Maryland Oyster Population Status Report
2020 Fall Survey

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Cover Photo: Oyster surveys in the time of Covid – Showing off the South River's finest. (Photo: C. Judy)

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Errata: In the 2019 Fall Survey report, Table 3 reported a dermo disease prevalence of 0% and intensity of 0.0 on Back Cove in 2019. The actual levels were 3% and 0.2 respectively. Consequently, the 30-yr average prevalence for that bar changed from 77.4% to 77.5% and the proportion of dermo positive bars for that year increased from 86% to 88%.

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 2020 Fall Survey was conducted from October 5 to November 24 throughout the Maryland portion of Chesapeake Bay and its tributaries, including the Potomac River. A total of 353 samples were collected from 281 oyster bars. Locations monitored included natural oyster bars, oyster seed production areas, seed and shell planting sites, and sanctuaries.

Among the environmental factors affecting oyster populations, freshwater streamflow is critical as it controls the salinity regime of the bay, which in turn influences spatset, diseases, mortality and growth of oysters. For 2020, the annual average freshwater input was close to normal following two years of record high streamflows.

The Spatfall Intensity Index of 109 spat/bu was five times the 36-year median and the third highest of the time series. Spatset intensity increased nearly five-fold from the previous year, with 58% of the 2020 index bars having higher spatfall when compared with 2019. The vast majority of good recruitment occurred in the Choptank River and Tangier Sound regions - especially in the tributaries, as well as the Little Choptank River. The highest spat counts were in Broad Creek, averaging over 900 spat/bu. Deep Neck bar in this tributary had an extraordinary count of over 1,800 spat/bu – the second highest on that bar since 1939 - and several neighboring bars had over 1,000 spat/bu. Few or no spat were found along the Western Shore upbay from the mouth of the Patuxent River, the upriver half of the Potomac oyster growing region, the upper Choptank River, parts of Eastern Bay and its tributaries, and the entire Chester River and bay north of the South River.

Disease levels were among the lowest on record for the 31-year time series. Although dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, being found on 84% of the sentinel bars, nonetheless this percentage was the lowest of the time series. The 2020 mean prevalence (33%) increased marginally from the record low (27%) of 2019, but was the second lowest of the time series and substantially below the 31-year average of 63.5%. The mean infection intensity for dermo disease (1.1) was half of the long-term average and the second lowest of the time series, just slightly higher than the record (1.0) of the previous year for the lowest average intensity. The MSX disease mean prevalence (0.1%) on the Disease Index bars was tied with the previous two years for the lowest in Fall Survey records over the past 31years. Only one oyster of the 1,290 examined from the Disease Index bars was lightly infected with MSX disease. MSX was also found in one additional oyster of 270 from the supplemental disease sites.

The baywide Observed Mortality Index was 10.5%, the fourth lowest in 36 years and the lowest since 2013. This was the 17th consecutive year that the mortality index was below the long-term average. A residual of elevated mortalities persisted in the upper reaches of the Potomac River and upper bay following the freshets in 2018/19. In addition, the upper St. Marys River, including the oyster sanctuary, suffered a major mortality event, with death rates among bars ranging from 21.7% to 95.6%. Aside from these areas, regional average observed mortalities were generally low. For example, Tangier Sound, typically a higher mortality area, experienced a remarkably low observed mortality for the second year in a row, averaging 3.5%.

The 2020 Oyster Biomass Index of 1.98 represents an 18% gain of this index from the previous year, ranking it third highest in the 28-year time series and the highest since 2014. The combined increases in both the number and size of oysters accounts for this improvement in the Biomass Index.

The 2020 Cultch Index of 0.86 bu/100 ft. was similar to the 16-year average of 0.90 bu/100 ft. However, some individual bars showed steep declines in recent years. Of the 53 bars used in this analysis, 23 (43%) had standardized volumes that were more than 25% below their respective 16-year averages. Nonetheless, the overall three-year rolling averages of cultch indices have been stable during the past five years. 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.

A total of 86 oyster bars within 31 sanctuaries were sampled during the 2020 Fall Survey. Trends in recruitment, disease, and mortality were in keeping with the baywide results. Recruitment within four of the five restoration sanctuaries - Harris Creek, Tred Avon, Little Choptank, and Manokin - was well above their long-term averages. The exception was the St. Marys Sanctuary, which had below normal recruitment and experienced a high mortality event. A comparison of spatset between the restoration sanctuaries and adjacent harvest areas showed the sanctuaries to have generally higher recruitment, aside from the Broad Creek harvest area. These results were proportionally consistent with their respective long-term averages. MSX disease was found in only one oyster in a lower bay sanctuary. Dermo disease prevalences and intensities were well below long-term averages, although they 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. The only exception was the St. Marys Sanctuary, which suffered a 66.6% mortality rate, likely due to a low dissolved oxygen event. The 2020 average biomass index was substantially higher (61%) than the 28-year average in the sanctuaries, indicating population growth over time. Similarly, there was a marked improvement (49%) between the 2020 average biomass index and the long-term average in the open harvest areas. The average biomass per index bar in 2020 was 33% higher in the sanctuaries than in the open harvest areas.

With reported harvests of 270,000 bushels and a dockside value of $12.2 million during the 2019-20 season, commercial oyster landings increased 86% with a gain of $5.6 million from the previous season, reversing a declining trend over the previous five years. Power dredging accounted for 42% of the landings, primarily from the lower Eastern Shore and Choptank regions. Patent tongs were the second dominant gear type, harvesting 26% of the total. The Tangier Sound region was the leading production area with 47% of the Maryland landings, primarily from upper Tangier Sound and Fishing Bay. The Choptank region followed with 21% of the landings, led by Broad Creek. Other productive areas in descending order included the Patuxent River, lower mainstem, St. Marys River, Little Choptank River, and Eastern Bay.

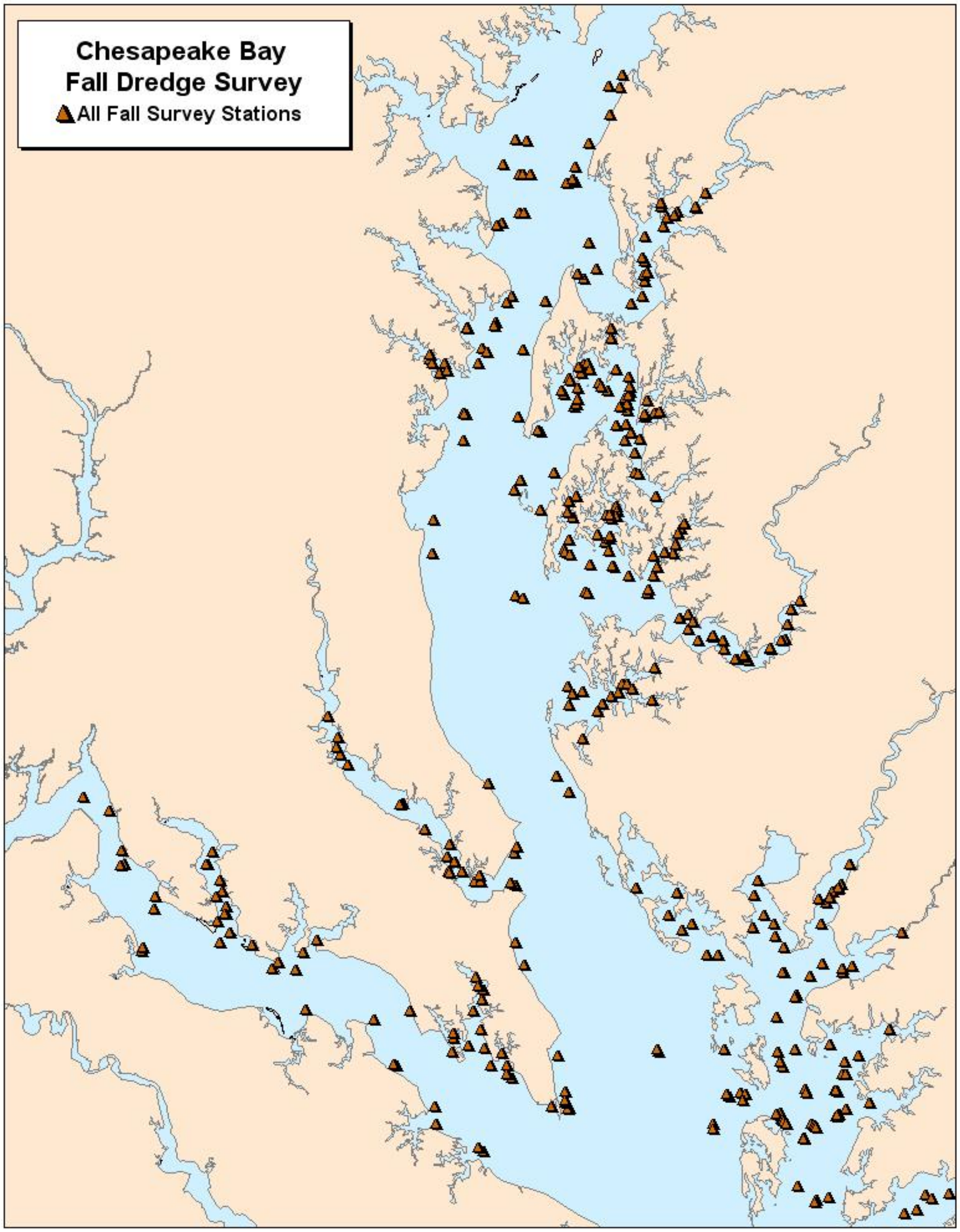

Figure 1a. 2020 Maryland Fall Survey station locations, all bar types (standard, Key, Disease, seed) included.

