1b) and Disease Bar (Figure 1c) fixed sentinel sites as well as 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 (MDNR 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 MDNR (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 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
$\sum$ dmw per size class = total dmw per 1.0 bu station sample

For **all** monitoring stations:
($\sum$ 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 MDNR 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.

Catch of red-beard sponge in Tangier Sound. (Photo: R. Bussell)

RESULTS

FRESHWATER DISCHARGE CONDITIONS

Salinity is a key quantifiable factor influencing oyster reproduction and recruitment, disease, mortality, condition, and growth. 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 2024 was close to the long-term mean (Figure 2a). However, the monthly streamflow shows a different picture (Figure 2b).
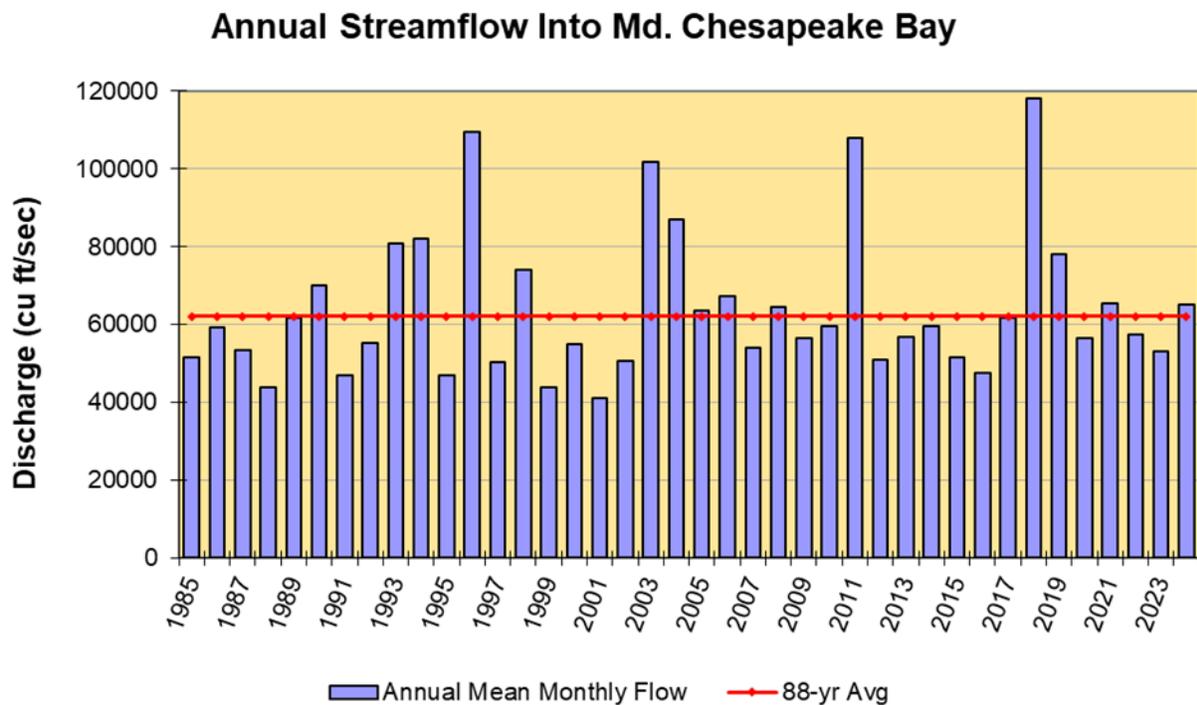
Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2024. USGS Section C: all Maryland tributaries and the Potomac River. *Data courtesy of USGS.*

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

Looking at the monthly streamflows rather than an annual average, 2024 was actually anything but normal. The monthly freshwater discharges had two periods of opposite extremes. Streamflows were above their respective 88-year averages during the winter through the spring, especially in January and April, averaging 130% of the long-term mean for those four months (Figure 2b). Between April and May, freshwater discharges decreased by 58% and remained

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below their respective long-term means for the remainder of the year, with the notable exception of August. Thus, high flow during the first four months, when averaged with the subsequent seven low-flow months, resulted in what was categorized as a normal year. The timing and extent of these varying freshwater discharge periods, especially following the drought condition of 2023, had profound implications for the oyster populations in Maryland.

2024 Monthly Streamflow into Md. Chesapeake Bay
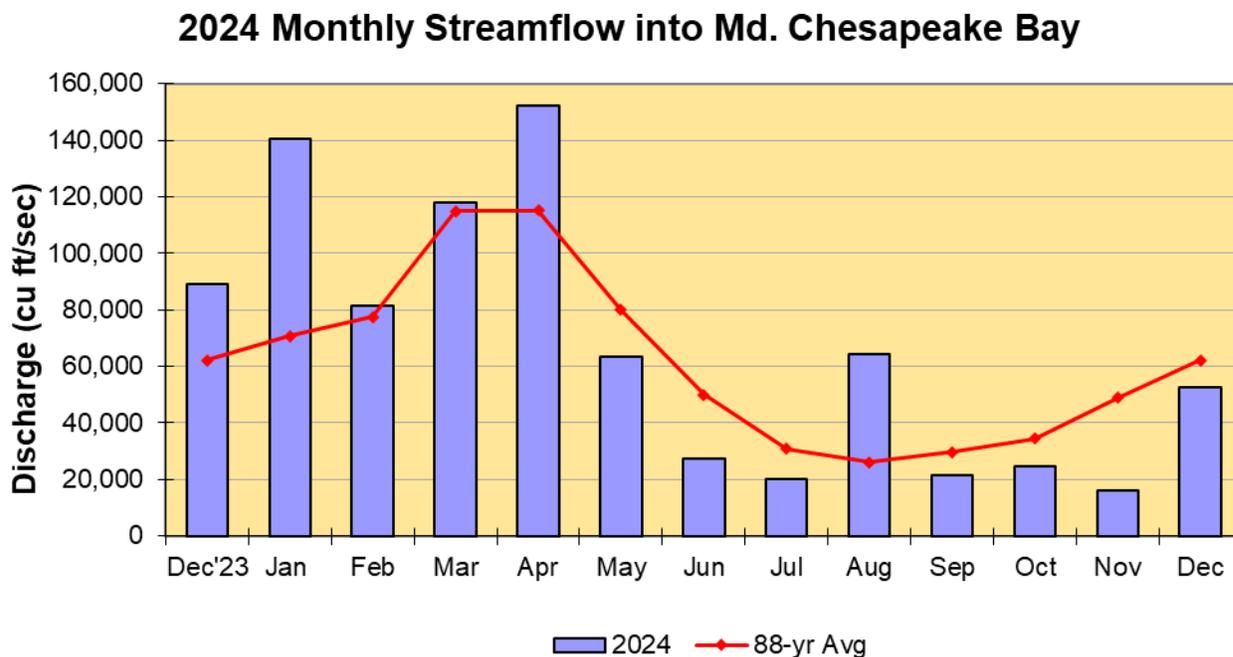
Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2024, including the 88-yr monthly average. *Data courtesy of USGS.*

Salinities
Monthly surface salinities for four regions of the Chesapeake Bay in Maryland and one location in the Potomac River during 2023 and 2024 are compared in Figure 2c. (Chesapeake Bay Program). 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 proximal freshwater input at the surface and the tidal intrusion of saltier water at the bottom.

The dominant environmental condition of 2023 was drought, which raised salinities above normal throughout the bay, in some cases to record high levels. Long-term maximum salinity records at the four representative Chesapeake Bay sites were broken on five occasions, all in the months of June or July with one exception (Figure 2c). 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.

Relief came in the form of persistent rains, which began in December and lasted through May of 2024 (Figure 2b). The resulting elevated streamflows led to a precipitous drop in salinities, especially in the mid- to upper bay and Potomac River. Salinities fell by as much as half in some areas such as the Choptank River (Appendix 1), and dropped to almost zero at Swan Point

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(Figure 2c). While slowly rebounding after the spring freshets and subsequent period of low streamflows, salinities generally remained below average until the fall. However, by October the salinities had risen sharply to the extent that the 15 ppt MSX threshold was exceeded in the mainstem as far upbay as the Bay Bridge (Chesapeake Bay Program).

Figure 2c. Monthly surface salinities during 2023 and 2024 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 at Morgantown. Sampling was not conducted in in months indicated by* nd. ** Record maximum monthly salinity.*

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SPATFALL INTENSITY

The Spatfall Intensity Index, a measure of recruitment success and potential increase in the population, was 40.7 spat/bushel (Table 2). Although this represents a 53% decrease from the previous year, the index was still well above the 40-year median of 25.2 spat/bushel, ranking it tenth highest of the time series (Figures 3a,b). This was the fifth consecutive year the index was above the long-term median. Nine of the last 15 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).

Maryland Spatfall Intensity Index, 1985-2024
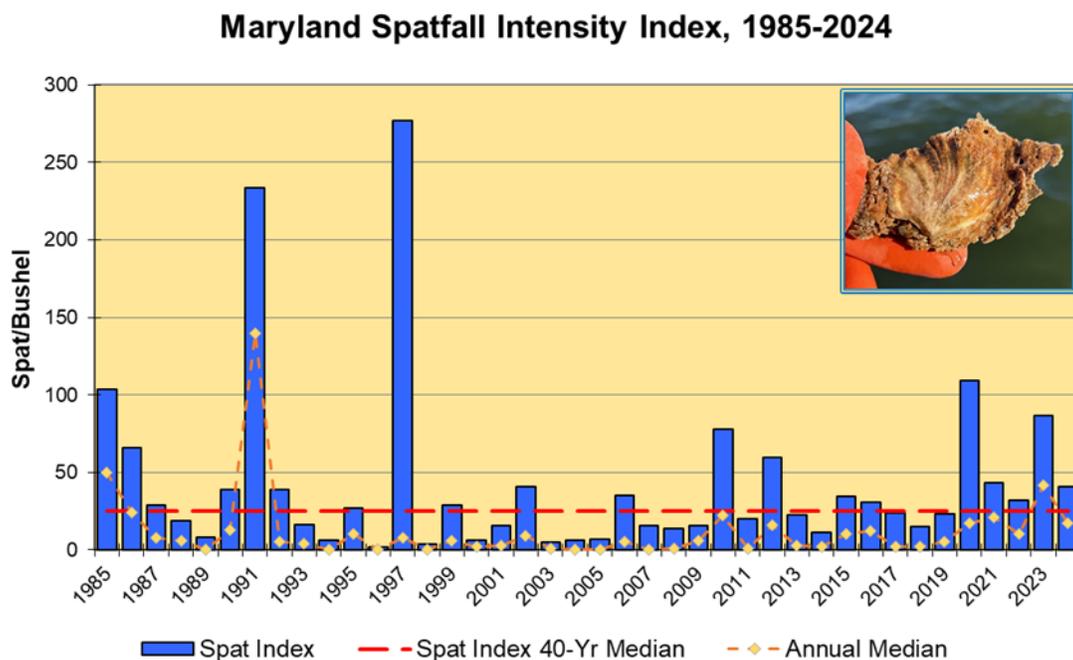
Figure 3a. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including annual median values.

Equally important as the index is how geographically extensive the spatset was. 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 2024 was 17 spat/bushel, compared with the long-term average of the medians of 12.1 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 51 of the 53 Key Bars, the highest number of bars with spat since 1985 (Table 2). As indicated by the spatfall median:spat index ratio, although the spat index was lower than the previous year, nevertheless spatfall was the fifth most equitably distributed in the 40-year time series (2023 had the third highest distribution) (Figure 3c). Spat were found as far upbay as Mountain Point bar above the Bay Bridge for the first time since 2002 and only the fifth time on record – a rare occurrence. The spat total from seven bars accounted for 50% of the index, compared with ten bars in 2023; furthermore, in 2024, 31 bars contributed to 95% of the spat index, down from 34 bars in 2023. The remaining 22 bars comprised just 5% of the Spat Intensity Index, averaging 4.8 spat/bu, a respectable number in areas that ordinarily don't receive much if any spat. As in the previous year, Deep Neck bar in Broad Creek had the highest count of the index bars with 251 spat/bu, or 11.6% of the entire 2024 Spat Index, another indication of

the more evenly distributed numbers, compared with the 2022 Spat Index, when Pagan bar dominated the index with 28% of the counts.

Maryland Spatfall Index, 2007-2024
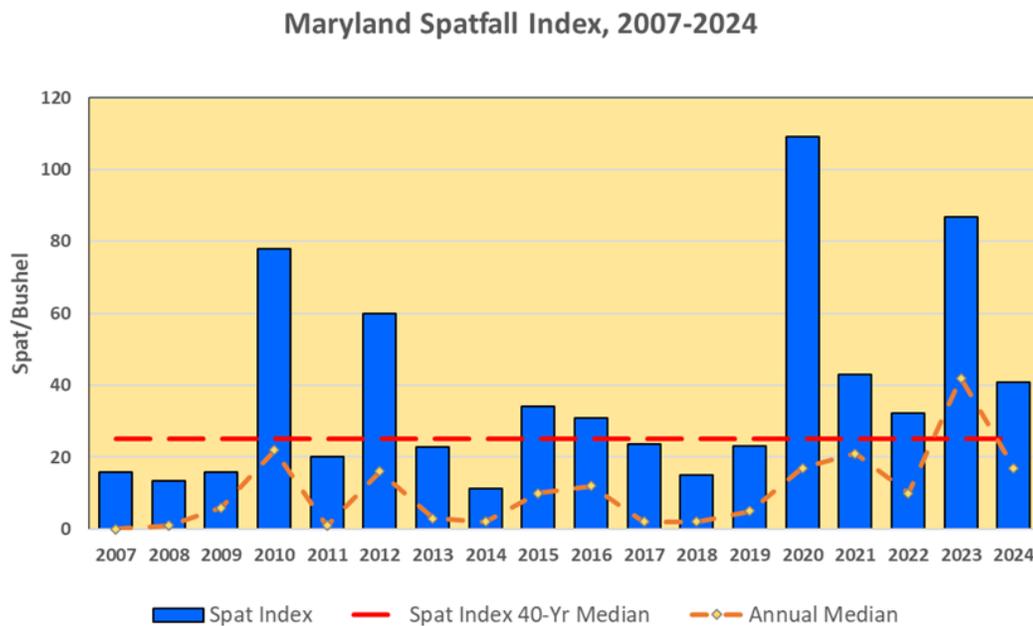
Figure 3b. Recent Maryland spatfall indices, 2007-2024, including annual and long-term median values.

Spatfall Distribution by Year
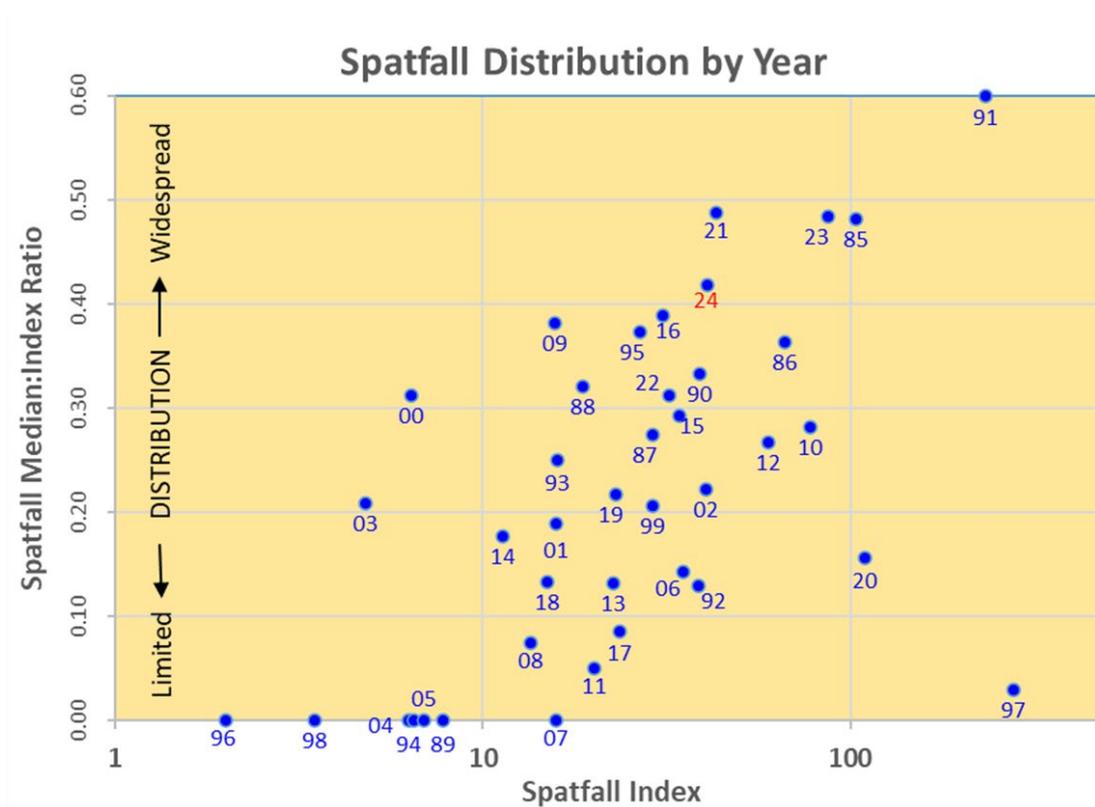
Figure 3c. Spatfall median:index ratios for the years 1985 to 2024 as denoted by "85" to "24" on the chart. The ratio integrates the geographic and numerical distributions of spat for a given year. A lower ratio indicates that the spat counts are concentrated on fewer index bars, while a higher ratio indicates the numerical distribution of spat is more evenly spread among the index bars.

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When considering all bars surveyed in addition to the Key Bars, the highest recruitment was observed throughout southern Maryland (Figure 4). The Honga River led all regions, averaging 188 spat/bu, followed closely by Pocomoke Sound with 183 spat/bu. Three other regions had recruitment averages greater than 100 spat/bu including Tangier Sound (157 spat/bu), the lower mainstem east of the channel (130 spat/bu), and the St. Marys River (124 spat/bu). Unfortunately, following the once-in-a-generation spatfall of 2023 (Tarnowski 2024), recruitment in the Potomac River reverted to its previous pattern of modest spatsets in the lower third of the river and nothing above that. The good news is that the numerous small oysters from the 2023 spatset on the upper bars of the Potomac River appear to have survived the high freshwater flows of the winter and spring. Little mortality was observed although their growth was stunted by the lower salinities. The only other regions where no spat were found were a portion of the bay north of the Bay Bridge and the Chester River. The highest spat count in an individual sample was 616 spat/bu on an experimental crushed concrete planting in Pocomoke Sound. The next two highest counts were 420 spat/bu on Old Woman's Leg in Tangier Sound and 378 spat/bu on Gravelly Run in the St. Marys River.
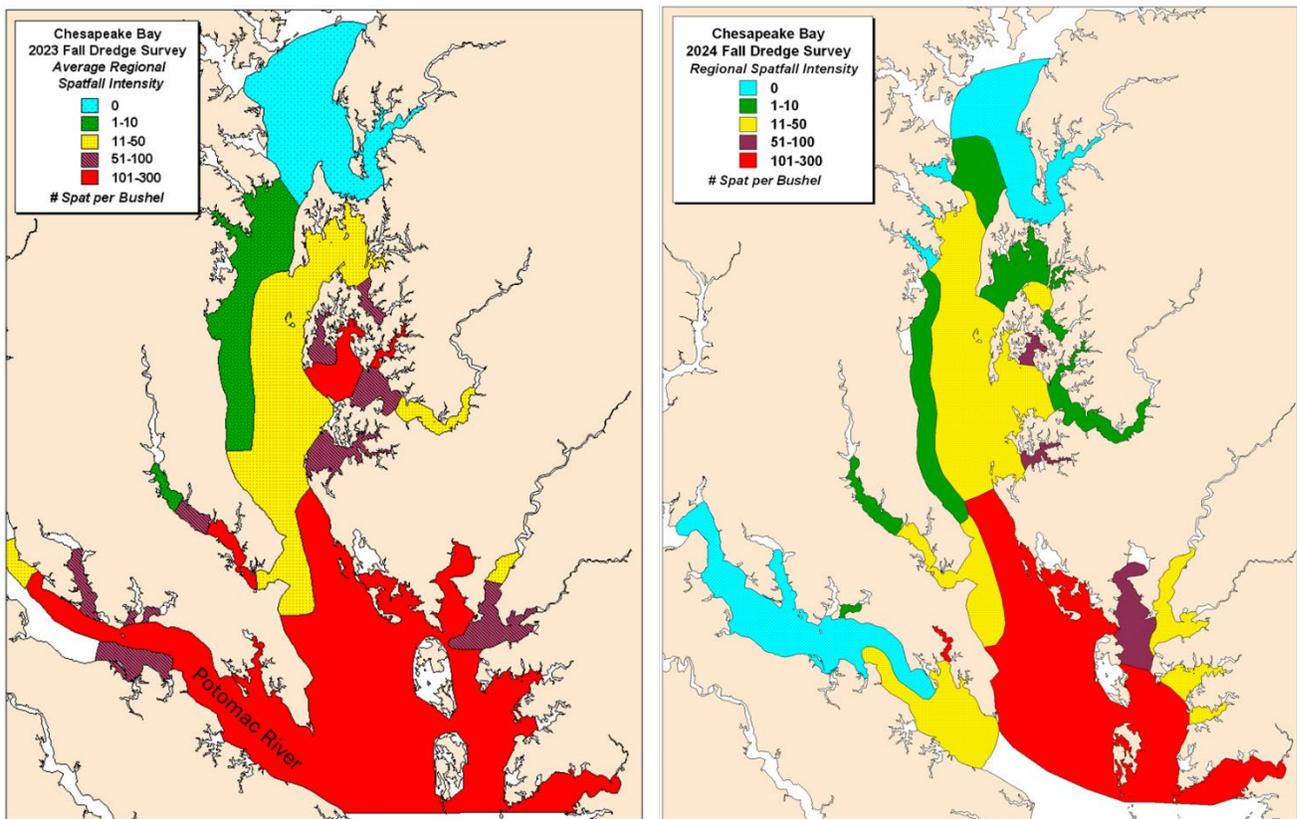
Figure 4. Oyster spatfall intensity and distribution in Maryland, 2023 vs. 2024. Intensity ranges represent regional averages.

OYSTER DISEASES

A total of 1,559 oysters were analyzed for diseases in 2024 – 1,289 from the 43 Disease Bars (sentinel bars) and 300 from ten 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.

