Maryland Oyster Population Status Report
2021 Fall Survey

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Maryland Department of Natural Resources
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Cover Photo: The Research Vessel* Miss Kay *underway during the 2021 Fall Survey (Photo: R. Bussell)

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EXECUTIVE SUMMARY

Since 1939, the Maryland Department of Natural Resources and its predecessor agencies have monitored the state's oyster population by means of annual field surveys – one of the longest running programs of this kind in the world. Currently over 250 bars are sampled annually.

Integral to the Fall Survey are five types of indices intended to assess the status and trends of Maryland's oyster populations: the *Spatfall Intensity Index*, a measure of recruitment success and potential increase of the population obtained from a subset of 53 oyster bars; *Oyster Disease Indices*, which document disease infection levels as derived from a subset of 43 sentinel oyster bars; the *Total Observed Mortality Index*, an indicator of annual mortality rates of post-spat stage oysters calculated from the 43 Disease Bar subset; the *Biomass Index*, which measures the number and weight of oysters from the 43 Disease Bar subset relative to the 1993 baseline; and the *Cultch Index*, a measure of habitat at the 53 Spat Intensity Index bars.

The 2021 Fall Survey was conducted from 5 October to 31 November throughout the Maryland portion of Chesapeake Bay and its tributaries, including the Potomac River. A total of 352 samples was collected from 278 oyster bars. Locations monitored included natural oyster bars, oyster seed production areas, seed and shell planting sites, and sanctuaries.

Among the environmental factors affecting oyster populations, freshwater streamflow is critical as it controls the salinity regime of the bay, which in turn influences spatset, diseases, mortality and growth of oysters. For 2021, the annual average freshwater input was close to normal for the second consecutive year, following two years of record high streamflows.

The Spatfall Intensity Index of 43.9 spat/bu was less than half of the previous year's index but almost double the 37-year median and the eighth highest of the time series. The spatset was well distributed, where good recruitment occurred in the lower bay –especially the Tangier Sound region – as well as the Choptank and Little Choptank regions. The tributaries with the highest spat counts were St. Marys River, followed closely by Broad Creek. Also noteworthy was the spatset in Eastern Bay. Although modest in scope, it was a considerable improvement for this once-productive area that has experienced repeated recruitment failures in recent years. In contrast, few or no spat were found along the Western Shore upbay from Cove Point, the upriver half of the Potomac oyster growing region, and the entire Chester River and bay north of the Bay Bridge.

Although showing a slight uptick from the previous two years, disease levels remained among the lowest on record for the 32-year time series. Dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, being found on 93% of the sentinel bars. The 2021 mean prevalence (36%) increased marginally from the previous year (33%), but was the third lowest of the time series and substantially below the 32-year average of 62.7%. The mean infection intensity for dermo disease (1.2 on a scale of 0-7) was almost half of the long-term average and the fourth lowest of the time series, just slightly higher than the record low (1.0) of 2019 for the lowest average intensity. The geographical distribution of MSX expanded somewhat during 2021, but remained restricted to the high salinity lower bay and the Tangier Sound region. The MSX disease mean prevalence (0.4%) on the Disease Index bars was only a slight increase over the previous three years, which had the lowest annual means in Fall Survey records over the past 31 years. Six oysters from five sites of the 1,290 oysters examined from the Disease Index bars were infected with MSX disease. MSX was also found in two additional oysters at two supplemental sites in the lower bay and Tangier Sound.

The baywide Observed Mortality Index was 6.0%, the lowest of the 37-year record. This was the 18th consecutive year that the mortality index was below the long-term average. A residual of higher observed mortalities from the major mortality event in 2020 persisted in the upper St. Marys River, including the oyster sanctuary. Moderate mortalities were also observed in the upper reaches of a couple of other tributaries. Aside from these areas, regional average observed mortalities were extremely low. For example, Tangier Sound, typically a higher mortality area, experienced a remarkably low observed mortality for the third year in a row, averaging 4.6%.

The 2021 Oyster Biomass Index of 2.69 represents a 36% gain of this index from the previous year, ranking it highest in the 29-year time series. The combined increases in both the number and size of

oysters, especially from the strong 2020 recruitment event, accounts for this improvement in the Biomass Index.

The 2021 three-year rolling average of the Cultch Index was 0.79 bu/100 ft., somewhat lower the 17-year average of 0.89 bu/100 ft. Some individual bars showed steep declines in recent years. Of the 53 bars used in this analysis, 31 (58%) had standardized volumes that were more than 25% below their respective 17-year averages. Strong regional differences in the Cultch Index were evident. The areas with the lowest cultch included most of the mainstem of the bay, followed by the combined Chester River/Eastern Bay region. The highest regional cultch indices were in areas with more favorable oyster recruitment and consequent addition to cultch, specifically the Tangier Sound and Choptank River regions.

Within 31 sanctuaries a total of 86 oyster bars were sampled during the 2021 Fall Survey to evaluate the status of their oyster populations. Trends in recruitment, disease, and mortality were in keeping with the baywide results. A Disease/Mortality/Biomass Index bar is located within each of 13 sanctuaries. In addition, seven supplemental disease sites are located in six additional sanctuaries. Dermo disease prevalences and intensities were well below long-term averages. Dermo levels trended somewhat higher in the sanctuaries than in adjacent harvest areas, likely because the sanctuaries had a higher proportion of larger, older oysters, which can accumulate higher burdens of the parasites. Despite the slightly higher dermo levels, observed mortality rates in the sanctuaries were comparable to those of harvest areas and continued to be markedly lower than the long-term average. Low prevalences of MSX disease were detected at two of the supplemental disease sites within sanctuaries but not in the priority sanctuaries, as well as at five Disease Bars in open harvest areas. The 2021 average biomass index in the sanctuaries was considerably higher (+67%) than the baywide 29-year average, indicating population growth over time. Similarly, there was a substantial improvement (+118%) between the 2021 average biomass index and the long-term average in the open harvest areas. These increases were largely driven by the strong recruitment event of the previous year. As a result, the average biomass per index bar in 2021 was 8% higher in the open harvest areas than in the adjacent sanctuaries.

The priority restoration sanctuaries were compared with adjacent open areas. The restoration sanctuaries had generally higher recruitment than their adjacent open areas, aside from the Broad Creek harvest area. Recruitment within four of the five restoration sanctuaries - Harris Creek, Tred Avon, Little Choptank, and St. Marys - was well above their long-term averages. The exception was the Manokin Sanctuary and its adjacent harvest area in mid-Tangier Sound, both which had below normal recruitment. The highest spat counts of any of the comparison areas was in St. Marys Sanctuary, which averaged 412 spat/100 ft. tow and was eight times as high as the open area. The average number of adult (small and market) oysters per 100 ft tow in the priority sanctuaries was consistently higher than in adjacent harvest areas, aside from Broad Creek without Royston bar. Disease and mortality trends were similar to the broader findings above, apart from an elevated mortality rate in the St. Marys Sanctuary. Cultch, the substrate required for spatset, generally was at lower densities in the open harvest areas than the sanctuaries, except for Broad Creek (omitting Royston bar).

With reported harvests of 347,000 bushels and a dockside value of $10.5 million during the 2020-21 season, commercial oyster landings increased 28% from the previous season. However, despite this jump in landings, the total dockside value actually declined by $1.7 million, reflecting the 32% lower price per bushel watermen received compared to the previous season. Power dredging accounted for 42% of the landings, mainly from the lower Eastern Shore and Choptank regions. Patent tongs were the second dominant gear type, harvesting 30% of the total. The Tangier Sound region was by far the leading production area with 69% of the Maryland landings, primarily from upper Tangier Sound and Fishing Bay. The Choptank region followed with 14% of the landings, led by Broad Creek.

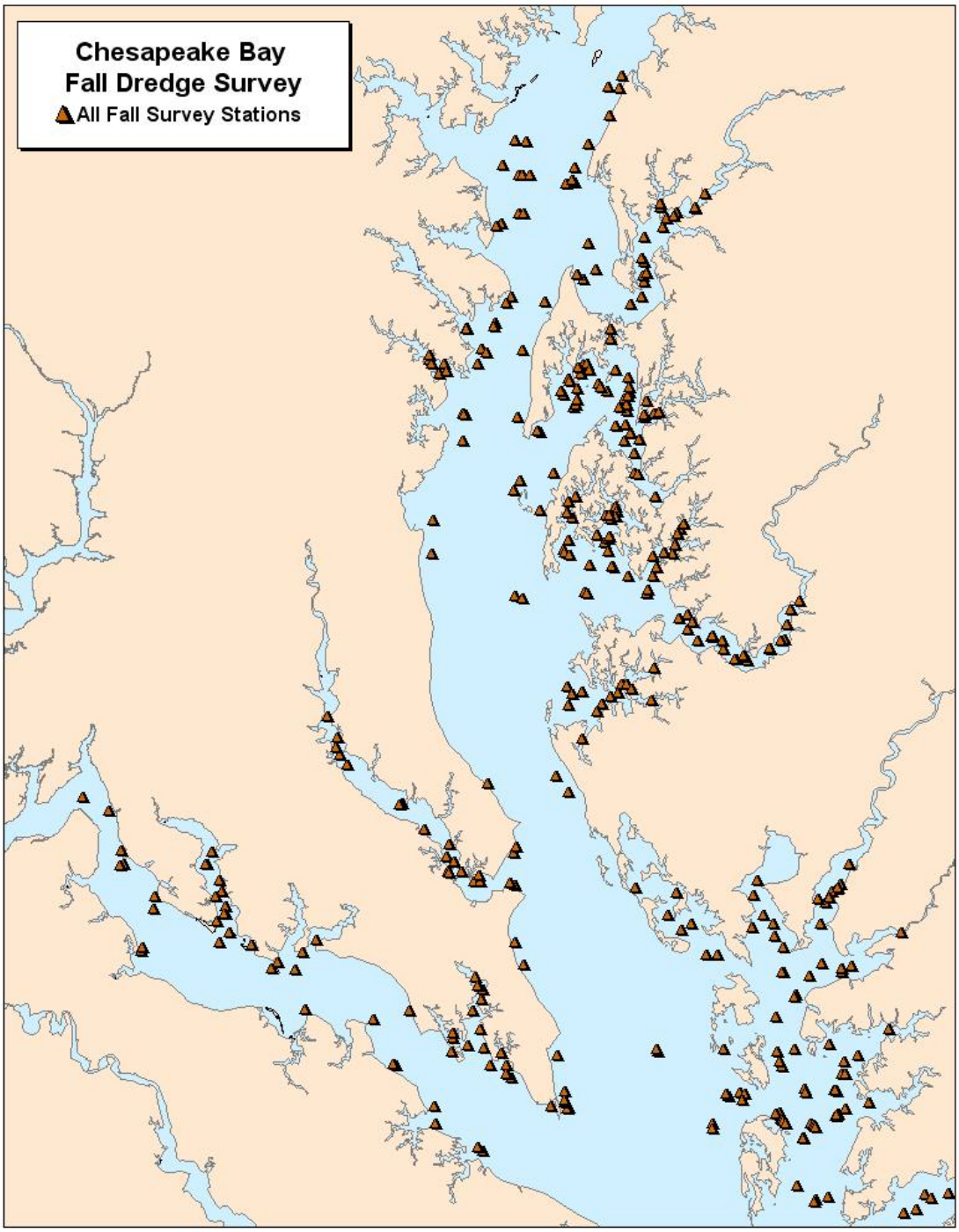

Figure 1a. 2021 Maryland Fall Survey station locations, all bar types (Standard, Key, Disease, Seed) included.

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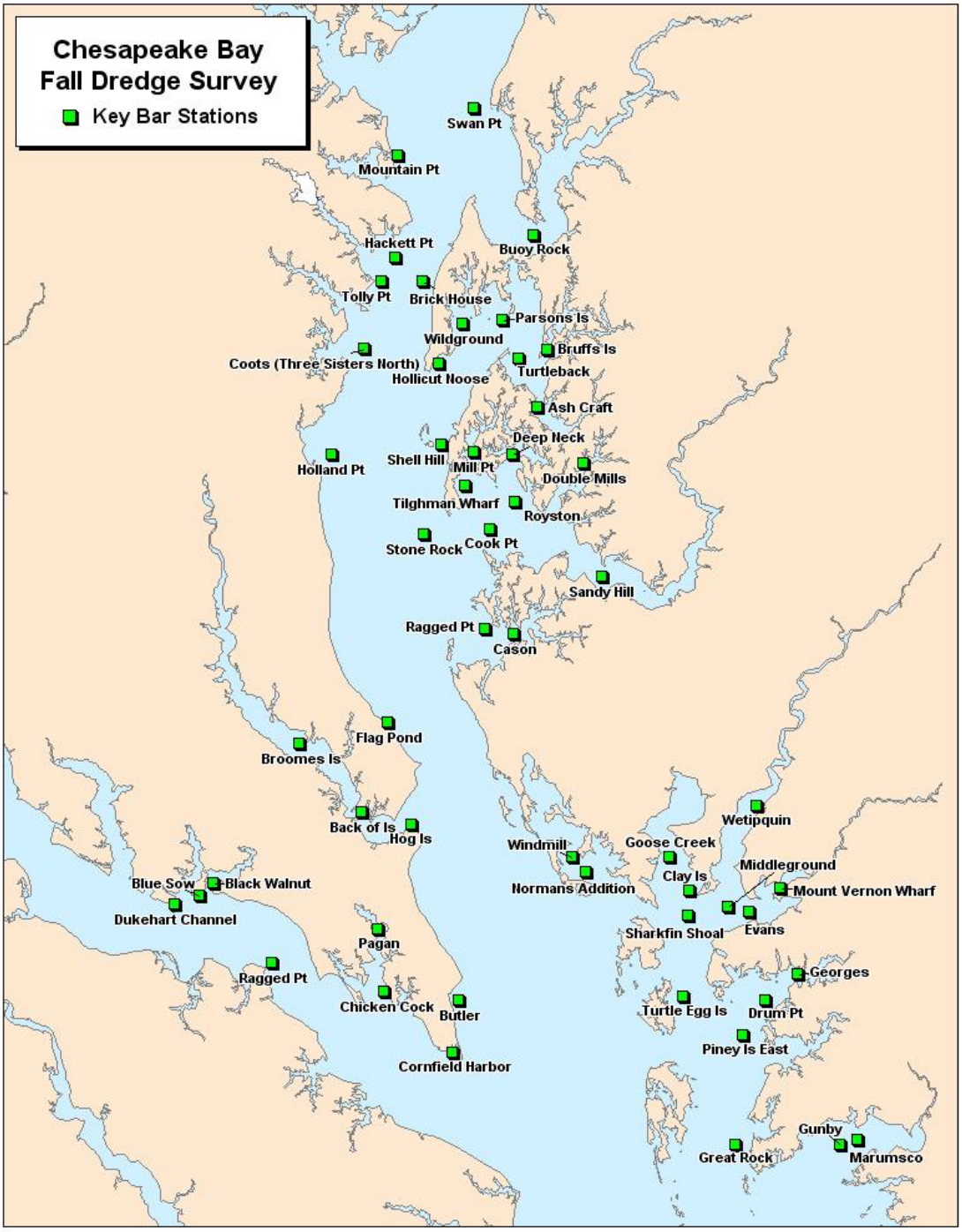

Figure 1b. Maryland Fall Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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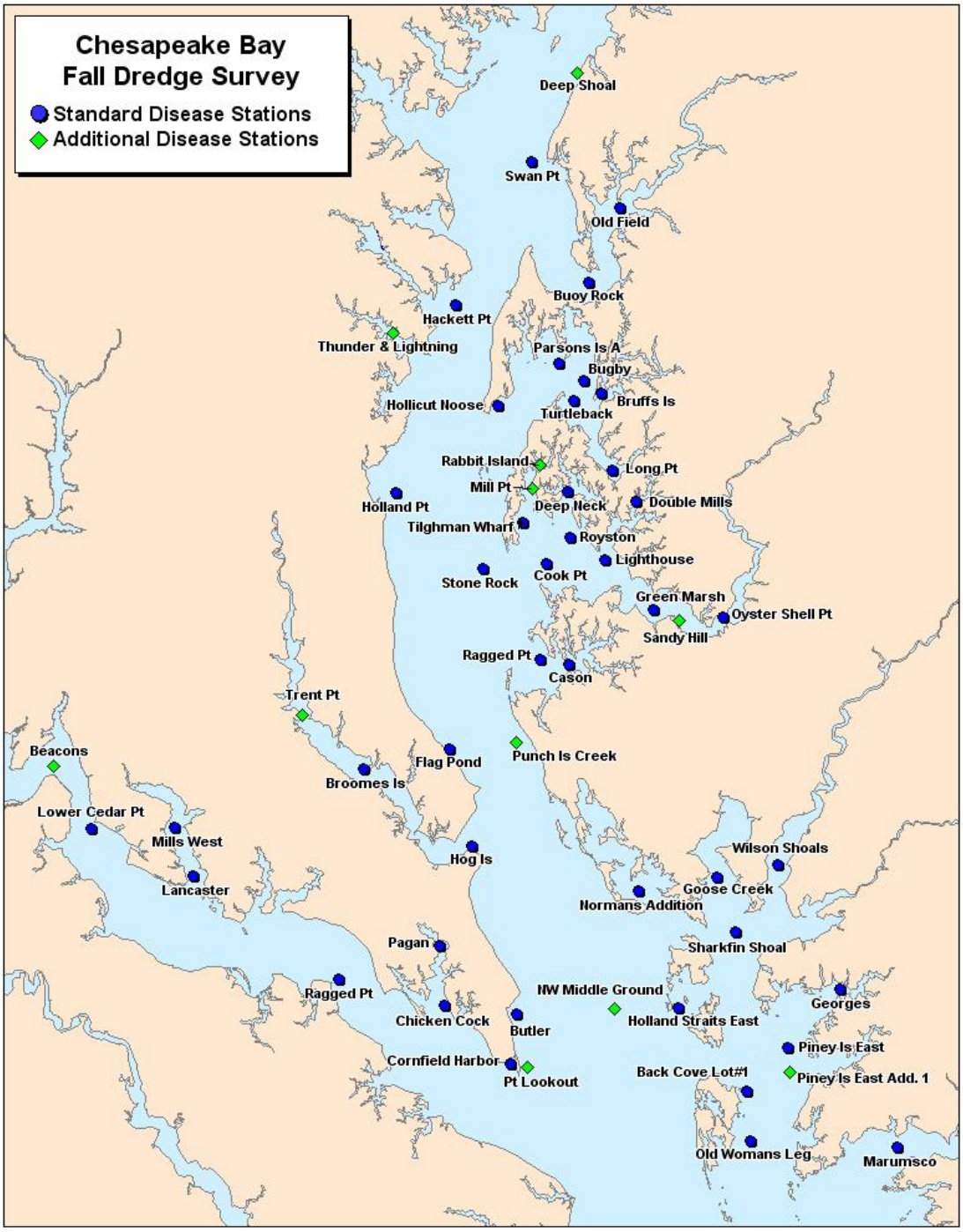

Figure 1c. Maryland Fall Survey standard Disease Bar monitoring locations and additional disease sample stations. Disease samples could not be obtained from the supplemental sites at Deep Shoal and Beacons in 2021.

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INTRODUCTION

Since 1939, a succession of Maryland state agencies have conducted annual dredge-based surveys of oyster bars. These oyster population assessments have provided biologists and managers with information on spatfall intensity, observed mortality, and more recently on parasitic infections 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 and Webster 1980). These sites were selected to provide both adequate geographic coverage and continuity with data going back to 1939. An oyster parasite diagnosis component was added in 1958, and in 1990 disease indexes were developed using standardized parasite prevalence and intensity data from a fixed 43-bar subset (Disease Bar set) (Appendix 2). Thirty-one of the Disease Bars are among the 53 spatfall index oyster bars (Key Bars). Mortality and Biomass Indexes are derived from the Disease Bar set, while a Cultch Index is based on the Key Bars.

Collaborative Studies and Outreach

Throughout the years, the Fall Survey has been a source of collaborative research opportunities for scientists and students within and outside of the Department of Natural Resources. The Fall Survey continued to assist the Potomac River Fisheries Commission with an innovative fishery management program, examining oyster plantings on two Oyster Management Reserves and evaluating several rotational seed planting areas. Data from the Fall Survey was used extensively by the multi-partner Oyster Restoration Project under the 2014 Chesapeake Bay Watershed Agreement, as well as the legislatively mandated Oyster Stock Assessment, a collaborative effort between the department and the University of Maryland Chesapeake Biological Laboratory, which was completed in 2018 and updated in 2021. 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. Several oyster plantings in three sanctuaries were also examined as part of The Nature Conservancy's Supporting Oyster Aquaculture and Restoration (SOAR) program. This program assisted oyster growers by purchasing unmarketable oysters during the COVID-19 epidemic and planting them in oyster sanctuaries to enhance restoration efforts.

METHODS

Field Collection

The 2021 Annual Fall Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources Fishing and Boating Services from 5 October to 31 November. A total of 352 samples were collected during surveys on 278 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 were noted before the subsamples were removed. Photos illustrating the collection process can be viewed at:

dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/sample.aspx

Fall 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 number of dead oysters (boxes and gapers) divided by the sum of live and dead oysters (Appendix 3). Although keyed to the Disease Index subset established in 1990, the Observed Mortality Index also includes data from 1985-1989. The Biomass Index measures the number and estimates the weight of post-spat oysters from the 43 Disease Bar subset relative to the 1993 survey year baseline. The Cultch Index is a relative measure of oyster habitat at the 53 Key spat index bars.

The time series for the Spat Intensity, Diseases, and Mortality indices are presented in Tables 2 - 5. The majority of Fall Survey data, including supplemental pathology data and disease indices, are entered into digital files. Fouling data and oyster condition are in paper files; the data on fouling (mussels, barnacles, tunicates, etc.) and other associated organisms are being converted to a digital format.

Spatfall Intensity Index

The annual Spatfall Intensity Index is the arithmetic mean of spat counts per bushel of cultch from the 53 fixed Key Bars. As such, it does not take into account geographic distribution (i.e., how widespread or concentrated the spatfall is around the bay), whereas the discontinued statistical tiers method did (see Tarnowski 2019, p.14 for explanation of discontinuing this

analysis). For example, the near-record high spatfall intensity in 1997 was actually limited in extent, being concentrated in the eastern portion of Eastern Bay, the northeast portion of the lower Choptank River, and to a lesser extent, in parts of the Little Choptank and St. Marys rivers (Homer & Scott 2001). Over 75% of the 1997 index was accounted for by only five of the 53 Key Bars, and only ten contributed nearly 95%. As a result, the 1997 spat index fell into the third statistical ranking tier (of six) despite being the second highest index on record and an order of magnitude higher than other Tier 3 index years (Tarnowski 2018, Figure 3a). In contrast, the 1991 spatfall (the third highest on record) was far more widespread. Fifteen Key Bars totaled 75% of the index that year, while 28 sites were needed to attain 95% of the spatfall intensity index, placing it in the top statistical ranking notwithstanding having a lower spatfall index than 1997.

Another approach to understanding these skewed spatfall distributions examines the annual medians of the index. Medians are generally higher when there is a more uniform geographic distribution and are lower when the geographic distribution is limited in extent or skewed. In cases such as in 2019, where 60% of the Key Bars accounted for only 5% of the spat index, the median was low even though the index was moderate, reflecting the disparity between the majority of bars which experienced low to zero spatset and the few relatively productive bars. In years when spatset is more widely distributed, the annual median is much higher, such as in 1985, 1991, and to a lesser extent 2010 and 2012. In contrast, most of the years had more geographically restricted spatset distributions, dominated by a few strong recruitment bars. Again, this is most vividly illustrated in 1997, when despite having the highest spat index of the time series, the median for that year was comparatively low (e.g., half of the 2012 median, even though the 1997 spat index was over four times higher than the 2012 index), resulting in a poor median:spat index ratio. Understanding the geographic distribution of recruitment in these terms provides a clearer picture of this component of oyster population dynamics.