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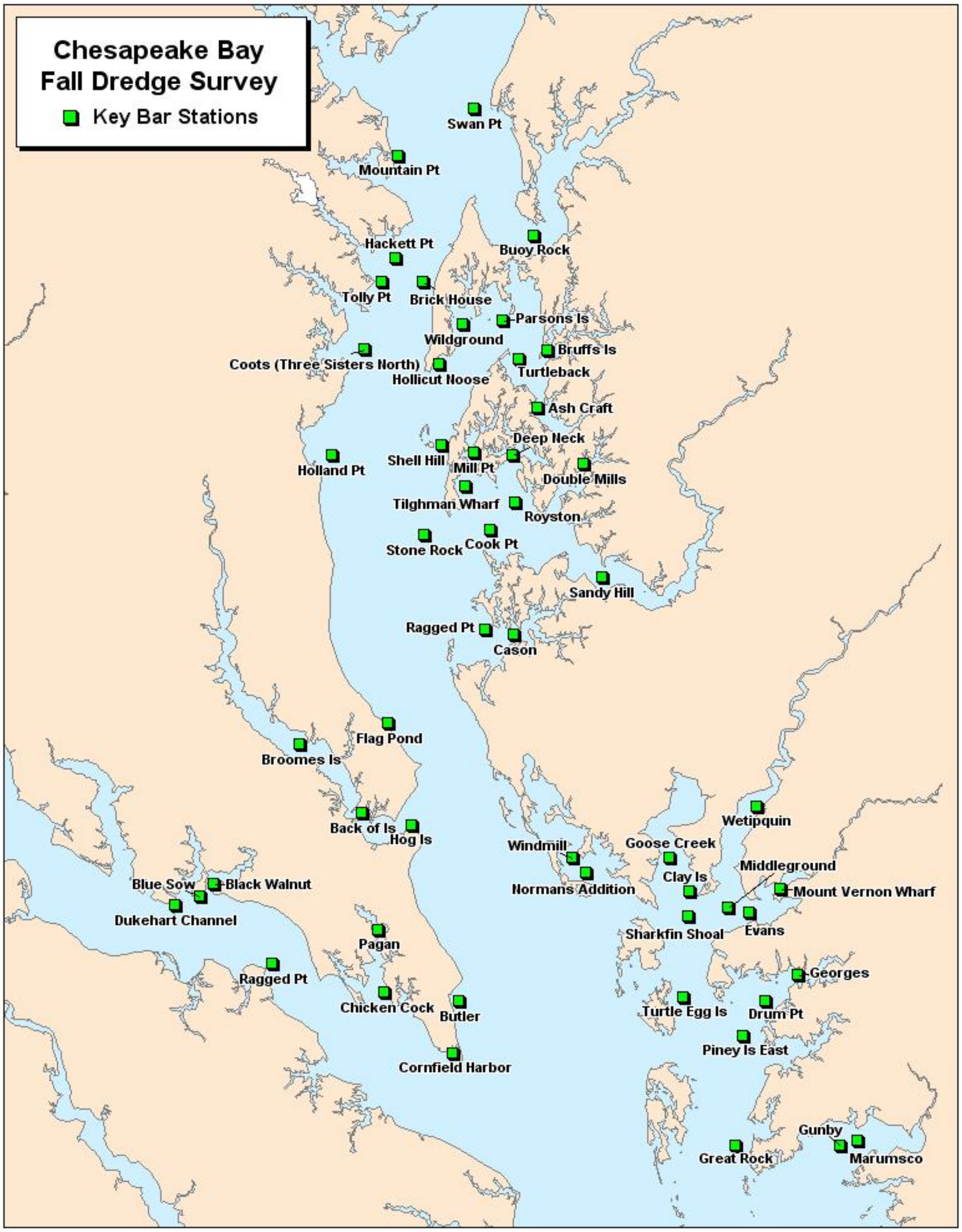

Figure 1b. Maryland Fall Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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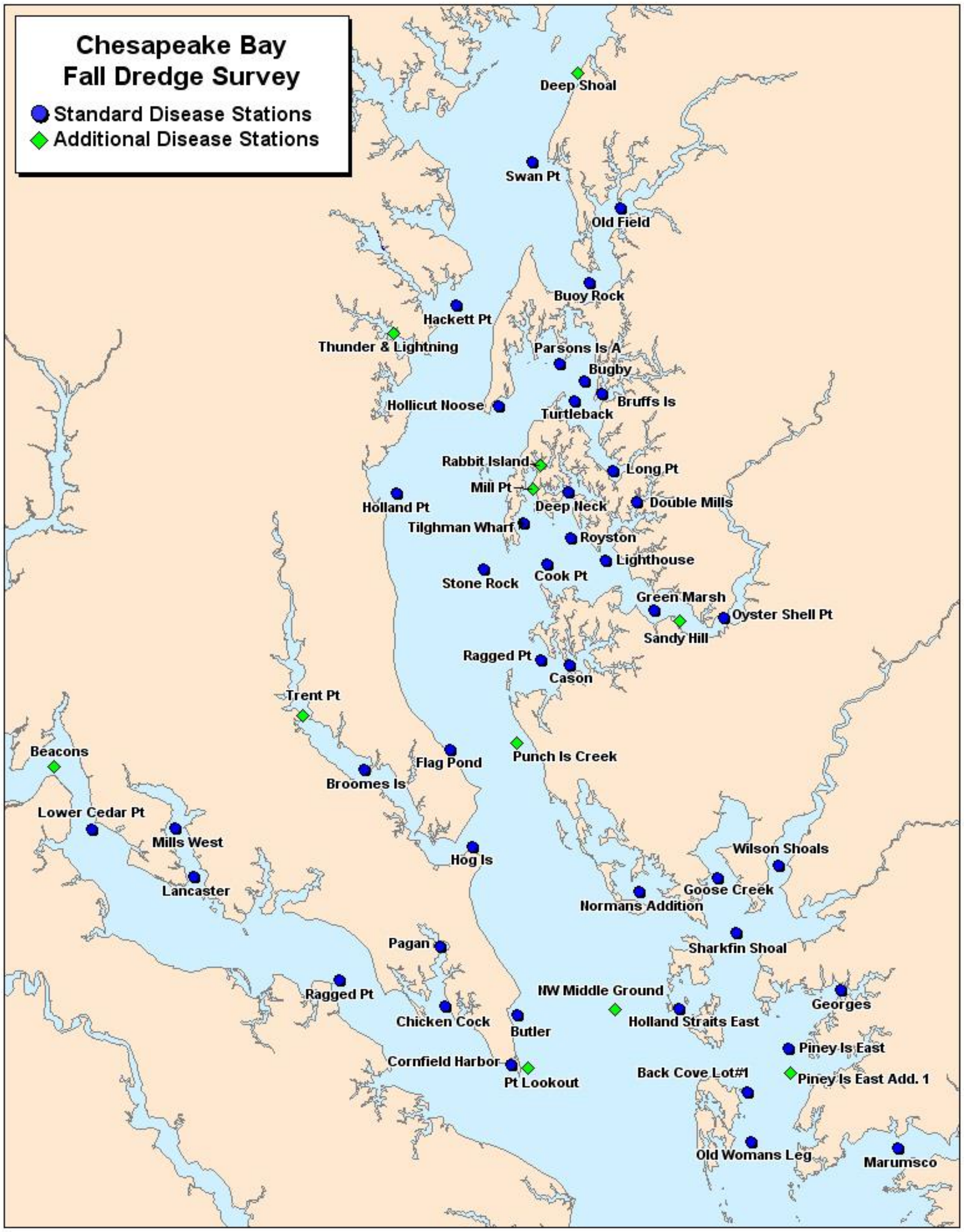

Figure 1c. Maryland Fall Survey standard Disease Bar monitoring locations and additional disease sample stations. Disease samples could not be obtained from the supplemental sites at Deep Shoal and Beacons in 2020.

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INTRODUCTION

Since 1939, a succession of Maryland state agencies has conducted annual dredge-based surveys of oyster bars. These oyster population assessments have provided biologists and managers with information on spatfall intensity, observed mortality, and more recently on parasitic infections and habitat in 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).

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. Unfortunately, collaborative initiatives were restricted in 2020 due to the COVID-19 pandemic. Nonetheless, 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 was updated in 2021. Disease data collected during the survey are now shared annually in a Rutgers University database intended to facilitate oyster aquaculture along the east coast of the United States. Disease data and shells collected from disease samples from selected sites were also provided to researchers at the Smithsonian Environmental Research Center who are exploring the potential impact of bioeroding organisms on Chesapeake Bay oyster restoration success, focusing on *Cliona* spp. (boring sponges) and *Polydora* spp. (mud blister worms), by comparing effects across harvested and sanctuary areas.

METHODS

Field Collection

The 2020 Annual Fall Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources Fishing and Boating Services from October 5 to November 24. A total of 353 samples was collected during surveys on 281 natural oyster bars (Figure 1a), including Key Bar (Figure 1b) and Disease Bar (Figure 1c) fixed sentinel sites as well as 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. An index 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 2020 Biomass Index is derived from the 2020 Fall Survey data.

Biomass Equations

For **each** monitoring station:

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

For **all** monitoring stations:

3. (∑ 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 100 by the actual tow distance and multiplying the result by the total cultch volume. If the dredge is full, that sample is dropped from the analysis. The Cultch Index is calculated as the annual average of the standardized cultch volumes from the 53 Key Bars used in the Spat Index. Because the dredge is less than 100% efficient in catching oysters and shells, this is not an absolute measure of cultch but provides a relative index for temporal and spatial comparisons.

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 2020 was close to normal (Figure 2a). This follows record-high flows in 2018 (calendar year)/2019 (water year).

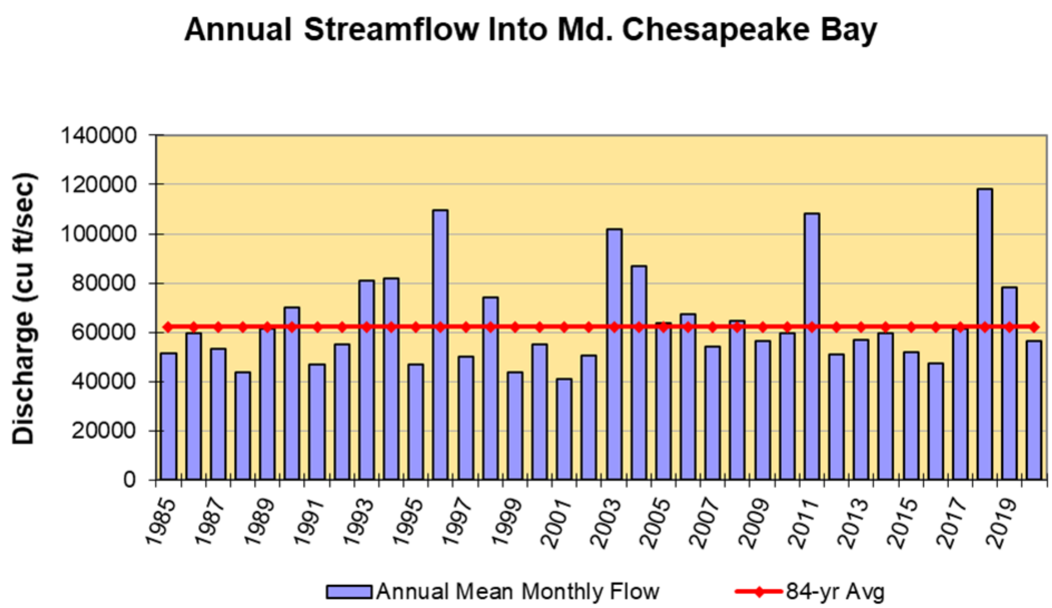

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2020. USGS Section C: all Maryland tributaries and the Potomac River.

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

Monthly freshwater flows were highly variable relative to their respective 84-year averages (Figure 2b). Streamflows from June through November averaged 65% of the long-term mean for that period, with October streamflows at only 41% of the long-term mean. This trend was reversed in December, when freshwater input exceeded the average by 29%.

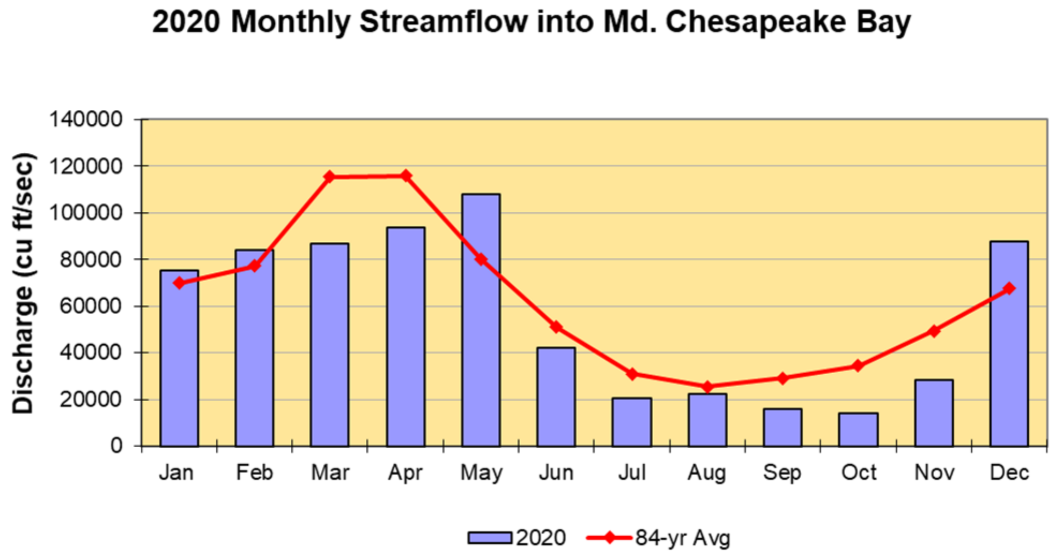

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2020, including the 84-yr monthly average.