Disease levels have largely receded. Dermo **disease prevalence** on the 43 Disease Bars was the sixth lowest on record, decreasing to 45.3% in 2024 from 67.3% in the preceding year - a drop of 33% (Table 3). Consequently, the 2024 prevalence fell below the 35-year average prevalence of 62.2% (Figure 5). This marks the eighteenth of the last 22 years that dermo disease mean prevalences have been under the long-term average since the record high epizootics at the turn of the millennium. From 2019 to 2021, the percentage of individual infected oysters were the lowest on record, but since 2022 the overall mean infection prevalence in oysters sampled on the Disease Bars had increased substantially, so the 2024 results were a welcome reversal. The disease was found throughout most of the bay and tributaries, being detected in oysters on 96% 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 sentinel subset was standardized in 1990.
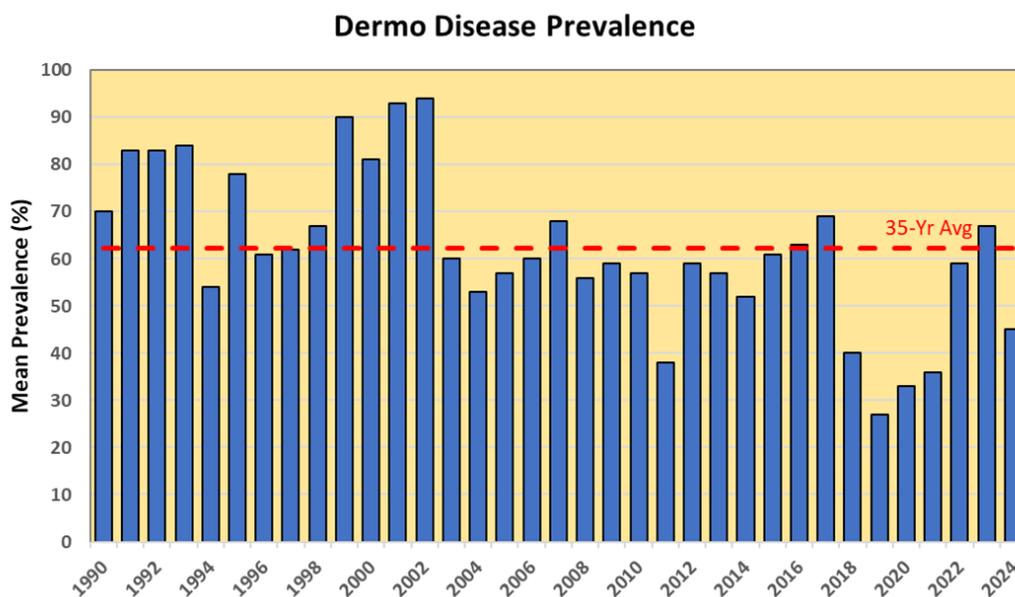
Figure 5. Annual mean *P. marinus* prevalences from Maryland disease monitoring bars.

The number of samples exhibiting high prevalences (>60%) had increased substantially over the previous four years from 19% of the Disease Bars in 2020 to 67% 2023, but dropped back to 37% in 2024. (Table 3, Figure 6). The distribution of elevated dermo prevalences was largely confined to the southern portion of the bay. In comparison, higher prevalences had a wider upbay distribution in 2023 (Figure 6).
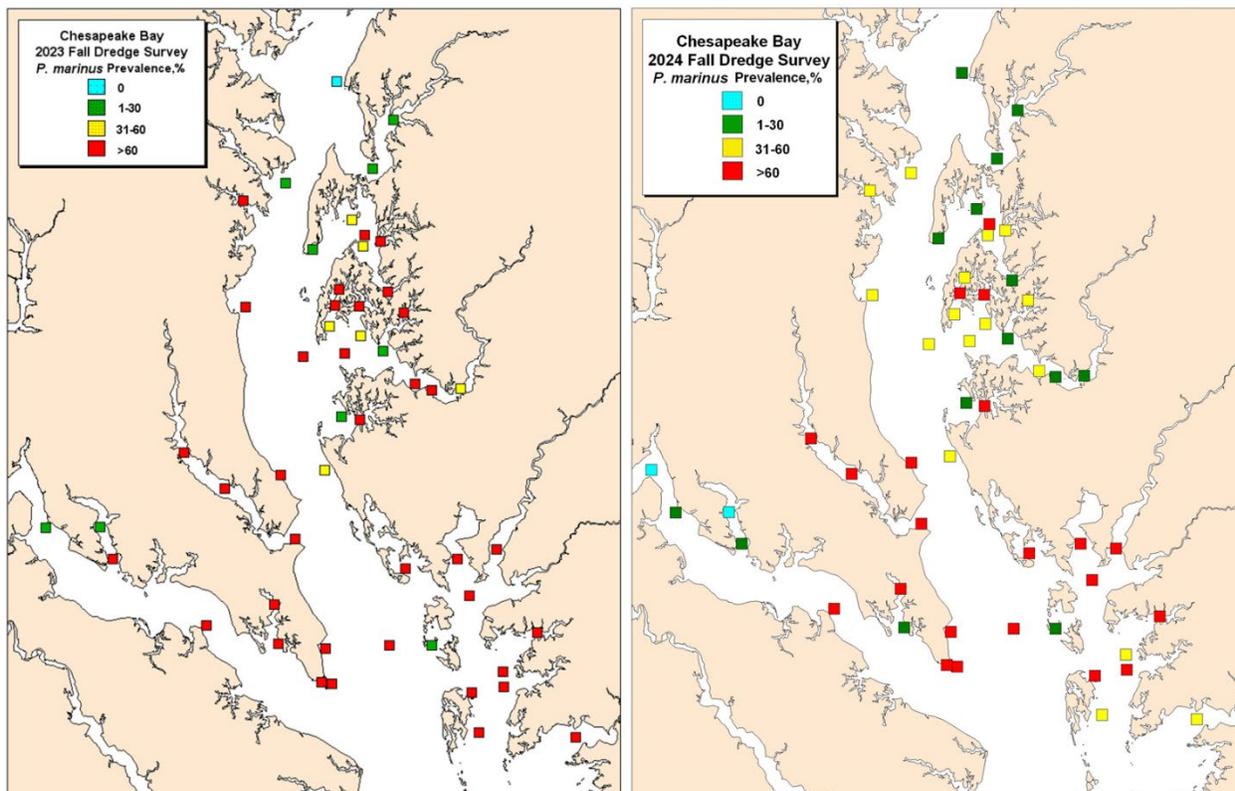
Figure 6. Geographic extent and prevalence of dermo disease in all disease samples, 2023 vs. 2024.

Outside of the sentinel disease monitoring sites, dermo disease was found at nine of the ten supplemental sites, with prevalences greater than 60% at five of the bars, compared to eight bars in 2023 and four bars in 2021. Dermo disease was not detected at Beacon bar in the Potomac River. The supplemental bar furthest upstream in the mainstem, Deep Shoal (Figure 1c), once again was not sampled for disease in 2024 because of low densities of oysters due to freshet-related mortalities in 2018/19.
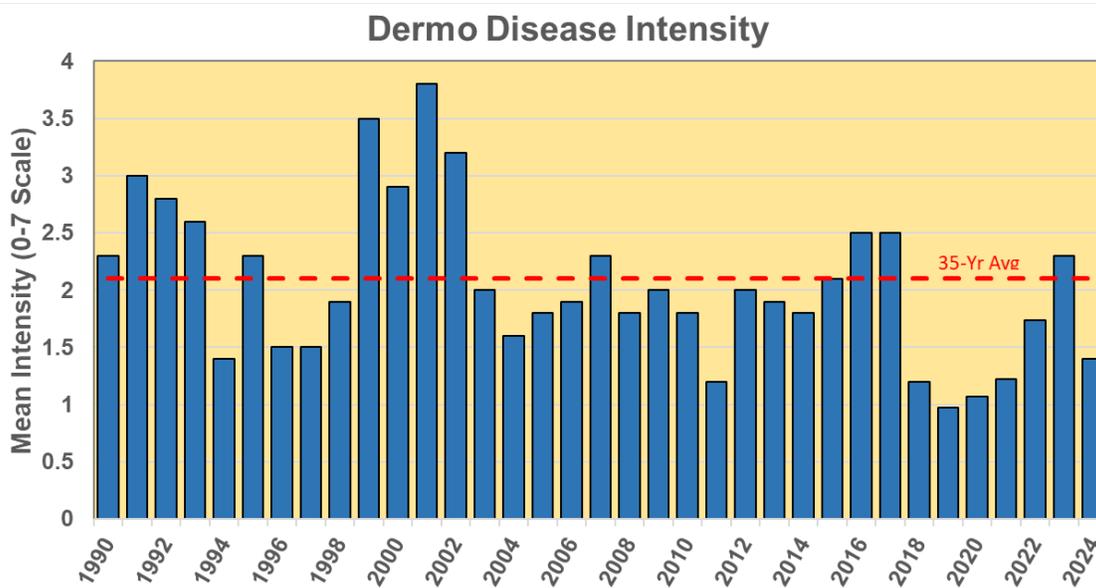
Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars.

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The mean **infection intensity** for dermo disease also decreased in 2024, falling below the long-term average for the seventeenth time in the 22 years following the millennial epizootic (Figure 7). The 2024 mean infection intensity (1.38 on a 0-7 scale) was 39% lower than in 2023 (2.28) (Table 3). The average infection intensity over the 22 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.

The 2024 frequency distributions of sample mean infection intensities on the Disease Bars dropped substantially from the high range (Figure 8). Only one of the sentinel bars (2%) had a mean intensity in the high range (3.0 or greater), compared to 17 bars (40%) in 2023. The proportion of bars that were in the lowest intensity categories of zero and less than 1.0 remained relatively low in 2024. Meanwhile, the proportion of bars in the moderate intensity (1.0 to <3.0) range also increased, from 33% in 2023 to 65% in 2024. This large reservoir of moderate intensity oysters can potentially shift to the problematic high intensity category given the right environmental conditions. Only two of the ten supplemental bars had mean infection intensities of 3.0 or greater in 2024 - Piney Island East Addition Sanctuary in Tangier Sound and Northwest Middleground in the lower bay (Figure 9). For perspective, over the last two decades dermo disease intensities for the entire population have remained 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.

Infection intensities in individual oysters that are ≥5.0 on a 0–7 scale are considered lethal; such infection intensities were found in at least one oyster at 77% of the sentinel sites in 2024, a decrease from 86% in 2023. However, as a percentage of all oysters sampled from sentinel and supplemental bars, lethal infections were detected in 11% of individual oysters in 2024, less than half of the 25% lethal prevalence in 2023.
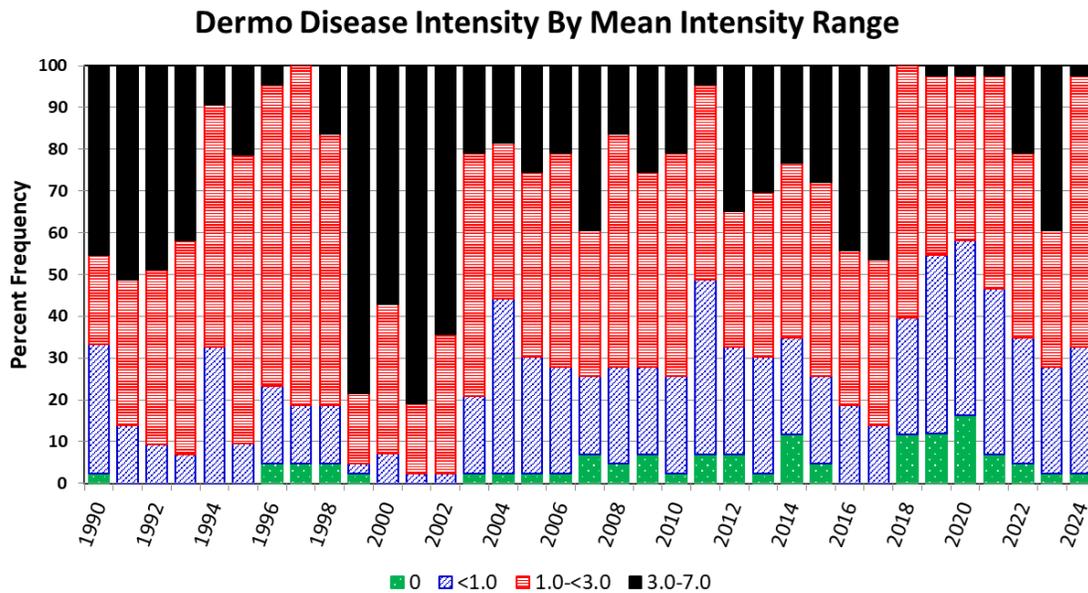
Figure 8. *Perkinsus marinus* infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.

The comparison between 2023 and 2024 in the geographic distribution of intensity ranges for both Disease Bars and supplemental sites are shown in Figure 9. In 2024, the highest intensities were seen at only three sites, all in the southeastern portion of the bay and Tangier Sound. In contrast, the highest intensity sites were much more numerous and widely distributed in 2023. The majority of the highest intensities that year 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 was noteworthy, especially in the Choptank River.
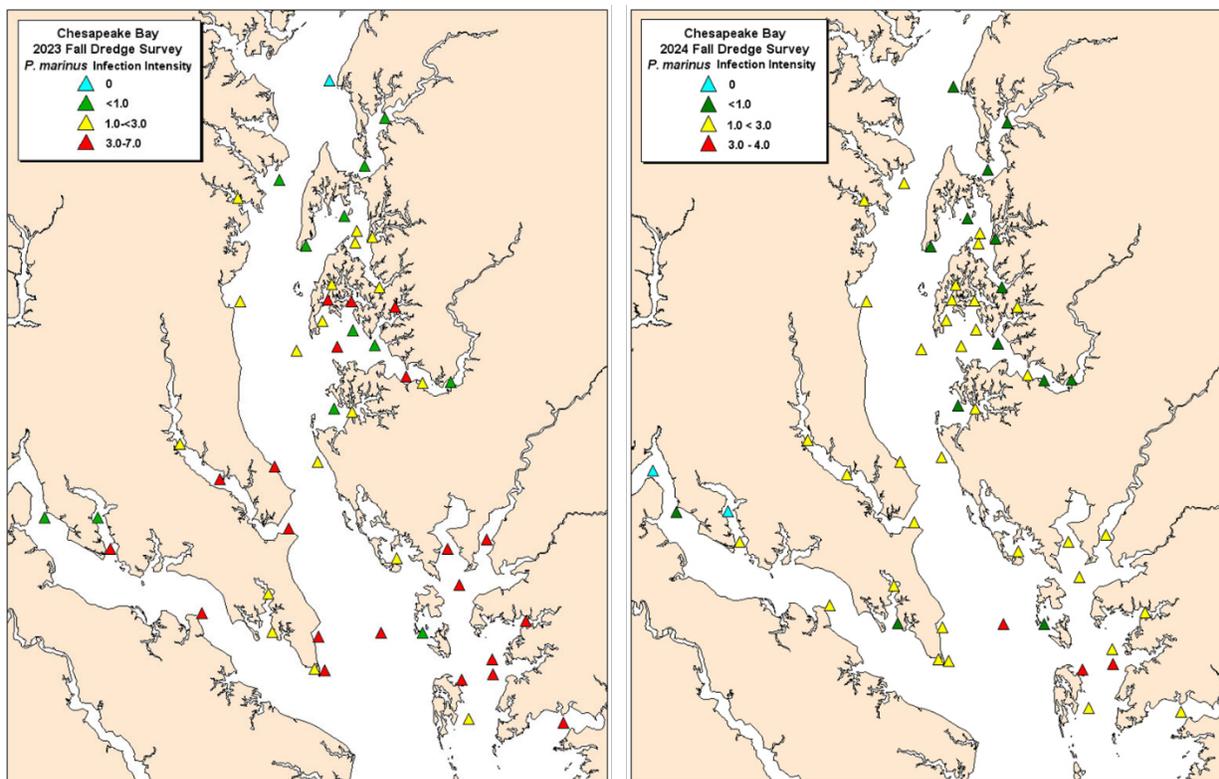
Figure 9. Geographic distribution of *P. marinus* infection intensity ranges in all disease samples, 2023 vs. 2024.

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 decreased substantially on the Disease Bars in 2024. The mean prevalence index of infected oysters plummeted from 17.6% to 0.6%. Seven of the last eight years have had prevalence indexes well below the long-term average, three of which were record lows (Table 4, Figure 9). The prevalences on the individual

Disease Bars where MSX was detected ranged from 3% to 7%, compared to a peak prevalence of 93% in 2023, which was the highest recorded prevalence for an individual bar in the 35-year time series.
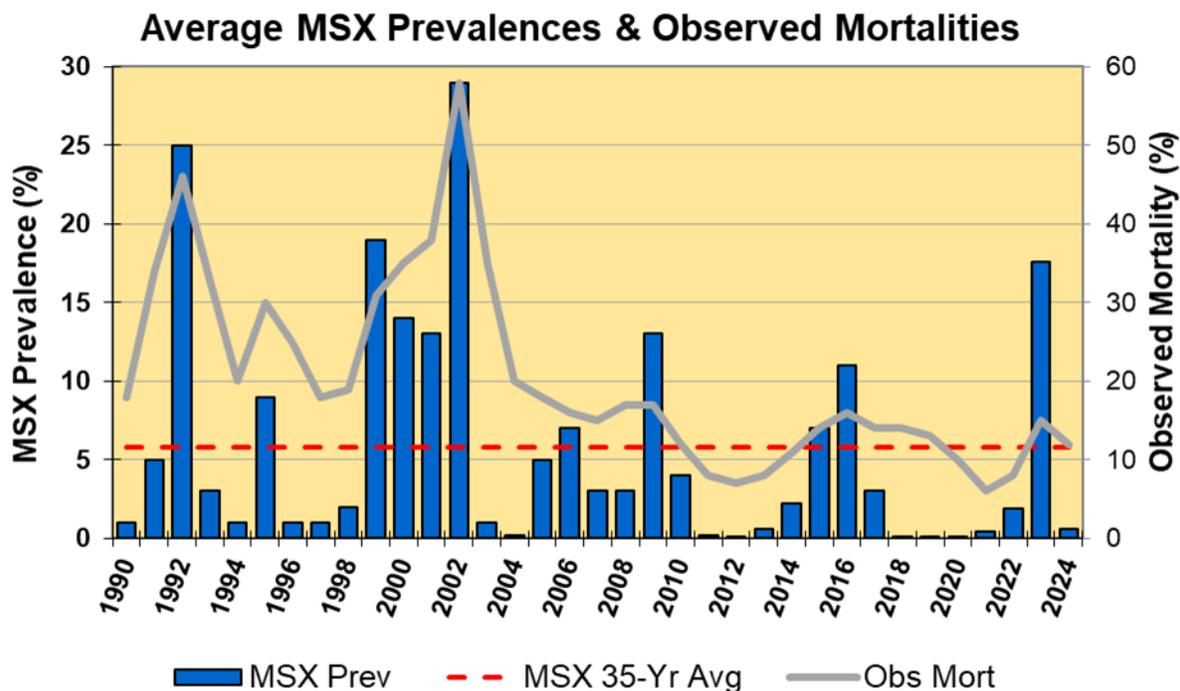
Figure 9. Annual percentage of Maryland oysters with MSX disease compared to 35-year mean and the correlation with observed mortalities on the disease monitoring bars from 1990-2024.

As a consequence of the winter/spring freshets and substantial drop in salinities, the geographic extent of MSX disease retreated throughout the mainstem and tributaries back to the lower bay (Figure 10). In only one year, the frequency of positive Disease Bars decreased from 28 bars (65%) in 2023 to 6 bars (14%) (Table 4). MSX was also detected on three of the ten supplemental disease sites, with the highest prevalence of only 7% on Point Lookout in the western lower mainstem. For reference, at its greatest extent the parasite occurred on 90% of the examined bars in 2002.

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, 2018). 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 (MDNR 2001; Tarnowski 2005, 2011). The recent six-year period (2017-2022) 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). This pattern repeated in 2024 with winter/spring freshets resulting in the reduction of MSX disease.
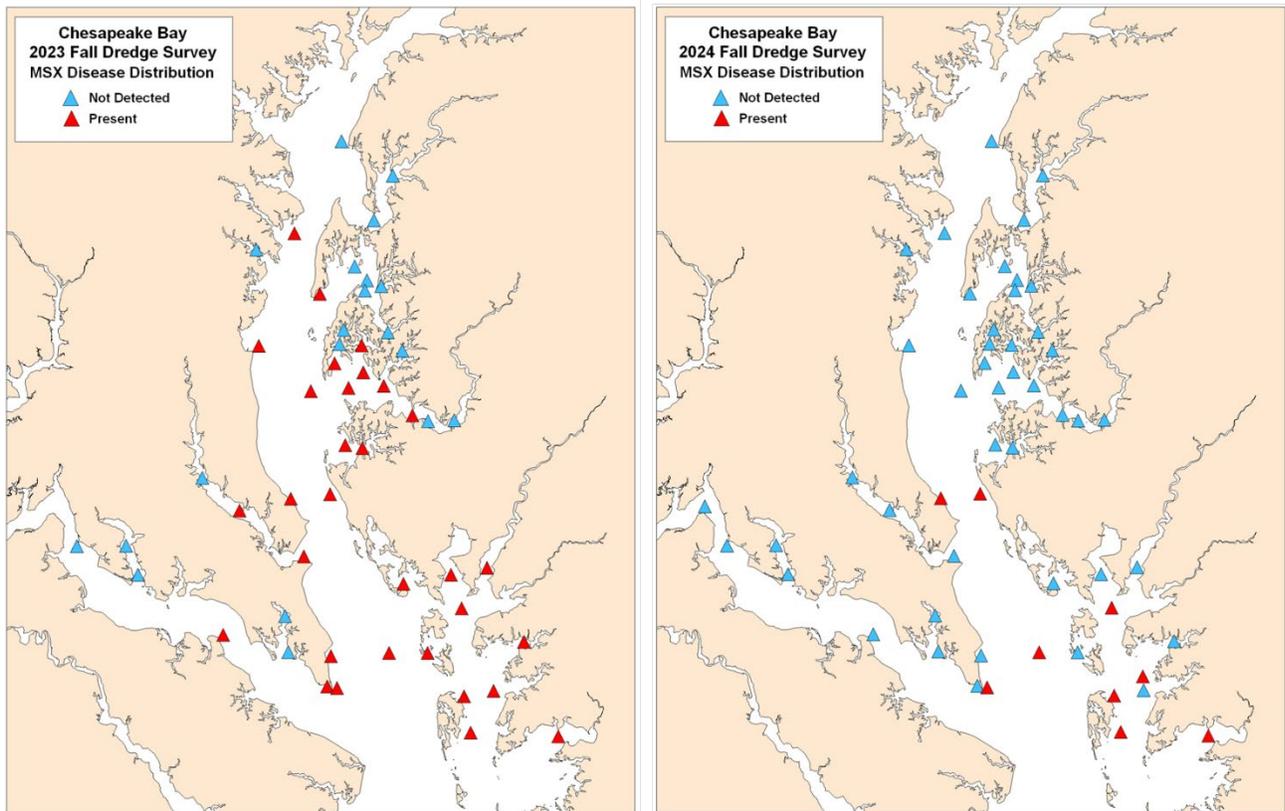
Figure 10. Geographic distribution and prevalence of MSX disease in Maryland waters in 2024 compared with 2023, illustrating how extensively the disease has retreated in one year of depressed salinities.