Oyster Disease Analyses

Representative samples of 30 oysters that were at least one-year-old were taken at each of 43 Disease Bar sites. An additional nine samples for disease diagnostics were collected from supplemental sites, sanctuaries, and other areas of special interest. Oyster parasite diagnostic tests were performed by Shellfish Health Project staff of the Cooperative Oxford Laboratory. Data reported for *Perkinsus marinus* (dermo disease) are from Ray's fluid thioglycollate medium (RFTM) assays of rectum tissues. Prior to 1999, less-sensitive hemolymph (blood) assays were performed. Data reported for *Haplosporidium nelsoni* (MSX disease) have been generated by histology since 1999. Before 1999, hemolymph cytology was the diagnostic method used for every sample, while solid tissue histology preparations were examined for *H. nelsoni* only from selected locations.

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

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

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

Note that the baseline data are from the 1993 Fall Survey. Prior to 2012, the Biomass Index year followed the year the data were actually collected; e.g., the 1994 baseline index was from the 1993 Fall Survey. To avoid the confusion this caused, in this report the biomass index refers to the year the data were collected (survey year). Therefore, the baseline index year is now 1993, since the data were collected during the 1993 Fall Survey, and the 2021 Biomass Index is derived from the 2021 Fall Survey data.

Biomass Equations
For **each** monitoring station:

1. (# post-spat oysters per size class) x (avg. dmw per size class) = total dmw per size class
2. $\sum$ dmw per size class = total dmw per 1.0 bu station sample

For **all** monitoring stations:

3. ($\sum$ dmw per 1.0 bu station sample)/43 = annual average biomass value
4. (annual average biomass value)/(1993 average biomass value) = Biomass Index

Cultch Index
The collection of quantitative cultch data was initiated during the 2005 Fall Survey. During a sampling tow, the distance covered by the dredge while sampling on the bottom is measured using a handheld GPS unit with an odometer function. After the dredge is retrieved, the total volume of oysters and shell is measured in bushel units. Since tow distances vary, the volume is standardized to a 100 ft. tow by dividing the total cultch volume by the actual tow distance, which yields the volume per foot of tow distance, and multiplying the result by 100. If the dredge is full, that sample is dropped from the analysis. The Cultch Index is calculated as the annual average of the standardized cultch volumes from the 53 Key Bars used in the Spat Index. Because the dredge is less than 100% efficient in catching oysters and shells, this is not an absolute measure of cultch but provides a relative index for temporal and spatial comparisons.

Harvest Records

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

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

RESULTS

FRESHWATER DISCHARGE CONDITIONS

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

Annual Streamflow

The annual average freshwater flow into the Maryland portion of the bay (Sec. "C" in Bue 1968) in 2021 was close to normal for the second consecutive year (Figure 2a). This follows record-high flows in 2018 (calendar year)/2019 (water year).

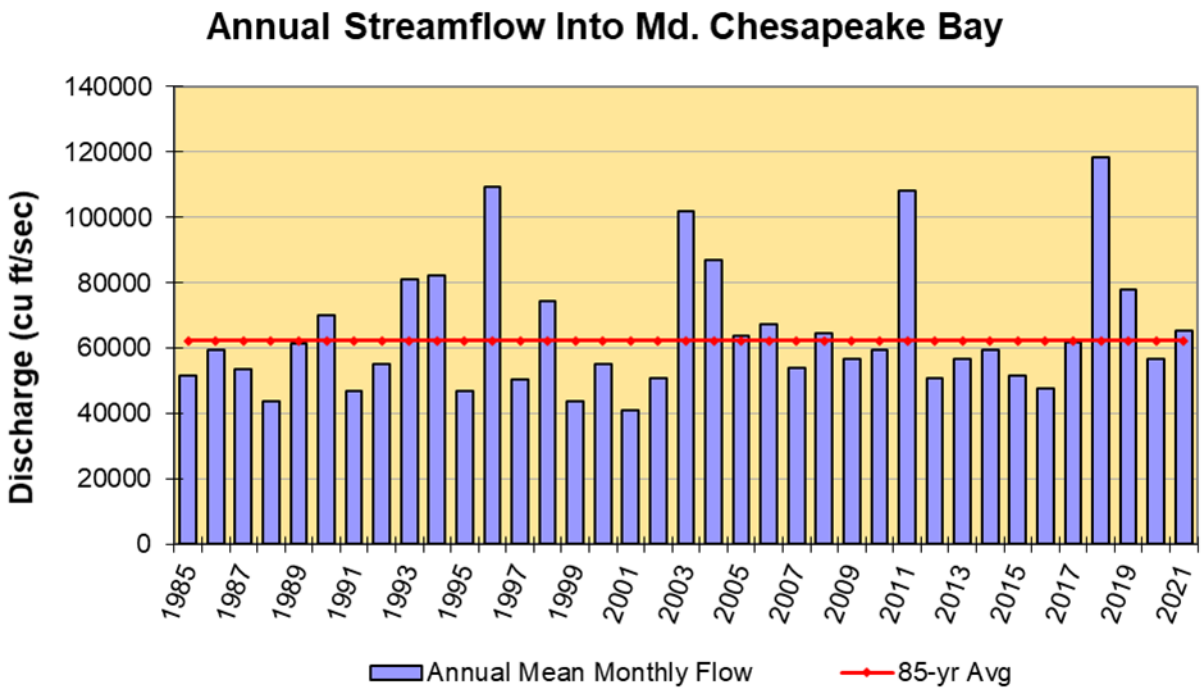

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2021. USGS Section C: all Maryland tributaries and the Potomac River.

Note that the U.S. Geological Survey (USGS) account of 2019 as the record high flow year refers to a *water* year, which runs from 1 October of the previous year (2018) to 30 September of the reporting year (2019) (USGS 2020). In contrast, this report refers to the *calendar* year, which results in 2018 being the record-high flow year.

Monthly Streamflow

Although the annual streamflow was close to normal in 2021, monthly freshwater flows were highly variable relative to their respective 85-year averages (Figure 2b). Streamflows in February and April were low, averaging 60% of the long-term mean for those months. In contrast, the second half of the year was wet following a succession of tropical storms, culminating in

September when the freshwater flow was more than three times higher than normal, largely due to the remnants of Hurricane Ida.

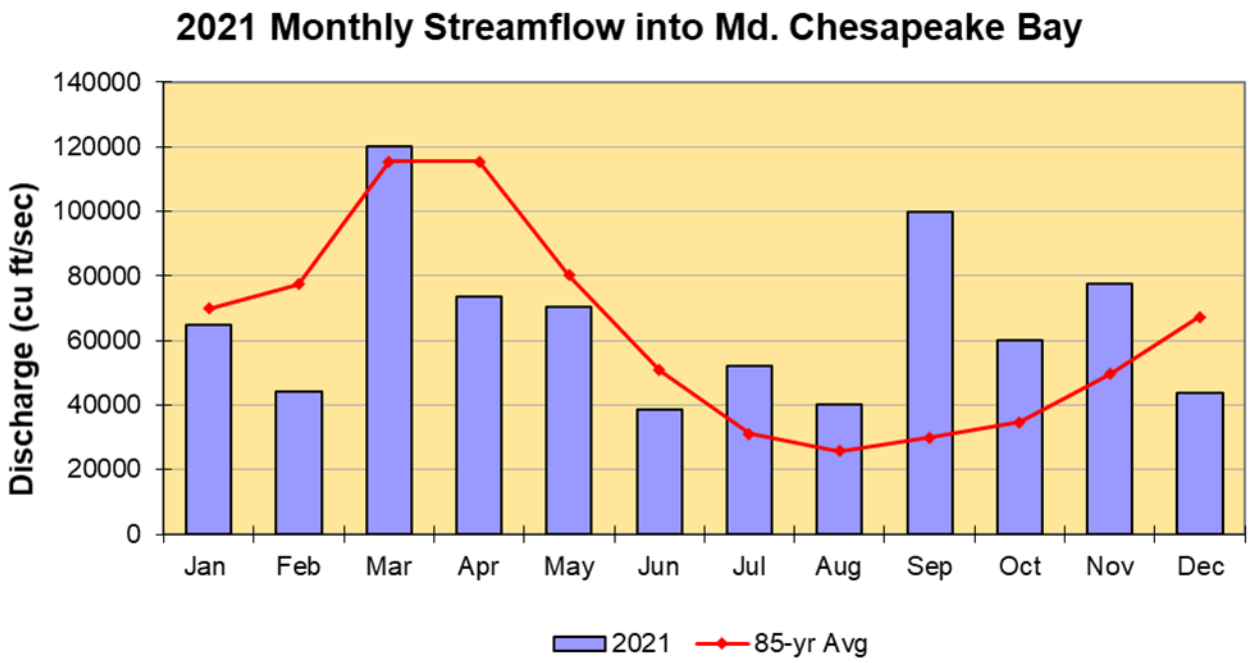

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2021, including the 85-yr monthly average.

Salinities

Salinities were close to normal during the first half of 2021, then dropped below average in the second half of the year due to the tropical storms that impacted the region. Monthly surface salinities for four regions of the Chesapeake Bay in Maryland during 2021 are shown in Figure 2c (Chesapeake Bay Program 2021). These examples demonstrate the influence of streamflow depending on distance from the Susquehanna River, the largest source of freshwater discharge into the bay. Swan Point in the upper bay showed the greatest variability in deviations from the long-term mean, reflecting its proximity to that river, with five of the monthly values that were greater than 25% below their means and three months that were above their means by more than 25%. In contrast, no months had salinities outside the 25% of the mean bounds at the South Tangier Sound station.

A critical threshold for a number of biological processes in oysters is about 5 parts per thousand (ppt) (Tarnowski 2019). Surface salinities at Swan Point in the upper bay dropped below this mark to 2.5 ppt in September following the passing of Hurricane Ida, but quickly rebounded to above 5 ppt by the following month. None of the other locations had salinities below 5 ppt reported in 2021. The peak salinity was in southern Tangier Sound, reaching a high of 17.5 ppt in August (Figure 2c). 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 fresh/brackish water at the surface and the tidal intrusion of saltier water at the bottom.

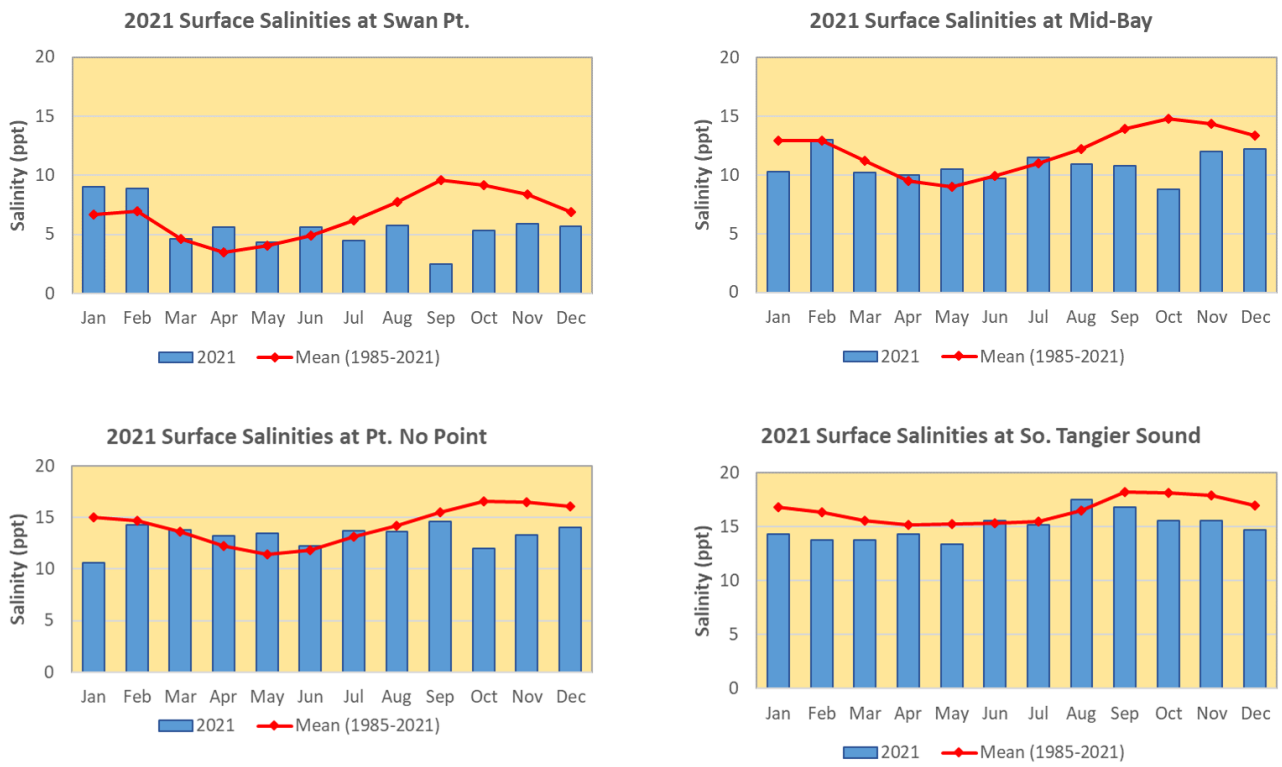

Figure 2c. Monthly surface salinities during 2021 at four monitoring stations along a salinity gradient in Chesapeake Bay. *Swan Pt. (CB3.2) is in the upper bay, the mid-bay station (CB4.2C) is off the mouth of the Choptank R., Pt. No Point (CB5.2) is in the lower mainstem, and the southern Tangier Sound station (EE3.2) is near the Virginia state line.*

SPATFALL INTENSITY

The Spatfall Intensity Index, a measure of recruitment success and potential increase in the population, was 43.9 spat/bu, a sharp decline from the exceptional 2020 Index but almost twice the median of the 37-year time series (Figure 3a). Despite the drop in the overall Spatfall Intensity Index, the number of index bars showing decreases vs. increases was evenly split at 41.5% each, with the balance showing no change (Table 2). Six of the last 12 years have had above-median spat indexes, three of which can be considered exceptional (i.e., three to five times higher than the long-term median), while only two years during this period were substantially (>25%) below the long-term median (Figure 3b).

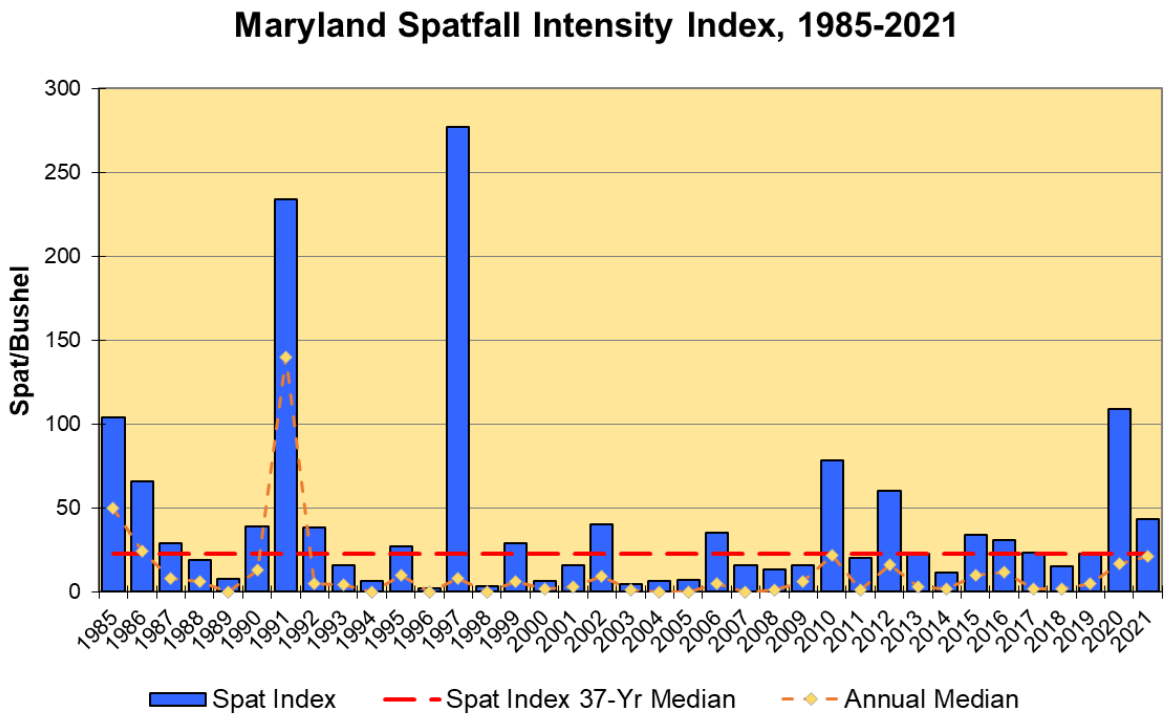

Figure 3a. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including annual median values.

Spatfall distribution among the Key Bars in 2021 expanded somewhat from the previous year. Spat were observed on 44 of the 53 Key Bars, whereas 40 Key Bars had spat in 2020 and 37 bars had spat in 2019, a 19% increase over the previous two years (Table 2). As indicated by the median:spat index ratio, the numerical distribution in 2021 was the second most widespread of the time series, whereas the 2020 distribution was heavily skewed towards fewer bars with high spat counts, placing it in the lower third of the time series for evenness of spatset, (Figure 3c). Seven bars accounted for 50% of the index, compared with three bars in 2020. Further confirming the widespread nature of spatset in 2021, 29 bars contributed to 95% of the spat index, the largest number of bars in the past 13 years. However, the remaining 24 bars made up just 5% of the Spat Intensity Index. In other words, 45% of the index bars were unproductive in 2021, with 8 bars (15.1%) having no spat found in the samples. Nonetheless, this was an improvement over the previous year, when 64% of the bars were unproductive, of which 13 bars (24.5%) had no spat in the samples. Six Key Bars reached triple-digit spat counts, led by Pagan

in the St. Marys River with 426 spat/bu. This represents a strong rebound on that bar after three years of poor spatsets and a high mortality event in 2020, which resulted in an observed mortality of 49% of the adult oysters.

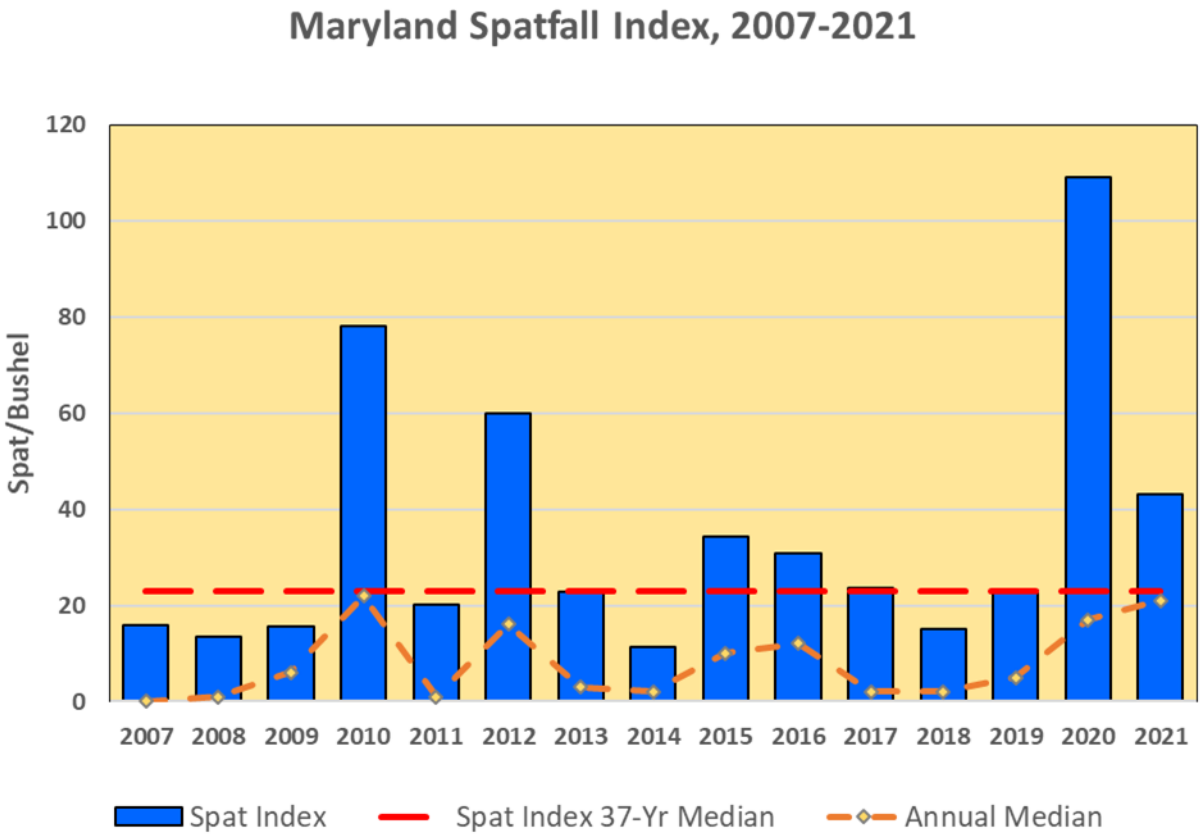

Figure 3b. Recent Maryland spatfall indices, 2007-2021, including annual median values.

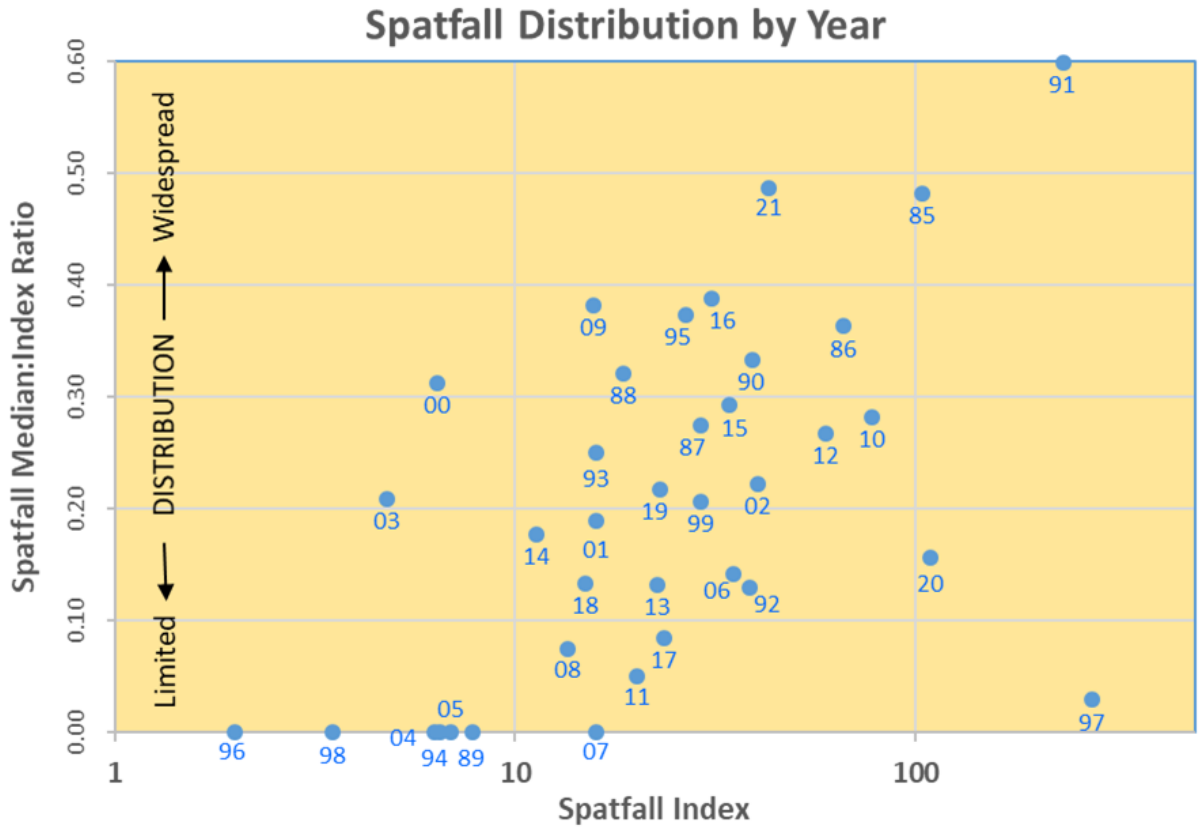

Figure 3c. Spatfall median:index ratios for the years 1985 to 2021 as denoted by "85" to "21" on the chart. The ratio measures the geographic distribution of spat counts for a given year. A lower ratio indicates that the spat counts are concentrated on fewer index bars, while a higher ratio indicates the numerical distribution of spat is more evenly spread among the index bars.