Salinities

Salinities were close to normal throughout the year, in contrast to the more volatile streamflow patterns. Monthly surface salinities for four regions of the Chesapeake Bay in Maryland during 2020 are shown in Figure 2c (Chesapeake Bay Program 2020). These examples demonstrate the influence of streamflow to varying degrees depending on distance from the Susquehanna River, the largest source of freshwater discharge into the bay. Swan Point in the upper bay showed the greatest variability in deviations from the long-term mean, reflecting its proximity to that river, but only three of the monthly values were more than 25% of their means. Salinity readings (as well as other water quality parameters) could not be obtained for some months due to COVID-19 constraints, as noted in Figure 2c (ND=no data).

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 dipped below this to 4.3 ppt in May, but this was actually slightly above average. No data were recorded for the adjacent months. None of the other locations had salinities below 5 ppt reported in 2020, while the salinity in southern Tangier Sound reached a high of 18.8 ppt in January (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.

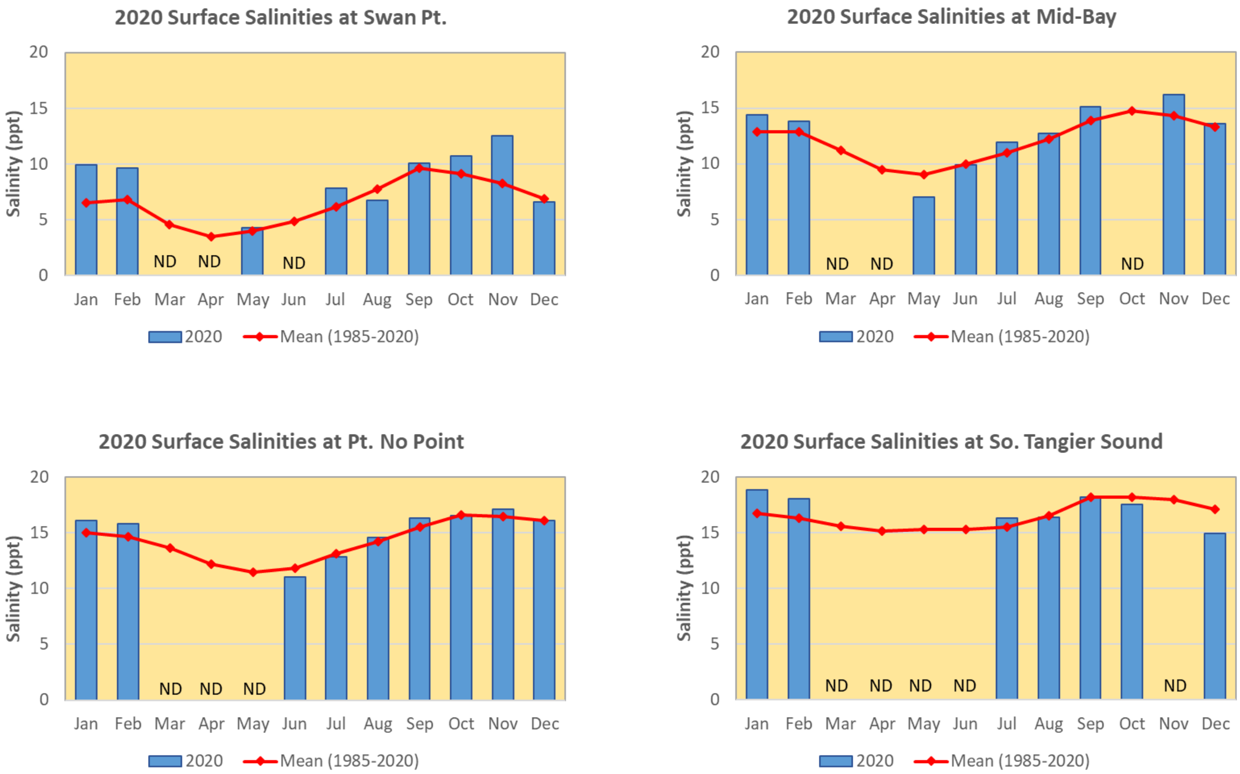

Figure 2c. Monthly surface salinities during 2020 at four monitoring stations along a salinity gradient in Chesapeake Bay. Swan Pt. (CB3.2) is in the upper bay, the mid-bay station (CB4.2C) is off the mouth of the Choptank R., Pt. No Point (CB5.2) is in the lower mainstem, and the southern Tangier Sound station (EE3.2) is near the Virginia state line. ND = Data not collected due to Covid-19 constraints.

SPATFALL INTENSITY

The Spatfall Intensity Index, a measure of recruitment success and potential increase in the population, was 109.1 spat/bu, the highest since 1997 and third highest of the 36-year time series (Figure 3a). Spatset intensity increased almost five-fold from the previous year, with 58.5% of the 2020 index bars having increased spatfall when compared with 2019 (Table 2). Five of the last 11 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) (Figure 3b).

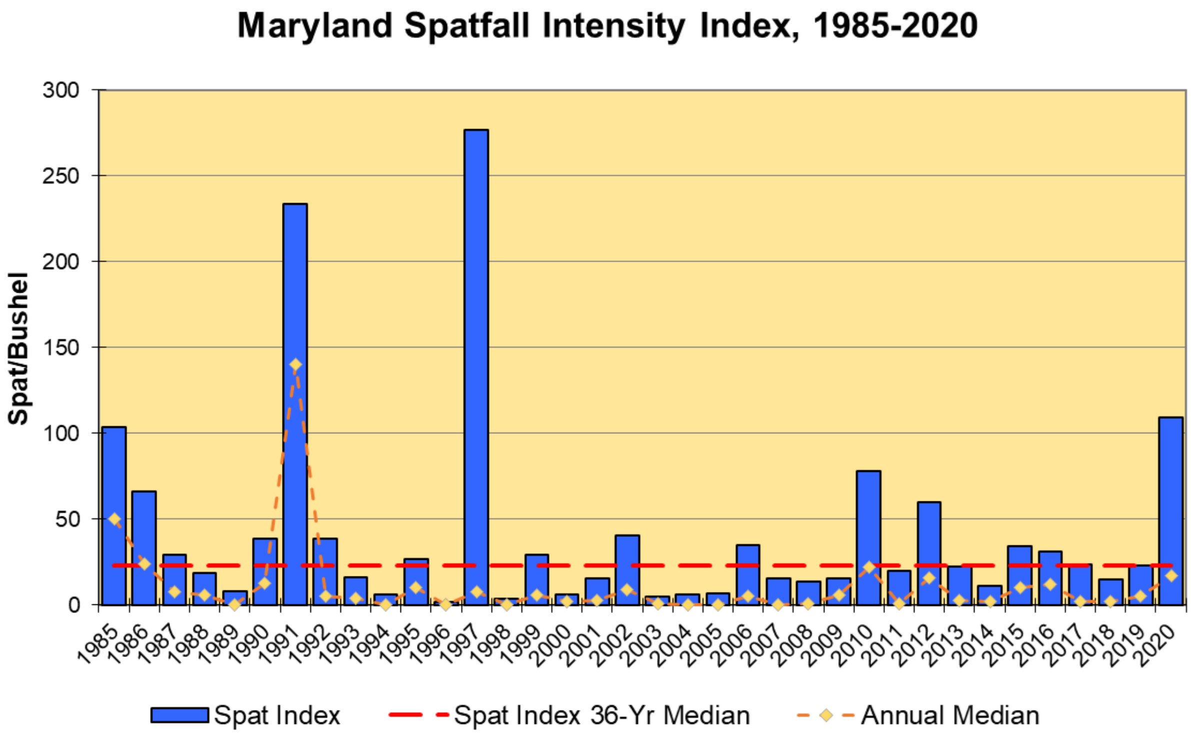

Figure 3a. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including annual median values.

Spatfall distribution among the Key Bars in 2020 expanded slightly from the previous year. Spat were observed on 40 of the 53 Key Bars, whereas 37 Key Bars had spat in 2019 (Table 2). However, the numerical distribution was heavily skewed, placing 2020 in the lower third of the time series for evenness of spatset, as indicated by the median:spat index ratio (Figure 3c). Only three bars accounted for 50% of the index, compared with five bars in 2017-2019 and nine bars in 2016. In 2020, only 20 bars contributed to 95% of the spat index; the remaining 33 bars made up just 5% of the Spat Intensity Index. In other words, 62% of the index bars were unproductive in 2020, with 13 bars (24.5%) receiving no spatset whatsoever. Thirteen Key Bars reached triple-digit spat counts, led by Deep Neck in Broad Creek, which actually had 1,838 spat/bu, the second highest count for that bar since 1939 and the highest for all bars in the 2020 survey. This was followed by Cason in the Little Choptank Sanctuary (613 spat/bu), Goose Creek in Fishing Bay (448 spat/bu), and Drum Point in the Manokin Sanctuary (445 spat/bu). Together these four bars comprised 58% of the Spat Index.

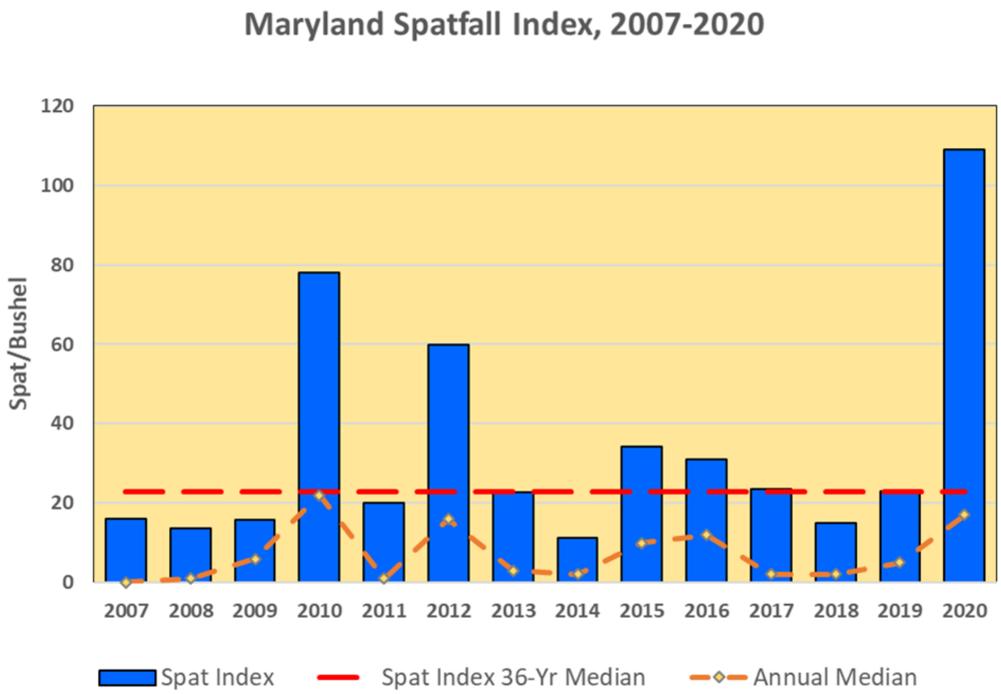

Figure 3b. Recent Maryland spatfall indices, 2007-2020, including annual median values.