OBSERVED MORTALITY

At 11.6%, the 2024 Observed Mortality Index was 25% lower than that of 2023 (Table 5). The 2024 mortality index marks the 21st consecutive year that mortalities were substantially below the long-term mean of 20.8% (Figure 11), largely as a consequence of low to moderate disease pressure during that time period. From 2010 to 2024, 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.

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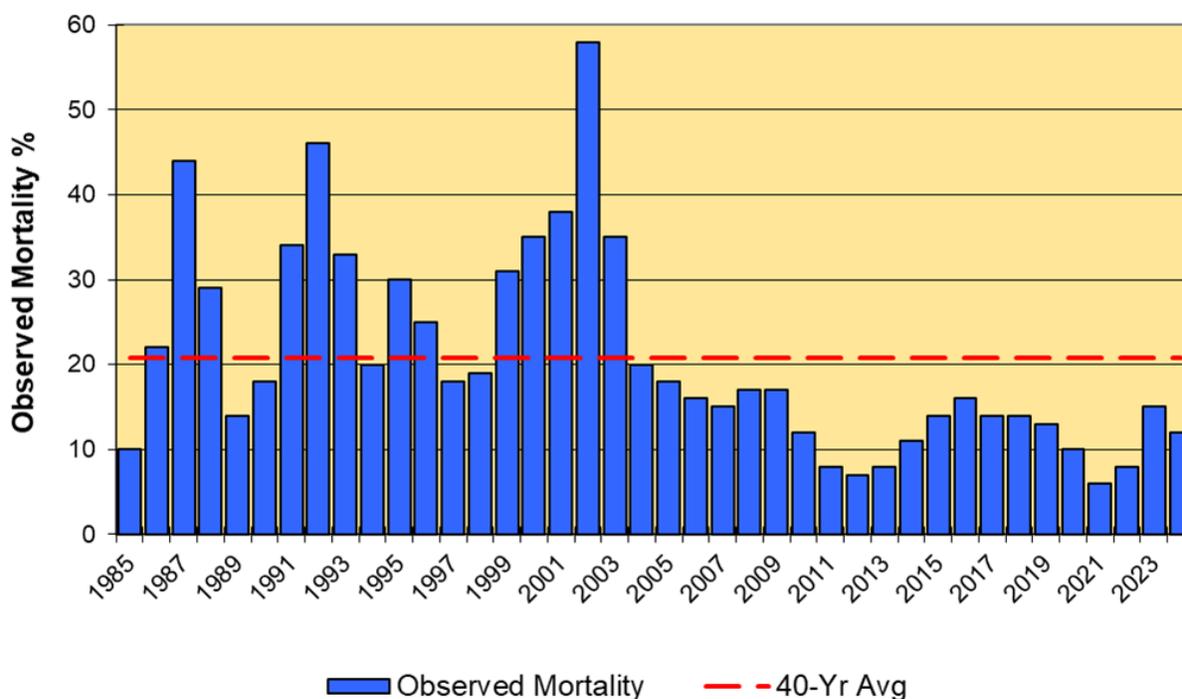
Figure 11. Mean annual observed mortality, small and market oysters combined.

Looking at all Fall Survey sites, regional observed mortalities were generally low throughout the bay and tributaries, with the moderate to high mortality categories receding from 2023 (Figure 12). Tangier Sound, typically a higher mortality area, averaged 12.4%, half of the 2023 average of 24.8%. For reference, the Tangier Sound observed mortalities at the start of the millennial epizootic in 1999 had average mortalities of 48.0%. The highest index bar mortality on bars with 40 or more small and market oysters was observed on Ragged Point (61.9%) in the Little Choptank River, the second year in a row it ranked in the top two, followed by Hog Island (34.3%) at the mouth of the Patuxent River (Table 5). For non-index bars with 40 or more oysters older than one year, the highest observed mortalities were both in the Little Choptank River - Susquehanna Reef Site (36.6%) and Slaughter Creek (36.1%). All three of the Little Choptank sites are outside of the sanctuary; the sanctuary bars in that river had an average observed mortality of 15.2% (see the Oyster Sanctuary section for additional details).

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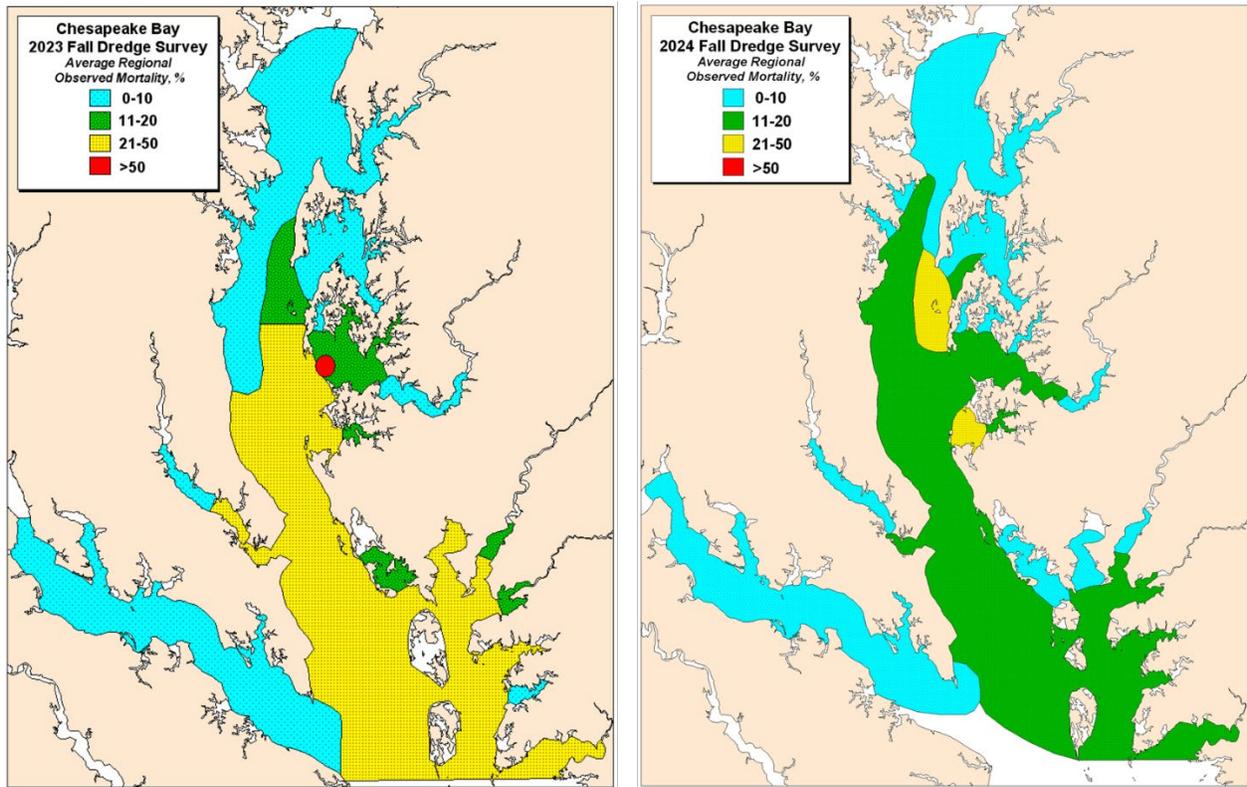
Figure 12. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2023 vs. 2024. Mortality ranges represent regional averages of all Fall Survey sites; individual bars may vary substantially.

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 2024 Maryland Oyster Biomass Index was 2.33, the third highest index of the 32-year record (Figure 13). This was a slight uptick from the 2023 index of 2.21 and represents a gain of 38% over the long-term average. While the index has trended downward slightly from the peak index in 2021, the last four indexes have been the highest in the time-series. Eleven of the last thirteen years have had biomass indexes above the 32-year mean.

The size distribution of index bars was heavily weighted toward sublegal oysters at a ratio of 1.70 sublegals to one market oyster, compared with the sublegal to market ratio of 0.98 in 2023. This can also be expressed as the percentage of sublegal oysters: 63.0% in 2024, up substantially from 49.5% in 2023. This shift is reflected in the decrease in average size of index bar oysters, from 76.8 mm in 2023 to 70.5 mm in 2024. As expected, the decrease in the average oyster size should result in a corresponding decrease in biomass. However, the second component of the Biomass Index, oyster abundance, showed an increase. For all index bars, the average number of oysters per one bushel sample rose from 125.7 in 2023 to 156.7 in 2024, a 24.6% jump. The large influx in the number of small oysters due to recent improved recruitment mitigated biomass removals (as related in the Commercial Harvest section). This balance between recruitment and harvests has resulted in the plateauing of the Biomass Index over the past three years.
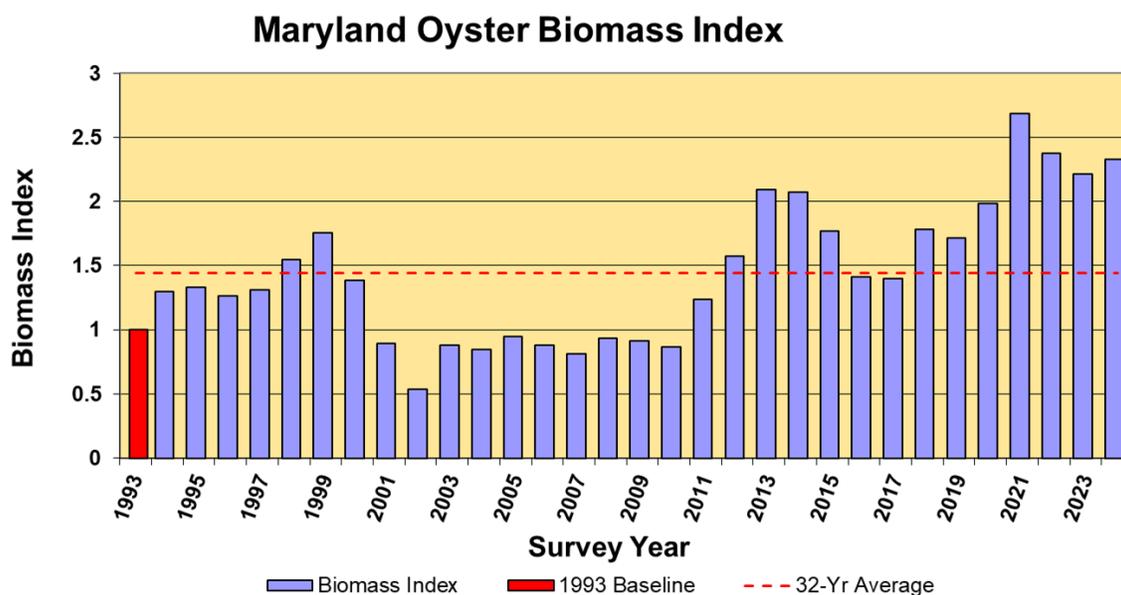
Figure 13. Maryland oyster Biomass Index. The year 1993 represents the baseline index of 1.0.

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 did 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 upward trajectory of the Biomass Index has been above the long-term average in eleven of the last thirteen years, with the 2024 index quadrupling the low point in 2002. With the strong spatsets of the last five 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.

The Biomass Index is calculated from the numbers and size distributions of oysters at the 43 Disease Bar sites.

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[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 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 2024 Cultch Index of 1.16 bu/100 ft. was the second highest in the time series. It represents a 26% increase over the 2023 average and is well above the 20-year average, both of 0.92 bu/100 ft. (Figure 14).
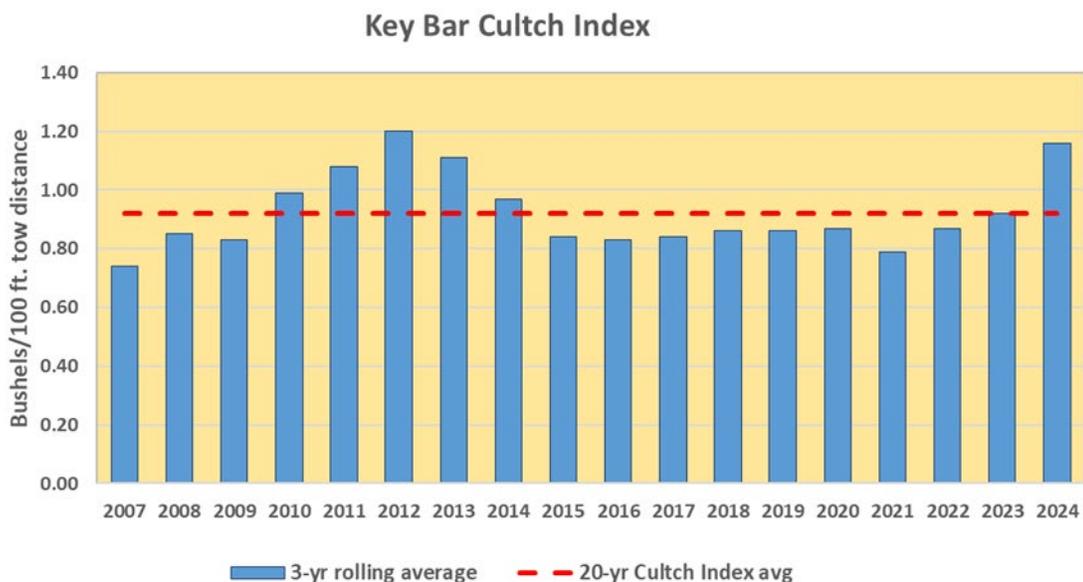
Figure 14. Three-year rolling average of annual means for the Key Bar Cultch Index, 2005-2024. The average is represented by the third year of the grouping (e.g., the 2005-07 average is graphed as 2007).

Although 20 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 responsible for the increasing trend in the index over the last three years.

Despite the overall positive trends, some individual bars showed steep declines and continue to struggle. Of the 53 bars used in this analysis, seven had three-year average standardized volumes that were less than 75% of their respective 20-year averages (Figure 15). In contrast, 18 bars had average cultch volumes greater than 125% of their long-term means. These percentages represent the most substantial changes from the long-term mean.
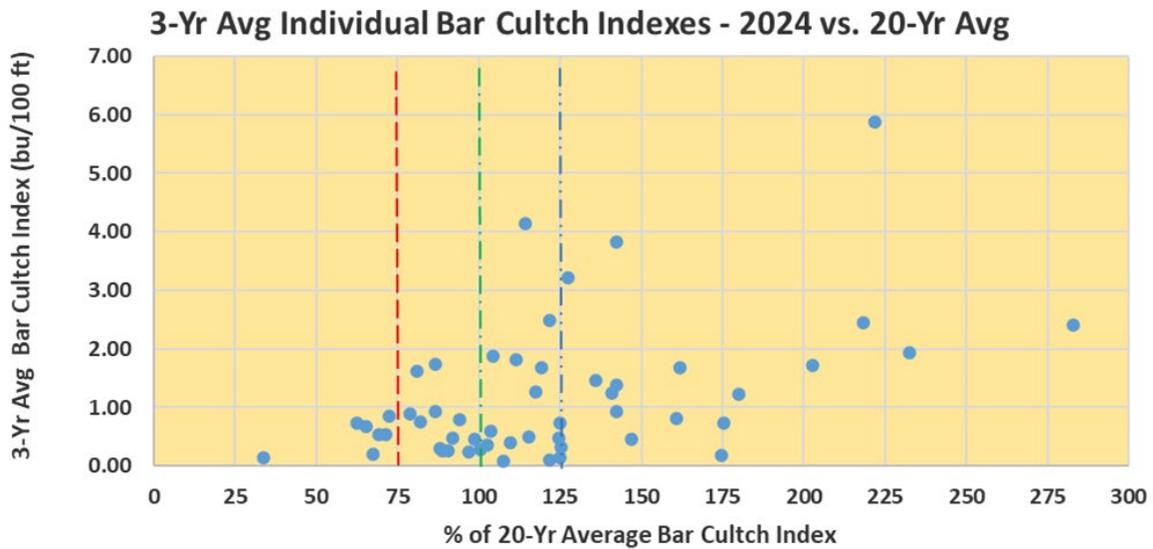
Figure 15. Range of cultch index values for individual Key bars for the average of three years ending in 2024 and the percent difference from their respective 20-year averages. The green dashed line represents the 20-year average; the red dashed line is 75% of that average and the blue dashed line is 125% of that 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 showed improved indexes above their 20-year averages (Figure 16).
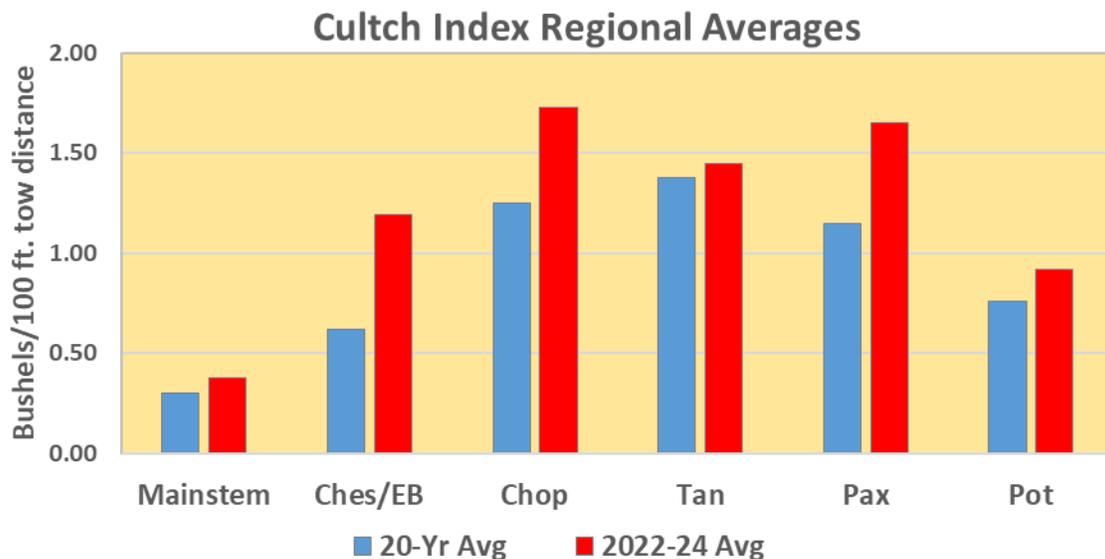
Figure 16. Regional cultch index averages for the 20-year time series and most recent three years.
Mainstem=bay mainstem; Ches/EB=Chester River/Eastern Bay region; Chop=Choptank River region; Tan=Tangier Sound region; Pax=Patuxent River; Pot=Potomac River tributaries

Cultch volumes among subregions of the broader regions can be highly variable. The greater part of the Tangier Sound regional cultch index (Figure 16) is contributed by the tributaries and not Tangier Sound proper (Figure 16a). In 2024, the three-year average of the index stations of the five subregional tributaries was 1.45 bu/100 ft. tow distance while the Tangier Sound proper stations averaged 0.92 bu/100 ft. The average cultch indices for the individual tributaries were substantially higher in the Nanticoke River (2.02 bu/100 ft) and the Manokin River (1.75 bu/100 ft) sanctuaries (Figure 16a).
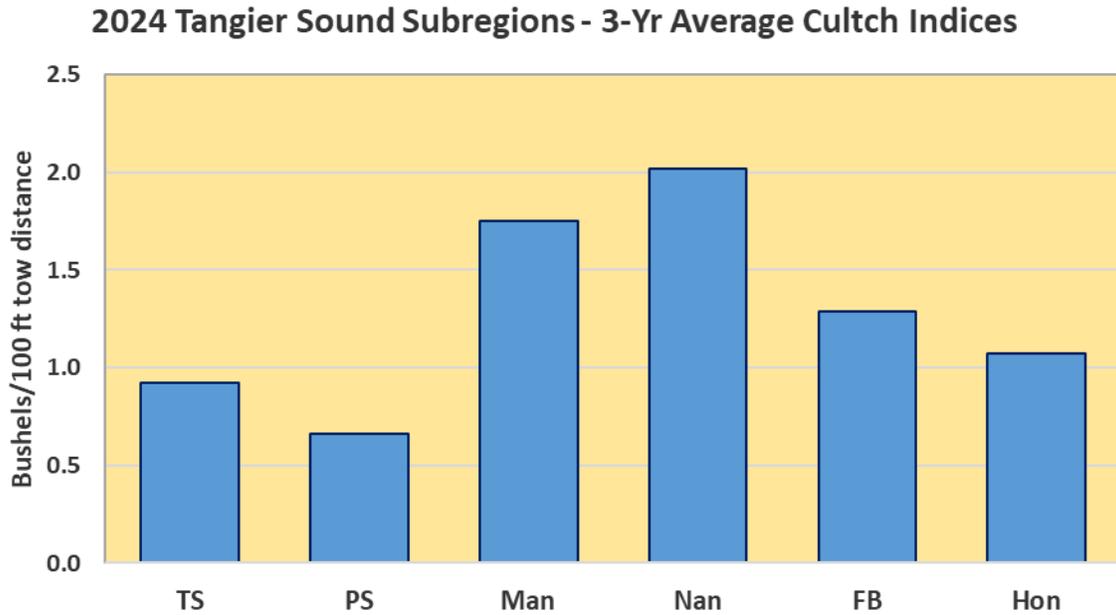
Figure 16a. Three-year averages (2022-2024) of bushels of cultch per 100 ft. tow distance for index stations by subregion within the Tangier Sound region. *TS=Tangier Sound; PS=Pocomoke Sound; Man=Manokin River; Nan=Nanticoke River; FB=Fishing Bay; Hon=Honga River*

COMMERCIAL HARVEST

Commercial oyster landings fell sharply from the exceptional 2022-23 season, which had the highest harvest in 36 years. With reported harvests of 438,000 bushels, oyster landings during the 2023-24 season were 39% lower than the previous season total of 720,000 bushels (Table 6, Figure 17a). Although substantially below the previous season, the 2023-24 landings were the third highest since the 1986/87 season and remained well above the 39-year average of 313,489 bu/yr. The average reported price also dropped to $35.69/bu from $43.00/bu in 2023. This combination of smaller harvest and lower price per bushel resulted in a 50% decrease in the total dockside value from $31.1 million in 2023 to $15.6 million in 2024 - nevertheless a not insubstantial sum (Table 7a.).