When considering all bars surveyed in addition to the Key Bars, recruitment was more broadly distributed compared to the previous year. The highest spatsets were observed in the lower bay and associated tributaries, the Little Choptank River, and two tributaries of the Choptank River (Figure 4). The lower mainstem east of the channel led all regions, averaging 170 spat/bu. Other areas with recruitment averages greater than 100 spat/bu include St. Marys River (130 spat/bu), Broad Creek (126 spat/bu), mid-Tangier Sound (122 spat/bu), Honga River (118 spat/bu), Pocomoke Sound (106 spat/bu), and Harris Creek (105 spat/bu). Light spatsets were observed in the upper reaches of several tributaries where recruitment tends to be more sporadic, including the Patuxent, Nanticoke, and Choptank rivers. The middle to upper Potomac River had few or no spat in the samples. No spat were found in samples along the Western Shore north of Cove Point, in the entire Chester River, and the bay north of the Bay Bridge.

Of note is the spatset found throughout the Eastern Bay region, including the Miles and Wye rivers. Although the spatset is modest in scope, it is a considerable improvement for the once-productive area that has endured repeated recruitment failures in recent years. The last comparable spatset in this region took place in the early 2000s.

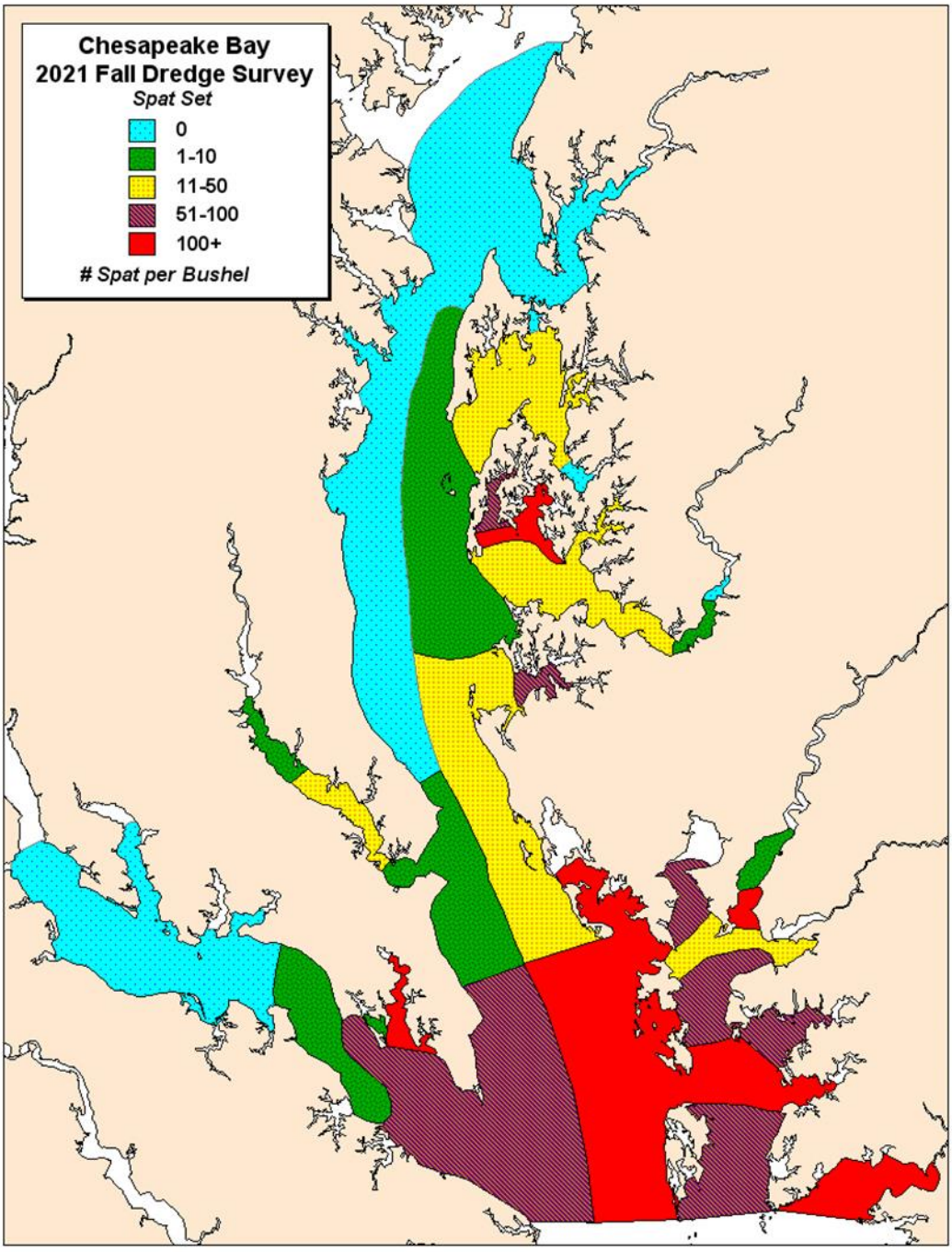

Figure 4a. Oyster spatfall intensity and distribution in Maryland, 2021. Intensity ranges represent regional averages.

OYSTER DISEASES

A total of 1,560 oysters were analyzed for diseases in 2021 – 1,290 from the 43 Disease Bars (sentinel bars) and 270 from nine supplemental sites.

Dermo disease is caused by the parasite *Perkinsus marinus*. Prevalences and intensities wax and wane seasonally, and infections may persist from year to year before oysters die from the disease. Over several years of drought during the 1980s, *P. marinus* expanded its Chesapeake Bay distribution into upstream areas where it had been previously rare or absent and has remained widespread throughout Maryland ever since.

Despite a slight uptick in the measures of dermo disease from the previous year, their levels remained low in Maryland oyster populations in 2021. Dermo disease was detected in oysters on 93% of the Disease Bars (Table 3) during 2021. In 2020, it was found at 84% of the bars, the lowest frequency since the 43-bar subset was standardized in 1990. While dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, over the past three years the percentage of individual infected oysters have been the lowest on record, though this has been gradually trending upward since 2019. The overall mean infection prevalence in oysters sampled on the Disease Bars rose slightly to 36%, compared to 33% in 2020; nevertheless, 2021 had the third lowest average prevalence of the 32-year time series (Figure 5). Since the record high epizootics at the turn of the millennium, dermo disease mean prevalences have been below the long-term average of 62.7% for 16 of the past 19 years.

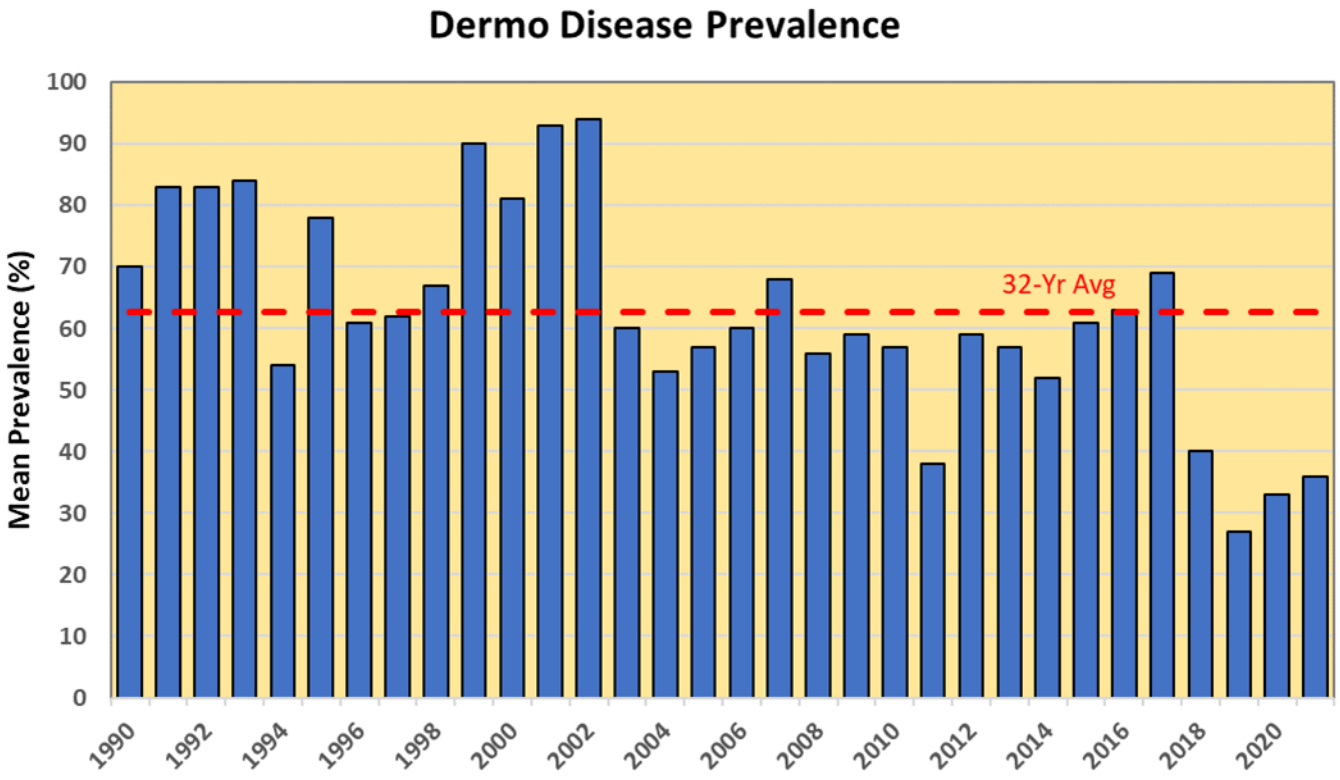

Figure 5. Annual mean *P. marinus* prevalences from Maryland disease monitoring bars.

The number of samples exhibiting high prevalences (>60%) declined substantially over the past four years from 60% of the Disease Bars in 2017 to 19% in 2020 and 21% in 2021, but remained widely distributed below the Bay Bridge (Figure 6). However, the number of locations where dermo disease was not detected dropped to three from the previous year's seven sites, though the 2021 prevalences were low at the four sites where dermo disease had not been detected in 2020 (Table 3).

Outside of the regular disease monitoring sites, dermo disease was found at all nine of the supplemental sites, with prevalences greater than 60% at four of the bars (Thunder and Lightning, Mill Point, Piney Island East Addition, and Point Lookout). The two supplemental bars furthest upstream, Deep Shoal in the mainstem and Beacon bar in the Potomac River (Figure 1c), were not sampled for disease in 2021 because of the absence or low densities of oysters due to freshet-related mortalities.

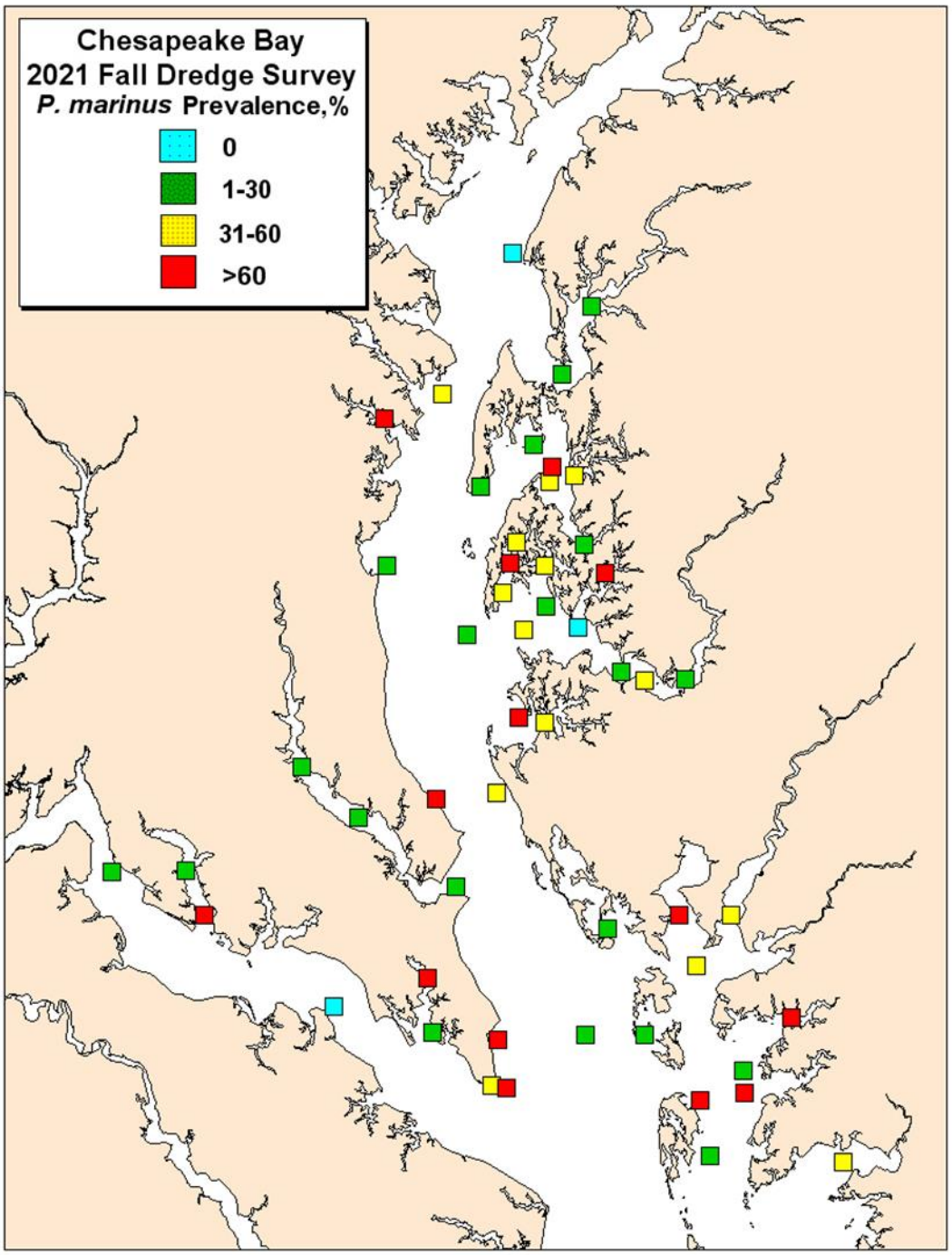

Figure 6. Geographic extent and prevalence of dermo disease in Maryland, 2021.

The trend in the mean infection intensity for dermo disease also remained stable at low levels. Although the 2021 mean infection intensity (1.2 on a 0-7 scale) was slightly higher than in 2020 (1.1), it was less than half that of 2017 (2.5) and tied for the third lowest infection intensity on record, well below the long-term average of 2.1 (Table 3). This is the 16th of the past 19 years that the infection intensity index has been at or below the long-term average (Figure 7). The average infection intensity over the 19 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 resulted in historically high mortalities.

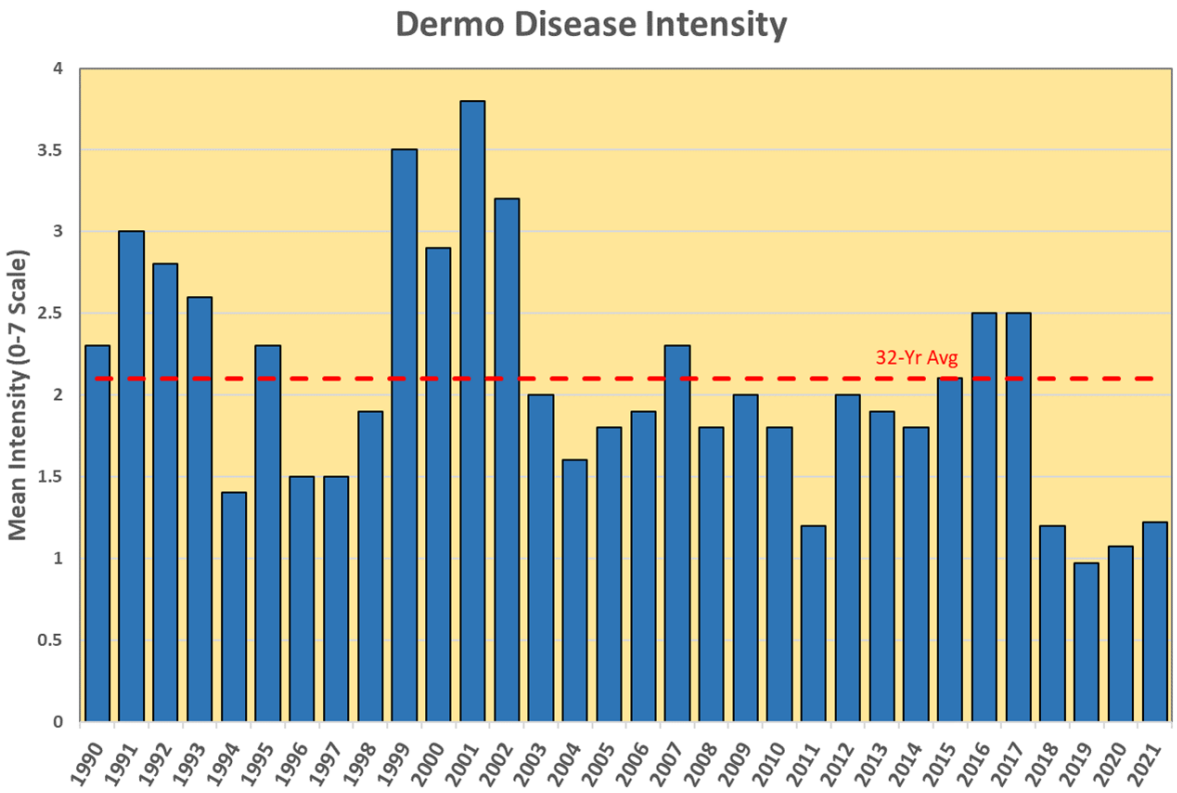

Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars.

The 2021 frequency distributions of sample mean infection intensities on the Disease Bars shifted slightly from the low to the moderate range, but remained truncated at the high end of the ranges (Figure 8). In 2021, only one of the sentinel bars (2%) had a mean intensity of 3.0 or greater, compared to 47% (20 bars) in 2017. For perspective, during the peak infection intensity year of 2001, 81% of the sentinel bars had dermo disease mean intensities equal to or greater than 3.0 and 51% had intensities equal to or greater than 4.0. The proportion of bars that were in the lowest intensity categories of zero and less than 1.0 was 47% in 2021, compared to 58% in 2020 and only14% in 2017. Meanwhile, the proportion of bars in the moderate intensity (1.0 to <3.0) range increased from 40% in 2020 to 51% in 2021. Dermo disease was not detected on 7% of the bars in 2021, a drop from the 16% of the previous year. None of the nine supplemental bars had mean infection intensities of 3.0 or greater in 2021.

Infection intensities in individual oysters that are ≥5.0 on a 0–7 scale are considered lethal; such infection intensities were found in 70% of sentinel samples in 2021. However, as a percentage of all oysters samples, lethal infections were detected in only 10% of oysters sampled in 2021, slightly up from 9% in 2020, but substantially lower than the 21% in 2017.

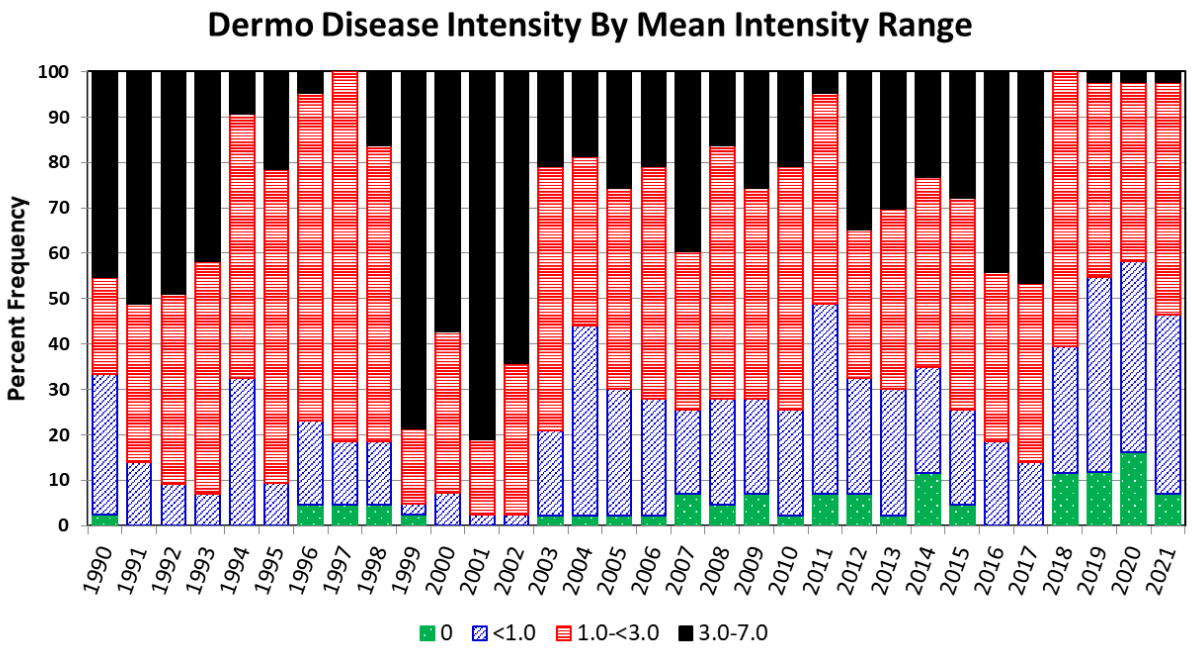

Figure 8. ***Perkinsus marinus*** **infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.**

MSX disease, resulting from the parasite *Haplosporidium nelsoni*, is another potentially devastating oyster disease. This parasite can cause rapid mortality in oysters and generally kills a wide range of year classes, including younger oysters, over a long seasonal period. When MSX disease coincides with elevated dermo disease intensities, mortality levels can be 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 range of MSX disease increased on the Disease Bars in 2021.The mean prevalence of infected oysters rose from 0.1% to 0.4%. Despite the increase, this was nearly two orders of magnitude lower than the most recent infection peak in 2016 (11.1%).This extends the trend of extremely low prevalences to four years, the previous three of which were record lows (Table 4, Figure 9). The prevalences ranged from 3% to 7% (one to two oysters) on the Disease Bars where MSX was detected. The highest prevalence, 10%, was found at Northwest Middleground, a supplemental disease site located in the lower mainstem east of the channel. This particular location is deeper than most Disease Bars, and is likely to be influenced by high salinities present in the estuarine salt wedge.

When considering both the Disease Bars and supplemental sites, the geographic range of MSX disease expanded throughout Tangier Sound and two adjacent areas (Figure 10). The percent frequency of positive Disease Bars increased from 2% (one bar) in 2020 to 12%, including four bars in Tangier Sound and one in Fishing Bay (Table 4). MSX was also detected on two supplemental disease sites, up from one site in the previous year, - NW Middleground (repeating from 2020) and Piney Island East Addition in Tangier Sound. Nevertheless, the number of bars with MSX infections remains relatively low. In contrast, as recently as 2017, 14 Disease Bars

(33%) had MSX-infected oysters, while 2016 was even higher with 24 (56%) infected bars (Table 4). For reference, at its greatest extent the parasite occurred on 90% of the bars in 2002.