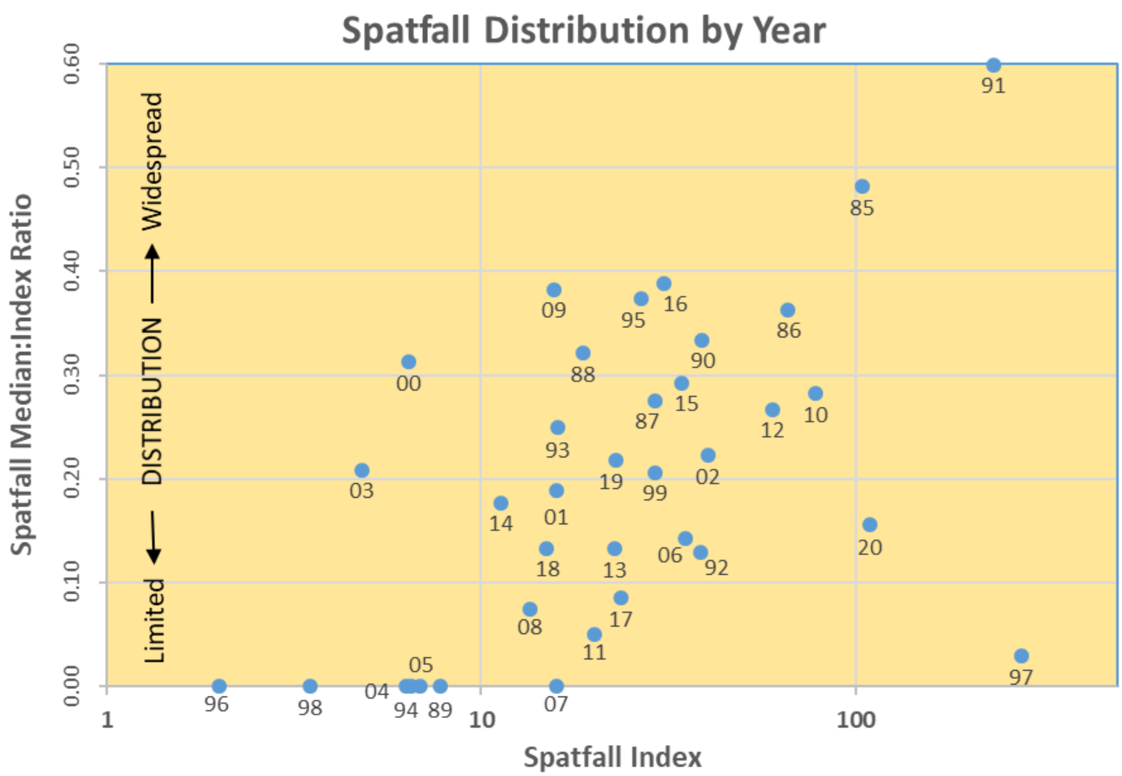

Figure 3c. Spatfall median:index ratios for the years 1985 to 2020. The ratio measures the distribution of spat counts for a given year. A lower ratio indicates that the spat counts are concentrated on fewer index bars, while a higher ratio indicates the numerical distribution of spat is more evenly spread among the index bars.

When considering all bars surveyed in addition to the Key Bars, the highest spatsets were observed along the lower Eastern Shore from the Choptank River tributaries to Tangier Sound

(Figure 4a). Broad Creek led all regions, averaging 913 spat/bu. Of the 13 bars surveyed in this tributary, six bars had quadruple digit counts and the remaining seven bars had spatsets in the hundreds (Figure 4b). Other areas with recruitment averages greater than 100 spat/bu include the Little Choptank Sanctuary (483 spat/bu), Harris Creek harvest area (369 spat/bu), Manokin Sanctuary (331 spat/bu), Fishing Bay (299 spat/bu), the southern half of Tangier Sound (298 spat/bu), Hooper Straits Sanctuary (253 spat/bu), Harris Creek Sanctuary (201spat/bu), and Honga River (149 spat/bu). Moderate spatsets occurred in other Eastern Shore areas, including the lower Choptank River, Tred Avon Sanctuary, Nanticoke Sanctuary, Pocomoke Sound, and the lower bay east of the channel. Recruitment was disappointing along the Western Shore and upper Eastern Shore. Aside from a modest spatset (11-50 spat/bu) around both the mainstem and Potomac sides of St. Marys County (including the normally highly productive St. Marys River), few or no spat were observed from the Patuxent River north, including Eastern Bay, upper Choptank River, and the middle to upper Potomac River. No spat were found in the entire Chester River and the bay north of the Bay Bridge.

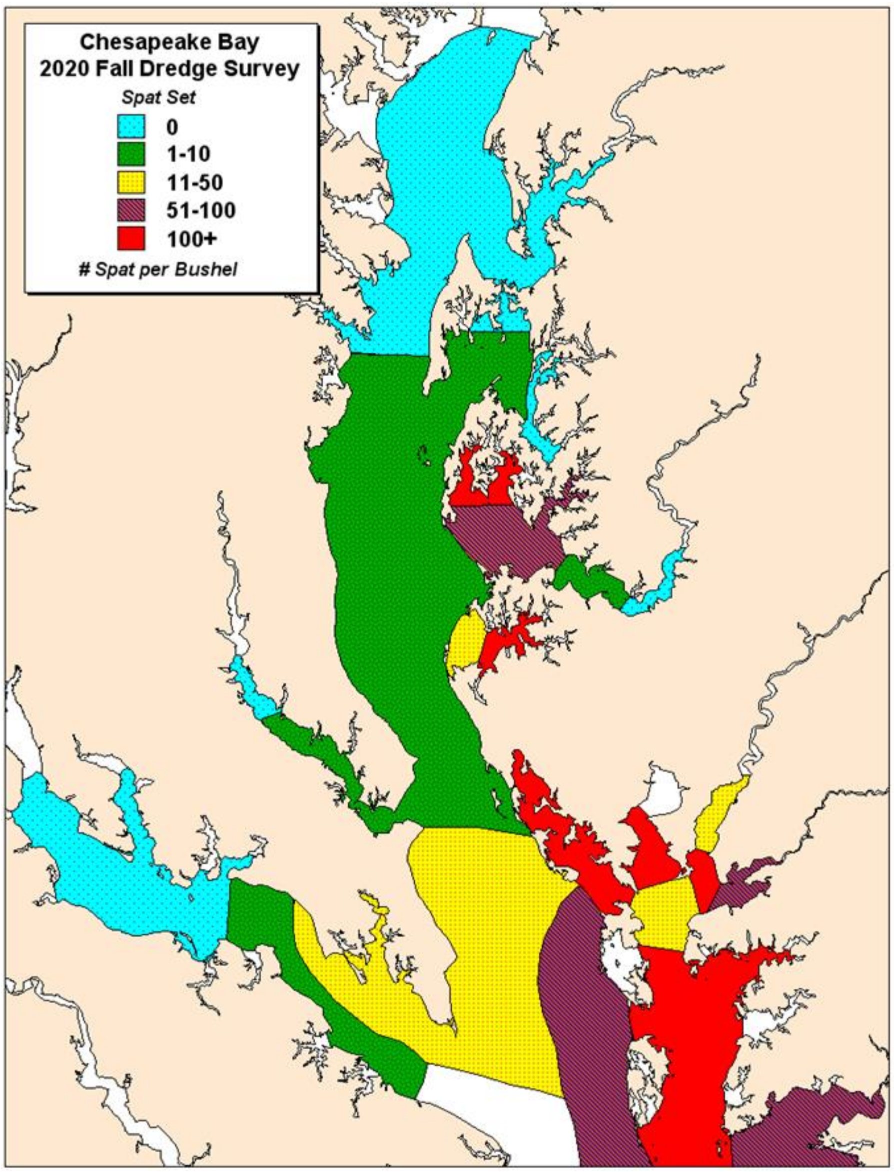

Figure 4a. Oyster spatfall intensity and distribution in Maryland, 2020. Intensity ranges represent regional averages.

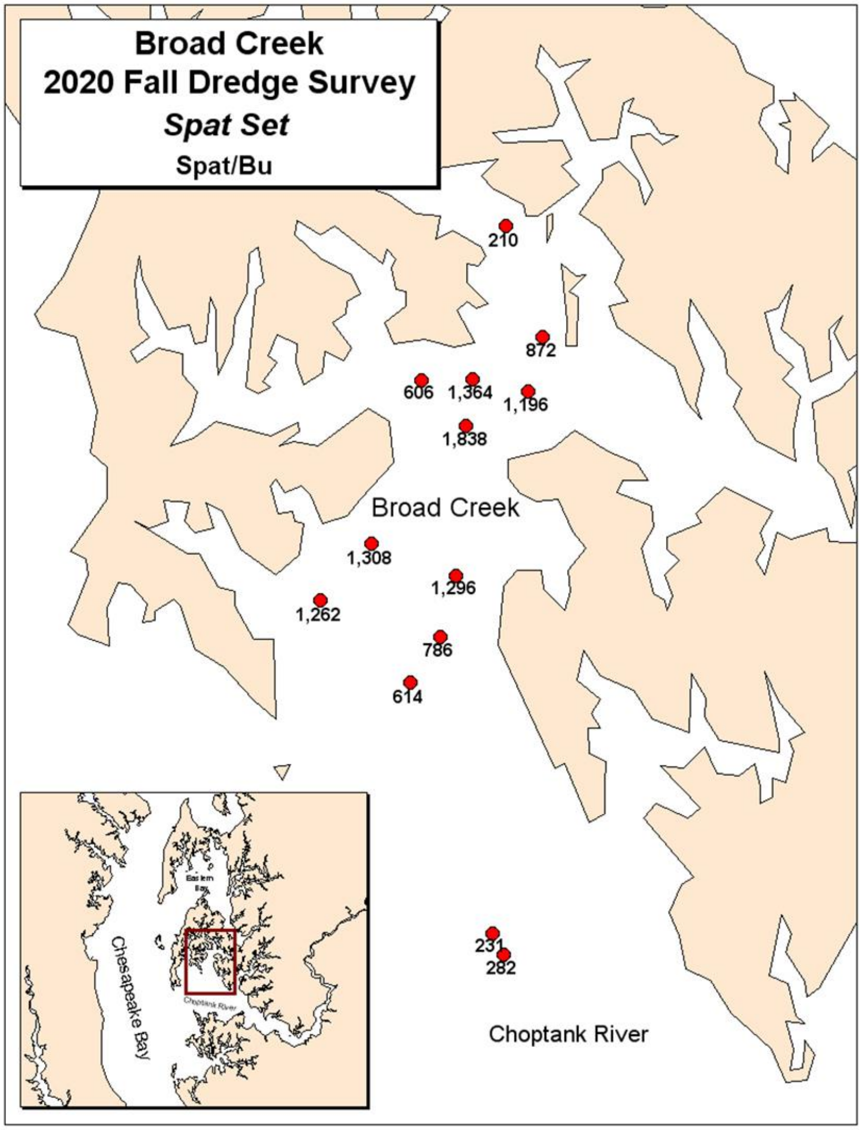

Figure 4b. Oyster spatfall intensity at individual Fall Survey stations in Broad Creek, 2020.