Md. Oyster Biomass Index and Harvests
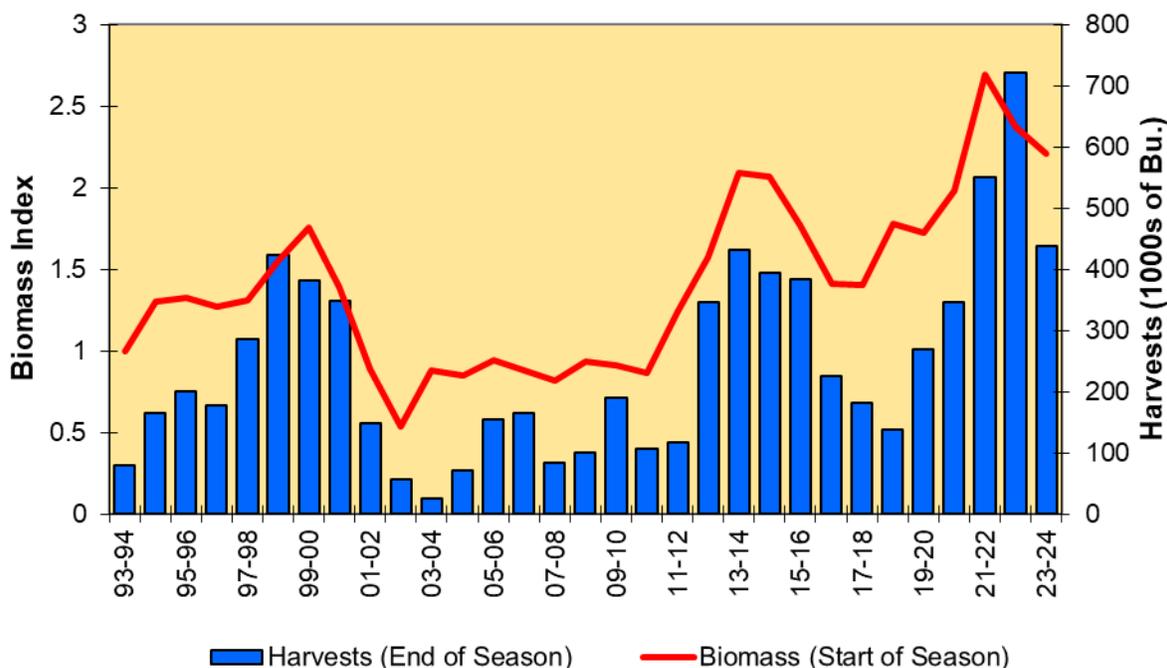
Figure 17a. Maryland oyster landings over the past 31 seasons and the relationship between the Biomass Index calculated at the start of the harvest season and total landings reported at the end of that same season. Note lag between the two metrics when abundant sublegal oysters add to the Biomass Index 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 autumn 2023 index was likely due to increased harvest activity during the previous season, which was reflected in the subsequent lower harvests during the 2023-24 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 lowest point that year, followed by the record low landings of 26,000 bu taken in 2003-04. The sizeable harvest increases of 2012-2016 (Figure 17a), following the below-average yields of the decade beforehand, were due to the strong 2010 and 2012 year-classes and subsequent good

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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 spatsets in 2011, 2013, and 2014 were insufficient to sustain harvests, leading to the considerable 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 higher landings over the last five years reflected in the rise of the index.
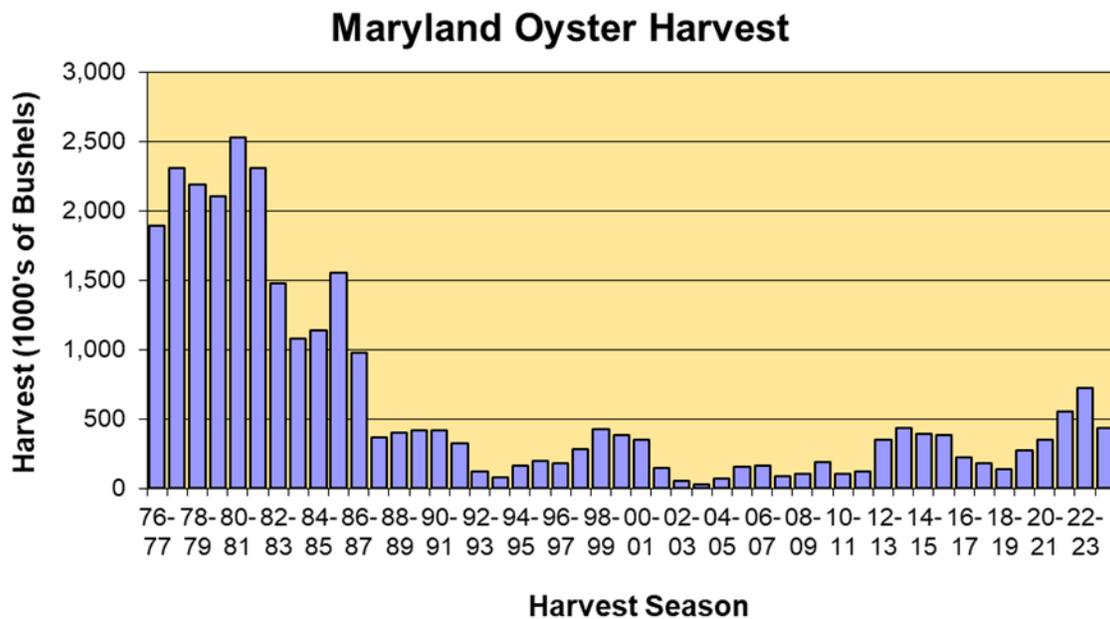
Figure 17b. Maryland seasonal oyster landings, 1976-77 to 2023-24.

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 31 years (and four of these in the most recent 22 years) following the onset of a series of disease epizootics beginning in the mid-1980s.

For the 2023-24 season, the Tangier Sound region, with landings of 223,000 bu, was the dominant harvest area, accounting for 51% of Maryland's landings (Figure 17c). The greatest proportion of these landings came from lower Tangier Sound (101,000 bu or 23% of the Maryland harvest) (Table 6). The Choptank region was second (126,000 bu, providing 28% of the total harvest), with the majority coming out of Broad Creek (74,000 bushels or 17% of the Maryland harvest).

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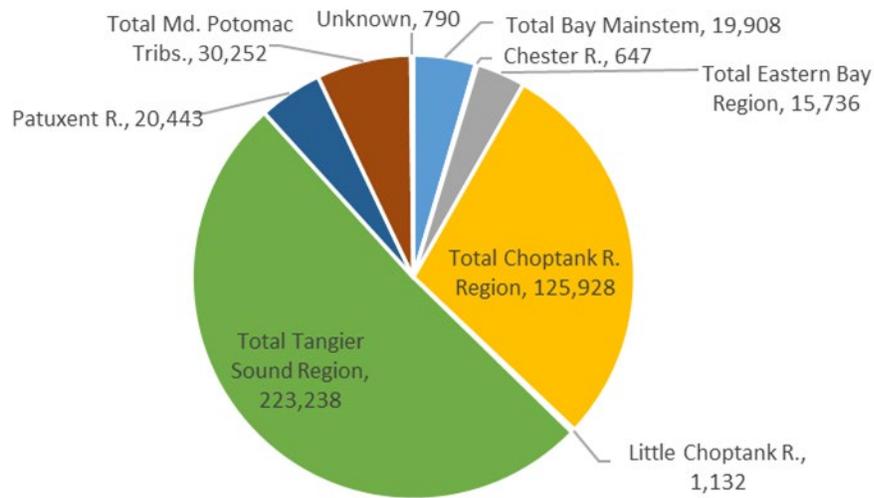
Figure 17c. Distribution of regional landings (in bushels) relative to Maryland total landings (438,000 bu) for the 2023-24 season.

In keeping with the overall losses in landings, most of the major harvest regions exhibited declines, including the Tangier region, the lower bay, and Patuxent and Little Choptank rivers. Regions that bucked this trend by showing gains were the Choptank and St. Marys rivers and Eastern Bay. The most substantial changes (>5,000 bu) in Maryland regional landings between the 2022-23 and 2023-24 seasons are listed in Table A.

Table A. Regional changes of more than 5,000 bu in landings between seasons ending in 2023 and 2024.

Region	2024 Landings (bu)	Change from 2023 (bu)	% Change
Choptank River	125,928	+30,298	+32%
Eastern Bay	15,736	+13,352	+560%
St. Mary River	23,335	+12,676	+119%
Tangier Sound	223,238	-256,779	-54%
Patuxent River	20,443	-58,027	-74%
Lower Bay	10,563	-18,749	-64%
Little Choptank River	1,132	-10,901	-91%

The heaviest losses were in the combined harvests for the entire Tangier Sound region, which dropped by 257,00 bushels or -54% from the 2022-23 season. On the other hand, the combined Choptank River region, the second most-productive area, showed an increase of 30,000 bu (+32%). Despite the recent declines, many regions remained above their long-term harvest averages, especially in 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 both 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 39-year harvest average for these two regions is 29,000 bu/year, primarily sustained by numerous seed plantings from the historic MDNR Repletion Program. In the once highly productive Eastern Bay region, despite an uptick in landings in 2024, they were only half of the region's 39-year average landings.

Not surprisingly, most gear types showed losses in harvests from the previous season (Table 7a). The exception was hand tongs, which had a modest increase from 2023. For the 17th consecutive season, power dredging was the predominant method of harvesting, accounting for 54% of the total landings (Table 7b). This activity was mainly in the lower Eastern Shore and Choptank regions. Although patent tonging was second, producing 18% of the total harvests, this was a drop from 34% in 2023. Meanwhile, hand tonging almost doubled to 17% of the landings, primarily from Broad Creek, but well below 74% of the landings during the 1996-97 season when power dredging was largely prohibited. Skipjacks (7%) and divers (4%) made up the remainder of the current landings.

Hand tonging up a full load. (Photo: R. Bussell)

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 (MDNR 2021, 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 2024 Fall Survey (Table 8). For comparison among areas, oyster counts were standardized to 100 ft dredge tows, as the number per bushel count does not take into account varying tow distances. Recruitment within the priority sanctuaries was generally below their respective Key Bar 20-year averages (Table S-1). The exception was the St. Marys River sanctuary, which had an above average spatset. In contrast, spatsets in most of the adjacent open harvest areas were at or well above the long-term averages, particularly in the St. Marys River open area, which experienced a ten-fold increase (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 20-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. 2024 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 2024 Sm+Ma (#/100 ft tow)	Regional 2024 Spat (#/100 ft tow)	*KB Spat 20-yr Avg* (#/100 ft tow)	2024 Regional Avg. Tow Dist. (ft)
Harris Cr.	Sanc.	380	16	52.9	71
Harris Cr.	Open	177	13	10.0	256
Broad Cr.	Open	1322	230	52.6	58
Broad Cr.[a]	Open	1546	269	260.2	32
Tred Avon R.	Sanc.	328	5	28.6	81
Tred Avon R.	Open	584	18	*n/a*	130
L.Choptank R.	Sanc.	94	34	56.2	61
L.Choptank R	Open	30	35	5.9	145
Manokin R.	Sanc.	184	47	155.5[b]	90
Mid-Tangier S.	Open	159	172	62.4[b]	123
St. Marys R.	Sanc.	940	388	233.5	44
St. Marys R.	Open	497	264	27.0	102

[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). Broad Creek, historically one of the highest oyster producing regions in Maryland (Table 6), had the greatest average number of adult oysters of any

area in this comparison, thanks to the extraordinary spatset in 2020 and a strong set in 2023 (Table 2). The St. Marys sanctuary averaged the second highest number of adults.

As in the general population, disease levels in the sanctuaries fell substantially from 2023. Oyster disease samples were obtained from the five priority oyster sanctuaries (Table S-2) and 14 non-priority sanctuaries. Although dermo disease was present in all thirteen sentinel Disease Bars (Table 3) and seven supplemental stations within these sanctuaries, prevalence declined from 85% in 2023 to 55% in 2024 and intensities fell from 2.9 to 1.6. Of these, six had dermo disease prevalences above their 35-year site averages, but only one of those had an intensity above the long-term average. Dermo disease levels in the comparison harvest areas also dropped, averaging 42.0% prevalence, down from 61.5% in 2023. The open baywide mean intensity was 1.3 (Table S-2), a decline from 2.1 in 2023. The somewhat 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 none of the five priority sanctuaries but at two of the associated harvest bars (Table S-2). Outside of the restoration sanctuaries/adjacent harvest areas, MSX disease was found at only three of fourteen other sanctuaries and four of twenty-six bars in open harvest areas. The 2024 average MSX disease prevalence for baywide sanctuary disease samples was 0.7%, compared with 11.6% in 2023. Baywide harvest area disease samples averaged 0.8%, a considerable decrease from 19.0% in 2023. The highest MSX prevalence observed in 2025 was 7% (Tables 4, S-2). In contrast, 2023 saw the highest MSX disease record of the 35-year time series with 93% on Lighthouse open harvest bar in the Choptank River.

Table S-2. 2024 oyster disease levels and observed mortality estimates for Disease Bars and regional averages on priority restoration sanctuaries and nearby harvest areas. Baywide disease and mortality averages for all Disease Bars and Supplemental sites combined 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.	63/40	1.9/1.2	0/0	7.2/3.5	7.5
Harris Cr.	Tilghman Wharf	Open	47	1.3	0	7.3	13.2
Tred Avon R.	Double Mills	Sanc.	57	1.6	0	3.2	3.5
Mid-Choptank R	Lighthouse	Open	3	0.1	0	12.8	7.4
Broad Cr.	Deep Neck	Open	70	1.9	0	6.1	7.9
L. Choptank R.	Cason	Sanc.	80	1.9	0	20.1	15.2
L. Choptank R.	Ragged Pt.	Open	70	2.3	0	61.9	27.2
Manokin R.	Georges	Sanc.	83	2.9	0	19.5	22.9
Mid-Tangier S.	Piney Is. E./Back Cove	Open	57/83	3.3/4.7	7/7	11.6/11.5	13.9
St. Marys R.	Pagan	Sanc.	63	1.8	0	3.8	4.3
St. Marys R.	Chicken Cock	Open	30	0.9	0	6.0	6.4
Average of Restoration Sanctuary Samples			69.3	2.3	0	8.5	13.2
Average of Adjacent Harvest Samples			68.0	2.3	2.3	12.1	11.2
Avg. of Baywide Sanctuary Disease Samples[b]			55.2	1.6	0.7	10.2	
Avg. of Baywide Harvest Disease Samples[b]			42.0	1.3	0.8	11.8	

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

The lower disease levels in the sanctuaries were accompanied by a drop in observed mortalities. The baywide average mortality for the sanctuary bars fell from 16.0% in 2023 to 10.2% in 2024. This remained lower than the long-term sanctuary index bar average of 20.3%; ten of eleven Mortality Index bars within sanctuaries had observed mortalities below their respective 40-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). In the restoration sanctuaries, the average regional mortality was 13.2%, while in the corresponding harvest areas the average mortality was 11.2% in 2024. The average observed mortality for individual disease and supplemental sites in the restoration sanctuaries was somewhat lower at 8.5%, compared to 12.1% at the adjacent harvest disease bars.

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 per index bar in the sanctuaries was 235.3 g/bu, a slight increase from 222.6 g/bu in 2023, and substantially higher (30%) than in the harvest areas (Table S-3). In the open harvest areas, the average biomass per index bar has slipped in the previous three years, from the high point in 2021 of 232.1 g/bu to 168.4 g/bu in 2023, but grew somewhat in 2024 to 180.4 g/bu. 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 2024 exceeding their long-term averages by 54% and 59% respectively.

Table S-3. Average biomass/bar comparisons between Biomass Index bars in the sanctuaries and open harvest areas for 2024, as well as average shell heights and the proportion of sublegal oysters (<76 mm).

Status	n	Average Total Biomass	Avg. Market Biomass	Avg. Sublegal Biomass	Average Height	% Sublegals
Sanctuaries	13	235.3 g/bu	180.6 g/bu	54.7 g/bu	79.6 mm	47.6%
Harvest Areas	30	180.4 g/bu	99.1 g/bu	81.4 g/bu	67.1 mm	69.1%

The distributions of oyster biomass between the two management areas were distinctly different (Table S-3). 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 drops off sooner above the minimum legal harvest size. The average biomass of sublegal oysters increased to 54.7 g/bu (+25.5%) in the sanctuaries, and jumped to 81.4 g/bu (+64.8%) in the harvest areas due to the influx of the strong 2023 cohort. The average market oyster biomass in the sanctuaries of 180.6 g/bu was almost unchanged (+0.8%) from the previous year, while the open harvest areas showed a loss to 99.1 g/bu (-20.1%).

Oyster Biomass - Sanctuaries vs. Open Areas 2024
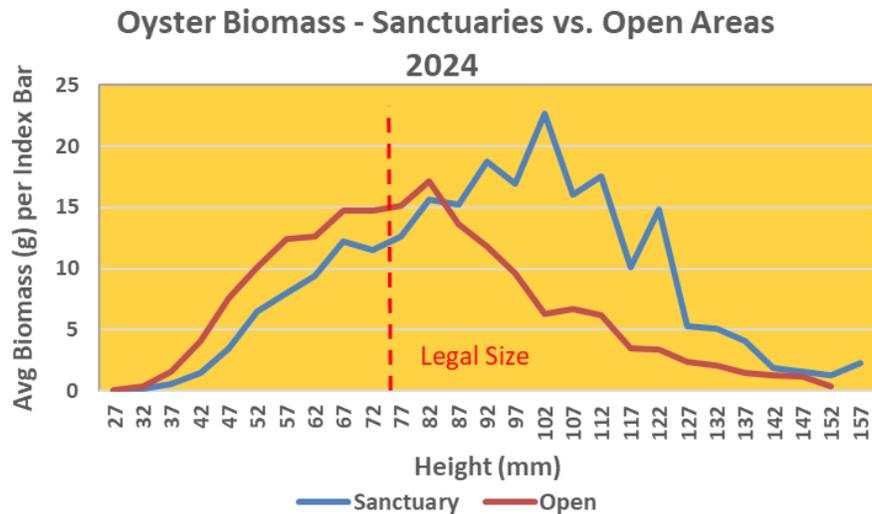
Figure 18. Average oyster biomass by 5 mm size classes on Biomass Index bars in harvest areas and sanctuaries. Dashed line indicates minimum legal harvest size.

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/bar standardized to a 100 ft tow distance for these five sanctuary bars was 756.0 g/bu, compared to the average biomass/100 ft tow on the seven Biomass Index bars in adjacent open harvest areas of 432.8 g/bu. If Deep Neck bar in Broad Creek is excluded, the average biomass/bar from the remaining six open harvest bars plummets to 87.2 g/bu. Aside from Deep Neck, 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 (53.6 ft for the five sanctuary bars versus 207.7 ft for the seven open area bars), as well as larger average size (Table S-3). The dominating biomass value for Deep Neck bar is the product of the exceptional 2020 recruitment event (Tarnowski 2022), followed by strong spatsets in 2021 and 2023 and low natural mortalities.

Restoration Sanctuaries vs Adjacent Open Areas 2024 Biomass Index Bars
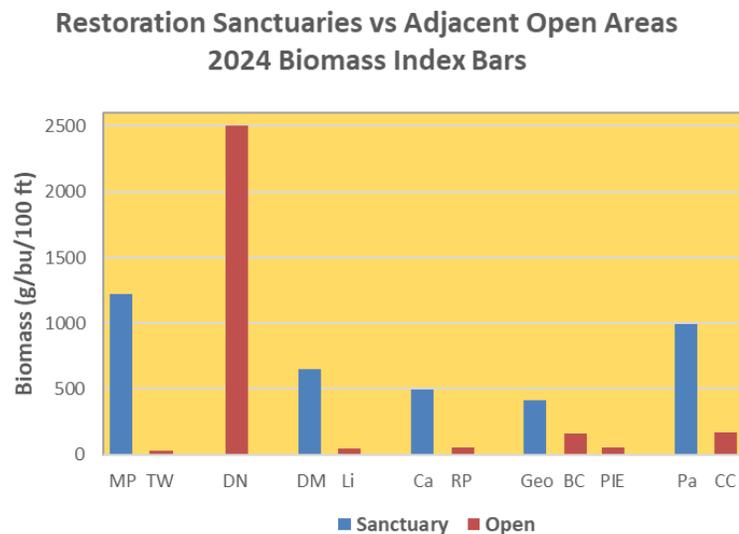
Figure 19. Comparison of biomass/100 ft tow between Biomass Index bars in the large-scale restoration sanctuaries and adjacent open areas. See Table S-2 for the regional locations of these bars. *MP=Mill Point (not a Biomass Index bar), TW=Tilghman Wharf, DN=Deep Neck, DM=Double Mills, Li=Lighthouse, Ca=Cason, RP=Ragged Point, Geo=Georges, BC =Back Cove, PIE=Piney Island East, Pa=Pagan, CC=Chicken Cock*

A sanctuary oyster. (Photo: R. Bussell)
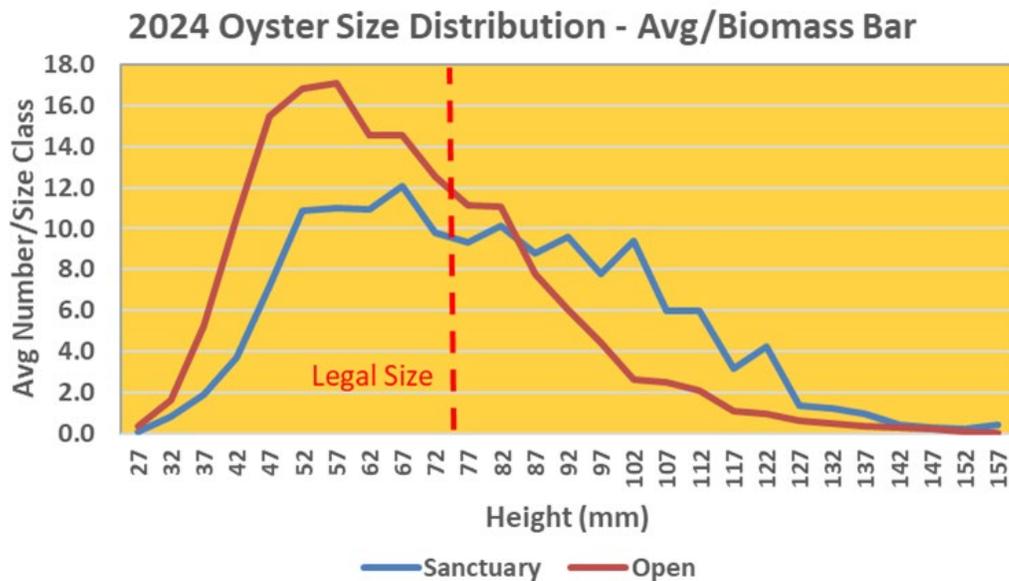
Figure 20. Size-frequency distributions of oysters in the sanctuaries and open harvest Biomass Bars in 2024. The open harvest area around the mode of 57 mm is due to the strong 2023 year class.