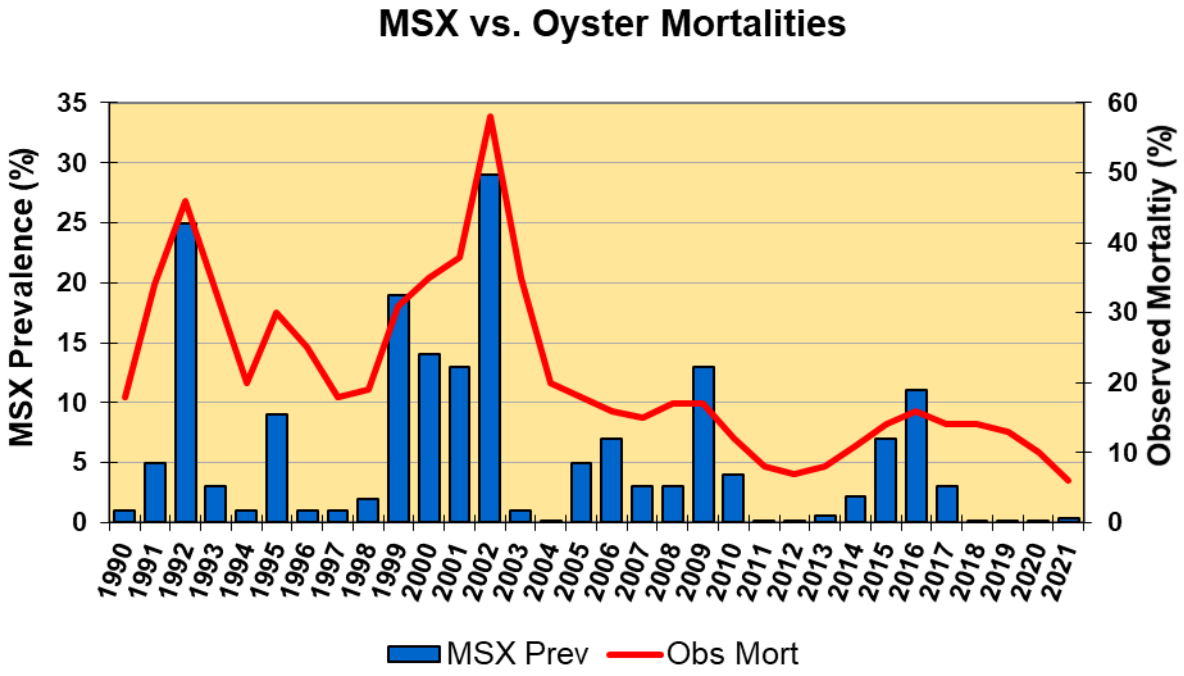

Figure 9. Percentage of Maryland oysters with MSX disease compared to annual means for observed mortalities on the disease monitoring bars from 1990-2021.

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 five *H. nelsoni* epizootics: 1991-92, 1995, 1999-2002, 2009, and 2015-16. The first three were associated with prominent spikes in observed mortalities (Figure 9), while the 2009 and 2016 outbreaks were accompanied by modest mortality increases that were ameliorated by timely freshwater flows (Tarnowski 2011). All of these epizootics coincided with dry years (Figure 2a) and consequent elevated salinities. These were followed closely by periods of unusually high freshwater inputs into parts of Chesapeake Bay, which purged *H. nelsoni* infections from most Maryland oyster populations (Homer & Scott 2001; Tarnowski 2005, 2011). The current four-year period of greatly diminished *H. nelsoni* infections is associated with the extraordinarily high streamflows of 2018 and 2019 (Figure 2a).

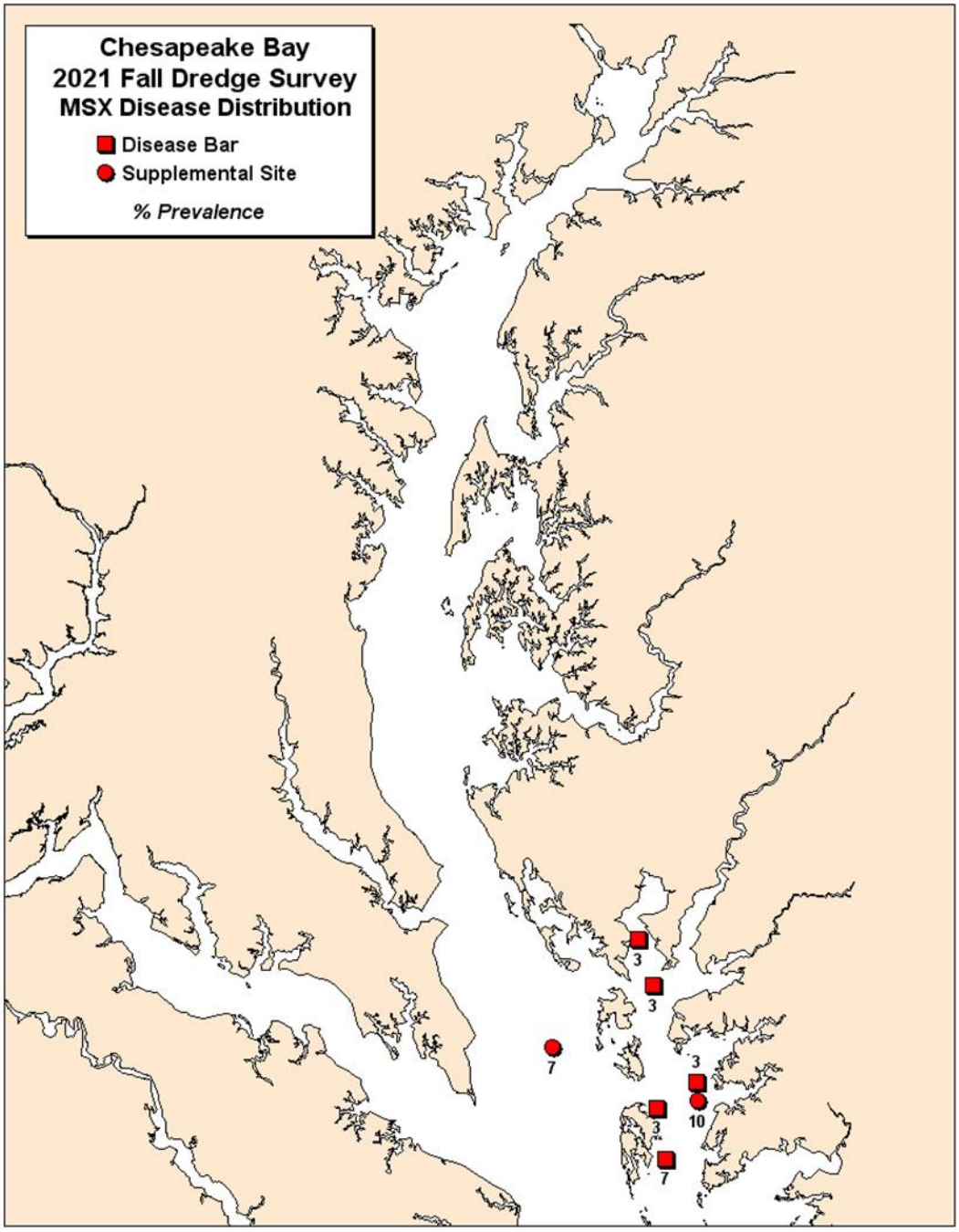

Figure 10. Geographic distribution and prevalence of MSX disease in Maryland waters, 2021.

OBSERVED MORTALITY

In a year of positive oyster population metrics, one of the most significant was the Maryland-wide Observed Mortality Index. At 6.0%, the 2021 index was the lowest of the 37-year time series and well below the long-term mean of 21.5% (Table 5), continuing an 18-year period of below average mortalities as a consequence of low to moderate disease pressure (Figure 11). The average observed mortality of 13.1% over these last 18 years approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (MDNR, unpubl. data). This is in remarkable contrast to 2002 when record-high disease levels devastated Maryland populations, resulting in a 58% observed mortality rate.

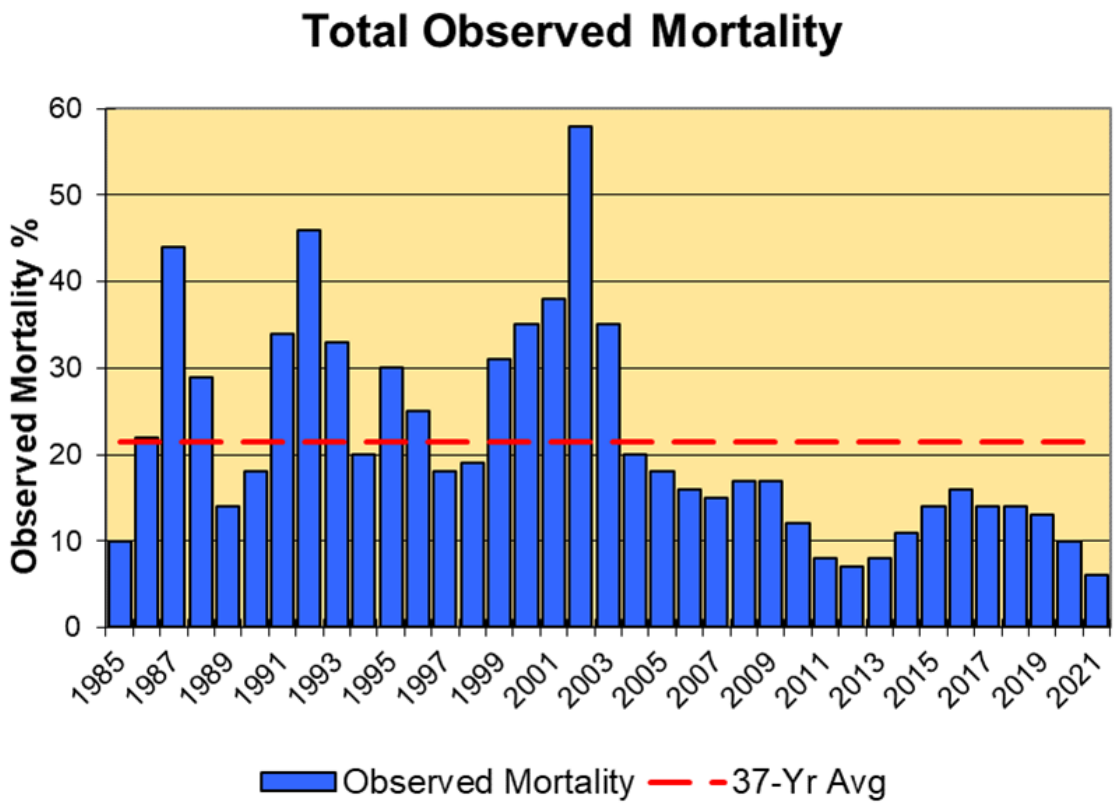

Figure 11. Mean annual observed mortality, small and market oysters combined.

Looking at all Fall Survey sites, observed mortalities were generally low. The north-south gradient in observed mortalities evident in most years was not apparent in 2021, with strikingly low average mortalities (10% or less) from the head of the bay to the Virginia line, including most tributaries (Figure 12a). A residual of higher observed mortalities from the major mortality event in 2020 persisted in the upper St. Marys River, including the oyster sanctuary. The highest mortality observed on an individual bar with more than 50 live oysters/bushel[1] was 31.8% on Gravelly Run-Green Pond in the St. Marys River. Low to moderate mortalities were also observed in the upper reaches of a couple of other tributaries. Aside from these areas, regional average observed mortalities were extremely low, with the majority of bars in single digits. For example, Tangier Sound, typically a higher mortality area, experienced a notably low observed mortality for the third year in a row, averaging 4.6%, in contrast to 1999 at the start of the millennial epizootic when the average observed mortalities climbed to 48.0%. The highest Index-

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

bar mortality (23%) was observed both on Bugby in Eastern Bay and Hackett Point in the mid-mainstem (Table 5).

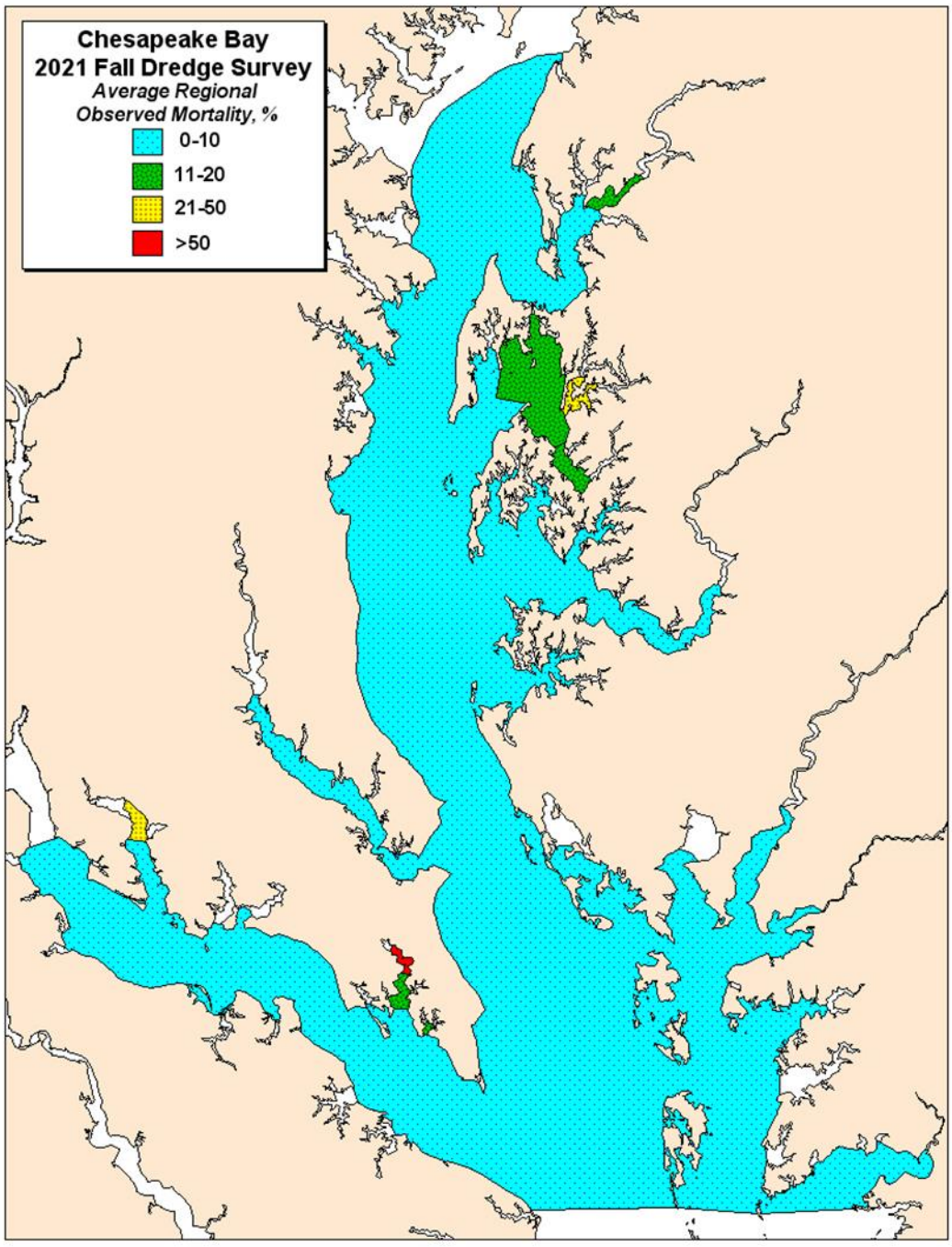

Figure 12a. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2020. Mortality ranges represent regional averages; individual bars may vary substantially.

BIOMASS INDEX

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

Another significant oyster population milestone was attained in 2021, when the Maryland Oyster Biomass Index reached 2.69, the highest index of the 29-year record (Figure 13). This represents a gain of 36% from the previous year and was double the long-term average.

The size distribution shifted to more sublegal oysters relative to market oysters at a ratio of 1.13 sublegals to one market oyster, compared with the sublegal to market ratio of 0.61 in 2020 and 0.80 in 2016. This can also be expressed as the percentage of sublegal oysters: 53.0% in 2021, up from 37.9% in 2020, and 44.5% in 2019. This shift is reflected in the increase in average size of index bar oysters, from 78.1 mm in 2019, to 79.8 mm in 2020, then down to 74.6 mm in 2021. As expected, the decrease in the average oyster size should result in a corresponding decline in biomass. However, the second component of the Biomass Index, oyster abundance, showed substantial improvement. For all index bars, the average number of oysters per sample rose from 108.0/bu in 2020 to 163.8/bu in 2021, a gain of 52%. The large influx in the number of small oysters greatly outweighed their smaller sizes, which accounts for the magnitude of increase in the Biomass Index.

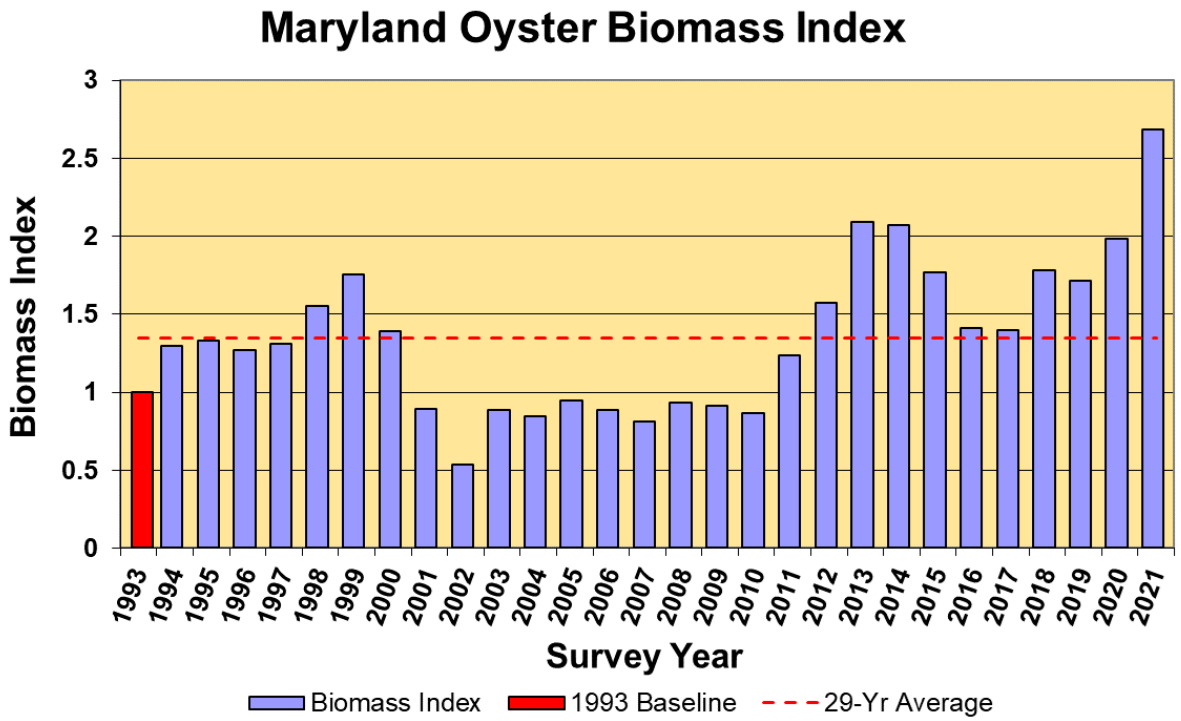

Figure 13. Maryland oyster Biomass Index. The year 1993 represents the baseline index of 1.0.

The oyster population had been slow to recover since its nadir in 2002, the last year of the devastating four-year disease epizootic. The Biomass Index remained below 1.0 for eight consecutive years despite low disease pressure and high oyster survivorship over this period.[2] Spatfall during this timeframe was sufficient to maintain the population at this level but not increase it. It was not until the strong recruitment event in 2010 - bolstered by another good spatset in 2012 - that the population began to grow, as mirrored in the increase in the Biomass Index. Since then, the Biomass Index has been above the long-term average in each of the last 10 years. With the strong spatsets of the last two years and ongoing restoration efforts in the sanctuaries, the index is expected to continue to improve in the near future.

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

CULTCH INDEX

The Cultch Index is a relative measure of oyster habitat; because the dredge is less than 100% efficient, the index is not an absolute measure of cultch. Cultch is crucial for providing hard substrate for oyster setting as well as habitat for the myriad other organisms associated with the oyster community. For the purpose of the Fall Survey, cultch is defined as primarily both live and dead oysters plus shell combined. The collection of quantitative cultch data was initiated during the 2005 Fall Survey.

The three-year rolling average for the 2021 Cultch Index of 0.79 bu/100 ft. was lower than the 17-year average of 0.91 bu/100 ft. (Figure 14). However, some individual bars showed much steeper declines. Of the 53 bars used in this analysis, 57% had standardized volumes that were less than 75% of their respective 17-year averages (Figure 15).

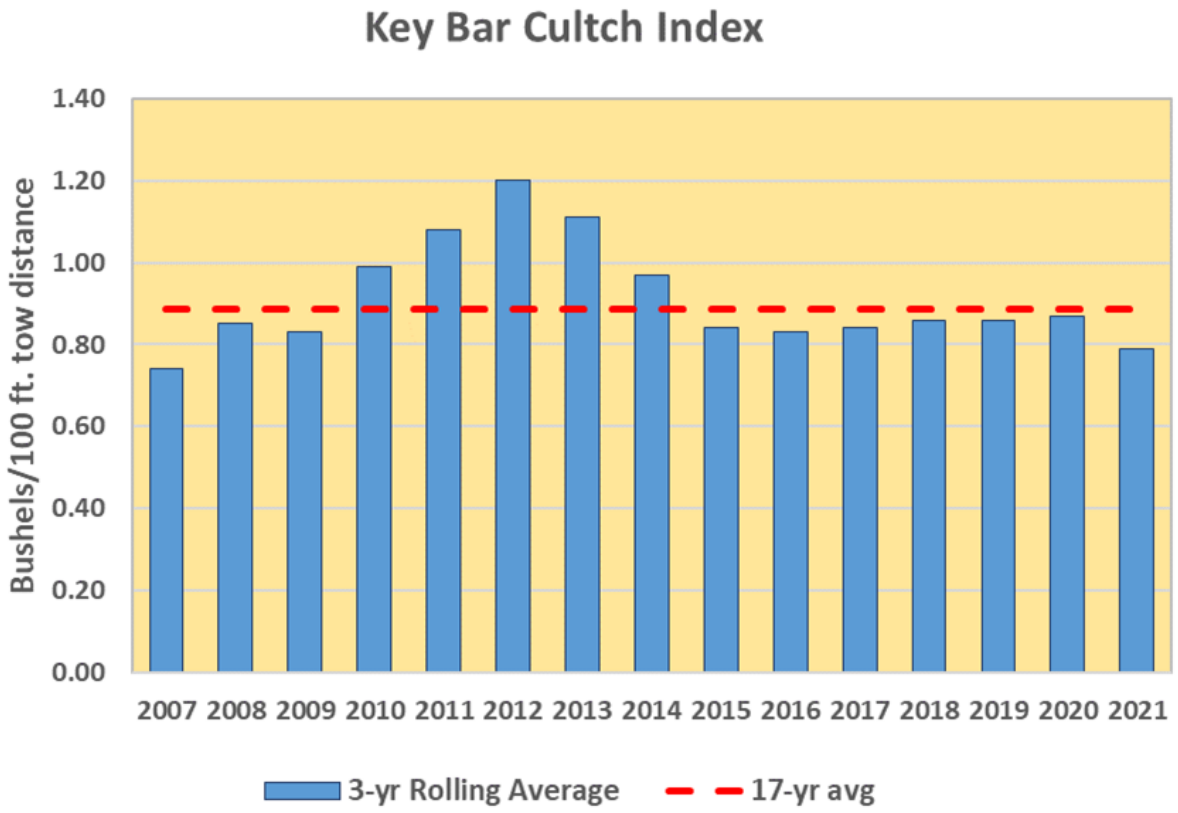

Figure 14. Three-year rolling average of annual means for the Key Bar Cultch Index, 2005-2021. The average is represented by the third year of the grouping (e.g., the 2005-07 average is graphed as 2007).