OYSTER DISEASES

A total of 1,560 oysters were analyzed for diseases in 2020 – 1,290 from the Disease Bars and 270 from 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.

The trend in low dermo disease levels in Maryland oyster populations continued in 2020. Dermo disease was detected in oysters on 84% of the Disease Bars (Table 3) during 2020, the lowest frequency since the 43-bar subset was standardized in 1990. Previously, the lowest frequency had been 88% in 2019. While dermo disease remained widely distributed throughout the oyster-growing waters of Maryland, the percentage of individual infected oysters has declined considerably over the past two years. Though the overall mean infection prevalence in oysters sampled on the Disease Bars rose slightly to 33%, compared to 27% in 2019, nevertheless it was the second lowest in the 31-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 63.5% for 16 of the past 18 years.

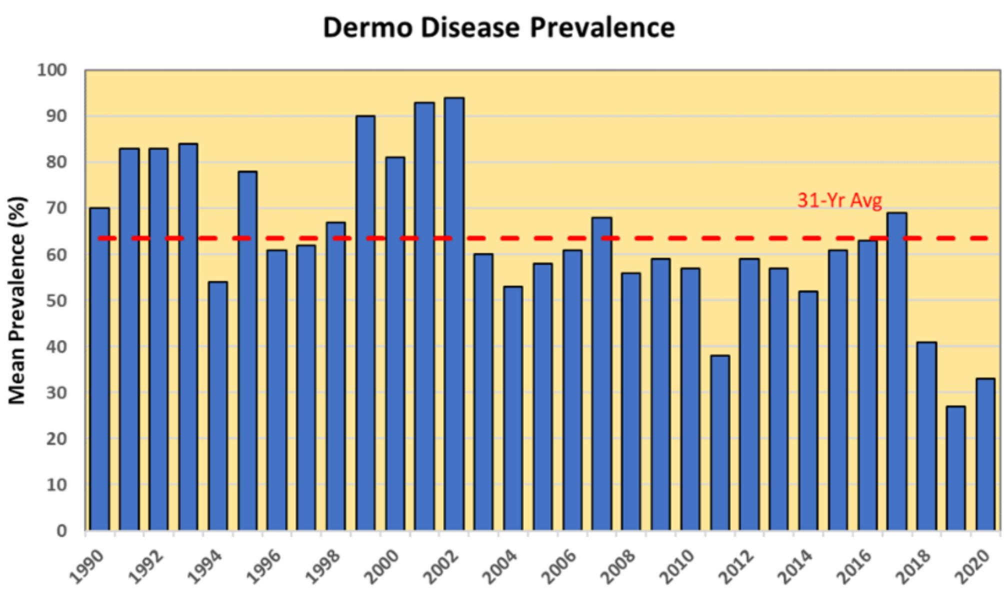

Figure 5. Annual mean *P. marinus* prevalences from Maryland disease monitoring bars.

The geographic distribution of high prevalences (>60%) contracted substantially over the past three years from 60% of the Disease Bars in 2017 to 19% in 2020. Overall, prevalences were relatively low throughout the remainder of the survey sites and dermo disease was not detected at seven locations, an improvement over the previous year's five sites (Figure 6). Outside of the regular disease monitoring sites, dermo disease was found at all nine of the supplemental sites, with prevalences greater than 60% at two of the bars (Mill Point 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 2020 because of the absence or low densities of oysters due to freshet-related mortalities. Dermo disease was undetected at these locations in 2011 when streamflows were also elevated.

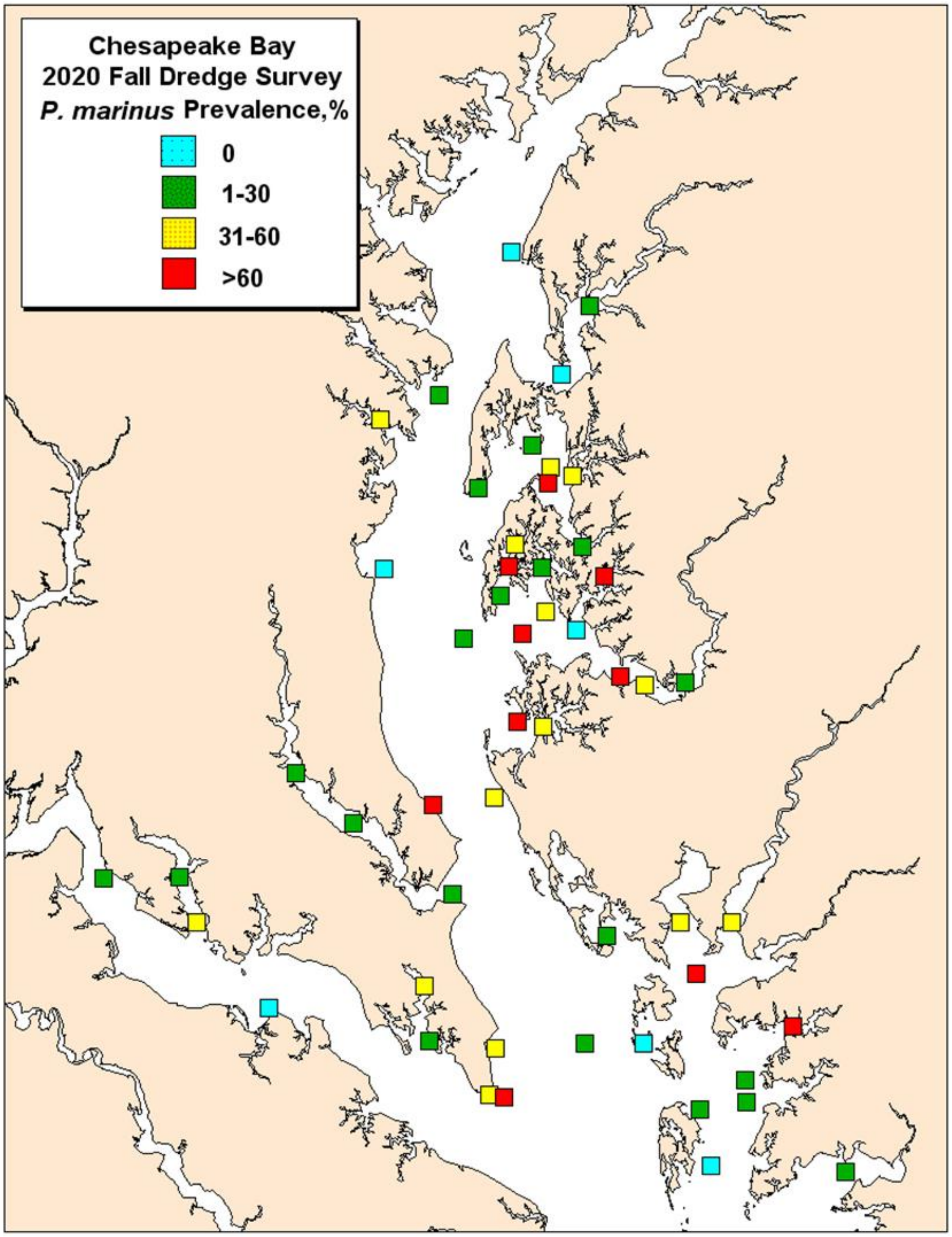

Figure 6. Geographic extent and prevalence of dermo disease in Maryland, 2020.

The trend in the mean infection intensity for dermo disease also remained stable at low levels. Although the 2020 mean infection intensity (1.07 on a 0-7 scale) was slightly higher than in 2019 (0.97), it was less than half that of 2017 (2.5) and the second lowest infection intensity on record, well below the long-term average (Table 3). This is the 15th of the past 18 years that the infection intensity index has been at or below the long-term average (Figure 7). The average infection intensity over the 18 years since the end of the 1999-2002 drought is 1.8, similar to another period of low to moderate dermo disease levels from 1994 to 1998 when annual mean infection intensities averaged 1.7. In comparison, the drought period of 1999-2002 had annual intensities that averaged 3.4.

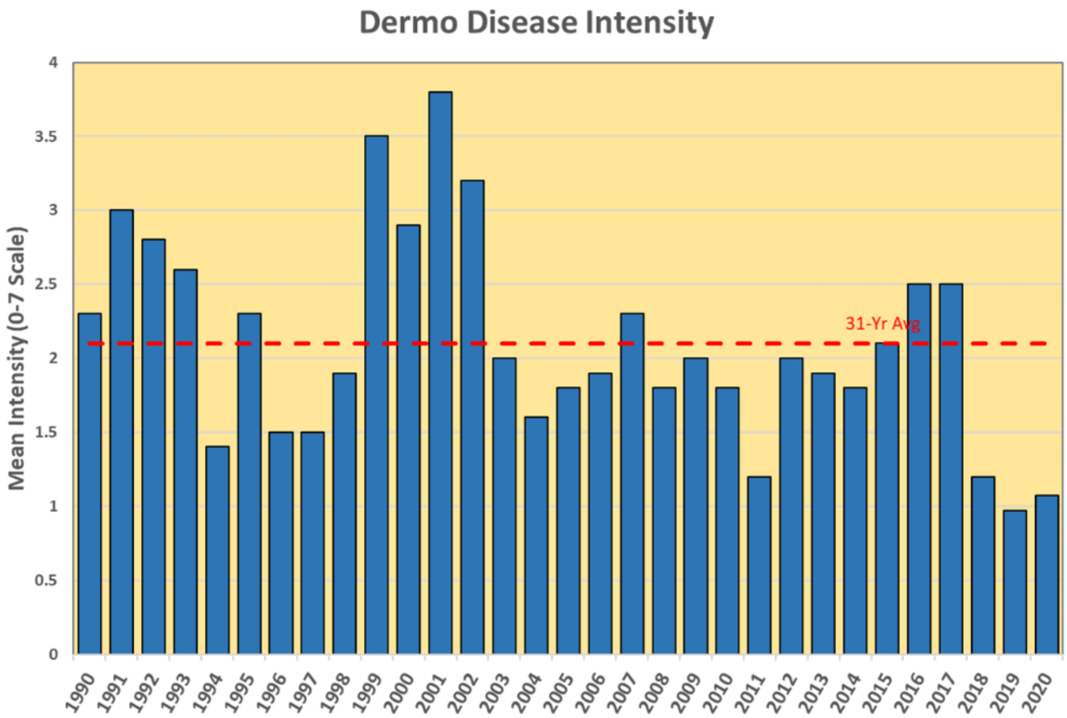

Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars.

The 2020 frequency distributions of sample mean infection intensities were similar to the previous year (Figure 8). In 2020, 2% of the sentinel bars (one bar) 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 58% in 2020, compared to 52% in 2019 and only14% in 2017. Dermo disease was not detected on 16% of the bars in 2020, a slight improvement over the previous year. In addition, none of the nine supplemental bars had mean infection intensities of 3.0 or greater in 2020. Infection intensities in individual oysters that are ≥5 on a 0–7 scale are considered lethal; such infection intensities were detected in 9% of oysters sampled in 2020, slightly up from 8% in 2019, but substantially lower than the 21% in 2017.