The size distribution of oysters is a reflection of the strong recruitment events in recent years. The dominant size classes of the sanctuary oysters were spread across a broad range of sizes, with peaks at 52 mm, 67 mm, 82 mm, 92 mm and 102 mm, whereas the modal height in the adjacent open areas was a more defined peak between 47 mm and 67 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 remained the same from the previous year (79.6 mm in 2024 vs.79.8 mm in 2023), while the harvest bar populations diminished in average size (67.1 mm in 2024 vs.75.3 mm in 2023). These changes in the harvest areas were driven by the cropping down of the legal-

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sized oysters and the influx of small oysters from the strong recruitment events over the past four years (Figure 20). There was a sizable difference between the two management types in the proportion of sublegal oysters in each. Sublegal oysters comprised 47.6% of the adult oysters in the sanctuaries, little changed from 2023, while in the open area it was 69.1%, a large increase from 51.5% in 2023.

Cultch, the shell and oyster 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. Within the paired comparison regions, 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 highest overall in three-year average cultch density, boosted by the tremendous 2020 spatset and a strong follow-up set in 2023. 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 the Harris Creek sanctuary was about double that of the harvest area in that river.
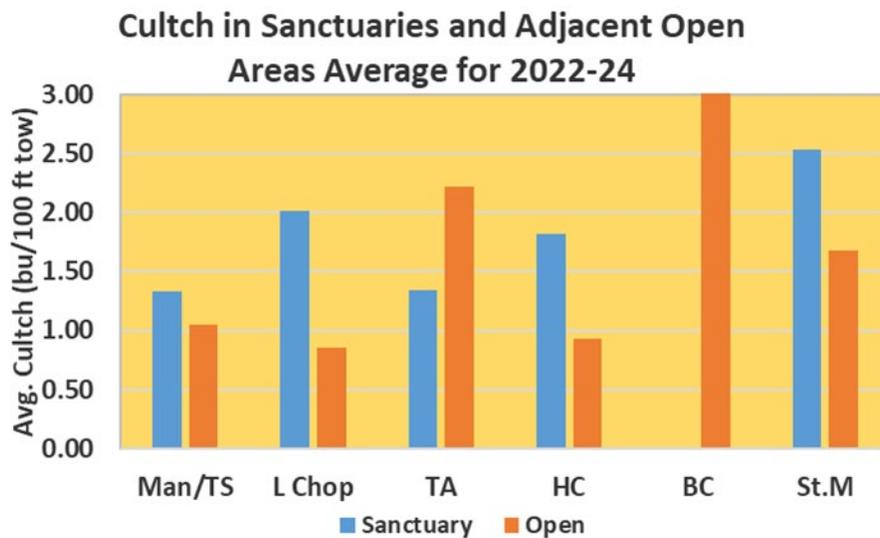
Figure 21. Comparison of cultch volumes between sanctuaries and adjacent open areas averaged for 2022-24. All stations with sufficient data within an area were included in the averages, standardized to 100 ft. tow distances. *Man=Manokin River; TS=mid-Tangier Sound; L Chop=Little Choptank River; TA=Tred Avon River; HC=Harris Creek; BC=Broad Creek; St.M=St. Marys River*

DISCUSSION
Timing is (Almost) Everything

The findings of the 2023 and 2024 Fall Oyster Surveys and an ancillary survey in the spring of 2024 illustrated the profound influence that salinity, both in terms of magnitude and timing, has on oyster population dynamics. An extended drought and consequent elevated salinities during 2023 enabled an exceptional recruitment event while allowing for the rapid and extensive spread of MSX disease and increase in dermo disease intensity. Previous experience with a similar situation was not encouraging. The millennial epizootics beginning in 1999 decimated the promising 1997 year class, which was the product of a record-high spatset, before most of those oysters attained market size. The average MSX prevalence in 2023 was the highest since the 2002 peak of that devastating epizootic, causing deep concern for the 2023 cohort. Was history going to repeat in 2024?

Serendipitously, the drought broke with heavy rains and freshets during the late winter and spring of 2024, causing a dramatic reversal in salinity levels. The result was a sharp decline and even disappearance of MSX from all but a few disease monitoring sites. For example, in the fall of 2023, the highest MSX prevalence ever recorded (93%) was on Lighthouse bar in the Choptank River, but by the spring of 2024, MSX disease was completely absent after the salinity had fallen to half of its fall peak. The remaining pockets of MSX disease were at low prevalences no higher than 7%.

While the abatement of MSX brought relief to the general oyster population, there was concern that streamflows had gone too far in the other direction, possibly dropping salinities on the upstream bars of tributaries to the extent that the rare spatsets that had occurred at those locations were in jeopardy. In particular, the portion of the Potomac River oyster grounds above the Route 301 bridge, which received an extraordinary spatset in 2023, was especially vulnerable to high freshwater flows and had previously suffered 100% mortality of oysters due to the prolonged 2018/19 freshets. Fortunately, the pre-existing elevated salinities initially buffered the effect of the 2024 freshets. Also, the freshets occurred during the cold winter months, when oysters are in a physiologically quiescent state and less susceptible to depressed salinities. Lastly, the 2024 freshets were relatively short-lived, subsiding as temperatures began to rise in the spring and the oysters became more active; by June salinities had returned to normal. The 2024 Fall Survey found that the upriver oysters survived the freshets, although their growth was stunted by the lower salinities. In comparison, the record-high streamflows of 2018 persisted for an extended period through the warmest months of the year and into the spring of 2019, resulting in the extensive loss of oysters in the upstream portion of the Potomac River population.

The timing of reduced freshwater input to the bay and return of salinity levels back to normal fortunately coincided with the spawning period of oysters. Subsequently, recruitment was above the long-term median. Also, spat were extensively distributed, occurring on 51 of 53 Spat Index bars. Spatset was observed as far upbay as Mountain Point bar above the Bay Bridge for the first time since 2002 and only the fifth time on record – a rare finding. In contrast, recruitment in the

high flow year of 2018 was only 60% of the long-term median with a limited distribution – spat were found on only 31 Spat Index bars; 16 of those had single-digit counts.

The Importance of Salinity to Oyster Recruitment
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 towards the latter portion of 2022 and throughout 2023, and again during the summer of 2024, 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 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 lengthier 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 for larvae 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 a strong recruitment event occurs. Oftentimes these depend on synergies of extremely localized conditions, such as the exceptional 2020 Broad Creek spatset. So, having successive widespread recruitment events such as in 2023 and 2024 is uncommon, given the host of variables that can negatively impact spatset even under optimal salinity conditions.

An Abundance of Small Oysters
As a result of the abatement of diseases and related lower mortalities, as well as good survivorship despite the freshets in the upper reaches of tributaries, abundant 2023 year class oysters were observed throughout the Chesapeake region during the 2024 Fall Survey. Referring back to the Potomac River, which in 2023 had the highest regional recruitment in Maryland, the average number of sublegal adult oysters in 2024 was two and a half times greater than in 2023. The change in the average number of small oysters in the western Wicomico River, a tributary of the Potomac, was even more pronounced, increasing from 27/bu in 2023 to 184/bu in 2024.

Similarly, increases in small oysters to varying degrees were found in almost every region save for areas where spatsets were not observed in 2023, such as the upper bay and Chester River.

The notable 2023 spatset and subsequent high survivorship benefited several major sanctuaries, especially those in areas that usually have lower recruitment. The number of sublegal adult oysters in the Tred Avon Sanctuary quadrupled in 2024 following a strong spatset in the previous year. Other sanctuaries, including Breton Bay, Manokin, Nanticoke, Upper Choptank, Harris Creek, Lower Patuxent, and St. Marys also showed increased numbers of small oysters in 2024.

The net result from the advantageous salinity conditions that have existed over the past two years has been natural population growth and an increase in biomass in the sanctuaries, reducing the need and considerable expense of planting spat-on-shell for restoration purposes. For example, timely stone plantings in the Manokin Sanctuary produced a considerable spatset in 2024, curtailing the need for spat plantings at a substantial cost savings. Noteworthy is the population expansion in the complex of sanctuaries in the upper Choptank River above Cambridge, where no recent restoration efforts have taken place. Ordinarily a lower salinity area with poor recruitment, the oyster population has tripled since 2021 coincident with higher salinities. On two bars in the upper reaches of the sanctuary that experience the lowest average salinities, the mean number of small oysters jumped from 7/bu in 2022 to 127/bu in 2024. In addition, this area usually is not affected by disease (Oyster Shell Point, the Disease Bar within this area, encountered MSX in two out of 35 years, and long-term average dermo levels are among the lowest of the Disease Bar set). The episodic spatsets and good survivorship due to low disease pressure should help assure a sustaining population, provided there is not another extreme freshet such as occurred in 2018/19, which heavily impacted these sanctuaries.

The main commercial harvest areas also benefited from the 2023 spatset and now have abundant sublegal oysters. The addition of these to the population compensated for the removals of market oysters to the extent that the Biomass Index in these areas increased somewhat in 2024. This bodes well for the fishery in the near term, especially with the lower disease levels observed in 2024 and the possibility of disease resistance/tolerance developing in populations that are consistently challenged by disease, where much of the harvesting takes place.

Salinity/Disease Dynamics
In addition to recruitment, salinity plays a determining role in oyster disease dynamics. 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 year-long span separating the 2023 and 2024 Fall surveys. There was considerable uneasiness following the 2023 Fall Survey regarding the direction MSX disease would take during the upcoming year. The average disease prevalence was the highest since the 2002 peak of the four-year millennial epizootic and was widely distributed – almost to the Bay Bridge. However, these elevated prevalences were not yet reflected in the observed mortality index, which although having increased to 15% was still below the long-term average. In contrast, nearly 60% of the Mortality Index oysters were observed to be dead during the 2002 Fall Survey.

An inkling of what to expect was seen in the spring 2024 survey. The drought had broken and salinities plummeted, in some cases to half of what they were during the previous fall and below the 15 ppt threshold where MSX becomes lethal. Admittedly, the Spring Survey provided a mere glimpse of the situation as only three sites were assayed for MSX disease, but the results were encouraging. MSX prevalence was either greatly reduced or completely purged from those bars, particularly in the Choptank River. The full extent of the impact of the elevated winter/spring streamflows on *H. nelsoni* was still unknown, or if there would be a resurgence of the parasite after the freshets slowed and salinities began to climb again – in fact, drought conditions returned through the summer and into the fall of 2024. Also, dermo disease, whose levels exceeded the long-term averages for both prevalence and intensity in 2023, is undetectable in the spring using standard methods, so its status was unknown going into the 2024 Fall Survey.

Despite rising salinities, by the fall of 2024 there was no indication of a resurgence of disease – in fact, the results of the survey showed just the opposite. MSX disease had been purged from most of the disease sentinel sites and the few locations where it remained had low prevalences, no higher than 7%. This once again demonstrated the sensitivity of MSX disease to lower salinities, as reported at the conclusion of earlier epizootics. Dermo disease levels also declined, though not to the dramatic extent as MSX disease.

Disease-Related Mortality
The drought of 2023 provided a natural experiment. The prolonged period of elevated salinities baywide tested the hypothesis that the lower observed mortalities of the last two decades were the result of disease resistance/tolerance in oysters (Appendix 4). A counter hypothesis is that oyster survival was due to favorable salinity conditions, not genetic improvements. There had been no extended or severe periods of drought during this span of time comparable to the four-year drought that enabled the 1999-2002 millennial epizootics so devastating to the Chesapeake oyster populations.

The degree and geographic extent that MSX disease was able to proliferate in 2023 was unexpected, though the system was already primed in 2022, when 19% of the assayed bars had MSX infections, all in southern Maryland. The disease spread a substantial distance upbay and reached a record-high prevalence in the lower Choptank River where it had not been detected in the previous year, accompanied by a heavy loss of oysters. In the opposite direction, the rapid purging of *H. nelsoni* from all but a few bars in 2024 was equally dramatic.

A striking aspect of the 2023 MSX epizootic was the lower prevalences in the normally disease-prone, higher salinity region of Tangier Sound compared with the elevated prevalences of areas further upbay. The disease-naïve oysters on bars where salinities are rarely above the lethal threshold for MSX disease (e.g., in the lower Choptank River) experienced higher prevalences and mortalities when salinities exceeded that threshold. Despite environmental conditions in the Tangier Sound region that were conducive to MSX acquisition and pathogenic activity, prevalences and related mortalities were relatively moderate in the fall of 2023. Also, the Tangier region likely was the epicenter of the disease outbreak, as most of the highest prevalences were found there in 2022. Yet there was not as severe an impact as was seen in the Choptank region. The most parsimonious answer is that the Tangier region population has developed

resistance/tolerance to MSX disease after years of being challenged by it, as opposed to the infrequent exposure of the Choptank region oysters to *H. nelsoni*. Resistance is suggested in the Tangier region oysters as prevalences never got very high, averaging 19.9% in the fall of 2023, compared to a regional average 50.7% in the more susceptible Choptank 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, Ford & Bushek 2012). Furthermore, selective breeding has produced oyster strains with genetically enhanced resistance/tolerance to MSX disease (Ford & Tripp 1996). Yet given that most of Maryland waters rarely or only intermittently experience elevated MSX levels, resistance/tolerance is less likely to develop there with the expectation of higher mortalities when MSX spikes.

Observed Mortalities
Observed mortalities in fall 2023 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 bar (18.9%). Surprisingly, 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%). These were the three bars assayed for MSX disease in the following spring.

This situation reversed in the following spring, as the anticipated mortalities that were not observed in the Choptank during the 2023 Fall Survey became evident. By the time of the 2024 Spring Survey, post-Fall Survey observed mortalities had doubled regionally and more than doubled at the two study bars with the highest fall *H. nelsoni* prevalences of the Choptank region. Because of unsuitable environmental conditions for *H. nelsoni* in late winter/spring that reduced its prevalence, it would be expected that the increased mortalities occurred soon after the 2023 Fall Survey while the parasite was still active. However, the 2024 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 even though the parasite was purged.

In the Choptank oysters, two possibilities for this incongruity between MSX prevalence and mortality during the fall of 2023 are that either they had only recently acquired the disease or environmental conditions had suppressed its impact. In both cases, there was still at least two months of suitable environmental conditions after the 2023 Fall Survey for the pathogens to proliferate before water temperatures below 5°C inhibited their activity (Ford and Haskin 1982). 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. 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). Disease-

stressed oysters may continue to die as metabolic demands 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 during January, but only for one month (Figure A1-3). This suggests that at least in the Choptank region the combination of low temperatures and dropping salinities was able to suppress pathogenic activity during the first half of 2024.

In contrast, observed mortalities in the Tangier region did not increase by the spring of 2024, even though the MSX prevalence on Piney Island East, for example, was still 26%. Perhaps the infected oysters were able to tolerate the pathogens 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 would have allowed pathogenic activity to continue.

In estimating the timing of observed mortalities from the Fall Survey data, it is assumed that the mortalities occurred during the intervening time between surveys and that boxes remain articulated for about a year (Doering et al. 2021). This second assumption was not the case on four high mortality bars in the spring of 2024. Between the fall of 2023 and spring 2024, the number of boxes at these sites had increased by an average of 71%. However, that increase in boxes in the spring did not persist into the fall, dropping 64% on average. This decrease in boxes is reflected in the observed mortalities at these bars. By the 2024 Fall Survey, the elevated mortalities observed during the spring on Royston and Lighthouse bars had dropped up to fourfold. Similarly, the observed mortality on Southeast Middleground in the Patuxent River fell from 65% in the spring to 16% the following fall, and Cook Pt. bar mortalities went from 68% in the spring to 17% six months later. In contrast to the shorter disarticulation rates on these high-mortality bars in 2024, the observed mortalities back in 2003 seem to be an overestimate due to residual boxes from the 2002 epizootic that were over one year old. A comparison of the box-count method used in this report and a Bayesian model for estimating oyster mortality is discussed in Doering et al. (2021).

The 2024 spring mortality event would have been missed if that survey had not been conducted, just leaving a comparison between the two Fall Surveys. The only clue would have been to examine the change in oyster numbers between 2023 and 2024, but this is fraught with ambiguity. The decrease in the number of market oysters that was recorded at all of the aforementioned sites could also be attributed to seasonal harvesting. In addition, sublegal oysters could not be considered since their numbers increased due to the strong 2023 spatset, a percentage of which transitioned to the sublegal oyster stage. A regular small-scale spring survey may be warranted moving forward, especially during years with abnormal freshwater flows or high fall MSX disease prevalences, with sampling locations targeted annually based on salinity and disease conditions.

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 alternation and timing of drought and freshets during the period of the last two Fall Surveys and the Spring Survey between the two provided considerable insight into this question. The answer appears to be both are correct, depending on the salinity regime and frequency of previous exposures to MSX disease pathogens.

Heading home (Photo: R. Bussell)

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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.*

Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 "Key" spat monitoring bars, 1985-2024. (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	2024	*40-Yr Avg*
Mountain Point	0	0	0	0	0	0	0	0	0	3	*0.4*
Swan Point	0	0	0	0	0	0	0	0	0	2	*0.4*
Brick House	0	0	0	0	0	0	1	0	10	37	*6.7*
Hackett Point	0	0	0	0	0	0	0	0	7	17	*1.2*
Tolly Point	0	2	0	0	1	0	0	0	15	21	*1.6*
Three Sisters	0	0	0	0	1	0	1	0	10	7	*1.1*
Holland Point (S)	0	0	0	0	0	1	0	0	3	3	*0.6*
Stone Rock	2	17	0	4	6	7	1	0	19	13	*21.9*
Flag Pond (S)	10	12	28	0	2	0	0	0	25	2	*20.5*
Hog Island	9	22	1	0	19	8	14	7	32	8	*17.3*
Butler	68	90	2	1	42	34	65	28	55	37	*40.3*
Buoy Rock	0	0	0	0	0	0	0	0	0	0	*1.2*
Parsons Island	8	0	0	0	2	0	13	5	15	3	*94.1*
Wild Ground	15	0	0	0	1	2	9	2	7	9	*35.6*
Hollicutt Noose	1	0	0	0	0	2	7	4	17	11	*5.2*
Bruffs Island (S)	0	0	0	0	0	0	28	10	29	4	*24.6*
Ash Craft	0	0	0	0	0	1	14	0	9	5	*61.3*
Turtle Back	13	4	0	0	0	5	42	7	12	17	*113.7*
Shell Hill	4	2	1	5	2	0	7	9	30	4	*7.5*
Sandy Hill (S)	0	3	1	0	2	5	18	13	32	10	*12.0*
Royston	21	13	23	22	0	231	96	17	75	23	*54.9*
Cook Point (S)	1	21	2	4	7	68	28	10	202	18	*22.8*
Eagle Pt./Mill Pt. (S)	34	68	55	28	0	187	51	7	8	15	*40.7*
Tilghman Wharf	45	58	13	40	5	247	134	22	91	35	*69.8*
Deep Neck	83	91	205	119	17	1838	162	75	371	251	*168.3*
Double Mills (S)	9	12	3	1	1	74	21	5	299	2	*25.4*
Ragged Point	19	125	35	2	1	18	6	0	27	16	*50.9*
Cason (S)	11	60	67	9	4	613	62	24	22	49	*96.1*
Windmill	16	9	9	4	12	62	66	8	203	101	*55.0*
Norman Addition	34	60	44	13	24	227	170	38	275	174	*89.7*
Goose Creek	11	44	27	23	18	448	44	65	137	69	*46.3*
Clay Island	43	68	41	43	14	43	35	79	167	41	*50.2*
Wetipquin (S)	2	6	0	21	33	15	13	17	6	15	*6.5*
Middleground	12	32	66	49	138	100	41	14	108	65	*33.7*
Evans	14	18	1	7	37	52	66	19	28	28	*15.6*
Mt. Vernon Wharf	1	3	1	10	7	42	4	11	34	28	*5.6*
Georges (S)	29	61	137	40	78	185	20	14	86	6	*68.3*
Drum Point (S)	59	172	78	110	160	445	61	58	105	56	*104.4*
Sharkfin Shoal	57	53	32	23	14	17	21	16	72	56	*29.2*
Turtle Egg Island	64	57	15	69	88	122	66	47	196	125	*92.1*
Piney Island East	3	0	2	0	68	196	103	95	206	71	*102.3*
Great Rock	13	4	14	93	151	258	44	288	120	204	*54.8*
Gunby	95	73	34	25	46	18	54	47	97	87	*58.7*
Marumsco	141	69	31	8	61	53	29	48	39	59	*41.3*
Broome Island	6	21	6	1	12	1	73	2	79	5	*10.0*
Back of Island	18	42	5	5	13	7	18	5	282	36	*21.1*
Chicken Cock	712	33	19	5	10	37	111	23	182	50	*80.0*
Pagan (S)	24	91	247	7	15	53	426	478	183	198	*178.1*
Black Walnut (S)	3	4	0	0	0	0	0	1	42	2	*2.5*
Blue Sow (S)	0	10	0	0	0	1	1	1	60	1	*5.5*
Dukehart Channel	0	3	0	0	0	0	0	2	175	0	*5.9*
Ragged Point	1	11	2	2	0	4	9	10	190	6	*10.2*
Cornfield Harbor	100	92	6	6	108	55	70	68	107	54	*73.0*
Spat Index	**34.2**	**30.9**	**23.6**	**15.0**	**23.0**	**109.1**	**43.9**	**32.1**	**86.8**	**40.7**	*42.2*
Median	**10**	**12**	**2**	**2**	**5**	**17**	**21**	**10**	**42**	**17**	*25.2**

*40-yr median of the Spat Indexes

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Table 3. *Perkinsus marinus* prevalence and mean intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2024. 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**	