Although 17 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). A three-year rolling average was used to smooth the interannual variability inherent in the index (the rolling average is assigned to the terminal or third year of each grouping). The increase in the Cultch Index during the early 2010s reflects improvements in recruitment and survivorship during that period, especially the strong spatsets in 2010 and 2012 (Figures 3b, 11). The growth and high survivorship of these year classes contributed substantially to the index. The subsequent decline may be due to harvesting and inconsistent recruitment, as well as ongoing taphonomic processes such as shell burial and degradation.

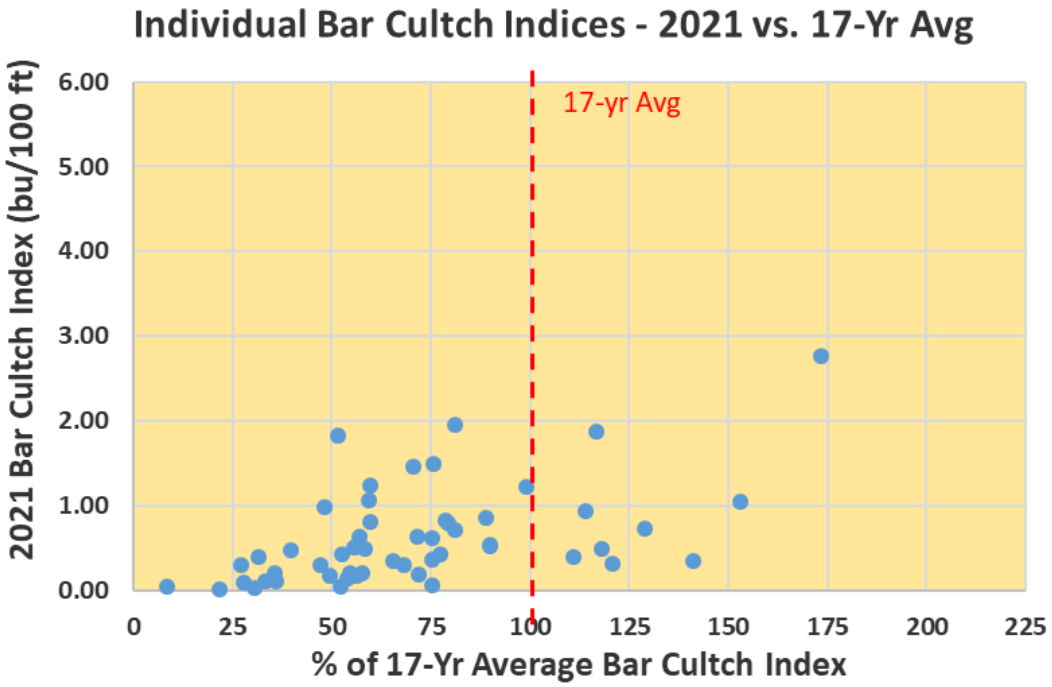

Figure 15. Range of cultch index values for individual Key bars in 2021 and the percent difference from their respective 17-year averages.

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 regions, and to a lesser extent the Patuxent River. All six regions had indexes below their 17-year average (Figure 16). The Potomac region index is somewhat deceptive since it is largely driven by Pagan bar, whose 3-year average is nearly six times as high as the three-year average of the other six bars in this region; if not for Pagan the Potomac region index would be 39% lower. Removing Pagan would also reduce the 17-year average for the Potomac region by 29%.

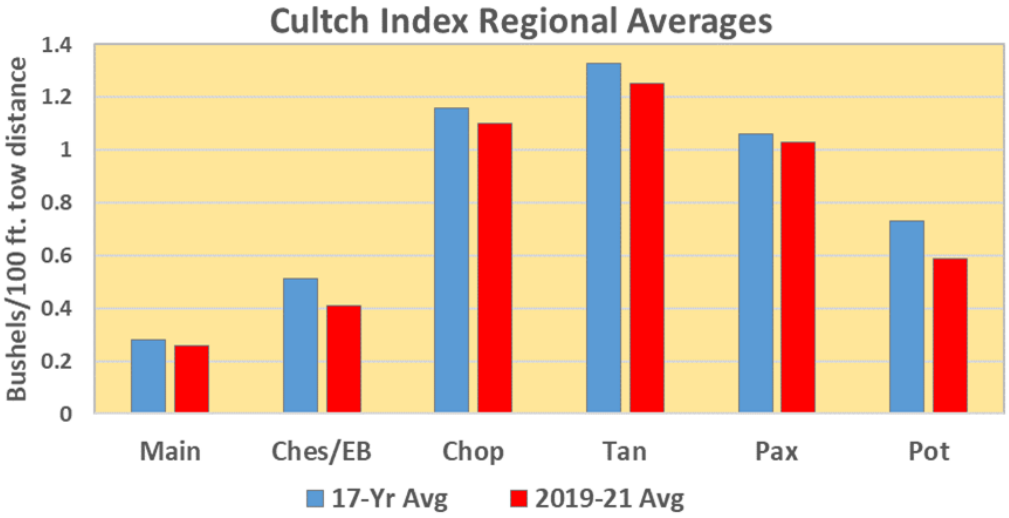

Figure 16. Regional cultch index averages for the 17-year time series and most recent three years. *Main=bay mainstem; Ch/EB=Chester River/Eastern Bay region; Chop=Choptank River region; Tan=Tangier Sound region; Pax=Patuxent River; Pot=Potomac River tributaries*

Cultch volumes among subregions of the broader regions can be highly variable. The greater part of the Tangier Sound region cultch index is contributed by the tributaries and not Tangier Sound proper (Figure 16a). In 2021, the three-year average of the index stations of the five subregional tributaries was 1.21 bu/100 ft. tow distance while the Tangier Sound proper stations averaged 0.85 bu/100 ft. The average cultch indexes for the individual tributaries were substantially higher in the Nanticoke River (1.72 bu/100 ft) and the Manokin River (1.57 bu/100 ft) sanctuaries (Figure 16a).

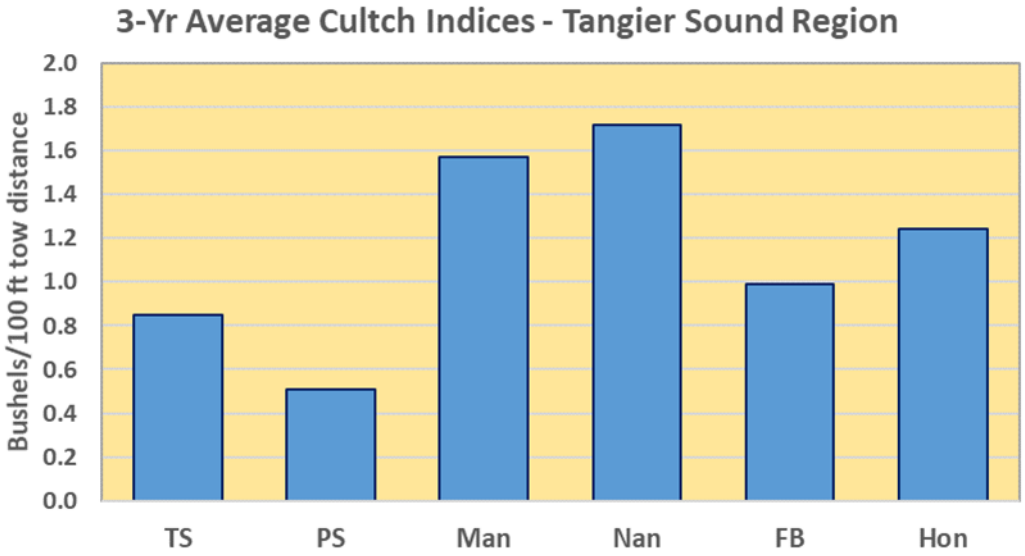

Figure 16a. Three-year rolling average (2019-2022) of bushels of cultch per 100 ft. tow distance for index stations by subregion within the Tangier Sound region. *TS=Tangier Sound; PS=Pocomoke Sound; Man=Manokin River; Nan=Nanticoke River; FB=Fishing Bay; Hon=Honga River*

COMMERCIAL HARVEST

Commercial oyster landings improved substantially during the 2020-21 season. With reported harvests of 347,000 bushels, oyster landings were 28.5% higher than the previous harvest season, the second year in a row of increased harvests (Table 6, Figure 17a). This was the highest harvest total of the past five years. From the long term perspective, landings during the 2020-21 season rose above the 36-year average of 292,000 bu/yr. The average reported price was the lowest in years, dropping to $30.43/bu from the previous year's $45.19/bu, most likely due to Covid-19 impacts to the market. Consequently, the total dockside value fell by $1.7 million to $10.5 million, despite the increase in landings (Table 7a.).

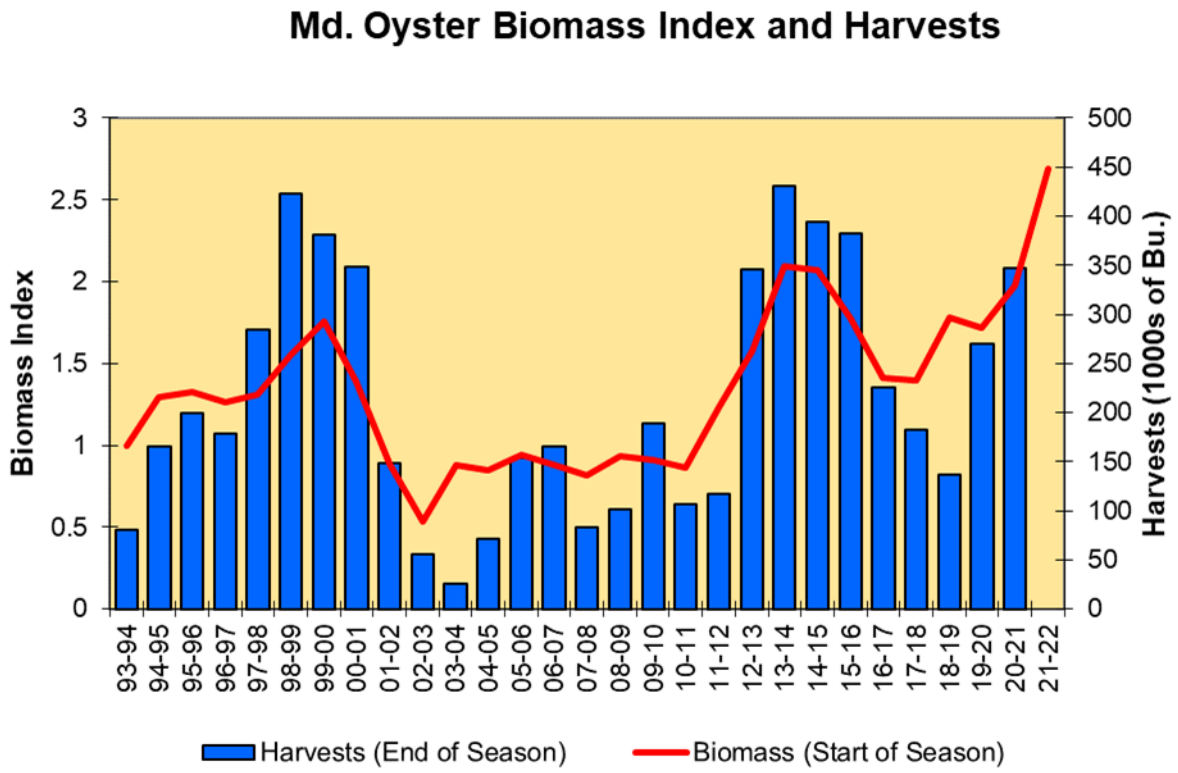

Figure 17a. Maryland oyster landings over the past 29 seasons and the relationship between the Biomass Index calculated at the start of the harvest season and total landings reported at the end of that same season. Note lag between the two metrics when abundant sublegal oysters add to the Biomass Index but have not yet entered the fishery.

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 28 years (and four of these in the most recent 19 years) following the onset of a series of disease epizootics beginning in the mid-1980s.

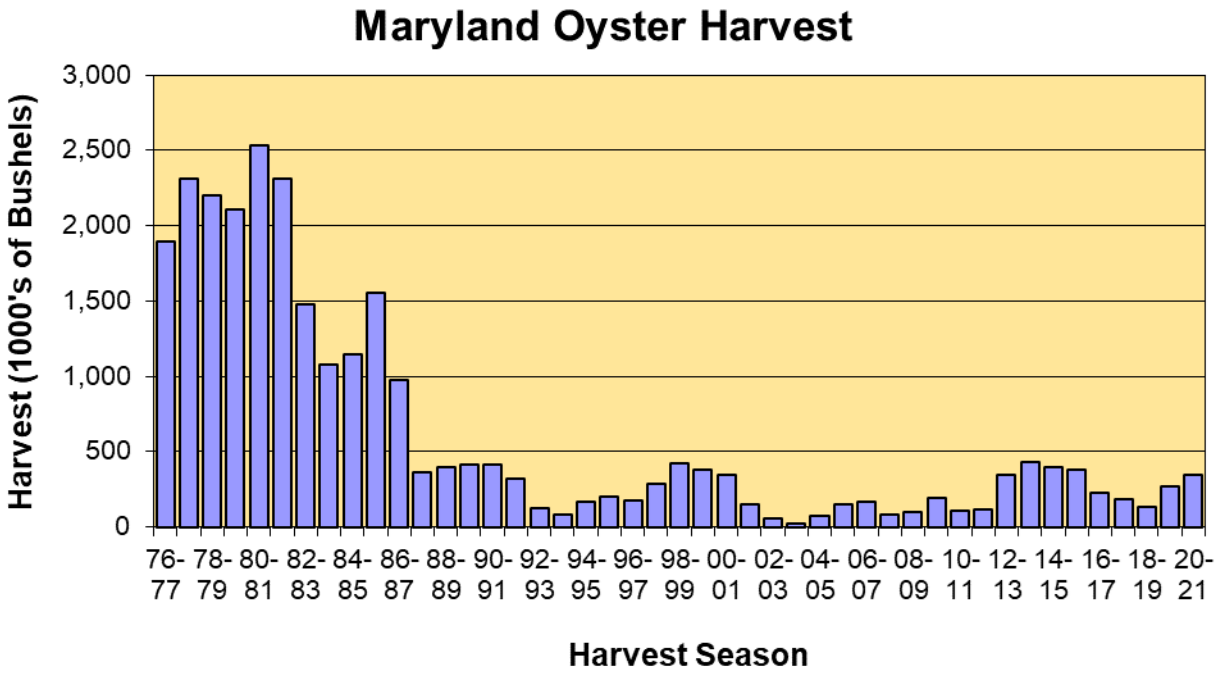

Figure 17b. Maryland seasonal oyster landings, 1976-77 to 2020-21.

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, 2018-19). Prior to the 2012-13 season, the fishery struggled to rebound from the devastating oyster blight of 2002, with the Biomass Index reaching its nadir that year, followed by the record low of 26,000 bu taken in 2003-04. The sizeable harvest increases of 2012-2016 (Figure 17a), following the below-average landings of the 11 years beforehand, were due to the strong 2010 and 2012 year-classes and subsequent good survivorship, allowing a larger proportion of those cohorts to attain market size. This abundance of oysters, as reflected in the Biomass Index, led to an increase in the number of harvesters and fishing effort, resulting in higher landings. However, unexceptional spat sets in 2011, 2013, and 2014 were insufficient to sustain harvests, leading to the substantial drop in landings in the 2016-17 to 2018-19 seasons. The Biomass Index did not parallel this harvest decline, but actually increased in 2019 because of above-median spatfalls in 2015 and 2016. As these two year classes of sublegal-size oysters accumulated, their subsequent growth as well as continued growth of oysters protected in sanctuaries contributed to maintaining the Biomass Index despite the drop in landings. Furthermore, the high streamflows in 2018/19 inhibited the growth of these sublegal oysters, delaying their reaching market size (Tarnowski 2020). As these year classes have entered the fishery, the general correlation between harvests and Biomass Index resumed in the 2019-20 season, with the landings increase in 2020-21 reflecting the rise in the 2020 index.

The Tangier Sound region, with landings of 238,000 bu, was the dominant harvest area, accounting for 69% of the 2019-20 landings in Maryland. The majority of these landings came from upper Tangier Sound (144,000 bu or 42% of the Maryland harvest) (Table 6). The Choptank River region was second with 50,000 bu, providing 14% of the total harvest, primarily from Broad Creek (34,000 bu). With the exceptions of the Tangier Sound Region and to a lesser extent the St. Marys River, the majority of the regions experienced declines in landings to

varying degrees. The most substantial changes (>4,000 bu) in Maryland landings between the 2019-20 and 2020-21 seasons are listed below:

Upper Tangier Sound
-Increased 62,162 bu (+76%)
Lower Tangier Sound
-Increased 23,099 bu (+318%)
Fishing Bay
-Increased 13,376 bu (+58%)
Nanticoke River
-Increased 5,907 bu (+71%)
Honga River
-Increased 5,291 bu (+188%)
Eastern Bay
-Decreased 4,883 bu (-51%)
Broad Creek
-Decreased 4,980 bu (-13%)
Lower Bay Mainstem
-Decreased 5,152 bu (-38%)
Patuxent River
-Decreased 5,685 bu (-25%)

The combined harvests in the entire Tangier Sound region increased by 110,904 bu or 87% from 2019-20. The combined Choptank River region, the second most-productive area, showed a loss of 14,099 bu (-22%). Most regions were below their long-term harvest averages, except several areas within the Tangier Sound region and the Patuxent and St. Marys rivers (Table 6).

The northern portion of the mainstem and associated tributaries continued to perform poorly due to a lack of recruitment and repletion activity. For example, the combined percentage of landings from the upper bay and Chester River, which in 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). Furthermore, most of the region above the Bay Bridge was closed to harvest during the 2020-2021 season. For reference, the 36-year harvest average for these two regions was 32,000 bu/year, primarily sustained by numerous seed plantings from the MDNR Repletion Program. Similarly, 2020-2021 harvests from the once-productive Eastern Bay region were only 17% of the 36-year average.

Gear types showing gains in harvests from the previous season included power dredging, patent tonging, and sail dredging, while hand tonging and diving declined (Table 7a). For the 14th consecutive season, power dredging was the predominant method of harvesting, accounting for 42% of the total landings (Table 7b). This activity was mainly in the lower Eastern Shore and Choptank regions. Patent tonging was second, producing 30% of the total harvests. Meanwhile, hand tonging slipped to 12% of the landings, primarily from Broad Creek - well below 74% of the landings during the 1996-97 season when power dredging was largely prohibited.

OYSTER SANCTUARIES

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

A total of 86 oyster bars within 31 sanctuaries were sampled during the 2021 Fall Survey (Table 8). For comparison among areas, oyster counts were standardized to 100 ft tows, as the number per bushel count does not take into account varying tow lengths. Recruitment within the priority sanctuaries and adjacent open harvest areas was generally above their respective Key Bar 17-year averages (Table S-1). The exceptions were Broad Creek (not including Royston bar), the Manokin River, and the adjacent mid-Tangier Sound open area. A comparison of spatset between the priority sanctuaries and adjacent harvest areas showed the sanctuaries to have consistently higher recruitment to varying degrees (Table S-1). The St. Marys Sanctuary had the highest regional recruitment, which was an order of magnitude higher than in 2020 (47 spat/100 ft). Broad Creek ran counter to this generalization with the second highest recruitment average, although well below the exceptional recruitment (1,022 spat/100 ft) of the previous year. However, the Broad Creek recruitment average is about five times as high as the Harris Creek Sanctuary over the 17-year time series, while in 2021 the difference in spatset between the tributaries was only twofold. Note that 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. 2021 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 2021 Sm+Ma** (#/100 ft tow)	**Regional 2021 Spat** (#/100 ft tow)	**2021 Avg. Tow Dist.** (ft)	***KB Spat*** *17-yr Avg* (#/100 ft tow)
Harris Cr.	Sanc.	326	72	103.7	47.8
Harris Cr.	Open	157	57	268.8	11.0
Broad Cr.	Open	398	86	146.3	51.2[b]
Broad Cr.[a]	Open	727	147	86.5	240.1
Tred Avon R.	Sanc.	353	38	76.0	12.9
Tred Avon R.	Open	116	31	142.2	*n/a*
L.Choptank R.	Sanc.	417	69	97.3	62.4
L.Choptank R	Open	119	13	195.9	6.5
Manokin R.	Sanc.	425	85	70.2	182.8[b]
Mid-Tangier S.	Open	174	55	181.2	67.0[b]
St. Marys R.	Sanc.	112	412	64.0	214.4
St. Marys R.	Open	87	50	160.5	25.0

[a] Not including Royston bar.

[b] Average of two Key Bars.

The average number of adult (small and market) oysters per 100 ft tow in the priority sanctuaries was consistently higher than in adjacent harvest areas, aside from Broad Creek without Royston. Excluding Broad Creek, the sanctuaries had two and a half times as many adult oysters as the adjacent open areas. 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 (Table S-1), thanks to the extraordinary spatset in 2020.

Twenty oyster disease samples from both Disease Bars and supplemental stations were obtained from 18 priority and non-priority sanctuaries. The average dermo disease levels in these sanctuaries have been slowly rising since the record lows in 2019 (average prevalences of 49.2% in 2021 vs. 43.6% in 2020 and 36.1% in 2019; mean intensities of 1.7 in 2021 vs. 1.4 in 2020 and 1.3 in 2019). Of the 13 sentinel Disease Bars within oyster sanctuaries, only Flag Pond had dermo disease prevalences and intensities above the 32-year site averages (Table 3). Dermo disease levels on Disease Bars in the open harvest areas were about two-thirds of those in the sanctuaries, averaging 32.8% prevalence and 1.1 mean intensity (Table S-2), which were slight increases from the previous year. The higher dermo disease levels in the sanctuaries can be attributed to the fact that they had a greater proportion of larger, older oysters than the harvest bars (Figure 18); parasite burdens tend to build up as oysters age (Ford & Tripp 1996). MSX disease was detected at two of the supplemental disease sites within sanctuaries (NW Middleground and Piney Island East Addition 1) but not in the priority sanctuaries, as well as five Disease Bars in open harvest areas, including two bars in this comparison (Back Cove and Piney Island East) (Table 4).

Table S-2. 2021 Dermo disease levels and observed mortality estimates for disease bars and regional averages on priority restoration sanctuaries and nearby harvest areas. In these comparisons, MSX disease was only detected at Piney Island East and Back Cove, each with 3% prevalence. Dermo disease and mortality averages for combined Disease Bars and Supplemental sites both within and outside sanctuaries are also presented.

Region	Disease Bar	Status	Dermo		Observed Mortality %	
			Prevalence%	Intensity	Disease Bar	Regional
Harris Cr.	Mill Pt./Rabbit I.[a,b]	Sanc.	56	1.8	5.9	4.0
Harris Cr.	Tilghman Wharf	Open	40	1.1	0.5	0.6
Tred Avon R.	Double Mills	Sanc.	70	2.3	5.5	2.8
Mid-Choptank R	Lighthouse	Open	0	0.0	1.1	1.8
Broad Cr.	Deep Neck	Open	57	1.4	1.3	1.3
L. Choptank R.	Cason	Sanc.	57	1.7	2.5	2.2
L. Choptank R.	Ragged Pt.	Open	77	2.2	3.5	6.7
Manokin R.	Georges	Sanc.	73	2.6	9.4	7.1
Mid-Tangier S.	Piney I E/Back Cove[a]	Open	53	1.6	5.2	3.7
St. Marys R.	Pagan	Sanc.	70	2.4	11.0	49.7
St. Marys R.	Chicken Cock	Open	30	1.1	5.6	13.1
Average of all Sanctuary Disease Samples[c]			49.2	1.7	5.8	
Average of all Harvest Disease Samples[c]			32.8	1.1	4.0	

[a] Dermo disease and mortality values are averages of the two bars. [b] Supplemental bars and not part of the Disease Index set.
[c] Including both Disease Bars and Supplemental sites.

The higher dermo disease levels in the sanctuaries did not appear to contribute to elevated observed mortalities. All 13 Mortality Index bars within sanctuaries had observed mortalities

below their respective 37-year individual bar averages (Table 5). For the Mortality Index bars, observed mortalities averaged slightly higher in sanctuary bars (5.8%) than their proximal open harvest bars (4.0%) (Table S-2). Aside from the St. Marys Sanctuary, the regional averages associated with the other four priority sanctuaries and adjacent harvest areas showed extremely low observed mortalities.