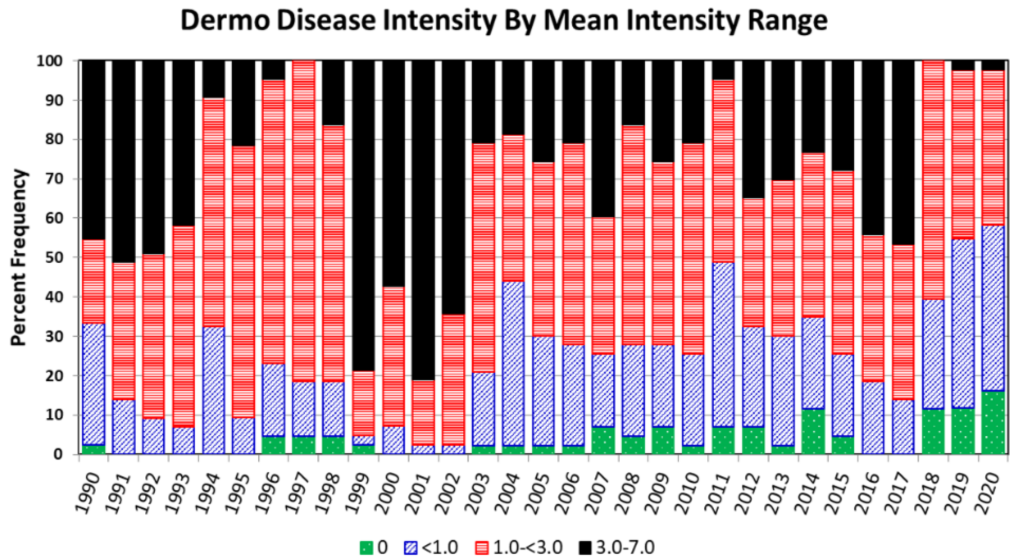

Figure 8. *Perkinsus marinus* infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.

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 2020, MSX disease mean prevalence (0.1%) of infected oysters on Disease Bars was identical to the previous two years and two orders of magnitude lower than the most recent peak in 2016 (11.1%). This equals 2018 and 2019 as having the lowest average prevalence recorded in the Disease Bar time series (Table 4, Figure 9). In terms of actual numbers of infected oysters, MSX disease was detected in only two oysters in 2020, one oyster on a Disease Bar and one on a supplemental site. This is slightly higher than in 2019, which had only one infected oyster, the smallest number of sampled oysters infected with *H. nelsoni* in Fall Survey records from the past 31 years.

When considering both the Disease Bars and supplemental sites, the geographic range of MSX disease was confined to two discrete locations: middle Tangier Sound (Piney Island East) and the lower mainstem east of the channel (Northwest Middleground) (Figure 10). The disease was no longer detected in Pocomoke Sound, the only site of an infection in 2019. Along with 2018 and 2019, 2020 was tied for the lowest number of infected sentinel Disease Bars on record. 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.

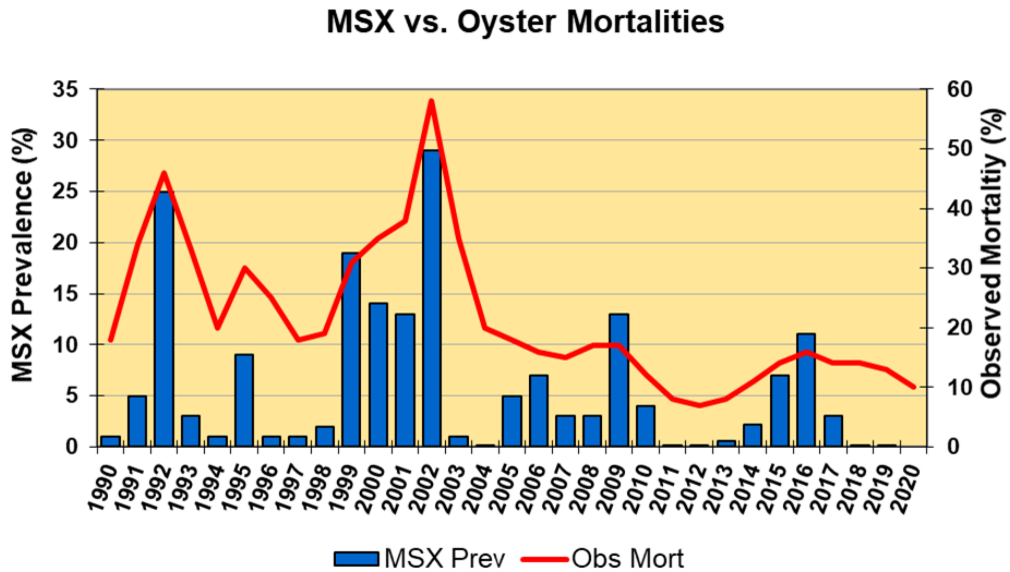

Figure 9. Percentage of Maryland oysters with MSX disease compared to annual means for observed mortalities on the disease monitoring bars from 1990-2020.

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).

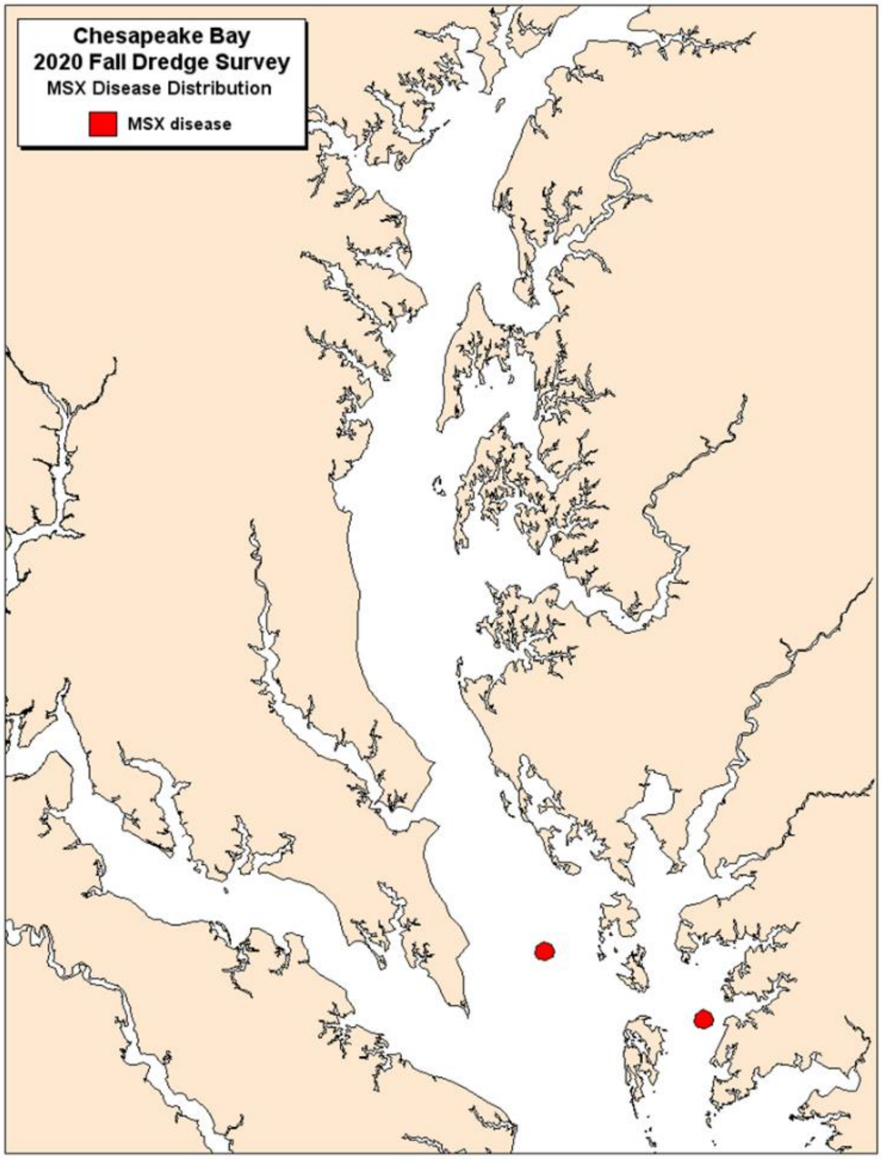

Figure 10. Geographic distribution of MSX disease in Maryland waters, 2020.

All of these epizootics coincided with dry years (Figure 2a). These were followed closely by periods of unusually high freshwater inputs into parts of Chesapeake Bay, which resulted in purging *H. nelsoni* infections from most Maryland oyster populations (Homer & Scott 2001; Tarnowski 2005, 2011). The current decrease in *H. nelsoni* infections is associated with the record high streamflows of 2018, which remained elevated into 2019 (Figure 2b).

OBSERVED MORTALITY

Following the abatement of locally devastating 2018/19 freshets, the 2020 Maryland-wide Observed Mortality Index declined from the previous year (Table 5). At 10%, the 2020 index was the lowest since 2013 and well below the 36-year mean of 21.9% (Figure 11), continuing a 17-year trend as a consequence of low to moderate disease pressure. For the 43 disease monitoring bar subset, the average observed mortality of 13.5% over the last 17 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.

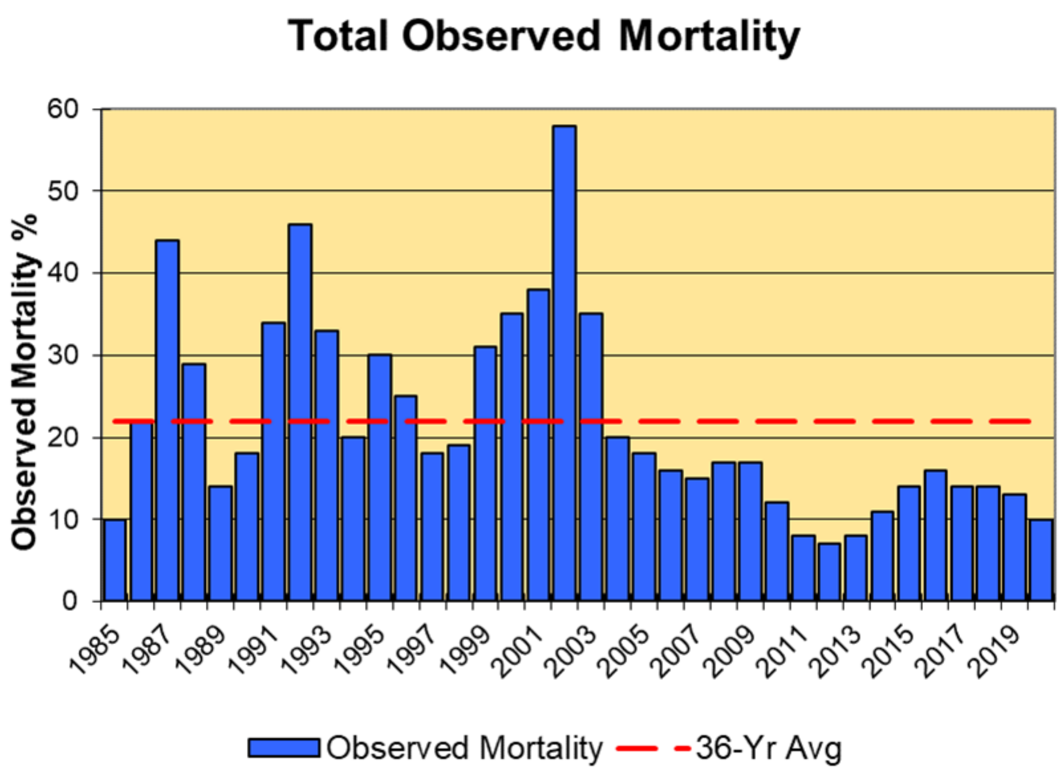

Figure 11. Mean annual observed mortality, small and market oysters combined.