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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 | | | | | | | | | |
| | 2019 | | 2020 | | 2021 | | 2022 | | 2023 | |
	%	I	%	I	%	I	%	I	%	I
Swan Point	3	0.1	0	0.0	0	0	13	0.2	0	0
Hackett Point	10	0.5	30	0.9	40	1.8	57	1.4	27	0.8
Holland Point (S)	0	0.0	0	0.0	3	0.1	3	0.1	90	2.1
Stone Rock	23	1.0	23	0.6	10	0.3	63	1.9	67	2
Flag Pond (S)	13	0.5	87	3.0	90	3.8	100	3.2	93	3.9
Hog Island	27	1.0	30	1.0	30	0.7	90	2.7	97	3.4
Butler	60	2.0	60	2.0	80	2.8	93	3.7	87	3.2
Buoy Rock	3	0.1	0	0.0	13	0.3	23	0.4	7	0.1
Old Field (S)	17	0.4	20	0.7	17	0.6	39	0.7	27	0.5
Bugby	90	2.8	57	1.6	67	2.2	90	2.5	93	2.3
Parsons Island	7	0.4	23	0.5	3	0.07	20	0.4	37	0.9
Hollicutt Noose	13	0.5	13	0.4	10	0.2	33	0.9	30	0.6
Bruffs Island (S)	70	2.3	33	0.8	57	2.3	13	0.3	63	1.2
Turtle Back	73	2.9	67	2.2	37	1	67	1.8	47	1.1
Long Point (S)	3	0.03	13	0.3	27	1	70	1.6	67	1.3
Cook Point (S)	37	1.2	80	2.6	57	2	90	2.2	100	4.3
Royston	20	0.6	60	1.5	13	0.5	27	0.5	33	0.9
Lighthouse	3	0.2	0	0.0	0	0	3	0	3	0.03
Sandy Hill (S)	53	2.4	67	2.1	27	0.7	70	1.5	97	3.6
Oyster Shell Pt. (S)	3	0.1	20	0.5	13	0.2	60	1.1	47	0.7
Tilghman Wharf	23	0.9	20	0.7	40	1.1	40	0.9	60	1.5
Deep Neck	33	1.2	30	0.9	57	1.4	93	2.7	100	3.9
Double Mills (S)	47	1.8	63	2.2	70	2.3	97	3	97	3.1
Cason (S)	60	2.0	50	1.7	57	1.7	90	2.6	87	2.6
Ragged Point	60	1.4	73	2.6	77	2.3	97	2.6	97	3.1
Norman Addition	37	1.5	23	0.8	7	0.3	67	1.9	67	2.4
Goose Creek	27	1.1	53	2.0	63	2.5	93	3.5	100	4.6
Wilson Shoals (S)	30	1.0	47	1.2	60	2	90	3	97	4.3
Georges (S)	77	3.1	77	2.9	73	2.6	90	4	100	4.3
Holland Straits	0	0.0	0	0.0	3	0.03	20	0.6	27	0.8
Sharkfin Shoal	63	2.4	67	2.7	57	2.8	93	4	100	3.6
Back Cove	3	0.2	10	0.3	83	2.6	93	4.1	97	4.7
Piney Island East	17	0.5	3	0.1	23	0.6	53	1.7	100	3.3
Old Woman's Leg	0	0.0	0	0.0	3	0.1	30	0.7	73	2.2
Marumsco	30	1.0	7	0.3	37	1.1	73	1.7	100	4.9
Broome Island	13	0.5	27	0.8	27	0.7	67	1.8	97	3.2
Chicken Cock	27	1.2	23	0.7	30	1.1	57	1.4	77	2.2
Pagan (S)	17	0.4	37	1.1	70	2.4	50	1.6	87	2.7
Lancaster	7	0.2	47	1.5	63	2	93	3.1	97	3.9
Mills West	0	0.0	3	0.2	3	0.2	3	0	7	0.1
Cornfield Harbor	40	1.3	53	2.0	43	1.6	90	2.3	83	2.3
Ragged Point	0	0.0	0	0.0	0	0	23	0.3	3	0.03
Lower Cedar Point	NA	NA	10	0.4	17	0.5	7	0.1	27	0.5
Annual Means	**27**	**1.0**	**33**	**1.1**	**36.2**	**1.2**	**58.9**	**1.7**	**67.3**	**2.28**
Bar Freq. (%)	**88**		**84**		**93**		**100**		**98**	

Table 3 - Dermo (continued).

Oyster Bar	*Perkinsus marinus* Prevalence (%) and Mean Intensity (I)			
	2024		*35-Yr Avg*	
	%	I	*%*	*I*
Swan Point	3	0.1	*23.5*	*0.6*
Hackett Point	43	1.7	*47.8*	*1.4*
Holland Point (S)	50	1.3	*37.8*	*1.1*
Stone Rock	50	1.7	*67.6*	*2.2*
Flag Pond (S)	63	1.5	*52.0*	*1.7*
Hog Island	67	2.7	*71.2*	*2.6*
Butler	77	2.3	*68.5*	*2.2*
Buoy Rock	7	0.3	*45.7*	*1.4*
Old Field (S)	24	0.7	*53.2*	*1.6*
Bugby	70	1.6	*80.5*	*2.6*
Parsons Island	20	0.6	*64.7*	*2.1*
Hollicutt Noose	3	0.1	*55.0*	*1.7*
Bruffs Island (S)	33	0.8	*69.3*	*2.2*
Turtle Back	57	1.6	*80.6*	*2.7*
Long Point (S)	3	0.1	*61.1*	*2.0*
Cook Point (S)	57	1.4	*61.2*	*2.0*
Royston	47	1.4	*51.7*	*1.8*
Lighthouse	3	0.1	*38.9*	*1.3*
Sandy Hill (S)	50	1.3	*73.6*	*2.7*
Oyster Shell Pt. (S)	10	0.1	*39.5*	*1.1*
Tilghman Wharf	47	1.3	*50.6*	*1.5*
Deep Neck	70	1.9	*77.5*	*2.7*
Double Mills (S)	57	1.6	*79.3*	*2.8*
Cason (S)	80	1.9	*78.1*	*2.6*
Ragged Point	70	2.3	*80.4*	*2.6*
Norman Addition	77	1.8	*73.6*	*2.6*
Goose Creek	70	2.3	*67.5*	*2.4*
Wilson Shoals (S)	67	2.1	*81.5*	*2.6*
Georges (S)	83	2.9	*81.8*	*2.9*
Holland Straits	10	0.3	*56.8*	*1.9*
Sharkfin Shoal	73	2	*81.7*	*3.0*
Back Cove	83	4	*76.7*	*2.8*
Piney Island East	57	1.9	*72.1*	*2.4*
Old Woman's Leg	40	1.3	*65.6*	*2.3*
Marumsco	47	1.8	*78.0*	*2.8*
Broome Island	80	2.9	*72.1*	*2.5*
Chicken Cock	30	0.9	*68.8*	*2.2*
Pagan (S)	63	1.8	*76.4*	*2.4*
Lancaster	30	1	*58.2*	*1.8*
Mills West	0	0	*49.5*	*1.5*
Cornfield Harbor	73	1.8	*76.7*	*2.4*
Ragged Point	3	0.03	*17.9*	*0.5*
Lower Cedar Point	3	0.1	*21.5*	*0.5*
Annual Means	**45.3**	**1.38**	**62.5**	**2.1**
Bar Freq. (%)	**98**		**96.5**	

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2024. 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

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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	2024	*35-yr avg*
Swan Point	0	0	0	0	0	0	*0.0*
Hackett Point	0	0	0	0	3	0	*0.6*
Holland Point (S)	0	0	0	0	27	0	*2.9*
Stone Rock	0	0	0	0	40	0	*8.9*
Flag Pond (S)	0	0	0	0	33	3	*5.7*
Hog Island	0	0	0	0	33	0	*8.9*
Butler	0	0	0	3	27	0	*10.8*
Buoy Rock	0	0	0	0	0	0	*0.0*
Old Field (S)	0	0	0	0	0	0	*0.0*
Bugby	0	0	0	0	0	0	*1.3*
Parsons Island	0	0	0	0	0	0	*1.0*
Hollicutt Noose	0	0	0	0	17	0	*3.8*
Bruffs Island (S)	0	0	0	0	0	0	*0.8*
Turtle Back	0	0	0	0	0	0	*2.1*
Long Point (S)	0	0	0	0	0	0	*0.2*
Cook Point (S)	0	0	0	0	47	0	*10.1*
Royston	0	0	0	0	67	0	*6.3*
Lighthouse	0	0	0	0	93	0	*8.5*
Sandy Hill (S)	0	0	0	0	17	0	*2.8*
Oyster Shell Pt. (S)	0	0	0	0	0	0	*1.1*
Tilghman Wharf	0	0	0	0	40	0	*6.3*
Deep Neck	0	0	0	0	3	0	*3.6*
Double Mills (S)	0	0	0	0	0	0	*1.6*
Cason (S)	0	0	0	0	37	0	*7.3*
Ragged Point	0	0	0	0	53	0	*9.7*
Norman Addition	0	0	0	13	37	0	*11.1*
Goose Creek	0	0	3	0	13	0	*7.3*
Wilson Shoals (S)	0	0	0	0	13	0	*4.4*
Georges (S)	0	0	0	0	17	0	*6.3*
Holland Straits	0	0	0	3	20	0	*13.8*
Sharkfin Shoal	0	0	3	7	23	3	*12.5*
Back Cove	0	0	3	13	7	7	*12.3*
Piney Island East	0	3	3	17	40	7	*15.1*
Old Woman's Leg	0	0	7	13	23	3	*15.5*
Marumsco	3	0	0	13	13	3	*8.1*
Broome Island	0	0	0	0	3	0	*2.0*
Chicken Cock	0	0	0	0	0	0	*11.0*
Pagan (S)	0	0	0	0	0	0	*2.9*
Lancaster	0	0	0	0	0	0	*0.3*
Mills West	0	0	0	0	0	0	*1.4*
Cornfield Harbor	0	0	0	0	7	0	*12.1*
Ragged Point	0	0	0	0	3	0	*3.1*
Lower Cedar Point	NA	0	0	0	0	0	*0.0*
Avg. Prev. (%)	**0.1**	**0.1**	**0.4**	**1.9**	**17.9**	**0.6**	*5.5*
Pos. Bars (%)	**2**	**2**	**12**	**19**	**65**	**14**	*28.7*

Table 5. Oyster population observed mortality estimates from the 43 disease monitoring bars, 1985-2024. 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
Swan Point	4	0	3	0	0	8	12	3	3	12	1
Hackett Point	0	0	0	3	19	3	5	21	23	4	4
Holland Point (S)	12	40	29	0	0	50	NA	NA	0	50	0
Stone Rock	2	5	31	36	30	9	5	4	3	6	24
Flag Pond (S)	15	13	5	6	50	3	1	7	17	17	37
Hog Island	2	2	12	38	27	18	0	5	3	3	31
Butler	7	7	10	11	4	5	7	14	8	14	30
Buoy Rock	5	9	3	12	4	12	9	13	5	0	3
Old Field (S)	0	3	0	5	33	10	31	33	7	33	18
Bugby	8	31	21	21	13	12	17	18	23	9	11
Parsons Island	2	4	15	2	10	14	0	5	0	0	1
Hollicutt Noose	1	9	6	7	29	30	8	2	10	4	3
Bruffs Island (S)	0	4	5	16	20	41	38	25	20	4	3
Turtle Back	0	8	14	18	3	15	8	3	0	7	2
Long Point (S)	20	0	0	17	0	0	37	NA	0	0	7
Cook Point (S)	9	12	16	48	45	24	13	12	5	8	56
Royston	1	6	9	16	4	2	4	3	2	0.3	18
Lighthouse	1	1	2	9	7	0	4	2	1	0	21
Sandy Hill (S)	3	13	11	15	15	11	11	4	4	7	10
Oyster Shell Pt. (S)	2	5	2	11	11	18	24	12	4	3	6
Tilghman Wharf	5	1	5	11	1	7	4	6	1	1	8
Deep Neck	5	7	16	8	2	3	3	2	1	6	9
Double Mills (S)	11	12	10	20	13	11	2	7	6	13	17
Cason (S)	11	8	17	26	33	8	4	2	2	2	12
Ragged Point	15	13	21	45	14	6	3	11	4	8	53
Norman Addition	9	7	13	14	15	8	2	2	1	2	18
Goose Creek	5	15	22	27	6	10	3	4	5	7	32
Wilson Shoals (S)	5	4	7	17	6	4	4	6	9	2	22
Georges (S)	15	5	8	23	15	9	5	7	9	26	27
Holland Straits	9	48	71	18	4	17	4	1	0	6	16
Sharkfin Shoal	16	18	24	19	3	7	4	5	13	20	29
Back Cove	11	19	14	1	2	8	1	1	4	22	41
Piney Island East	7	10	9	21	25	38	33	4	9	6	19
Old Woman's Leg	50	75	15	0	50	25	10	5	5	5	12
Marumsco	13	13	17	13	20	34	36	4	8	23	26
Broome Island	7	8	14	21	3	4	0	4	1	2	7
Chicken Cock	1	7	16	32	20	17	20	2	6	3	3
Pagan (S)	4	13	22	28	6	4	4	49	11	7	3
Lancaster	13	0	3	1	1	10	5	2	5	10	10
Mills West	20	9	5	14	0	5	15	21	5	0	0
Cornfield Harbor	10	16	10	36	8	3	5	2	3	4	6
Ragged Point	0	0	50	10	8	4	33	0	12	0	1
Lower Cedar Point	0	0	6	8	27	96	100	100	1	1	0
Annual Means	**8**	**11**	**14**	**16**	**14**	**14**	**13**	**10**	**6**	**8**	**15**

Table 5 - Mortality (continued).

Oyster Bar	Total Observed Mortality (%)	
	2024	*40-yr Avg*
Swan Point	5	*10.0*
Hackett Point	14	*12.8*
Holland Point (S)	NA	*23.2*
Stone Rock	31	*20.8*
Flag Pond (S)	26	*21.1*
Hog Island	34	*25.7*
Butler	15	*22.9*
Buoy Rock	0	*14.9*
Old Field (S)	0	*14.2*
Bugby	3	*23.7*
Parsons Island	4	*18.4*
Hollicutt Noose	5	*18.9*
Bruffs Island (S)	3	*21.7*
Turtle Back	6	*21.8*
Long Point (S)	6	*20.4*
Cook Point (S)	17	*25.5*
Royston	18	*16.2*
Lighthouse	13	*18.2*
Sandy Hill (S)	15	*22.8*
Oyster Shell Pt. (S)	6	*10.3*
Tilghman Wharf	7	*15.5*
Deep Neck	6	*18.6*
Double Mills (S)	3	*19.1*
Cason (S)	20	*23.2*
Ragged Point	62	*26.5*
Norman Addition	8	*22.3*
Goose Creek	7	*29.6*
Wilson Shoals (S)	16	*19.2*
Georges (S)	20	*27.0*
Holland Straits	13	*26.5*
Sharkfin Shoal	19	*29.3*
Back Cove	12	*21.5*
Piney Island East	12	*27.1*
Old Woman's Leg	7	*28.1*
Marumsco	22	*24.3*
Broome Island	5	*18.4*
Chicken Cock	6	*24.6*
Pagan (S)	4	*19.7*
Lancaster	2	*13.8*
Mills West	2	*13.5*
Cornfield Harbor	2	*25.0*
Ragged Point	6	*19.9*
Lower Cedar Point	6	*18.1*
Annual Means	**11.6**	***20.8***

Table 6. Regional summary of oyster harvests (bu.) in Maryland from buy tickets, 1985-86 through 2023-24 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.

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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 2022-23 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 2022-23 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	2023-24	*39-yr Avg*
Upper Bay	7,351	146	3,338	*10,992*
Middle Bay	1,545	4,126	2,737	*13,612*
Middle Bay Tributaries	889	439	3,270	*1,335*
Lower Bay	17,583	29,312	10,563	*7,298*
Total Bay Mainstem	*27,368*	*34,022*	19,908	*31,841*
Chester R.	856	26	646	*18,398*
Eastern Bay	3,181	2,384	15,631	*25,784*
Miles R.	3	0	105	*4,492*
Wye R.	0	0	0	*1,590*
Total Eastern Bay Region	*3,184*	*2,384*	15,736	*31,864*
Upper Choptank R.	0	0	0	*8,048*
Middle Choptank R.	2,518	2,970	7,261	*16,172*
Lower Choptank R.	6,722	13,012	16,381	*14,586*
Tred Avon R.	553	3,663	6,333	*9,525*
Broad Cr.	37,441	57,017	73,687	*25,258*
Harris Cr.	7,892	18,969	22,266	*8,322*
Total Choptank R. Region	*55,127*	*95,630*	*125,927*	*81,911*
Little Choptank R.	12,882	12,032	1,132	*10,869*
Upper Tangier Sound	215,101	147,541	53,095	*32,072*
Lower Tangier Sound	80,687	218,643	100,904	*23,425*
Honga R.	24,997	47,403	27,205	*9,492*
Fishing Bay	46,032	42,056	33,059	*17,164*
Nanticoke R.	22,043	9,061	3,028	*7,744*
Wicomico R.	1,646	4,404	660	*1,429*
Manokin R.	1,037	20	504	*2,985*
Big Annemessex R.	0	44	243	*219*
Pocomoke Sound	4,821	10,847	4,543	*5,263*
Total Tangier Sound Region	*396,363*	*480,017*	*223,238*	*99,791*
Patuxent R.	38,800	78,470	20,443	*15,567*
Wicomico R., St. Clement and Breton bays	4,697	2,190	6,917	*9,093*
St. Marys R. and Smith Cr.	8,004	10,659	23,335	*9,345*
Total Potomac Md. Tribs.	*12,700*	*12,849*	30,252	*18,420*
Total Maryland (bu.)[1]	**548,155**	**719,716**	**438,072**	***313,489***

[1] Includes harvests from unidentified regions.

Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2023-24 seasons as reported by seafood dealer buy tickets. Dockside value is in millions of dollars. Landing figures for the 2015-16 through 2022-23 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
2023-24	72,546	17,520	77,370	238,560	31,950	438,072	$15.6M

[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 2023-24 seasons as reported by seafood dealer buy tickets. Some years may not total 100% due to incomplete data. Percentages for the 2015-16 through 2022-23 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
2023-24	17	4	18	54	7

Table 8. Oyster bars within sanctuaries sampled during the 2024 Fall Survey.

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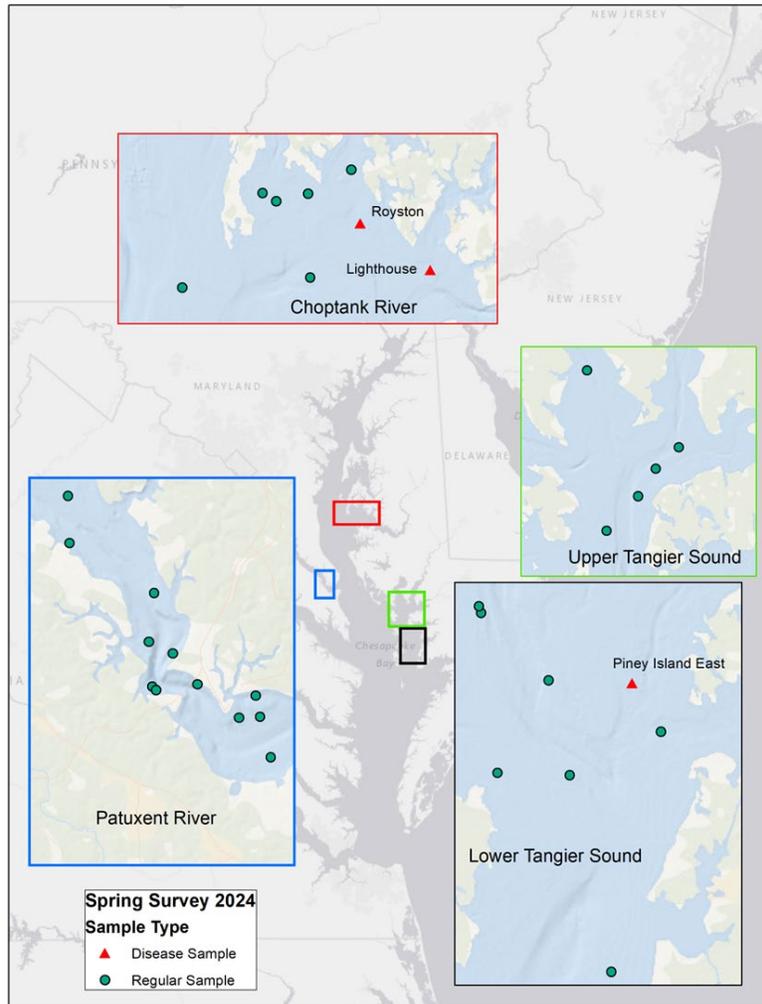
Figure A1-1. Location of 2024 Spring Dredge Survey sample locations and disease sentinel sites.

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.
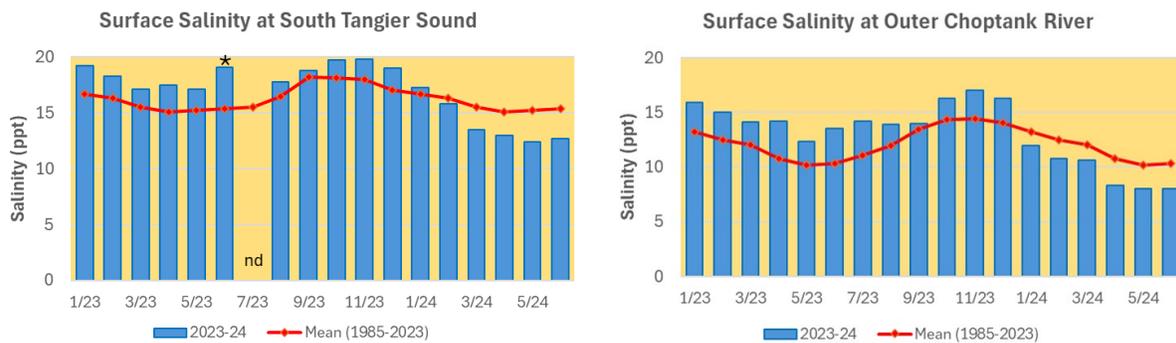
Figure A1-2. Monthly surface salinities during 2023 and the first half of 2024 at monitoring stations closest to sentinel sites for disease samples obtained during the Spring Dredge Survey. The average difference between surface salinity and at 5 m was 0.18 ppt at both locations. * Record maximum monthly 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.
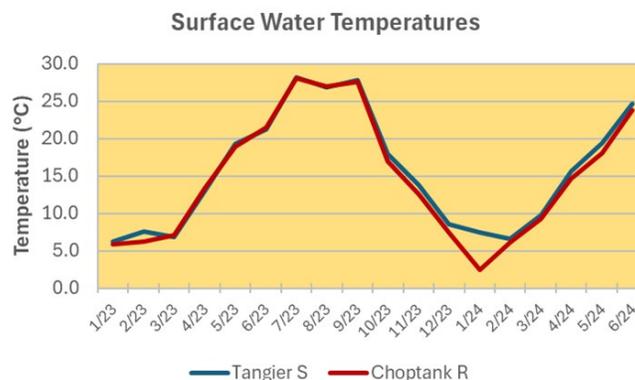
Figure A1-3. Monthly surface temperatures during 2023 and the first half of 2024 at monitoring stations closest to sentinel sites for disease samples obtained during the Spring Dredge Survey.