Of the 43 Biomass Index bars, 13 bars are within sanctuaries (Table 8). Recent trends in biomass, as measured in grams/bushel (g/bu), have been positive both in sanctuaries and harvest areas, with the results from 2021 exceeding their long-term averages by 67% and 118% respectively. In the open harvest areas, the average biomass per index bar in 2021 rose substantially higher from the previous year, from 152.2 g/bu to 232.1 g/bu. The average biomass gain in the sanctuaries was more modest, increasing from 202.3 g/bu in 2020 to 214.1 g/bu in 2021.

The distributions of oyster biomass between the two management areas were distinctly different. The Biomass Index bars in the sanctuaries had higher biomass in the larger size classes, while the open areas had greater biomass in the sublegal and smaller market size classes (Figure 18). Both management categories experienced growth in the average market biomass per bar from the previous year. Although the average market oyster biomass in the sanctuaries declined slightly to 171.3 g/bu (-1.7%), it remained higher than the open harvest areas, which showed strong growth to 154.4 g/bu (+35.9%). The average biomass of sublegal oysters increased substantially to 42.9 g/bu (+52.7%) in the sanctuaries and 77.6 g/bu (+101.0%) in the harvest areas.

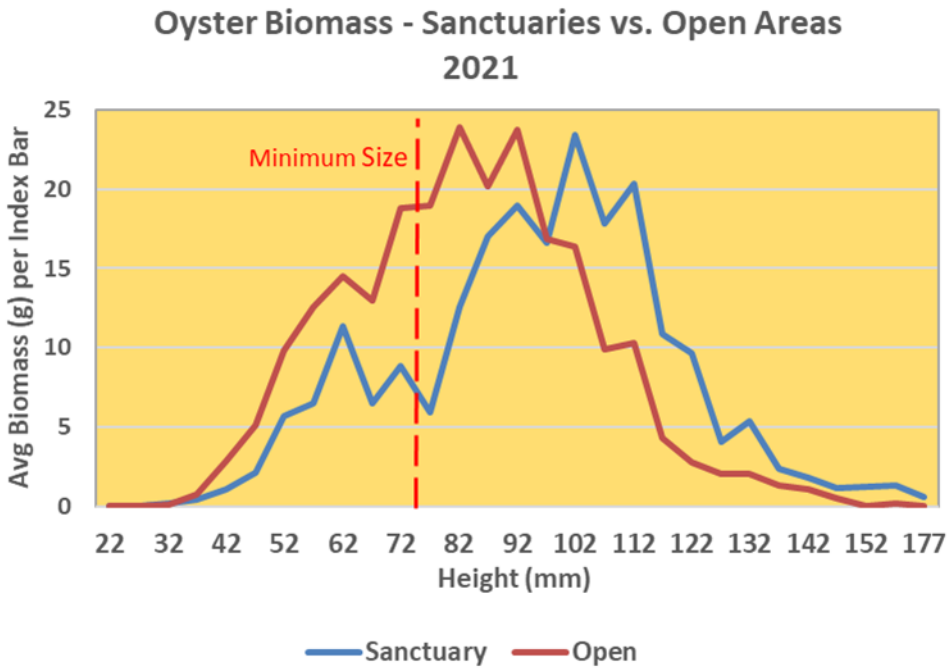

Figure 18. Average oyster biomass by 5 mm size classes on Biomass Index bars in harvest areas and sanctuaries. Dashed line indicates minimum legal harvest size.

A different picture emerges when comparing the Biomass Index bars in the large-scale restoration sanctuaries with their respective adjacent open areas. The average biomass standardized to a 100 ft tow distance for these five sanctuary bars was 524.6 g/bu, compared to

the average biomass/100 ft tow on the seven Biomass Index bars in adjacent open areas of 239.1 g/bu. Aside from Deep Neck bar in Broad Creek, the biomass on the sanctuary Index bars was substantially higher than their respective open area Index bars (Figure 19). This was a function of higher oyster densities in the sanctuaries as reflected by the shorter average tow distance (71.1 ft for the five sanctuary bars versus 246.2 ft for the seven open area bars). In addition, the sanctuary oysters were generally larger with a modal height of 62 mm, whereas the modal height in the adjacent open areas was 52 mm.

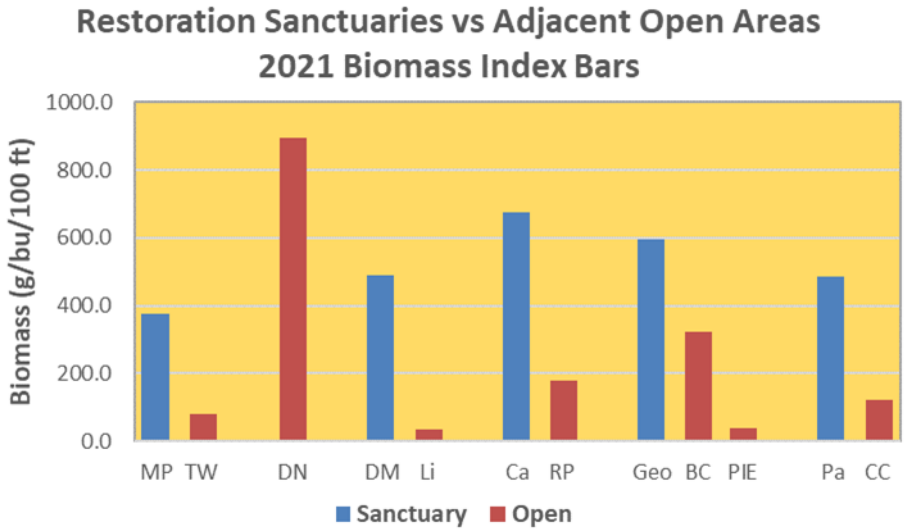

Figure 19. Comparison of biomass/100 ft tow between Biomass Index bars in the large-scale restoration sanctuaries and adjacent open areas. See Table S-2 for the locations of these bars. *MP=Mill Point (not a Biomass Index bar), TW=Tilghman Wharf, DN=Deep Neck, BM=Double Mills, Li=Lighthouse, Ca=Cason,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

The average size of adult oysters (equal to or greater than one-year old) on the Biomass Index bars in the sanctuaries decreased from the previous year (81.5 mm in 2021 vs. 86.4 mm in 2020), while the harvest bars also showed a decline in average size (72.4 mm in 2021 vs.76.8 mm in 2020). These decreases were driven by the influx of small oysters from the recent strong recruitment events. The difference in average sizes between the two management types is reflected in the proportion of sublegal oysters in each. Sublegal oysters comprised 42.9% of the adult oysters in the sanctuaries and 56.1% in the open areas. The largest oyster observed in a sanctuary had a shell height of 177 mm, compared with 157 mm maximum shell height on a harvest bar.

Cultch, the substrate required for spatset, was at lower densities in the open harvest areas than the restoration sanctuaries, as indicated by the longer tow distances required to obtain a sample in the open areas (Table S-1). Again, Broad Creek was the exception when Royston bar was not included in the average, falling close to the range of sanctuary tow distances. This is supported by the actual cultch volume per sample, standardized to 100 ft. tows. Four of the five sanctuaries had higher cultch volumes compared to their immediately adjacent open areas (Figure 19). Cultch volumes were about the same between open and closed areas in the Tred Avon River. The St. Marys had substantially more cultch than the other areas; Broad Creek was second. The lowest cultch volume was found in the mid-Tangier Sound harvest area, which was half of that in the proximal Manokin River Sanctuary.

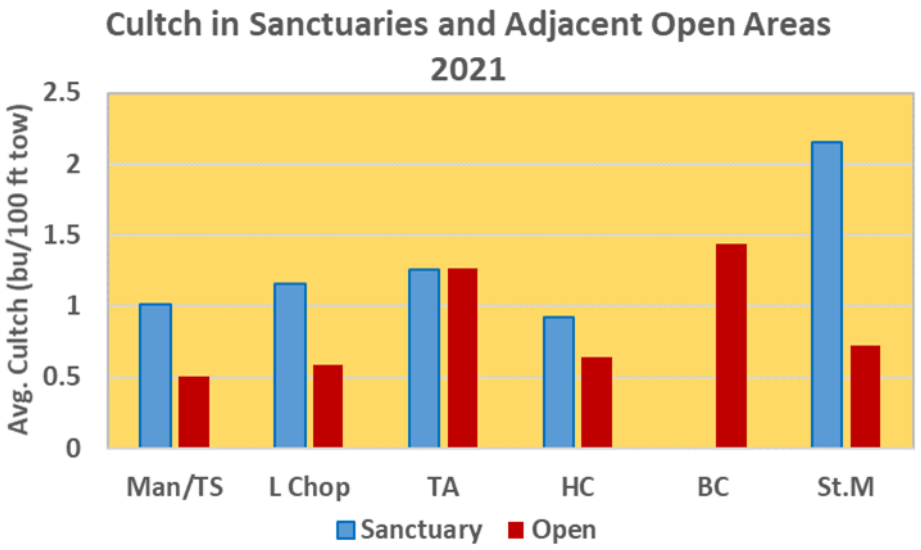

Figure 19. Comparison of cultch volumes between sanctuaries and adjacent open areas in 2021. All stations with sufficient data within an area were included in the averages, standardized to 100 ft. tow distances. *Man=Manokin River; TS=mid-Tangier Sound; L Chop=Little Choptank River; TA=Tred Avon River; HC=Harris Creek; BC=Broad Creek; St.M=St. Marys River*

DISCUSSION

Resiliency and the Road to Recovery

The Eastern Oyster *Crassostrea virginica* is a resilient species, living as it does in the harsh and highly variable environment of coastal estuaries. There it is subjected to seasonal variations if temperature ranging from -2°C to 30°C. It can inhabit a wide range of salinities down to as low as 5 ppt and can survive extended bouts of freshwater input. Another key to this species' success is its method of reproduction. It is a broadcast spawner, releasing vast quantities of gametes into the environment. Once fertilized, the resulting larvae reside in the water column for about two weeks, carried along by the vagaries of wind and current. This potentially allows them to recolonize bars where oysters have been devastated by freshets or disease, or occupy new areas such as directed shell plantings.

Beginning in the mid-1980s through 2002, the resiliency of Maryland's oyster population was tested by successive waves of disease epizootics, culminating in record high levels of dermo disease and MSX at the turn of the millennium. The result was catastrophic – in 2002 the Maryland-wide oyster observed mortality index was 58%, with populations in some tributaries such as the Little Choptank River suffering mortalities of over 90%. Harvests plummeted to their lowest point in 150 years of oystering due to these extreme disease impacts.

The extended drought that fueled these epizootics finally came to an end in 2003 with higher than normal freshwater input dropping disease levels and lowering mortalities. But recovery was stagnant for the remainder of that decade, with the Biomass Index remaining below the baseline of 1.0 established by the previous low point in 1993. The strong recruitment event in 2010, marked a turning point – the start of recovery for at least some segments of the population. Since then the parameters used to assess the status of the population have generally trended in a positive direction over the past 12 years, continuing with notable markers in 2021.

Recruitment as the First Step to Recovery

The first positive indicator to discuss is the Spat Index, which measures annual recruitment or spatset at fixed stations throughout the bay. The 2021 Spat Index was almost double the 37-year time series, continuing a trend that began in 2010. Six of the last 12 years have had above-median spat indexes, three of which can be considered exceptional (i.e., three to five times higher than the long-term median). Only two years during this period were substantially (>25%) below the long-term median, both during periods of high freshwater inputs.

Resilience and recovery is predicated on recruitment to build the population and survival to sustain it. A sustainable recovery cannot be expected without recruitment. Conditions for different regions can vary considerably, enhancing or impeding recovery. The upper bay is an area with severely depleted oyster populations due to consistently poor to non-existent spatsets, but in reality this example can be extended down the mainstem and Western Shore tributaries almost to the Patuxent River.

Over the past two decades, Eastern Bay has been in a similar situation of poor spatsets. At one time this was a highly productive region where the state had even established seed production areas, which routinely produced millions of oyster spat. The record high Spat Index in 1997 was driven by the Eastern Bay region, where spat counts on many bars were in the thousands per bushel. Consequent harvest in the region rose to as high as 152,000 bu. But the disease outbreak

began, with observed mortalities averaging up to 50% in 2002 and as high as 85% on individual bars. Annual landings since then have been well below the long-term average. Recovery has stalled, and the Eastern Bay remains a vestige of its former productive self. That said, the 2021 spatset in this region, including the Miles and Wye rivers, offers a glimmer of hope that the situation can turn around. Although the spatset is modest in scope, it is a considerable improvement for the once-thriving area that has endured repeated recruitment failures in recent years.

In contrast to Eastern Bay, a prime example of resiliency and recovery is the oyster population in the St. Marys River. Observed mortalities were even higher than in Eastern Bay in 2001, averaging 80%, yet harvests, which had been nonexistent in 2003 and 2004, exceeded the long-term average by 2013. A rapid start to recovery from another high mortality event was also observed in 2021. During 2020, what is believed to have been an extended hypoxic event in the sanctuary portion of the river resulted in an average observed mortality of 66.6%. Pagan bar, one of the index sentinel sites, had 49% mortality. Yet in 2021, the St. Marys River had the highest average spatset of any region and Pagan bar had the highest spat count of the Index bars and second highest for all bars.

While success or failure of recruitment have many known factors and likely some unknown, certain differences in the course and timing of recovery stand out between Eastern Bay and the St. Marys River:

- In Eastern Bay, the epizootics were widespread and devastating, severely depleting broodstock necessary for spawning. On the other hand, the heaviest losses in the St. Marys were largely confined to the sanctuary portion of the upper river. Adequate numbers of broodstock oysters remained in the lower harvest portion of the river, as well as on Pagan bar in the sanctuary despite the high mortality at that location.
-An insidious problem in many parts of the bay including the Eastern Bay region is the disappearance of hard surface substrate or cultch –primarily oyster shell - for the oyster larvae to attach to. This paucity of cultch is well documented by the Fall Survey, and by the simple fact that it requires longer tow distances to obtain a sample. Taphonomic processes such as burial, settling into the bottom, displacement from the bar, etc. resulting in shell loss are exacerbated by the long open wind fetch from western points into Eastern Bay. In contrast, the St. Marys River has good quantities of cultch. And because the high mortalities of the previous year occurred in the sanctuary, additional shell was retained within the system rather than if the oysters had been harvested. This part of the river is relatively sheltered from severe wave action, reducing some taphonomic processes.
-Hydrodynamics also play an important role in how the larvae are distributed and where the ultimately settle out. The smaller and more confined St. Marys River is considered a trap estuary, one which retains larvae and consistently produces good spat sets. Eastern Bay obviously must have had favorable hydrodynamics to be so productive in the past, but it is a much more open system than the St. Marys River. Whether flow patterns have changed is unknown. More likely, broodstock that had been strategically located as sources of larvae within those currents have disappeared, which, along with the loss of cultch, have led to repeated recruitment failures.

Cultch is Critical to Recruitment

A key factor for successful recruitment is adequate hard surface such as clean oyster shells on which the oyster larvae can attach. This was illustrated by a series of demonstration shell plantings made in recent years just outside the restored Harris Creek and Little Choptank sanctuaries. Spatset on the plantings outperformed samples from the unplanted part of the same bars by factors ranging from 1.6 to 3.7. The one exception when the spatset was about the same low count for both planted and unplanted samples was during a poor recruitment year overall. The location of these plantings just outside of the sanctuaries suggest that the sanctuaries may be the source of the larvae, although it is impossible to ascertain where the spat originated.

Unfortunately, the cultch situation on unrestored or unplanted bars appears to be deteriorating. For example, in 2021 it took an average tow of 507 ft to obtain a sample from Tilghman Wharf, an index bar in the open harvest portion of Harris Creek. In 2006, it took an average tow of 180 ft to obtain a sample at that same location. For comparison, the average tow distance for the sanctuary samples was 104 ft in 2021. Similar examples can be found throughout the bay.

Improved Survivorship

The second necessary ingredient for recovery of oyster populations is good survivorship to first reproduction and beyond. In a year of positive oyster population metrics, one of the most significant was the Maryland-wide Observed Mortality Index. At 6.0%, the 2021 index was the lowest of the 37-year time series and well below the long-term mean of 21.5%, continuing an 18-year period of below average mortalities as a consequence of low to moderate disease pressure. The average observed mortality of 13.1% over these last 18 years approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (MDNR, unpubl. data). This is in remarkable contrast to 2002 when record-high disease levels devastated Maryland populations, resulting in a 58% observed mortality rate.

This trend in improved survivorship has been driven by the subsidence of diseases over the past two decades, with record low levels of both dermo disease and MSX following the freshwater deluge of 2018/19. Although still low, the measures of both diseases crept up slightly in 2021 with the return of normal salinities.

Record High Biomass Index

The Biomass Index is a relative measure of how the oyster population is growing or shrinking over time, integrating several population metrics into a single value. As a consequence of the good recruitment, low disease, and high survivorship in recent years, another significant oyster population milestone was attained in 2021, when the Maryland Oyster Biomass Index reached 2.69, the highest index of the 29-year record and double the long-term average of indexes. This represents a gain of 36% from the previous year and 92% over the last four years. Consequently, another increase in landings can be anticipated for the 2021-22 season and beyond – further sustained in the future by the strong 2020 and 2021 year classes as they attain market size should conditions remain stable.

Conclusion

Two decades after the devastation from the last of the great epizootics, the oyster population in Maryland remains a long way from its pre-disease status of the early 1980s. Even with reduced disease pressure, recovery has been slow and uneven, and some recruitment-poor areas may

never return to historical levels. But the positive trends in population indicators that began 12 years ago and have substantially improved over the past three years offer encouragement that a corner has been turned. Three years is a relatively short period of time for predicting trends, and it remains to be seen whether the oyster population continues to grow. Nevertheless, the past dozen years has seen a net gain for oysters in Maryland, especially when compared with the devastated post-epizootics populations of the previous decade:

- Six of the last 12 years had spat indexes well above the long-term median. Only two indexes during this time frame were substantially below the median, both in high streamflow years.
- Four to six years (depending on the metric) during this period had the lowest disease levels of the 32-year time series.
- The average observed mortality for this period was lower than any but one year[3] of the 25 mortality index years prior to 2010.
- The six highest annual biomass indexes of the 29-year time series occurred during the past decade.

Whether these trends will continue remains to be seen. But barring the resurgence of disease or some yet unknown threat, there is every reason to believe that oysters can continue to flourish in Maryland. They are a resilient species.

[3] 1985 – the last pre-epizootics year

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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.

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Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 "Key" spat monitoring bars, 1985-2021. (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	*37-Yr Avg*
Mountain Point	0	0	0	0	0	0	0	*0.3*
Swan Point	0	0	0	0	0	0	0	*0.4*
Brick House	0	0	0	0	0	0	1	*5.9*
Hackett Point	0	0	0	0	0	0	0	*0.6*
Tolly Point	0	2	0	0	1	0	0	*0.7*
Three Sisters	0	0	0	0	1	0	1	*0.7*
Holland Point (S)	0	0	0	0	0	1	0	*0.5*
Stone Rock	2	17	0	4	6	7	1	*22.8*
Flag Pond (S)	10	12	28	0	2	0	0	*21.4*
Hog Island	9	22	1	0	19	8	14	*17.4*
Butler	68	90	2	1	42	34	65	*40.3*
Buoy Rock	0	0	0	0	0	0	0	*1.2*
Parsons Island	8	0	0	0	2	0	13	*101.1*
Wild Ground	15	0	0	0	1	2	9	*38.0*
Hollicutt Noose	1	0	0	0	0	2	7	*4.8*
Bruffs Island (S)	0	0	0	0	0	0	28	*25.4*
Ash Craft	0	0	0	0	0	1	14	*65.9*
Turtle Back	13	4	0	0	0	5	42	*121.9*
Shell Hill	4	2	1	5	2	0	7	*7.0*
Sandy Hill (S)	0	3	1	0	2	5	18	*11.5*
Royston	21	13	23	22	0	231	96	*56.2*
Cook Point (S)	1	21	2	4	7	68	28	*18.4*
Eagle Pt./Mill Pt. (S	34	68	55	28	0	187	51	*43.2*
Tilghman Wharf	45	58	13	40	5	247	134	*71.4*
Deep Neck	83	91	205	119	17	1838	162	*163.1*
Double Mills (S)	9	12	3	1	1	74	21	*19.2*
Ragged Point	19	125	35	2	1	18	6	*53.8*
Cason (S)	11	60	67	9	4	613	62	*101.3*
Windmill	16	9	9	4	12	62	66	*51.1*
Norman Addition	34	60	44	13	24	227	170	*83.8*
Goose Creek	11	44	27	23	18	448	44	*42.7*
Clay Island	43	68	41	43	14	43	35	*46.5*
Wetipquin (S)	2	6	0	21	33	15	13	*6.0*
Middleground	12	32	66	49	138	100	41	*31.4*
Evans	14	18	1	7	37	52	66	*14.8*
Mt. Vernon Wharf	1	3	1	10	7	42	4	*4.0*
Georges (S)	29	61	137	40	78	185	20	*70.9*
Drum Point (S)	59	172	78	110	160	445	61	*106.9*
Sharkfin Shoal	57	53	32	23	14	17	21	*27.6*
Turtle Egg Island	64	57	15	69	88	122	66	*89.6*
Piney Island East	3	0	2	0	68	196	103	*100.5*
Great Rock	13	4	14	93	151	258	44	*42.7*
Gunby	95	73	34	25	46	18	54	*57.2*
Marumsco	141	69	31	8	61	53	29	*40.7*
Broome Island	6	21	6	1	12	1	73	*8.4*
Back of Island	18	42	5	5	13	7	18	*14.1*
Chicken Cock	712	33	19	5	10	37	111	*79.5*
Pagan (S)	24	91	247	7	15	53	426	*169.4*
Black Walnut (S)	3	4	0	0	0	0	0	*1.4*
Blue Sow (S)	0	10	0	0	0	1	1	*4.3*
Dukehart Channel	0	3	0	0	0	0	0	*1.6*
Ragged Point	1	11	2	2	0	4	9	*5.4*
Cornfield Harbor	100	92	6	6	108	55	70	*72.7*
Spat Index	**34.2**	**30.9**	**23.6**	**15.0**	**23.0**	**109.1**	**43.9**	***41.3***
Median	**10**	**12**	**2**	**2**	**5**	**17**	**21**	***23.0***

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Table 3. *Perkinsus marinus* prevalence and mean intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2021. NA = insufficient quantity of oysters for analytical sample. (S) = bar within an oyster sanctuary since 2010.

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

Table 3 - Dermo (continued).

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

Table 3 - Dermo (continued).

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

Table 3 - Dermo (continued).

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

Table 3 - Dermo (continued).