Looking at all Fall Survey sites, observed mortalities were generally low. Aside from the upper St. Marys River (see below), the highest mortality observed on an individual bar with more than 50 live oysters/bushel[1] was 28.6% on Neal Addition Sanctuary in the Patuxent River. The north-south gradient in observed mortalities evident in most years was not apparent in 2020, with strikingly low average mortalities (10% or less) throughout most of the bay and tributaries (Figure 12a). Tangier Sound itself, typically a higher mortality area, averaged a remarkably low observed mortality of 3.5%, in contrast to 1999 at the start of the millennial epizootic when the average observed mortalities climbed to 48.0%. The exceptions were residual mortalities observed in the upper bay and upper Potomac and Choptank rivers, typically lower salinity areas that periodically suffer from freshet effects. The highest Index-bar mortality was observed on Lower Cedar Point in the upper Potomac River, where 100% of the oysters were dead from the aforementioned freshets, followed by Pagan bar in the upper St. Marys River (49.2%) (Table 5).

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

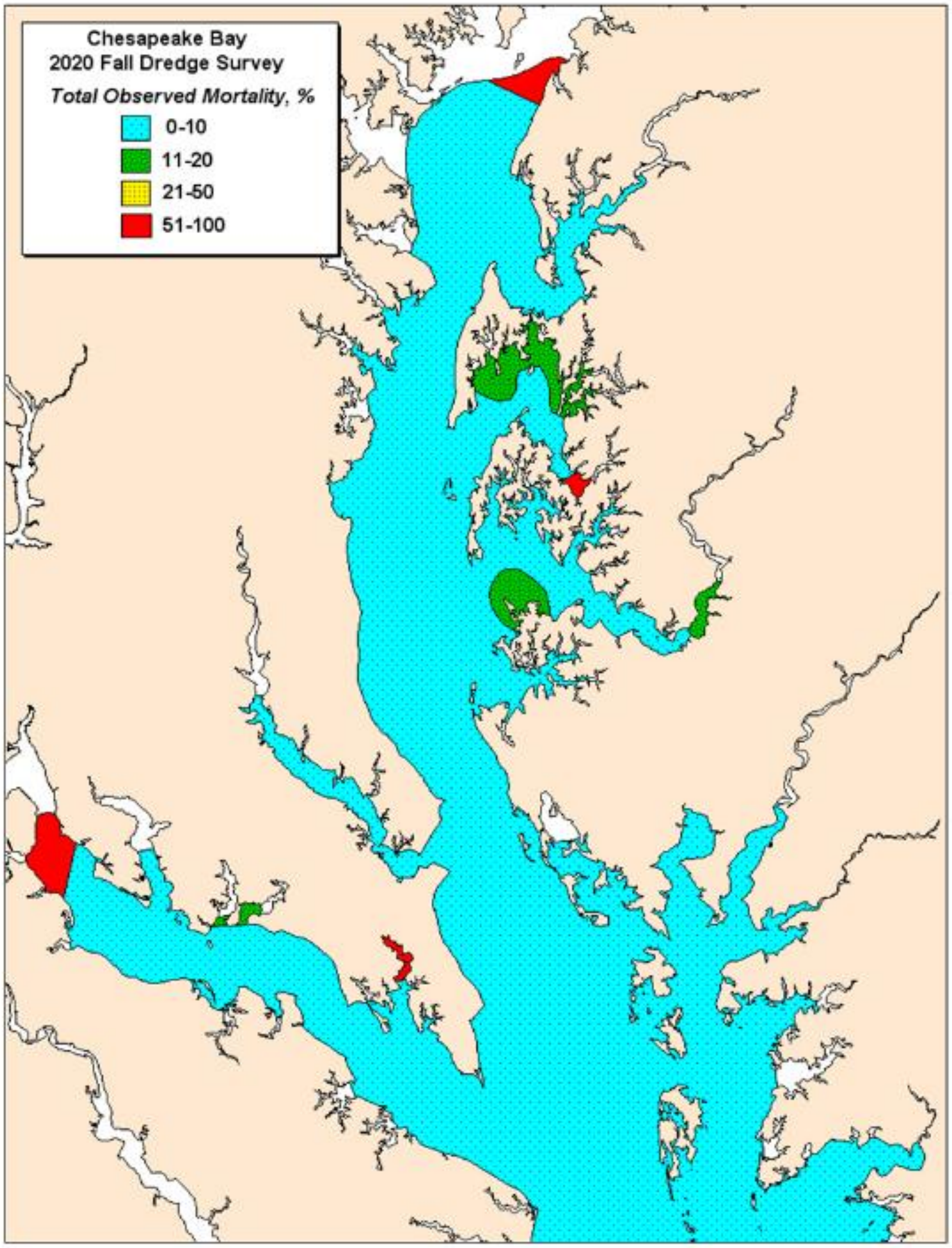

Figure 12a. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2020. Mortality ranges represent regional averages; individual bars may vary substantially.

Upper St. Marys River Mortality Event

The upper St. Marys River oyster population was severely impacted by a high mortality event, particularly in the oyster sanctuary where the observed mortality averaged 66.6%. The causative agent is believed to be low dissolved oxygen levels, possibly due to mahogany tide blooms that followed heavy rainfalls from Tropical Storm Isaias and beyond (Bob Lewis, St. Marys River Association, personal communication). Dissolved oxygen levels off the St. Mary's College pier on August 15 were 2.40 mg/l at the surface and 0.04 mg/l at the bottom. The water at this time was observed to be mahogany colored.

The mortality rates followed a gradient with the highest being upriver in the sanctuary (Figure 12b). The Horseshoe bar population was devastated with 95.6% of the oysters dead, followed by Pagan bar with an observed mortality rate of 49.2%. The actual number of oysters lost in the sanctuary was no small matter, averaging 162 dead oysters/bushel sample. Outside of the sanctuary, the observed mortality on Gravelly Run-Green Pond was 41.3%, after which mortalities dropped quickly. Gravelly Run followed at 21.7%, while the remainder of the bars sampled downstream averaged a mere 3.8% dead oysters. Of the total number of boxes from the bars with elevated mortalities, 28% had recently died (i.e., boxes clean inside without fouling), indicating a prolonged mortality event (sampling took place on October 21 2020).

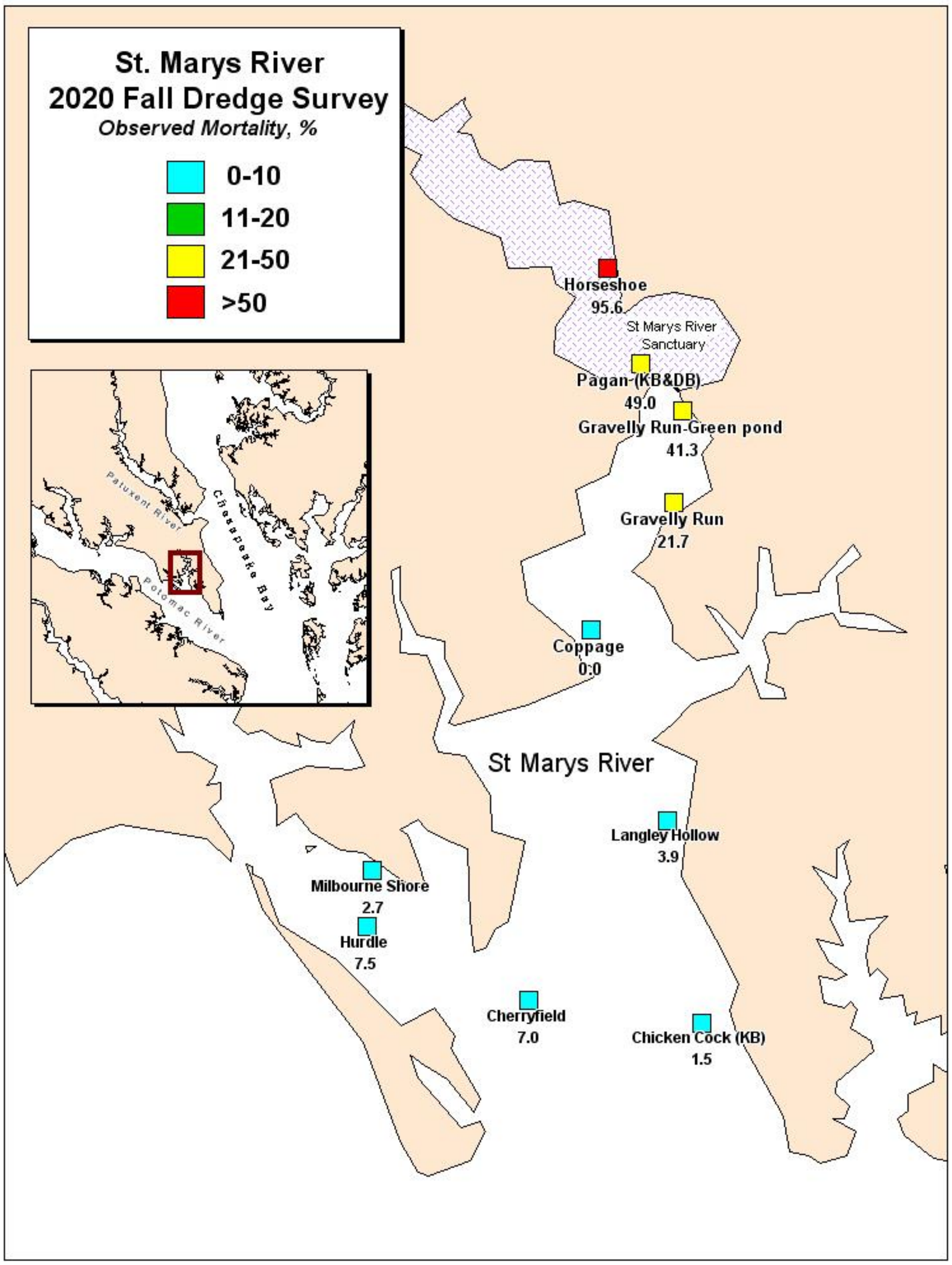

Figure 12b. Observed mortalities on the oyster bars of the St. Marys River sampled in October 2020.

Elevated mortalities have commonly occurred in the upper St. Marys River since the end of the millennial disease epizootics in 2002. These events are extremely localized and tend to be focused on Gravelly Run bar, especially the Green Pond site located just outside of the sanctuary line near Church Point. From 2005 to 2020, this station had an average observed mortality of 33%, with mortalities greater than 50% in four of the 16 years. The second Gravelly Run station further down river had a similar average observed mortality of 30%, but peak mortality years did not always coincide between the two sites. In contrast, the average observed mortality at Pagan bar, situated directly across the river from the Green Pond site, at 17% was just over half of the latter location for the same time period, while the baywide Mortality Index was even lower, averaging 13%. Observed mortalities at Gravelly Run-Green Pond substantially exceeded (double or more) the Mortality Index in 10 of 16 years.