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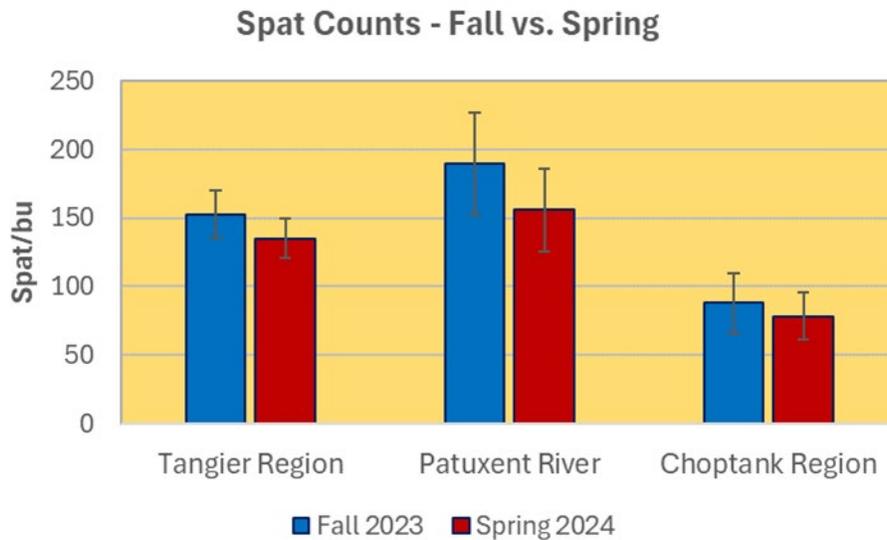
Figure A1-4. Mean ±SE spat counts comparing between fall and spring surveys in three recruitment regions.

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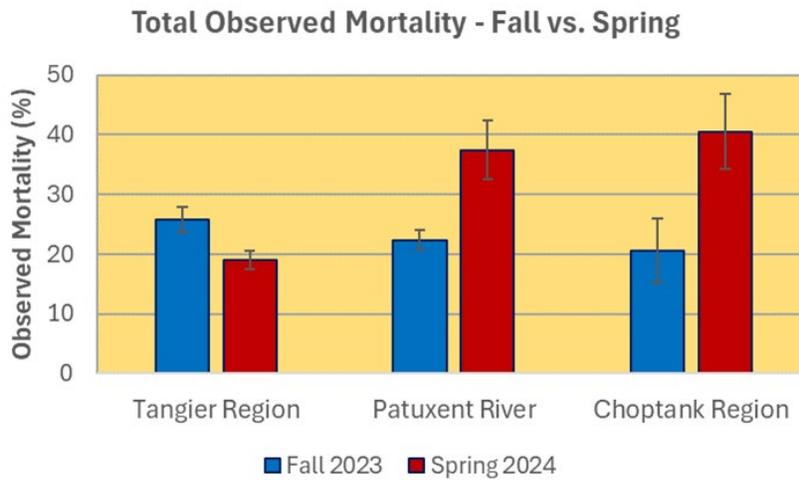
Figure A1-5. Mean ±SE of observed mortalities during the fall and spring surveys in three regions.

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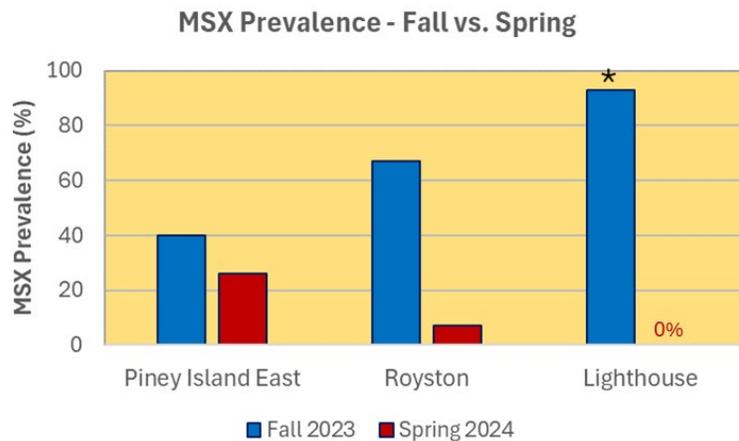
Figure A1-6. Changes in MSX disease between fall 2023 and spring 2024 surveys at three disease sentinel bars. *Highest MSX prevalence on a bar in the 34-year time series.

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.
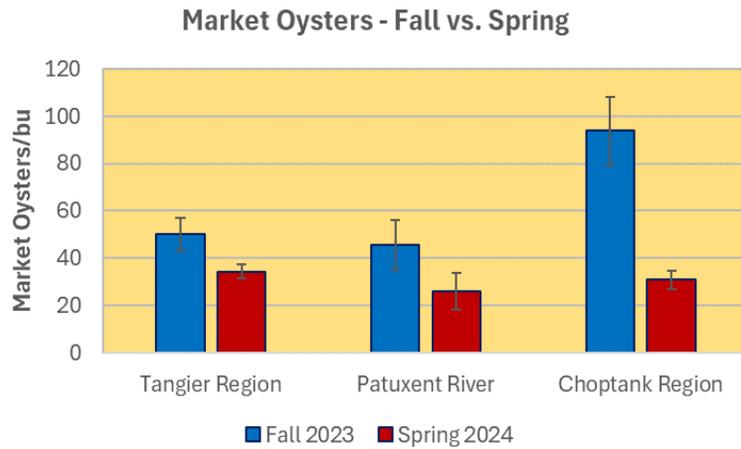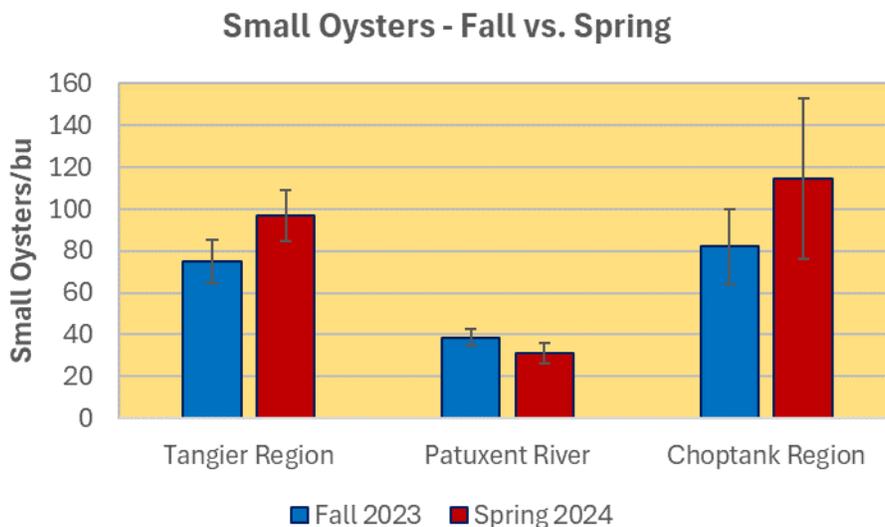
Market Oysters - Fall vs. Spring

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 the 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).

Small Oysters - Fall vs. Spring

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.

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 elevated 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 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 substantial at 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 was likely 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 was 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.

APPENDIX 2
Hatchery Seed Plantings
Amy Larimer

Over 700 million hatchery spat-on-shell were planted on 38 oysters bars sampled by the Fall Survey in the during 2024, covering 191 acres (Table A2-1). Mean density was 4 million spat per acre. The Fall Survey sampled 18 of these plantings (Figure A2-1; Table A2-2). Most were new locations on bars with other Fall Survey samples. Although some triploid spat were planted in 2024, none of those plantings were sampled.

The amount of hatchery spat-on-shell planted was less than half of the total from 2023 but was similar to 2021-2022. Most of the increase in 2023 was due to restoration work in the Manokin River. In 2024, a slight majority of the plantings occurred on non-sanctuary bars, the reverse of most other years (Table A2-3).

For each of the sampled plantings, spat were counted and the number of spat per bushel was enumerated (Table A2-2). No spat were measured for these samples; a size range was determined, including a "typical" middle value. The overall range was 5 to 70 mm, with a mean of 35.

The "average" number of days since planting is the average of the number of days between the sampling date and the planting date. This ranged from 26 days to 175 days, with a mean of 101 (Table A2-3). In 2024, in contrast to previous years, the beginning and ending planting dates were often several months apart. The information on hatchery spat-on-shell plantings comes from a GIS file that is based on data provided by the organizations that perform the work. There was no information on the number of planting events on these sites or even if there were multiple planting events. In 2020-2023, that interval between the beginning and ending of planting was typically 30 days. Because some of these intervals were wider in 2024 than in past years, the mid-point of the interval was chosen as the effective planting date to calculate the growth rates of spat. Growth rates were calculated by dividing the "typical" size by the number of days (Table A2-2; Figure A2-2). Swan Point South was planted between July and October and was sampled in November. The elapsed time was shorter than most other locations, resulting in higher growth rate.

The number of spat per bushel ranged from 4 to 3149, with a mean of 608 (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. The average elapsed time in 2024 was 101 days, the second shortest of the time series (after 2022). The low number of spat per bushel at Outer Round Point and Mares Point was likely the result of the sample not being near the center of the plantings. Those samples were not specifically directed at 2024 plantings.

Because some hatchery planting sites are sampled repeatedly, we can follow them over time (Table A2-4). 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). Other repeated plantings or combined samples are noted in the comments.

Table A2-1. Hatchery spat-on-shell plantings on Fall Survey bars. Locations in bold were sampled during the survey.

| Region	Bar Name	Area (acres)	#Planted (millions)	Density (Millions per acre)
Choptank River	Dickinson	2.98	9.31	3.12
Eastern Bay	Bald Eagle Add 2	5.52	24.27	4.40
	Bugby	1.09	4.64	4.27
	Cedar Island	2.50	12.48	4.99
	Crab Alley Lumps	3.35	17.11	5.11
	Lows Point (2)	7.15	28.35	3.97
	Norman's Fine Eyes	0.70	3.59	5.11
	Saw Mill Creek	8.74	33.64	3.85
Fishing Bay	Hill	2.15	13.05	6.06
	Thorough	1.43	5.07	3.54
Little Choptank River	Barn Point (Town Point)	1.22	2.80	2.30
	McKeils Point	5.52	16.75	3.03
	Susquehanna	3.51	16.24	4.63
Manokin River	**Cow Pen/Marshy Island Lower**	9.43	10.19	4.26
	Drum Point	35.64	132.56	3.72
	Marshy Island	13.71	50.65	3.69
Mid-Bay West	**Coots**	2.81	14.31	5.09
	Lulu/Saunders	2.59	13.38	5.16
Miles River	**Bozman Neck**	3.52	13.90	3.95
	Herring Island	6.56	40.04	6.11
	Persimmon Tree	0.89	2.89	3.25
	Sycamore	6.26	30.16	4.81
	Turtle Back	8.06	24.63	3.06
Nanticoke River	Middleground	5.31	28.23	5.31
South River	**Outer Round Point**	3.71	18.37	4.95
	Thunder and Lightning	2.95	18.65	6.32
Tred Avon River	Double Mills	1.70	7.17	4.23
	Louis Cove	0.84	6.81	8.11
	Mares Point	5.41	17.67	3.27
	Town Point (2)	2.63	9.78	3.72
Upper Bay East	**Swan Point (2)**	10.34	26.31	2.54
Upper Bay West	**Man O War Shoals**	3.60	13.87	3.85
	Mountain Point	3.17	13.72	4.33
Wicomico River West	Wicomico Middleground	3.09	6.42	2.08
	Bramleigh Creek	0.59	5.08	8.58
	White Point	2.72	5.48	2.01
	Windmill	2.56	13.91	5.42
Wye River	**Mills**	7.29	26.93	4.07
Total		*191.26*	*771.12*	*4.03*
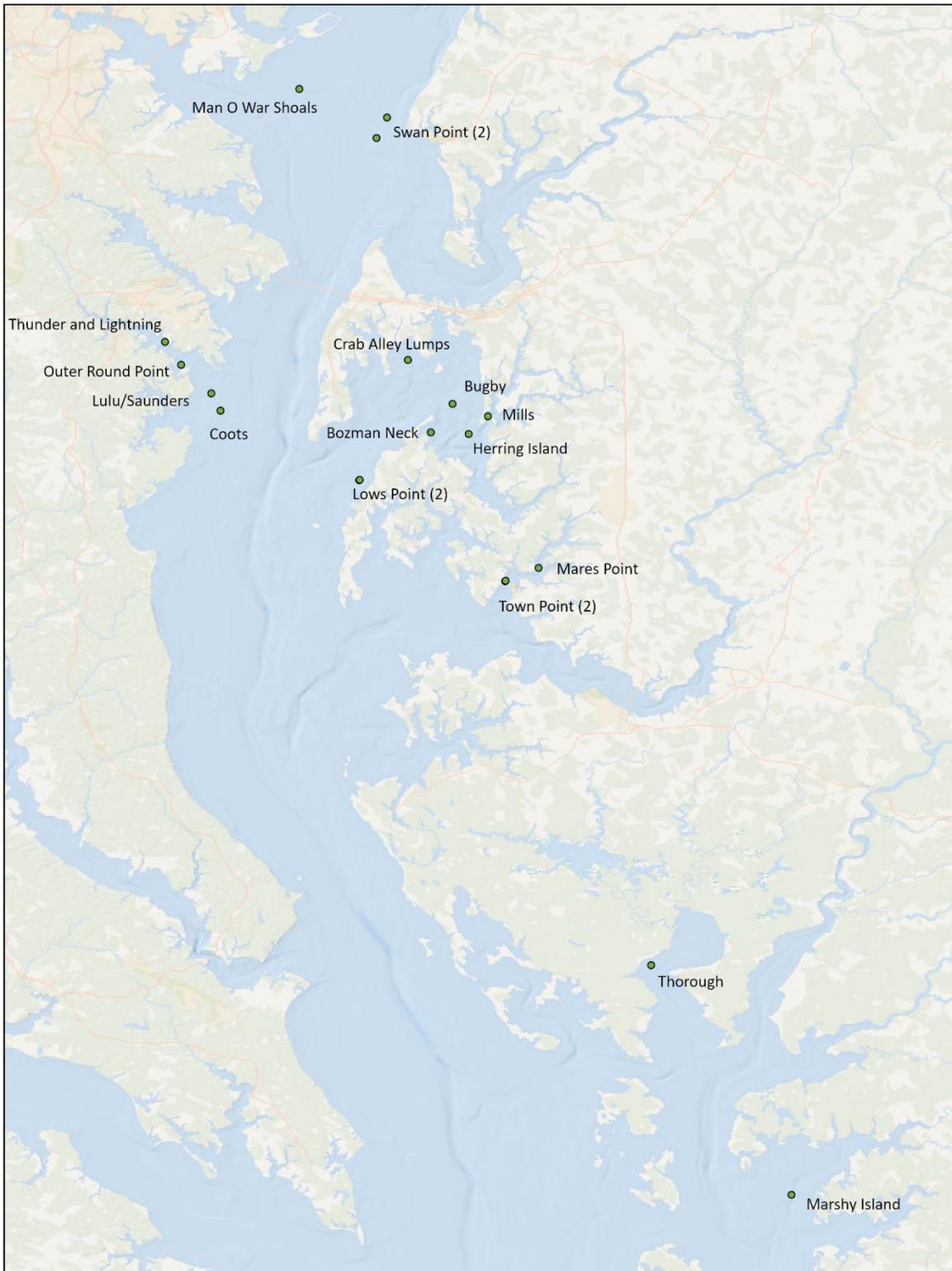
Figure A2-1. Map of Fall Survey stations on 2024 hatchery plantings.

Table A2-1. Hatchery planting spat counts, sizes, mean elapsed time since planting in days, and growth rate.

Region	Bar Name	Spat (#/bu)	Min. Size (mm)	Max. Size (mm)	Avg. Size (mm)	Avg. Days from Planting	Growth Rate (mm/day)
Eastern Bay	Bugby	282	20	40	33	106	0.31
	Crab Alley Lumps	300	16	36	28	70	0.40
	Lows Point (2)	1050	23	53	40	86	0.46
Fishing Bay	Thorough	186	22	47	33	112	0.29
Manokin River	Marshy Island	86	12	47	29	109.5	0.26
Mid-Bay West	Coots	1636	7	53	25	69	0.36
	Lulu/Saunders	692	20	70	42	122	0.34
Miles River	Bozman Neck	1517	18	63	37	131	0.28
	Herring Island	3149	5	57	25	81	0.31
South River	Outer Round Point	4	NA	NA	25	63	0.40
	Thunder and Lightning	698	22	56	40	116	0.34
Tred Avon River	Mares Point	8	26	35	33	112	0.29
	Town Point	160	30	65	40	118	0.34
Upper Bay East	Swan Point North	114	33	45	40	126	0.32
	Swan Point South	422	26	55	44	71	0.62
Upper Bay West	Man O War Shoals	570	15	55	35	123	0.28
Wye River	Mills	67	NA	NA	NA	NA	NA
	Averages	*608*	*20*	*52*	*35*	*100*	*0.36*

Table A2-2. Table comparing sizes, elapsed time, spat counts and planting volumes for 2020-2024.

|	2020	2021	2022	2023	2024
Min. Size	22 mm	17 mm	16 mm	25 mm	20 mm
Mean Size	41 mm	33 mm	32 mm	45 mm	34 mm
Max. Size	60 mm	53 mm	49 mm	65 mm	51 mm
Min. Days Since Planting	72	42	21	110	26
Mean Days Since Planting	132	108	83	136	101
Max Days Since Planting	181	161	129	173	175
Min. Spat per Bushel	26	32	268	76	4
Mean Spat per Bushel	299	680	874	339	608
Max. Spat per Bushel	1288	4068	2436	932	3149
Volume (millions of spat)	387	712	725	1,686	771
Sanctuary	124	464	503	1,257	354
Non-Sanctuary	253	248	222	429	417
Acres Planted	209	220	258	470	191
Sanctuary	38	96	125	250	93
Non-Sanctuary	171	124	133	220	98
Average density (millions per acre)	2.5	3.5	2.8	4.1	4.0
Sanctuary	3.8	6.4	4.0	6.9	3.8
Non-Sanctuary	1.5	2.0	1.7	1.9	4.2
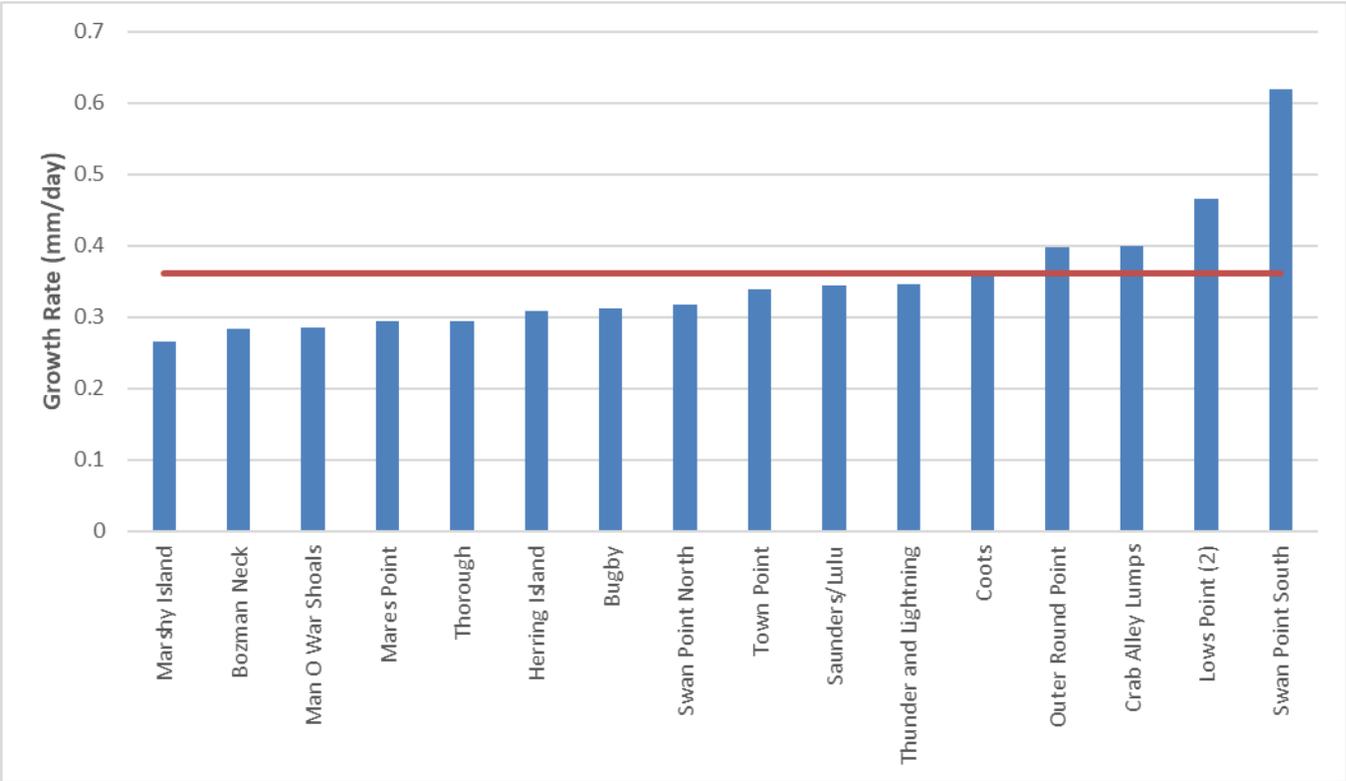
Figure A2-2. Growth rates of spat on hatchery plantings on Fall Survey sites in 2024. The red line is the mean (0.36 mm/day).