Oyster Bar	***Perkinsus marinus* Prevalence (%) and Mean Intensity (I)**											
	2013		2014		2015		2016		2017		2018	
	%	I	%	I	%	I	%	I	%	I	%	I
Swan Point	27	0.4	3	0.0	33	0.3	3	0.0	3	0.0	0	0.0
Hackett Point	13	0.6	0	0.0	10	0.3	40	1.2	56	1.6	27	0.9
Holland Point (S)	5	0.1	0	0.0	0	0.0	27	0.6	47	1.2	7	0.1
Stone Rock	67	2.0	100	4.0	93	4.5	97	4.4	83	3.4	53	1.7
Flag Pond (S)	23	0.8	10	0.3	18	0.5	50	1.9	52	1.6	27	0.6
Hog Island	27	0.9	43	1.2	87	3.0	97	4.3	100	4.5	63	2.1
Butler	70	2.4	73	2.4	60	2.0	37	1.5	63	2.2	73	2.1
Buoy Rock	27	0.6	13	0.4	17	0.2	20	0.7	30	0.8	0	0.0
Old Field (S)	57	1.5	47	1.5	57	1.7	63	2.1	60	2.1	27	0.7
Bugby	73	2.5	83	2.8	87	3.3	90	3.3	97	3.3	43	1.1
Parsons Island	30	0.9	15	0.4	53	1.3	77	2.2	83	2.9	43	1.3
Hollicutt Noose	13	0.4	23	0.6	33	0.7	50	1.5	57	1.8	17	0.5
Bruffs Island (S)	37	1.2	23	0.7	77	2.0	100	4.2	97	4.3	63	1.9
Turtle Back	63	2.2	80	2.5	100	4.2	83	3.5	83	3.2	70	2.1
Long Point (S)	37	1.2	10	0.4	20	0.5	73	2.6	36	1.1	7	0.3
Cook Point (S)	97	3.2	80	3.1	90	3.3	100	4.6	90	3.5	63	1.6
Royston	60	2.0	60	2.0	63	2.1	47	1.5	43	1.5	17	0.5
Lighthouse	10	0.3	10	0.3	23	0.5	10	0.4	17	0.4	7	0.2
Sandy Hill (S)	93	2.8	77	2.4	93	3.3	93	4.0	96	3.9	53	1.4
Oyster Shell Pt. (S)	7	0.2	3	0.0	40	1.0	80	2.6	77	2.8	57	1.8
Tilghman Wharf	10	0.2	7	0.1	20	0.6	47	1.5	70	2.2	47	1.2
Deep Neck	80	3.1	67	1.8	93	2.9	80	3.1	77	2.4	57	1.3
Double Mills (S)	83	3.1	73	2.6	70	2.9	87	3.6	97	3.9	67	2.1
Cason (S)	80	2.8	90	2.8	93	2.8	100	4.2	97	3.3	77	2.2
Ragged Point	97	3.0	83	2.3	100	3.2	93	4.0	97	3.7	67	1.7
Norman Addition	80	3.1	87	3.7	77	2.7	93	3.6	93	3.2	63	2.0
Goose Creek	80	2.6	83	2.5	100	3.4	93	4.3	80	3.0	70	2.7
Wilson Shoals (S)	93	3.0	90	3.4	80	2.8	90	3.2	87	3.2	73	2.1
Georges (S)	83	3.4	97	3.9	93	3.9	83	3.4	97	3.9	77	2.7
Holland Straits	90	3.7	80	3.6	83	3.0	13	0.3	30	0.6	7	0.2
Sharkfin Shoal	93	3.5	90	3.4	77	2.8	90	4.1	93	4.1	57	2.1
Back Cove	93	3.9	80	3.1	77	3.2	30	0.9	30	0.9	3	0.1
Piney Island East	63	2.0	40	1.4	53	1.8	60	2.4	70	2.3	27	1.1
Old Woman's Leg	52	1.3	60	2.6	67	2.1	11	0.2	50	1.6	6	0.1
Marumsco	100	4.4	80	3.5	90	3.6	93	3.7	100	3.9	63	1.6
Broome Island	93	3.2	70	1.9	80	2.6	90	3.8	93	4.0	50	1.3
Chicken Cock	50	1.2	67	1.9	67	2.1	73	2.4	97	3.1	63	2.1
Pagan (S)	77	2.4	83	2.1	83	2.9	83	3.1	80	3.1	63	1.4
Lancaster	30	1.2	20	0.8	3	0.2	37	1.6	47	1.8	10	0.1
Mills West	70	2.1	53	1.8	57	1.7	40	1.8	60	2.0	3	0.1
Cornfield Harbor	90	3.1	80	3.1	57	1.8	63	2.6	97	3.6	63	1.9
Ragged Point	0	0.0	3	0.0	0	0.0	3	0.0	7	0.1	0	0.0
Lower Cedar Point	20	0.4	3	0.1	55	1.6	33	1.1	50	1.6	0	0.0
Annual Means	**57**	**1.9**	**52**	**1.8**	**61**	**2.1**	**63**	**2.5**	**69**	**2.5**	**40**	**1.2**
Bar Freq. (%)	**98**		**95**		**95**		**100**		**100**		**91**	

Table 3 - Dermo (continued).

Oyster Bar	***Perkinsus marinus* Prevalence (%) and Mean Intensity (I)**							
	2019		2020		2021		*32-Yr Avg*	
	%	I	%	I	%	I	*%*	*I*
Swan Point	3	0.1	0	0.0	0	0.0	*25.3*	*0.6*
Hackett Point	10	0.5	30	0.9	40	1.8	*48.2*	*1.5*
Holland Point (S)	0	0.0	0	0.0	3	0.1	*37.2*	*1.1*
Stone Rock	23	1.0	23	0.6	10	0.3	*67.8*	*2.3*
Flag Pond (S)	13	0.5	87	3.0	90	3.8	*48.9*	*1.6*
Hog Island	27	1.0	30	1.0	30	0.7	*69.8*	*2.6*
Butler	60	2.0	60	2.0	80	2.8	*67.1*	*2.1*
Buoy Rock	3	0.1	0	0.0	13	0.3	*47.7*	*1.5*
Old Field (S)	17	0.4	20	0.7	17	0.6	*54.4*	*1.6*
Bugby	90	2.8	57	1.6	67	2.2	*79.8*	*2.6*
Parsons Island	7	0.4	23	0.5	3	0.07	*67.0*	*2.2*
Hollicutt Noose	13	0.5	13	0.4	10	0.2	*56.4*	*1.8*
Bruffs Island (S)	70	2.3	33	0.8	57	2.3	*71.3*	*2.3*
Turtle Back	73	2.9	67	2.2	37	1	*82.1*	*2.8*
Long Point (S)	3	0.03	13	0.3	27	1	*60.6*	*2.0*
Cook Point (S)	37	1.2	80	2.6	57	2	*58.9*	*2.0*
Royston	20	0.6	60	1.5	13	0.5	*53.1*	*1.9*
Lighthouse	3	0.2	0	0.0	0	0	*41.2*	*1.3*
Sandy Hill (S)	53	2.4	67	2.1	27	0.7	*73.0*	*2.7*
Oyster Shell Pt. (S)	3	0.1	20	0.5	13	0.2	*38.6*	*1.1*
Tilghman Wharf	23	0.9	20	0.7	40	1.1	*50.6*	*1.5*
Deep Neck	33	1.2	30	0.9	57	1.4	*76.3*	*2.6*
Double Mills (S)	47	1.8	63	2.2	70	2.3	*78.2*	*2.8*
Cason (S)	60	2.0	50	1.7	57	1.7	*77.5*	*2.6*
Ragged Point	60	1.4	73	2.6	77	2.3	*79.4*	*2.6*
Norman Addition	37	1.5	23	0.8	7	0.3	*74.0*	*2.6*
Goose Creek	27	1.1	53	2.0	63	2.5	*65.7*	*2.3*
Wilson Shoals (S)	30	1.0	47	1.2	60	2	*80.8*	*2.5*
Georges (S)	77	3.1	77	2.9	73	2.6	*80.9*	*2.9*
Holland Straits	0	0.0	0	0.0	3	0.03	*58.9*	*1.9*
Sharkfin Shoal	63	2.4	67	2.7	57	2.8	*80.8*	*2.9*
Back Cove	3	0.2	10	0.3	83	2.6	*75.6*	*2.7*
Piney Island East	17	0.5	3	0.1	23	0.6	*71.8*	*2.4*
Old Woman's Leg	0	0.0	0	0.0	3	0.1	*66.5*	*2.4*
Marumsco	30	1.0	7	0.3	37	1.1	*77.4*	*2.7*
Broome Island	13	0.5	27	0.8	27	0.7	*71.5*	*2.5*
Chicken Cock	27	1.2	23	0.7	30	1.1	*68.9*	*2.3*
Pagan (S)	17	0.4	37	1.1	70	2.4	*76.9*	*2.4*
Lancaster	7	0.2	47	1.5	63	2	*55.9*	*1.7*
Mills West	0	0.0	3	0.2	3	0.2	*52.3*	*1.6*
Cornfield Harbor	40	1.3	53	2.0	43	1.6	*76.1*	*2.4*
Ragged Point	0	0.0	0	0.0	0	0	*18.2*	*0.5*
Lower Cedar Point	NA	NA	10	0.4	17	0.5	*21.8*	*0.6*
Annual Means	**27**	**1.0**	**33**	**1.1**	***36.2***	***1.2***	***62.7***	***2.1***
Bar Freq. (%)	**88**		**84**		***93***		***96.4***	

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2021. NA = insufficient quantity of oysters for analytical sample. ND = sample collected but diagnostics not performed; prevalence assumed to be 0. (S) = bar within an oyster sanctuary since 2010.

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

Table 4 – MSX (continued).

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

Table 4 - MSX (continued).

Oyster Bar	*Haplosporidium nelsoni* Prevalence (%)										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Swan Point	0	0	0	0	0	0	0	0	0	0	0
Hackett Point	0	0	0	0	0	0	0	0	0	3	0
Holland Point (S)	0	0	3	0	0	0	0	0	0	3	0
Stone Rock	10	23	3	0	0	0	0	7	13	10	0
Flag Pond (S)	3	13	7	0	0	0	0	12	10	0	0
Hog Island	7	17	0	0	0	0	0	10	40	3	0
Butler	7	37	17	0	0	0	3	13	48	0	0
Buoy Rock	0	0	0	0	0	0	0	0	0	0	0
Old Field (S)	0	0	0	0	0	0	0	0	0	0	0
Bugby	0	0	0	0	0	0	0	3	3	0	0
Parsons Island	0	0	0	0	0	0	0	0	7	0	0
Hollicutt Noose	0	13	0	0	0	0	0	0	10	0	0
Bruffs Island (S)	0	3	0	0	0	0	0	0	3	0	0
Turtle Back	0	0	0	0	0	0	0	3	7	0	0
Long Point (S)	0	0	3	0	0	0	0	0	0	0	0
Cook Point (S)	7	43	10	0	0	0	0	13	30	3	0
Royston	0	0	0	0	0	0	0	7	30	0	0
Lighthouse	0	13	3	0	0	0	0	0	37	0	0
Sandy Hill (S)	0	0	0	0	0	0	0	0	0	0	0
Oyster Shell Pt. (S)	0	0	0	0	0	0	0	0	0	0	0
Tilghman Wharf	0	3	0	0	0	0	0	7	27	0	0
Deep Neck	0	13	0	0	0	0	0	3	0	0	0
Double Mills (S)	0	0	0	0	0	0	0	0	0	0	0
Cason (S)	0	20	0	0	0	0	0	23	0	0	0
Ragged Point	0	13	10	0	0	0	0	20	17	3	0
Norman Addition	10	33	10	0	0	0	3	3	7	0	0
Goose Creek	7	27	0	0	0	0	0	13	7	0	0
Wilson Shoals (S)	0	7	0	0	0	0	0	3	0	0	0
Georges (S)	0	10	0	0	0	0	0	3	0	0	0
Holland Straits	7	33	23	0	0	0	3	10	13	0	0
Sharkfin Shoal	17	17	10	0	0	0	10	10	0	0	0
Back Cove	13	27	7	0	0	3	10	17	37	13	0
Piney Island East	0	33	7	0	0	10	27	33	10	13	3
Old Woman's Leg	0	27	20	7	3	3	20	23	17	25	0
Marumsco	0	17	3	0	3	0	10	10	0	3	0
Broome Island	0	3	0	0	0	0	0	0	7	7	0
Chicken Cock	13	57	10	0	0	0	0	23	60	7	0
Pagan (S)	0	30	0	0	0	0	0	0	0	0	0
Lancaster	0	0	0	0	0	0	0	0	0	0	0
Mills West	0	0	0	0	0	0	0	0	0	0	0
Cornfield Harbor	10	30	7	0	0	10	10	30	33	7	0
Ragged Point	0	0	0	0	0	0	0	0	3	10	0
Lower Cedar Point	0	0	0	0	0	0	0	0	0	0	0
Avg. Prev. (%)	**2.7**	**13.0**	**3.6**	**0.2**	**0.1**	**0.6**	**2.2**	**7.0**	**11.1**	**2.6**	**0.1**
Pos. Bars (%)	**30**	**60**	**40**	**2**	**5**	**9**	**21**	**56**	**56**	**33**	**2**

Table 4 - MSX (continued).

Oyster Bar	***Haplosporidium nelsoni* Prevalence (%)**			
	2019	2020	2021	*32-yr avg*
Swan Point	0	0	0	*0.0*
Hackett Point	0	0	0	*0.6*
Holland Point (S)	0	0	0	*2.3*
Stone Rock	0	0	0	*8.2*
Flag Pond (S)	0	0	0	*5.0*
Hog Island	0	0	0	*8.4*
Butler	0	0	0	*10.6*
Buoy Rock	0	0	0	*0.0*
Old Field (S)	0	0	0	*0.0*
Bugby	0	0	0	*1.3*
Parsons Island	0	0	0	*1.1*
Hollicutt Noose	0	0	0	*3.5*
Bruffs Island (S)	0	0	0	*0.8*
Turtle Back	0	0	0	*2.3*
Long Point (S)	0	0	0	*0.2*
Cook Point (S)	0	0	0	*9.2*
Royston	0	0	0	*4.5*
Lighthouse	0	0	0	*6.1*
Sandy Hill (S)	0	0	0	*2.5*
Oyster Shell Pt. (S)	0	0	0	*1.2*
Tilghman Wharf	0	0	0	*5.4*
Deep Neck	0	0	0	*3.7*
Double Mills (S)	0	0	0	*1.7*
Cason (S)	0	0	0	*6.6*
Ragged Point	0	0	0	*8.7*
Norman Addition	0	0	0	*10.3*
Goose Creek	0	0	3	*7.3*
Wilson Shoals (S)	0	0	0	*4.3*
Georges (S)	0	0	0	*6.1*
Holland Straits	0	0	0	*14.0*
Sharkfin Shoal	0	0	3	*12.3*
Back Cove	0	0	3	*12.4*
Piney Island East	0	3	3	*14.2*
Old Woman's Leg	0	0	7	*15.4*
Marumsco	3	0	0	*7.8*
Broome Island	0	0	0	*2.0*
Chicken Cock	0	0	0	*11.7*
Pagan (S)	0	0	0	*3.1*
Lancaster	0	0	0	*0.3*
Mills West	0	0	0	*1.5*
Cornfield Harbor	0	0	0	*12.6*
Ragged Point	0	0	0	*3.2*
Lower Cedar Point	NA	0	0	*0.0*
Avg. Prev. (%)	**0.1**	**0.1**	**0.4**	***5.4***
Pos. Bars (%)	**2**	**2**	**12**	***28.4***

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Table 5. Oyster population observed mortality estimates from the 43 disease monitoring bars, 1985-2021.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	*37-yr Avg*
Swan Point	4	0	3	0	0	8	12	3	3	*10.6*
Hackett Point	0	0	0	3	19	3	5	21	23	*12.9*
Holland Point (S)	12	40	29	0	0	50	nd	nd	0	*23.8*
Stone Rock	2	5	31	36	30	9	5	4	3	*21.4*
Flag Pond (S)	15	13	5	6	50	3	1	7	17	*20.7*
Hog Island	2	2	12	38	27	18	0	5	3	*26.6*
Butler	7	7	10	11	4	5	7	14	8	*23.6*
Buoy Rock	5	9	3	12	4	12	9	13	5	*16.4*
Old Field (S)	0	3	0	5	33	10	31	33	7	*14.1*
Bugby	8	31	21	21	13	12	17	18	23	*25.1*
Parsons Island	2	4	15	2	10	14	0	5	0	*20.4*
Hollicutt Noose	1	9	6	7	29	30	8	2	10	*20.4*
Bruffs Island (S)	0	4	5	16	20	41	38	25	20	*23.3*
Turtle Back	0	8	14	18	3	15	8	3	0	*23.9*
Long Point (S)	20	0	0	17	0	0	37	nd	0	*22.3*
Cook Point (S)	9	12	16	48	45	24	13	12	5	*25.9*
Royston	1	6	9	16	4	2	4	3	2	*16.9*
Lighthouse	1	1	2	9	7	0	4	2	1	*19.3*
Sandy Hill (S)	3	13	11	15	15	11	11	4	4	*24.3*
Oyster Shell Pt. (S)	2	5	2	11	11	18	24	12	4	*10.9*
Tilghman Wharf	5	1	5	11	1	7	4	6	1	*16.8*
Deep Neck	5	7	16	8	2	3	3	2	1	*20.0*
Double Mills (S)	11	12	10	20	13	11	2	7	6	*20.1*
Cason (S)	11	8	17	26	33	8	4	2	2	*24.8*
Ragged Point	15	13	21	45	14	6	3	11	4	*25.9*
Norman Addition	9	7	13	14	15	8	2	2	1	*24.0*
Goose Creek	5	15	22	27	6	10	3	4	5	*31.5*
Wilson Shoals (S)	5	4	7	17	6	4	4	6	9	*20.0*
Georges (S)	15	5	8	23	15	9	5	7	9	*27.8*
Holland Straits	9	48	71	18	4	17	4	1	0	*28.5*
Sharkfin Shoal	16	18	24	19	3	7	4	5	13	*30.3*
Back Cove	11	19	14	1	2	8	1	1	4	*21.7*
Piney Island East	7	10	9	21	25	38	33	4	9	*28.8*
Old Woman's Leg	50	75	15	0	50	25	10	5	5	*30.4*
Marumsco	13	13	17	13	20	34	36	4	8	*24.9*
Broome Island	7	8	14	21	3	4	0	4	1	*20.0*
Chicken Cock	1	7	16	32	20	17	20	2	6	*26.8*
Pagan (S)	4	13	22	28	6	4	4	49	11	*21.1*
Lancaster	13	0	3	1	1	10	5	2	5	*14.6*
Mills West	20	9	5	14	0	5	15	21	5	*14.8*
Cornfield Harbor	10	16	10	36	8	3	5	2	3	*27.4*
Ragged Point	0	0	50	10	8	4	33	0	12	*21.8*
Lower Cedar Point	0	0	6	8	27	96	100	100	1	*19.8*
Annual Means	**8**	**11**	**14**	**16**	**14**	**14**	**13**	**10**	**6**	***21.9***

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland from buy tickets, 1985-86 through 2020-21 seasons as reported by seafood dealer buy tickets.

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

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

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

Maryland Oyster Harvests (bu)							
Region/Tributary	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	*36-yr Avg*
Upper Bay	3,648	4,693	2,580	747	48	69	*11,608*
Middle Bay	13,019	11,072	5,134	3,005	4,715	4,020	*14,535*
Middle Bay Tributaries	2,409	1,876	1,169	184	804	1,005	*1,241*
Lower Bay	4,285	4,314	9,112	11,083	13,380	8,228	*6,281*
Total Bay Mainstem	*23,360*	*21,955*	*17,995*	*15,019*	*18,947*	*13,322*	*32,232*
Chester R.	1,547	569	5,135	613	690	23	*19,902*
Eastern Bay	13,091	15,576	9,663	8,566	9,553	4,670	*27,335*
Miles R.	3,335	1,666	527	962	180	0	*4,862*
Wye R.	18	17	21	0	0	0	*1,723*
Total Eastern Bay Region	*16,444*	*17,259*	*10,211*	*9,528*	*9,733*	*4,670*	*33,919*
Upper Choptank R.	192	42	129	183	8	0	*8,725*
Middle Choptank R.	8,420	5,749	6,563	3,930	4,395	2,209	*17,130*
Lower Choptank R.	22,141	10,979	6,458	11,849	13,235	10,264	*14,735*
Tred Avon R.	4,007	2,403	889	2,704	616	229	*10,022*
Broad Cr.	67,375	32,063	32,516	32,295	39,228	34,248	*22,656*
Harris Cr.	7,072	2,704	3,901	5,240	6,542	2,974	*7,655*
Total Choptank R. Region	*109,207*	*53,940*	*50,456*	*56,201*	*64,023*	*49,924*	*80,923*
Little Choptank R.	2,027	2,048	453	246	10,063	8,432	*11,033*
Upper Tangier Sound	64,305	35,521	33,322	22,060	82,224	144,386	*19,595*
Lower Tangier Sound	28,269	9,471	7,244	2,806	7,264	30,362	*13,810*
Honga R.	13,241	11,114	2,051	925	2,811	8,102	*7,507*
Fishing Bay	20,195	13,608	7,441	5,728	22,869	36,245	*14,683*
Nanticoke R.	7,095	7,430	8,017	4,201	8,355	14,262	*7,278*
Wicomico R.	10,122	4,735	1,044	939	1,177	992	*1,371*
Manokin R.	1,431	1,128	1,914	1,045	430	20	*3,288*
Big Annemessex R.	4,037	473	90	74	24	37	*234*
Pocomoke Sound	10,261	6,131	5,269	2,166	2,054	3,705	*5,177*
Total Tangier Sound Region	*158,956*	*89,611*	*66,392*	*39,943*	*127,207*	*238,111*	*77,529*
Patuxent R.	50,048	22,669	9,446	9,290	22,912	17,227	*12,918*
Wicomico R., St. Clement and Breton bays	5,596	5,130	891	1,160	356	487	*9,521*
St. Marys R. and Smith Cr.	10,537	8,716	18,759	12,371	11,564	13,419	*8,967*
Total Potomac Md. Tribs.	*16,133*	*13,846*	*19,650*	*13,531*	*11,920*	*13,906*	*18,469*
Total Maryland (bu.)[1]	**383,534**	**224,758**	**182,310**	**145,161**	**270,043**	**346,914**	***292,093***

[1] Includes harvests from unidentified regions.

(Return to Text)

Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2020-21 seasons as reported by seafood dealer buy tickets. Dockside value is in millions of dollars.

Season	Hand Tongs	Diver	Patent Tongs	Power Dredge	Skipjack	*Total Harvest*[1]	*Dockside Value*
1989-90	309,723	47,861	31,307	11,424	14,007	*414,445*	*$ 9.9 M*
1990-91	219,510	74,333	105,825	4,080	14,555	*418,393*	*$ 9.4 M*
1991-92	124,038	53,232	108,123	6,344	31,165	*323,189*	*$ 6.4 M*
1992-93	71,929	24,968	18,074	1,997	8,821	*123,618*	*$ 2.6 M*
1993-94	47,309	19,589	11,644	787	133	*79,618*	*$ 1.4 M*
1994-95	99,853	29,073	31,388	1,816	2,410	*164,641*	*$ 3.2 M*
1995-96	115,677	25,657	46,040	6,347	7,630	*199,798*	*$ 3.2 M*
1996-97	130,861	16,780	15,716	8,448	6,088	*177,600*	*$ 3.8 M*
1997-98	191,079	37,477	30,340	14,937	10,543	*284,980*	*$ 5.7 M*
1998-99	294,342	58,837	36,151	25,541	8,773	*423,219*	*$ 7.8 M*
1999-2000	237,892	60,547	44,524	18,131	12,194	*380,675*	*$ 7.2 M*
2000-01	193,259	75,535	43,233	18,336	8,820	*347,968*	*$ 6.8 M*
2001-02	62,358	30,284	26,848	17,574	8,322	*148,155*	*$ 2.9 M*
2002-03	11,508	9,745	18,627	12,386	2,432	*55,840*	*$ 1.6 M*
2003-04	1,561	5,422	3,867	13,436	1,728	*26,471*	*$ 0.7 M*
2004-05	5,438	14,258	6,548	37,641	4,000	*72,218*	*$ 1.1 M*
2005-06	28,098	38,460	49,227	30,824	3,576	*154,436*	*$ 4.7 M*
2006-07	55,906	36,271	31,535	35,125	3,250	*165,059*	*$ 5.0 M*
2007-08	24,175	11,745	15,997	25,324	4,243	*82,958*	*$ 2.6 M*
2008-09	11,274	9,941	15,833	50,628	5,370	*101,141*	*$ 2.7 M*
2009-10	7,697	6,609	48,969	107,952	12,479	*185,245*	*$4.5 M*
2010-11	13,234	5,927	27,780	65,445	10,550	*123,613*	*$4.3 M*
2011-12	4,885	12,382	22,675	84,950	11,305	*137,317*	*$4.6M*
2012-13	53,622	8,107	48,095	212,837	18,471	*341,132*	*$10.9 M*
2013-14	67,093	21,510	75,937	242,964	9,074	*416,578*	*$14.1 M*
2014-15	57,289	25,126	98,187	154,716	33,518	*388,658*	*$17.1 M*
2015-16	71,296	31,110	91,852	107,781	32,815	*383,534*	*$14.9 M*
2016-17	45,929	24,434	52,740	80,586	17,724	*224,758*	*$10.6 M*
2017-18	35,717	14,787	26,673	61,882	19,161	*182,310*	*$8.7 M*
2018-19	35,574	11,461	21,532	64,073	12,487	*145,161*	*$6.6 M*
2019-20	44,522	18,724	69,089	113,707	25,051	*270,043*	*$12.2 M*
2020-21	39,936	14,711	104,232	147,060	40,533	*346,914*	*$10.5 M*

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

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Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2020-21 seasons as reported by seafood dealer buy tickets. Some years may not total 100% due to incomplete data.