Table A2-4. Hatchery planting results for Fall Survey sites from 2020-2024. All counts are in number per bushel. *A mix of spat planted in 2021 and smalls from the 2020 planting

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Comments
Chester River	Durdin	2020	52			Hatchery seed plantings 2016, 2017, 2018, 2020, 2021, 2023. No hatchery seed found in 2021 or 2023. No natural spat sets.
		2021		80	36	
		2022		4	38	
		2023		102	46	
		2024		24	54	
	Piney Point	2020	54			
		2021		28	38	
		2022		4	4	
	Piney Point	2021	46			Multiple plantings in this area (2021, 2023). Includes data from 3 sampling sites combined.
		2022		26	12	
		2023	348	140	20	
		2024		48	42	
Choptank River	Dickinson	2020	290			2021-2024 samples taken on a different location in planting polygon (2020 sample was on the center point). Possible natural spat also occurring here.
		2021		28	76	
		2022		114	42	
		2023		60	136	
		2024		46	50	
	Howells Point	2020	286			Two plantings (2020 and 2021) and two sampling sites very close together.
		2021	186	144	86	
		2022		122	76	
	Howells Point Add 2	2020	358			Plantings in 2020 and 2021. Two sites combined. Natural spat also occurring.
		2021	18	26	38	
		2022		74	36	
		2023		34	90	
		2024		108	66	
	Lighthouse	2023	932			
		2024		188	24	
Eastern Bay	Bald Eagle Add 2	2020	658			Plantings in 2020 and 2021
		2021	524	12	24	
	Bugby	2020	152			Plantings in 2020, 2021, 2023
		2021	318*			
		2022		76	36	
		2023	86	162	42	
		2024		70	128	
	Bugby	2020	84			Plantings in 2020 and 2024
		2024	282	114	82	
	Crab Alley Lumps	2020	52			
		2021		202	18	
		2022		58	14	
		2023		20	30	
		2024		14	82	
	Hood	2021	32			
		2022		124	8	
	Hood	2023	190	170		Plantings in 2022 and 2023
		2024		88	94	
	Sawmill Creek	2023	76			
		2024		50	36	

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Comments
Eastern Bay	Well Cove	2020	110			Triploids; planted in 2020 and 2021. Sample in 2021 taken only from 2020 planting.
		2021		30	146	
		2022			112	
		2023			104	
		2024			50	
	Well Cove	2023	425			
		2024		16	80	
Lower Bay East	Punch Island Creek	2020	1288			
		2021		160	120	
		2022		16	108	
Mid-Bay West	Coots	2020	226			
		2021		30	24	
	Coots	2022	2436			
		2023		320		
	Hackett Point	2020	856			
		2021		154	10	
		2022		12	18	
	Tolly Point	2020	368			
		2021		110		
Miles River	Herring Island	2022	750			
		2023		118	100	
		2024		66	82	
	Persimmon Tree	2022	1740			
		2023		54	98	
	Bazzles Hill	2023	88			
		2024		36	26	
Nanticoke River	Middleground	2020	282			Triploids
		2021		28	104	
	Middleground	2021	626			
		2022		125	62	
	Middleground	2021	4068			Triploids
		2022		90	58	
		2023		22	18	
	Middleground	2022	505			Triploids
		2023		36	54	
		2024		28	12	
	Middleground	2023	314			
		2024		120	18	
Severn River	Chinks Point	2022	1000			2 sites combined. Planting in 2022, with an MGO planting in 2023.
		2023		76	116	
		2024		22	122	
South River	Outer Round Point	2020	550			
		2021		105	153	
		2022		44	168	
	Outer Round Point	2020	92			
		2021		162	42	
		2022		52	186	
		2023		4	82	
		2024	4	124	48	
	Thunder and Lightning	2021	852			2 samples on the same planting in 2021.
		2021	260			

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Comments
	Thunder and Lightning (cont'd)	2022		404	64	
		2023			182	
Tred Avon River	Mares Point	2020	1150			
		2021		266	30	
		2022		122	146	
		2023			146	
		2024	8	192	128	
	Town Point/Ferry Bar	2020	194			
		2021		252	50	
		2022		158	116	
		2023		56	102	
		2024	160	228	60	
	Town Point	2020	130			
		2021		108	54	
		2022		26	52	
		2023		54	58	
		2024	6	206	62	
Upper Bay East	Swan Point North	2020	520			Plantings in every year 2020-2024
		2021	406	236	40	
		2022	324	138	32	
		2023	80	66	80	
		2024	520	14	40	
	Swan Point North (Peach Orchard)	2020	254			On the same plantings as the above samples.
		2021	316	102	2	
		2022	374	32	92	
		2023	32	142	60	
	Swan Point KB/DB	2020	59			Just barely into the planting area.
		2021		17	83	
		2022		8	51	
		2023		5	107	
	Swan Point/Peach Orchard S	2020	94			Plantings in 2020 and 2021
		2021	410	70		
	Swan Point	2022	268			
		2023		60	6	
	Swan Point	2023	395			Triploids
		2024		40	24	
Upper Bay West	Man O War Shoals	2020	168			Planting in 2021 near this site.
		2021	100	70		
		2022		102	16	
		2023		48	36	
Wicomico River East	Evans	2020	70			
		2021		64	108	
		2022		18	112	
	Great Shoal	2022	1505			Triploids
		2023		54	50	
		2024		42	34	
Wicomico River West	Lancaster	2022	364			
		2023		186	12	
		2024		282	18	
	Rock Point	2023	254			Also included some natural spat
		2024		340	26	

Region	Bar Name	Year	Spat/Bu	Small/Bu	Market/Bu	Comments
Wicomico River West (cont'd)	White Point	2020	226			
		2021		358	42	
		2022		86	104	
		2023		34	72	
		2024		166	64	
	Wicomico Middleground	2022	606			Plantings in 2022 and 2023
		2023	48	30	102	
		2024		154	82	

Substrate Plantings

In 2024, three types of substrate were planted on Fall Survey bars with the goal of attracting spat. One was an experimental planting of small concrete pieces on Flat Rock in Pocomoke Sound and the rest were planted with either Eastern oyster shell (*Crassostrea virginica*), acquired from regional shucking houses and other locations, or Pacific oyster shells (*Magallana gigas*), sourced from Washington state. Pacific oysters are native to Asia but are used extensively in oyster farms on the west coast of the United States. Shells are allowed to dry for weeks or months and then placed back in the water or used in hatcheries for spat-on-shell production. Over 223,000 bushels (Eastern oyster shell, Pacific oyster shell and concrete) were planted on 145 acres in 2024, with most of that on the fall survey sample locations. Four sites (Pecks Point, Piney Island East, Susquehanna, and Wild Cherry Tree) were demonstration projects of small amounts of shell (1,000 or 2,000 bushels) over much smaller areas (Table A2-5).

For most of the Fall Survey samples on these sites, the spat counts per bushel exceeded the average of other sites in the area (Table A2-6) that were not planted with either fresh shell or hatchery spat-on-shell. The highest count was on the concrete planting in Pocomoke Sound, which was more than twice the count at the nearby shell planting that was also sampled (Table A2-6). Fresh shell plantings appear to attract spat at a greater rate than non-planted areas (Figure A2-4). Pacific oyster shells appear to be more variable, but this may be a result of methodology. Because Pacific oysters shells look different than eastern oysters, an attempt was made to separate them, but this may have resulted in some shells being missed. For the eastern oyster plantings, most spat counts were greater than the regional mean, except for Wild Cherry Tree in Harris Creek. This was one of the small demonstration plantings, with an area of 0.06 acres, much smaller than the others. It is possible the bulk of the planting was missed, or some other information (GPS coordinates) was incorrect. The sample on Goad, in the St. Marys River, had both eastern oyster and Pacific oyster shells planted on it, but counts were made only on Pacific oyster shells. This may have undercounted the actual number of spat occurring there.

In years with very good spat sets (2020 and 2023), the number of spat per bushel was approximately twice that of non-planted areas (Figure A2-5). Four of the last five years have been above average for spat and this is reflected in the higher counts on shell-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 A2-6. The shell heights of spat on fresh shell plantings were similar to shell heights of spat from spat key bars, which ranged from 4 mm to 63 mm, with a mean of 26 mm.

Substrate is a key issue in oyster management. Removing oysters also removes their habitat and most of the oyster shell is not returned to the bay. The limited supply of shell has led to searches for alternate materials such as rock or concrete. Rock (usually in the form of approximately three-inch pieces) has been used in restoration work in some sanctuaries. The single concrete planting had the highest spat count (616 spat/bu) of all substrate plantings in 2024, but more study is needed.

Table A2-5. Substrate plantings on Fall Survey bars in 2024. These included two types of fresh shell plantings: Eastern oyster (*Crassostrea virginica*) and Pacific oyster (*Magallana gigas*), sourced from Washington state. There was a single planting of concrete pieces on Flat Rock in Pocomoke Sound. Fall Survey samples are in bold.

| Region	Bar Name	Acres	#Planted (bushels)	Density (bushels per acre)
Alternate Materials (concrete)				
Pocomoke Sound	**Flat Rock**	7.49	5,005	668.4
Fresh Shell Plantings (Eastern oyster)				
Broad Creek	Great Bar	10.99	26,216	2,385.14
Fishing Bay	**Clay Island**	7.16	8,816	1,231.82
Harris Creek	Great Marsh	2.84	5,022	1,805.98
	Wild Cherry Tree	0.06	1,000	16,135.97
Honga River	Lakes Cove	4.66	11,948	2,565.40
	Long Point	3.16	5,800	1,834.12
Little Choptank River	**Susquehanna**	0.62	1,000	1,625.07
Lower Bay West	Butler	4.15	10,572	2,547.66
	Little Cove Point	4.45	2,610	586.16
Patuxent River	Hawks Nest	4.64	8,990	1,938.29
Pocomoke Sound	**Flat Rock**	1.55	3,016	1,948.13
Potomac River	**Great Neck**	5.36	6,452	1,204.82
St. Marys River	**Goad**	5.51	5,046	915.50
Tangier Sound	Mud Rock	10.05	13,804	1,373.12
	Piney Island East Addition	0.85	2,000	2,346.52
Tred Avon River	**Pecks Point**	0.28	1,000	3,258.28
Wicomico River West	Halls Point	8.8	14,268	1,620.67
Subtotal		**75.1**	**127,561**	**1,699.22**
Pacific Oyster Shell Plantings				
Fishing Bay	**Duck Island**	14.94	14,400	963.56
	Goose Creek	3.12	6,900	2,209.97
	Goose Creek Add 2	5.40	4,422	819.13
Harris Creek	**Great Marsh**	5.70	9,500	1,666.32
	Wild Cherry Tree	3.95	12,261	3,100.82
Honga River	**Wroten Island**	4.44	6,500	1,464.57
St. Marys River	**Goad**	1.97	3,000	1,520.29
Tangier Sound	**Great Rock**	10.82	18,600	1,718.39
	Terrapin Sands Add 1	12.23	15,600	1,275.38
Subtotal		**62.6**	**91,183**	**1,456.88**
Total		*145.15*	*223,749*	*1,541.54*
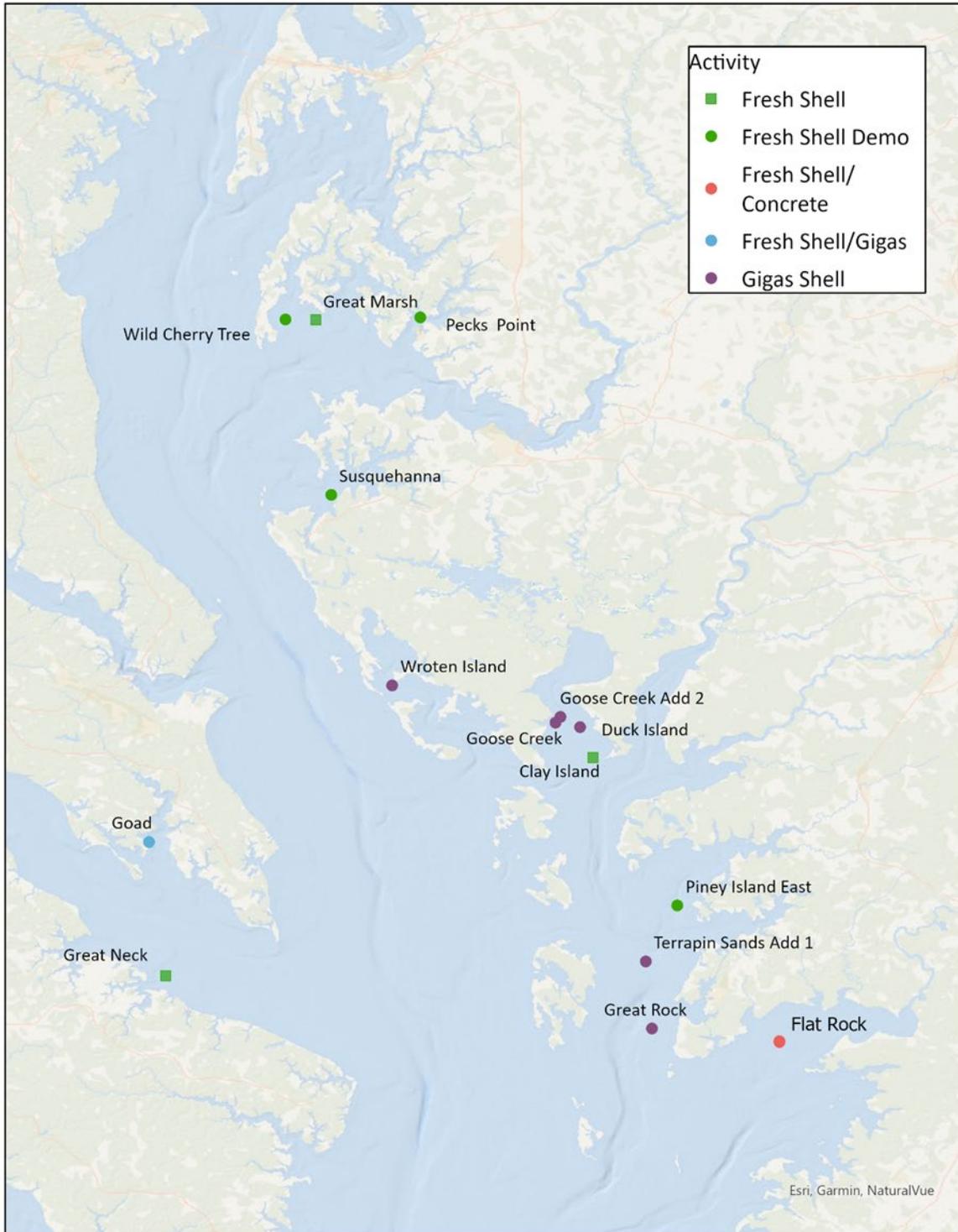
Figure A2-3. Fall Survey samples on substrate plantings in 2024. Fresh Shell= Eastern oyster shell; Gigas = Pacific oyster shell. Flat Rock was two separate sites close together, one with concrete pieces and one with shell.

Table A2-6. Fall Survey samples on substrate plantings in 2024: number of spat per bushel, sizes and the average spat count in the area.

Region	Bar Name	Spat (#/bu)	Min. Size (mm)	Max. Size (mm)	Avg. Size (mm)	Avg. Spat Count in Area
Alternative Materials (Concrete)						
Pocomoke Sound	Flat Rock	616	4	43	27	97
Eastern Oyster Shell						
Fishing Bay	Clay Island	96	23	55	35	91
Harris Creek	Wild Cherry Tree	6	26	37	28	119
Little Choptank River	Susquehanna	183	9	49	33	73
Pocomoke Sound	Flat Rock	266	15	60	22	97
Potomac River	Great Neck	18	15	40	29	13
Tangier Sound	Piney Island East	270	18	50	30	102
Tred Avon River	Pecks Point	24	24	42	33	10
	Average	**123**	**18**	**48**	**30**	**72**
Pacific Oyster Shell						
Fishing Bay	Duck Island	34	15	39	30	121
	Goose Creek	34	20	40	30	121
	Goose Creek Add 2	110	23	54	35	121
Harris Creek	Great Marsh	64	26	52	38	19
Honga River	Wroten Island	292	10	58	28	172
St. Marys River	Goad	36	12	39	28	92
Tangier Sound	Great Rock	170	5	42	23	247
	Terrapin Sands Add 1	336	3	40	28	185
	Average	**134**	**14**	**45**	**30**	**139**
	Overall Averages	*160*	*16*	*46*	*30*	*103*
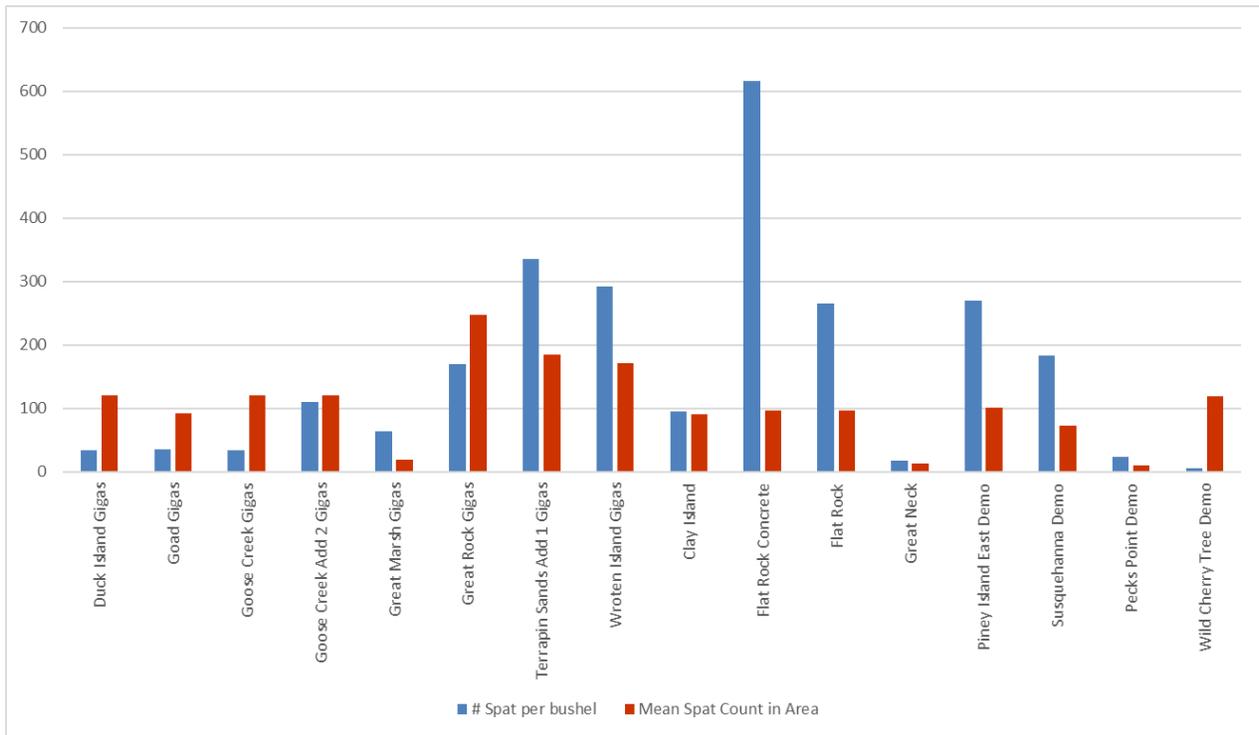
Figure A2-4. Spat counts for substrate plantings on Fall Survey sites in 2024 and the mean spat count for other, unplanted sites in the vicinity. Gigas = Pacific oyster shell.
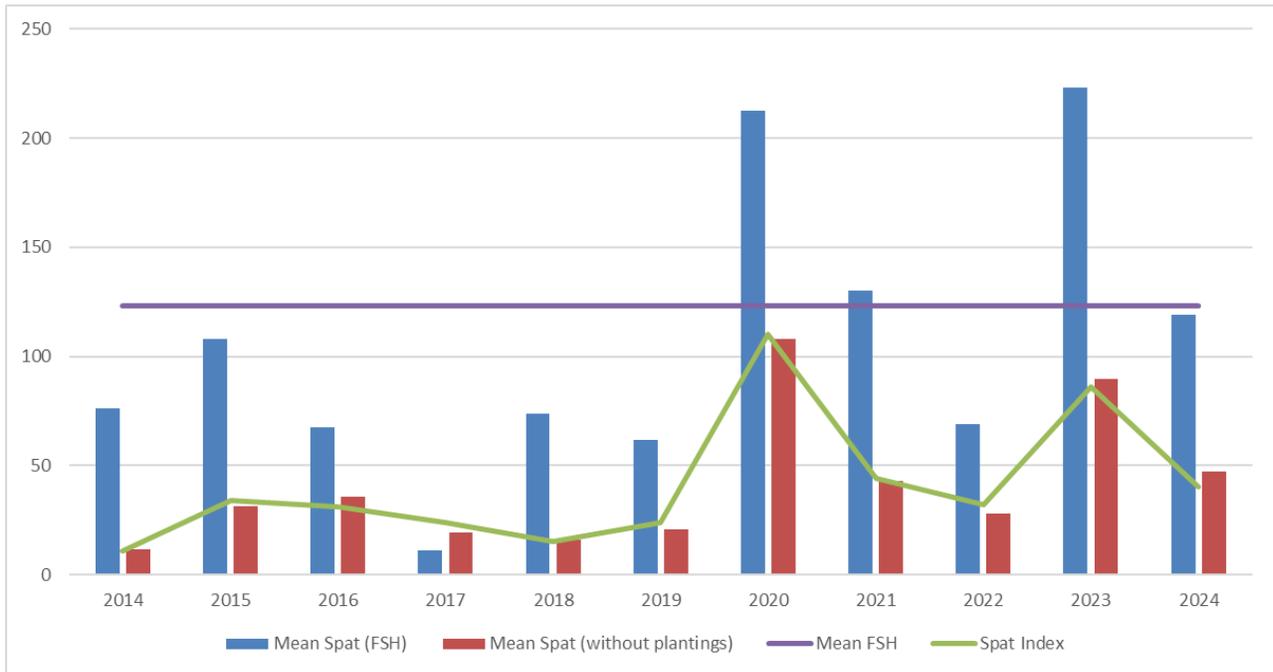
Figure A2-5. Average spat counts (spat per bushel) on fresh shell plantings (blue), average spat counts on areas without either shell or seed plantings (red), mean fresh shell spat count for all years (purple) and the annual spat index (green). For 2024, this included both Eastern oyster and Pacific oyster shell plantings, but not the concrete planting in Pocomoke Sound.

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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).

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.

R/V *Miss Kay* returning to port. (Photo: R. Bussell)