Season	Hand Tongs	Diver	Patent Tongs	Power Dredge	Skipjack
1989-90	75	12	8	3	3
1990-91	52	18	25	1	3
1991-92	38	16	33	2	10
1992-93	57	20	14	2	7
1993-94	60	25	15	<1	<1
1994-95	61	18	19	1	1
1995-96	57	13	23	3	4
1996-97	74	9	9	5	3
1997-98	67	13	11	5	4
1998-99	69	14	9	6	2
1999-2000	62	16	12	5	3
2000-01	56	22	12	5	3
2001-02	41	20	18	12	6
2002-03	21	17	33	22	4
2003-04	6	20	15	51	7
2004-05	8	20	9	52	6
2005-06	18	25	32	20	2
2006-07	34	22	19	21	2
2007-08	29	14	19	30	5
2008-09	12	11	17	54	6
2009-10	4	4	26	58	7
2010-11	11	5	23	53	8
2011-12	4	9	17	62	8
2012-13	16	2	14	62	5
2013-14	16	5	18	58	2
2014-15	16	7	27	42	9
2015-16	21	9	27	32	10
2016-17	20	11	23	36	8
2017-18	23	9	17	39	12
2018-19	25	8	15	44	9
2019-20	16	7	26	42	9
2020-21	12	4	30	42	12

(Return to Text)

Table 8. Oyster bars within sanctuaries sampled during the 2021 Fall Survey.

Region	Oyster Sanctuary	Surveyed Bars Within Sanctuary
Upper Bay	Man O War/Gales Lump	Man O War Shoals
Middle Bay	Poplar Island	Poplar I.
	Herring Bay	Holland Pt.[1,2]
	Calvert Shore	Flag Pond[1,2]
Lower Bay	Lower Mainstem East	Northwest Middleground[3]
	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
	Cox Creek	Ringold Middleground
Wye River	Wye River	Bruffs I.[1,2], Mills, Race Horse, Whetstone, Wye River Middleground
Miles River	Miles River	Long Pt.[2]
Choptank River	Cook Point	Cook Pt.[1,2]
	Lower Choptank River	Chlora Pt.
	Sandy Hill	Sandy Hill[1,2]
	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]
Severn River	Severn River	Chinks Pt.
Patuxent River	Upper Patuxent	Thomas, Broad Neck, Trent Hall, Buzzard I., Holland Pt.
	Neal Addition	Neale
St. Marys River	St. Marys River	Pagan[1,2], Horseshoe
Breton Bay	Breton Bay	Black Walnut[1]

[1] Key Spat Bar [2] Disease/Biomass Index Bar [3] Supplemental Disease Bar

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Appendix 1
Hatchery Seed Plantings

Amy Larimer

During 2021, a total of 31 hatchery seed plantings were made throughout the Maryland portion of the bay, where 711.6 million spat were planted over 220.4 acres, for an average density of 3.5 million spat per acre (Table A1-1). The Fall Survey sampled 13 of these plantings (Figure A1-1). Seven sites were new, with five of those on bars with other samples. Approximately 140 million hatchery seed were planted at these locations (Table A1-1), covering 80 acres. The mean density of these plantings was 1.8 million spat per acre. All areas received diploid spat except Well Cove in Eastern Bay and Nanticoke Middleground, where triploid spat were planted. Of the two Nanticoke Middleground sites, one received 100% triploid spat and the other received 68% triploid spat. Well Cove was sampled but spat from 2021 were not found. Piney Point, Swan Point, and Thunder and Lightning each had multiple samples on a single planting; these results were combined (Table A1-2). The two Nanticoke Middleground samples were on separate plantings and the results were not combined.

For most of these sites, spat were enumerated and approximately 50 were measured. At Hood (Eastern Bay) and Stoddard (Wicomico River West), only the minimum and maximum sizes were measured and mean sizes were estimated. The number of spat per bushel on these sites ranged from 32 to 4068, with a mean of 680 spat per bushel. The averages for 2020 (Tarnowski 2022) were similar to 2021, with the exception of mean spat count per bushel (661 for 2021 and 255 for 2020) and the mean maximum days since planting (108 for 2021 and 132 for 2020). The mean spat counts are a function of the density of spat planted on the bar, mortality rate, and the elapsed time between planting and sampling. Locations with high planting densities or shorter elapsed times had the highest spat counts (Nanticoke Middleground, Stoddard).

Unlike 2020, the 2021 spat did not appear to be unusually large at most locations. Spat sizes ranged from 4 to 85 mm shell height, with a mean of 35 mm (the mean in 2020 was 41mm). The maximum sizes from all plantings averaged 56 mm (compared to 60 mm for 2020). Fewer spat were close to or above market size (76.2 mm) compared to the previous year. In 2020, 34 hatchery planting sites were sampled, compared to 13 for 2021. In 2020, the time elapsed between planting and the Fall Survey ranged from 72 to 181 days, with a mean of 132. In 2021, the elapsed time ranged from 42 to 161 days, with a mean of 108 (Table A1-2). This likely accounts for the relatively smaller spat in 2021. Nanticoke Middleground 2 was planted with 100% triploid spat and had the highest growth rate at 0.49 mm/day but was sampled 42 days after planting. The largest oysters were found on Piney Point, in the Chester River (Figure A1-2). The spat average growth rate for all samples was similar between the two years – 0.34 mm/day in 2021 and 0.31 mm/day in 2020.

There appeared to be less of a correlation between spat size and the time since planting than there was in 2020 (Figure A1-3). The sample size was small, 11 sites in 2021 and 18 in 2020. Planting of hatchery spat began much earlier in 2020 than in 2021, with a few sites planted as early as April. In 2021, no site was planted before June. The mean planting start date was over a

month later in 2021 than in 2020, resulting in smaller spat when the Fall Survey was conducted. The highest growth rates were Hood, Nanticoke Middleground 2 (100% triploid spat) and Stoddard (Figure A1-4). Both of these locations were sampled 64 days or less from the planting date.

Two triploid spat plantings made in 2020 were resurveyed in 2021 (Table A1-3). Nanticoke Middleground triploids, which had among the fastest growth rates in 2020, had an average shell height of 88.5 mm after 491 days post-planting. The largest oyster was 140 mm, and 78.8% of the oysters were of market size (≥ 76.2 mm).This site was devoid of oysters prior to the planting. Resampling of the Well Cove 2020 triploid spat planting in Eastern Bay also took place in 2021. The average size was similar at 90 mm after 531 days post-planting, with sizes ranging from 60 mm to 130 mm. Market-size oysters make up 89.8% of the oysters in the sample. The daily growth rates were almost identical between the two sites – 0.18 mm/day at Middleground and 0.17 mm/day at Well Cove. This was about half of the initial growth rates in 2020 but included the normal slowdown in growth during the winter months. Considering that the rule-of-thumb for growth to market size is three years in the Chesapeake, the high percentages of markets in the year after planting is impressive.

References

Tarnowski, M. 2022. Maryland Oyster Population Status Report: 2020 Fall Survey. Maryland Department of Natural Resources Publ. No. 17-062521-282. Annapolis, MD. 88 pp. dnr.maryland.gov/fisheries/Pages/shellfish-monitoring/reports.aspx

Figure A1-1. Map showing the locations of 2021 Fall Survey samples on hatchery plantings. Figure A1-1. Map showing the locations of 2021 Fall Survey samples on hatchery plantings.

Table A1-1. 2021 Hatchery seed plantings. Sites with Fall Survey samples are in bold. Number in parentheses is the total number of sites.

Region	Bar Name	Acres Planted	# Seed (millions)	Density (millions/acre)
Chester River	Durdin	2.28	4.54	1.99
	Piney Point (2)	6.49	13.72	2.11
Choptank River	Dickinson	1.75	6.30	3.60
	Howells Point	2.64	7.24	2.74
	Howells Point Add 2	2.68	6.34	2.37
Eastern Bay	**Bugby**	2.22	3.91	1.76
	Cedar Island	1.20	5.68	4.73
	Hood[1]	3.52	13.08	3.72
	Well Cove	1.16	3.58	3.08
Little Choptank River	Susquehanna	5.07	20.56	4.05
Manokin River	Marshy Island	15.40	73.41	4.77
Mid-Bay West	Coots	5.59	7.37	1.32
	Hackett Point	5.69	19.39	3.41
Nanticoke River	**Middleground (2)**	5.76	32.43	5.84
Potomac River Northshore	Knotts Hollow	8.28	41.32	4.99
South River	Hill Point East	3.09	9.24	2.99
	Thunder and Lightning (2)	3.45	7.29	2.12
St. Marys River	Cason (3)	14.33	48.14	3.35
	Horseshoe Bend (3)	12.22	57.31	5.08
Tred Avon River	Double Mills (4)	4.17	36.71	9.08
	Louis Cove (7)	20.46	102.90	6.94
	Mares Point (5)	13.10	68.78	7.14
	Orem (2)	1.82	13.39	7.30
	Pecks Point (3)	9.81	42.40	5.93
Upper Bay East	**Swan Point (3)**	31.70	19.16	0.60
Upper Bay West	**Man O War**	4.48	6.24	1.39
Wicomico River West	Lancaster	8.31	10.38	1.25
	Mills East	3.88	6.48	1.67
	Mouth of River	4.00	7.33	1.83
	Stoddard[1]	13.99	15.62	1.12
	Wicomico Lumps	1.85	1.39	0.75
	Grand Total	**220.39**	**711.63**	**3.52**

[1] No measurements were taken at these sites.

Table A1-2. Fall Survey sites on hatchery seed plantings for 2021, including counts, sizes, elapsed time since planting, daily growth rates, and averages for those values.

Region	Bar Name	Spat /bu	Min (mm)	Mean (mm)	Max (mm)	Max days since planting	Growth (mm/day)
Chester River	Piney Point (2)	74	36	50	70	161	0.31
Choptank River	Howell Point South	186	16	36	57	155	0.23
Eastern Bay	Bugby	318	15	38	78	96	0.40
	Hood[1]	32	17	30	40	59	0.51
Mid-Bay West	Hackett Point	302	20	31	58	123	0.25
Nanticoke River	Middleground	626	6	38	55	96	0.39
	Middleground 2	4068	4	21	39	42	0.49
South River	Thunder and Lightning (2)	1112	23	39	52	138	0.29
Upper Bay East	Swan Point (Peach Orchard) (2)	722	11	27	38	155	0.17
	Swan Point (Peach Orchard S.)	410	19	29	46	94	0.31
Upper Bay West	Man-O-War Shoals	100	17	24	40	106	0.23
Wicomico River West	Stoddard[1]	774	22	30	45	64	0.47
	Averages	727	17	33	53	108	0.34

[1] Mean was estimated.

Table A1-3. Resurvey of 2020 triploid hatchery seed plantings on Nanticoke Middleground and Well Cove in Eastern Bay during the 2021 Fall Survey. Market oysters are ≥ 76.2 mm SH. *SH=shell height*

Bar	Year	Min SH (mm)	Avg SH (mm)	Max SH (mm)	Growth (mm/day)	Markets %
Middleground	2020	22	51	75	0.42	n/a
	2021	38	88.5	140	0.18	78.8
Well Cove	2020	38	59	85	0.35	n/a
	2021	60	90	130	1.17	89.8

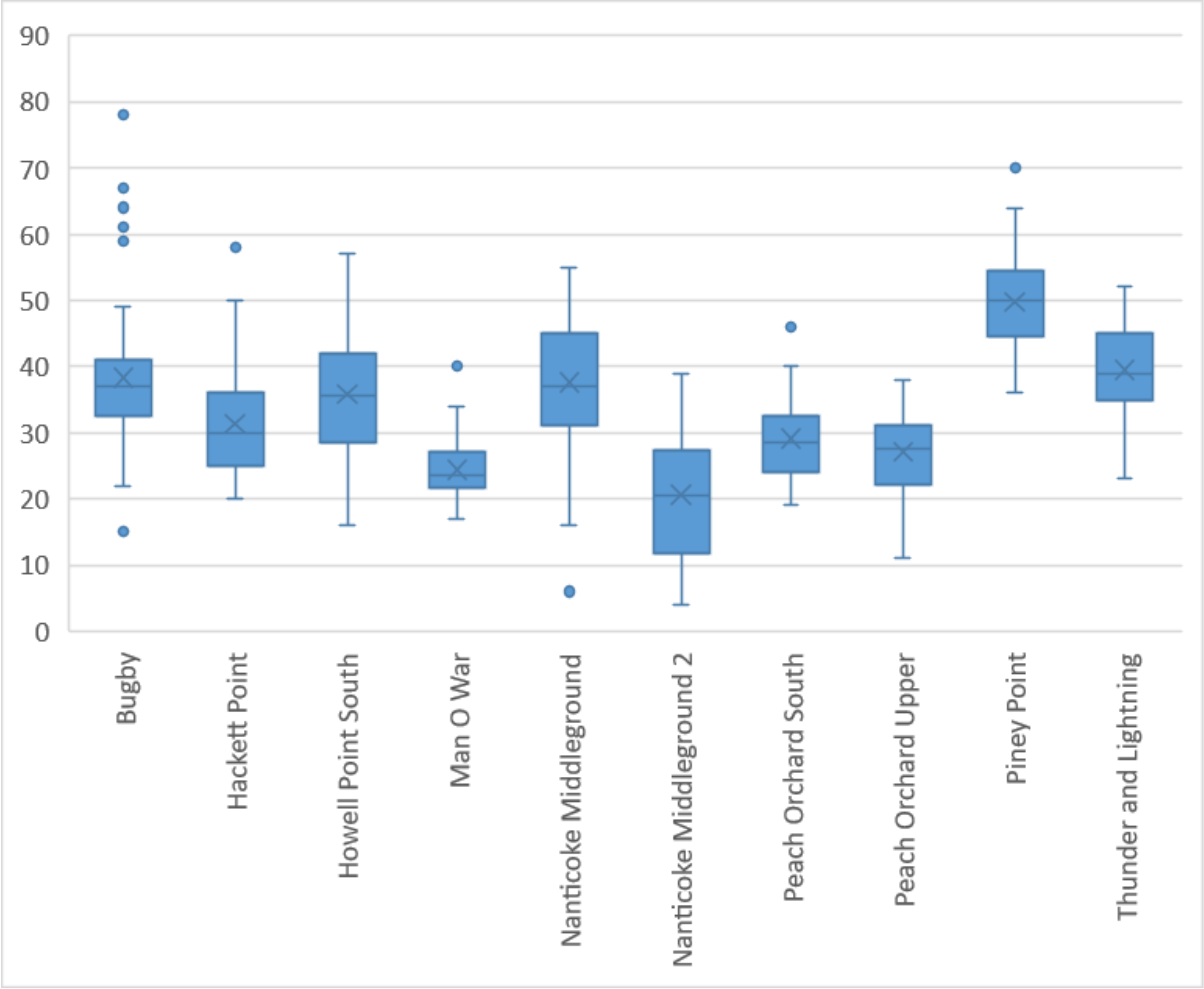

Figure A1-2. Box Plots of shell heights taken from hatchery plantings in 2021.

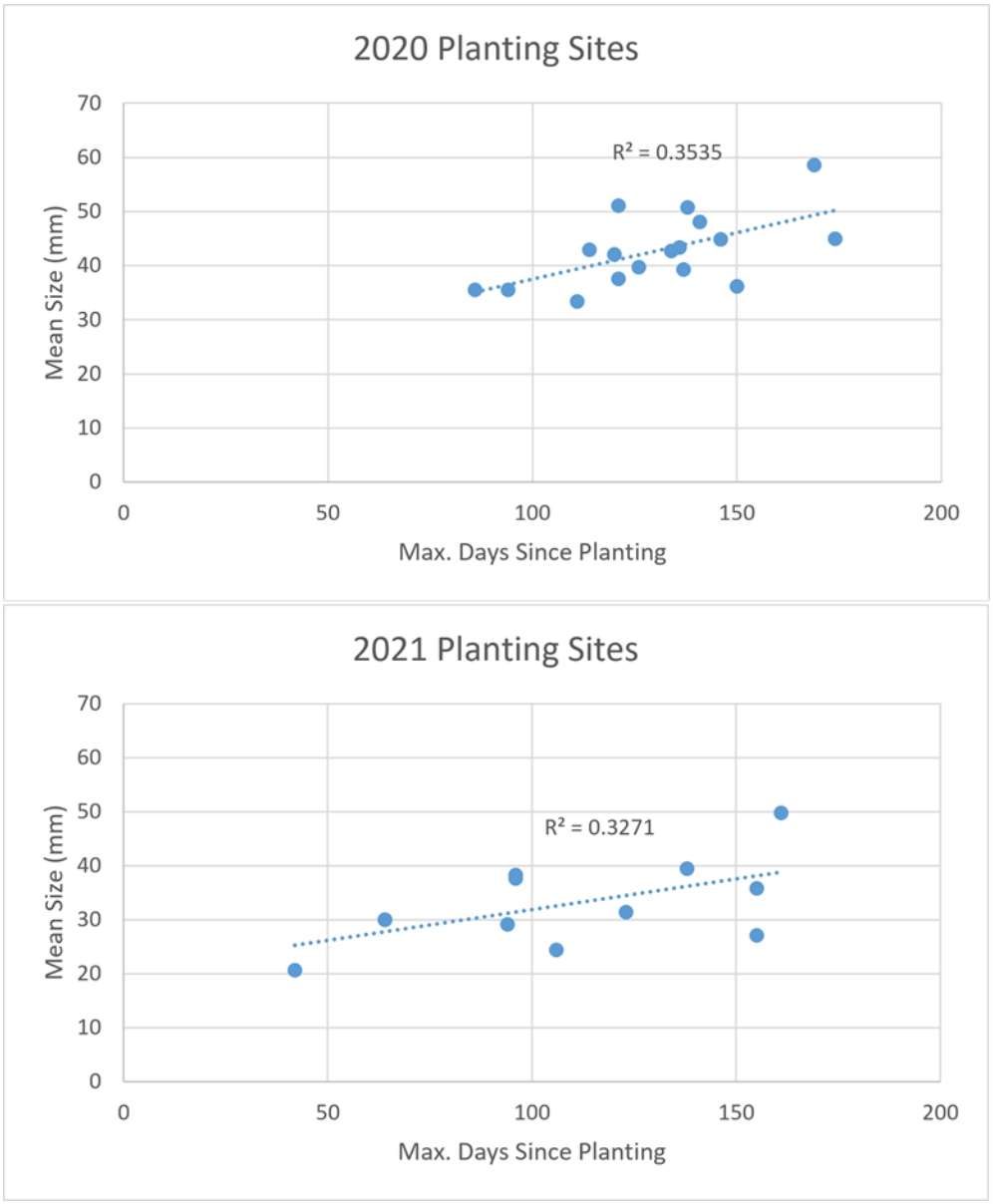

Figure A1-3. Scatterplots of spat mean size (mm) with the maximum days since planting, including a trend line and R^2 value for comparison. Top figure is for 202*0* and the bottom is for 202*1*.

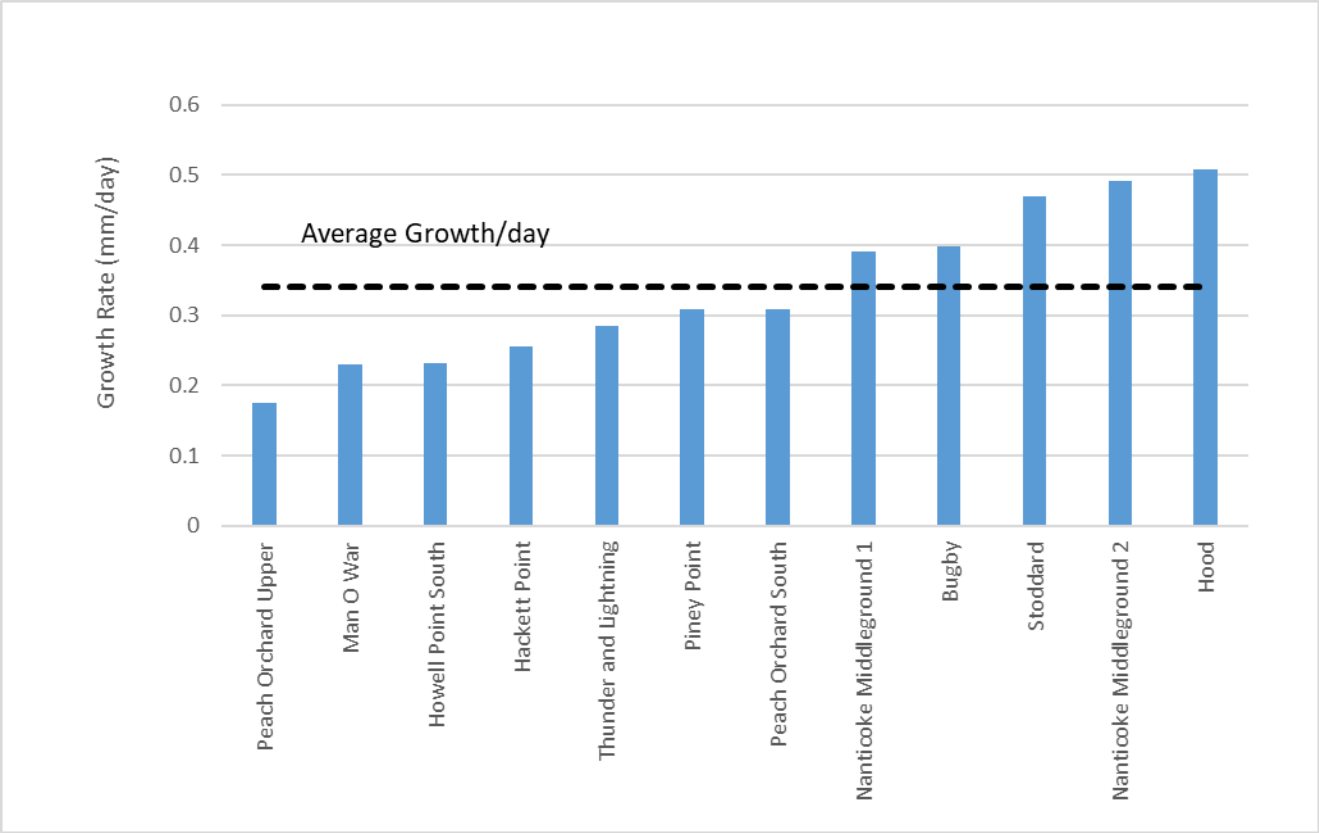

Figure A1-4. Growth rates in mm/day for Fall Survey sites planted with hatchery spat. The average was 0.34 mm/day for all sites.

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APPENDIX 2
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 3
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).

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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.*

dredged shell — Oyster shell dredged from buried ancient (3000+ years old) shell deposits. Since 1960 this shell has been the backbone of the Maryland shell planting efforts to produce seed oysters and restore oyster bars.

fresh shell — Oyster shells from shucked oysters. It is used to supplement the dredged shell plantings.

gaper — Dead or moribund oyster with gaping valves and tissue still present (see **box oyster**).

Haplosporidium nelsoni — The protozoan oyster parasite that causes MSX disease.

infection intensity, individual — *Perkinsus* sp. parasite burdens of individual oysters, estimated by RFTM assays and categorized on 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).

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

sample site density at a specific location, which may be used to calculate the annual spatfall intensity index.

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

sum of Key Bar spatfall intensities ÷ number of Key Bars

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

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

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