BIOMASS INDEX

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

The 2020 Maryland Oyster Biomass Index of 1.98 was a gain of 18% from the previous year and the highest since 2014, ranking it third highest in the 28-year time series (Figure 13). The size distribution shifted even further to more market oysters relative to sublegal oysters at a ratio of 0.61 sublegals to one market oyster, compared with the sublegal to market ratio of 0.80 in 2019 and 1.32 in 2018. This can also be expressed as the percentage of sublegal oysters: 37.9% in 2020, down from 44.5% in 2019, and 56.6% in the previous year. This shift is reflected in the increase in average size of index bar oysters, from 72.7 mm in 2018 to 78.1 mm in 2019 and 79.8 mm in 2020. As expected, the increase in oyster size should result in a corresponding growth in biomass, but the average size increase of 1.7 mm did not appear to be sufficient to explain the entire biomass gain. However, the second component of the Biomass Index, oyster abundance, also showed improvement. For all index bars, the average number of oysters per sample rose from 97.8/bu in 2019 to 108.0/bu in 2020. The combined gains in the two components likely accounts for the magnitude of increase in the Biomass Index.

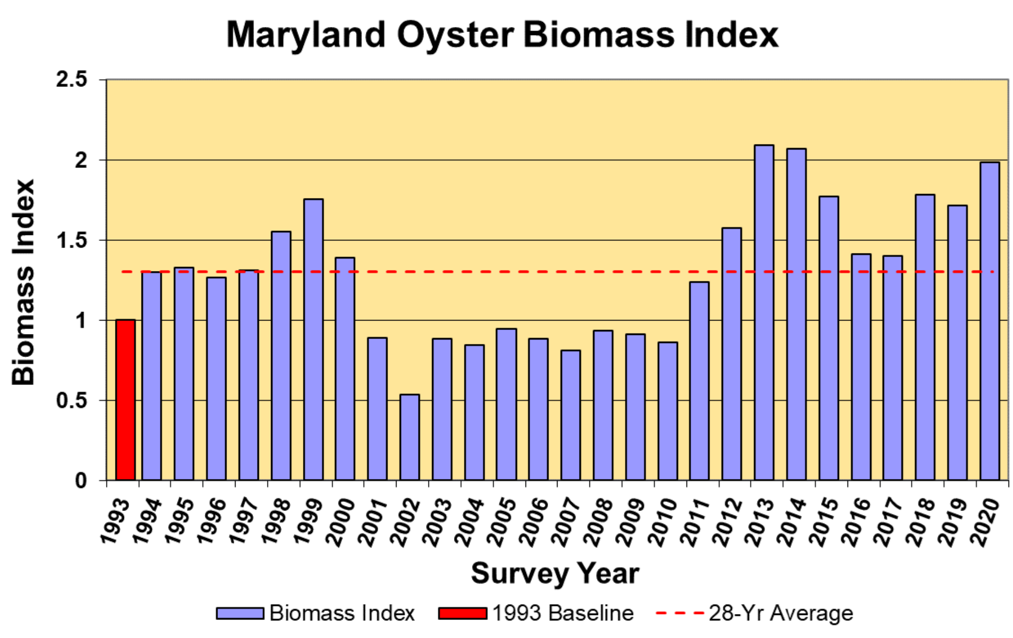

Figure 13. Maryland oyster Biomass Index. The year 1993 represents the baseline index of (1.0).

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]

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

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. With the improved 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.

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

The 2020 Cultch Index of 0.86 bu/100 ft. was slightly lower than the 16-year average of 0.90 bu/100 ft. However, some individual bars showed much steeper declines. Of the 53 bars used in this analysis, 42% had standardized volumes that were over 25% below their respective 16-year averages (Figure 14).

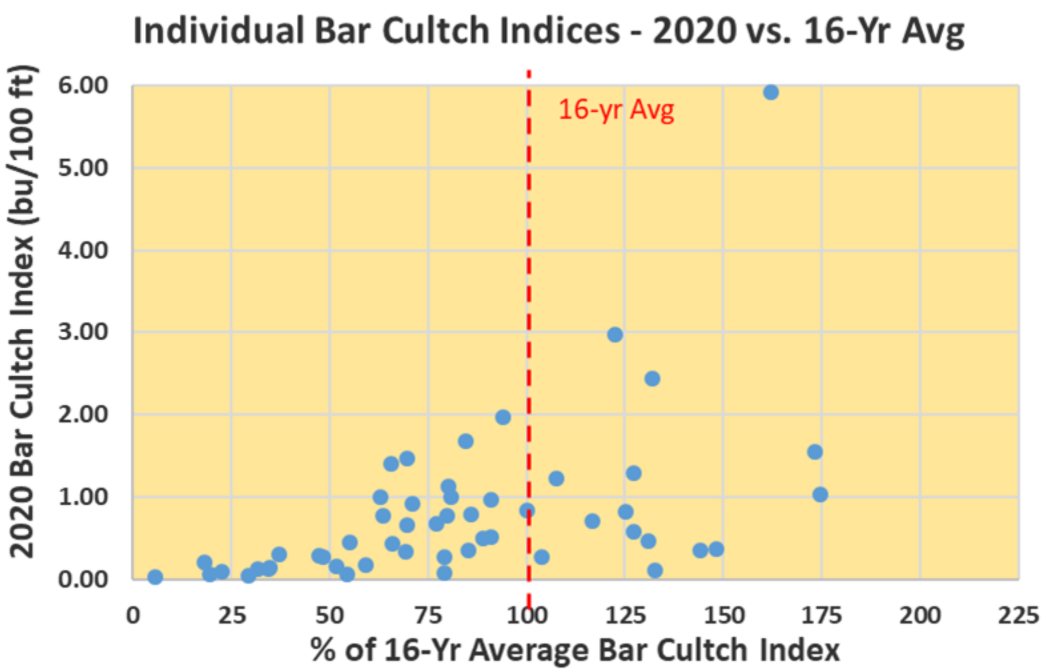

Figure 14. Range of cultch index values for individual Key bars in 2020 and the percent difference from their 16-year averages.

Although 16 years is a comparatively short time frame for discerning long-term trends in the Cultch Index, a distinctive pattern emerged over this period (Figure 15). A three-year rolling average was used to smooth the interannual variability inherent in the index (the rolling average is assigned to the terminal or third year of each grouping). The increase in the Cultch Index during the early 2010s reflects improvements in recruitment and survivorship during that period, especially the strong spatsets in 2010 and 2012 (Figures 3b, 11). The growth and high survivorship of these year classes contributed substantially to the index. The subsequent decline may be due to harvesting and lower recruitment, as well as ongoing taphonomic processes such as shell burial and degradation.

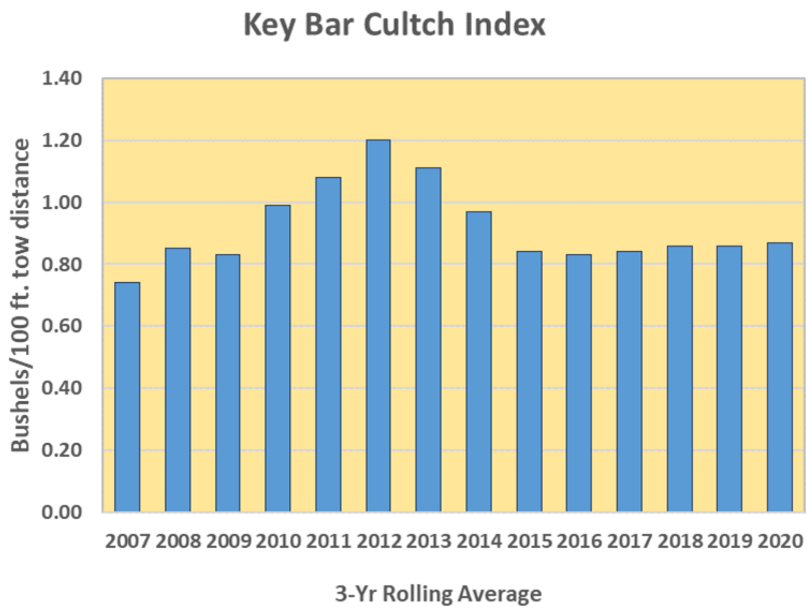

Figure 15. Three-year rolling average of annual means for the Key Bar Cultch Index, 2005-2020. The average is represented by the third year of the grouping (e.g., the 2005-07 average is graphed as 2007).

Strong regional differences in cultch mean volumes were evident (Figure 16). The areas with the lowest standardized cultch averages included the 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. Three of the six regions had indexes below the 16-year average (Figure 16). The largest decline in regional indexes occurred in the Chester River/Eastern Bay region. The Tangier Sound region saw improvement in its index, as did the Choptank region and Patuxent River. The Potomac region index is somewhat deceptive since it is largely driven by Pagan bar, whose 3-year average is six times as high as the three-year average of the other six bars in this region; if not for Pagan the Potomac region index would be 42% lower. Removing Pagan would also reduce the 16-year average for the Potomac region by 29%.

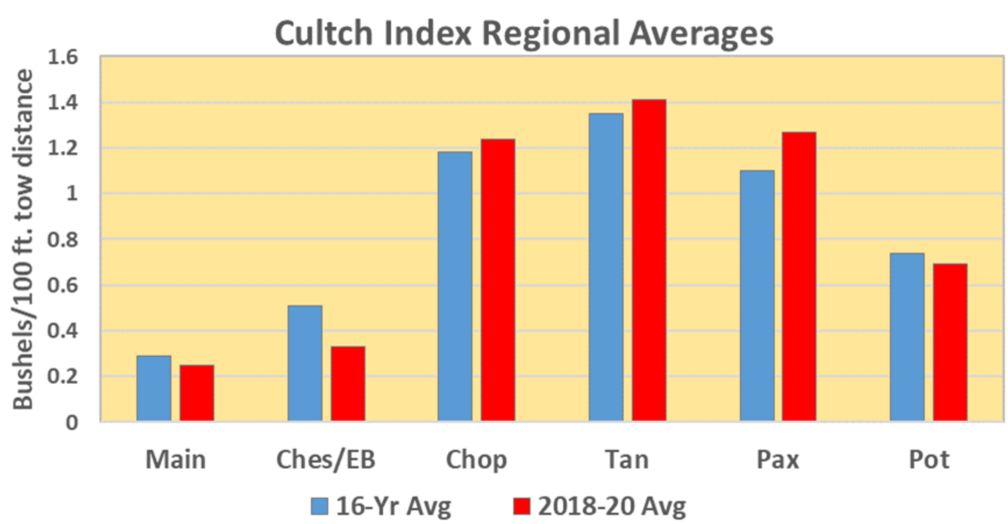

Figure 16. Regional cultch index averages for the 16-year time series and most recent three years. *Main=bay mainstem; Ch/EB=Chester River/Eastern Bay region; Chop=Choptank River region; Tan=Tangier Sound region; Pax=Patuxent River; Pot=Potomac River tributaries*

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 2020, the index stations of the subregional tributaries averaged 1.77 bu/100 ft. tow distance while the Tangier Sound proper stations averaged 0.74 bu/100 ft. The average cultch indexes for the individual tributaries were substantially higher in the Nanticoke River (2.51 bu/100 ft) and the Manokin River (1.91 bu/100 ft) sanctuaries (Figure 16a).

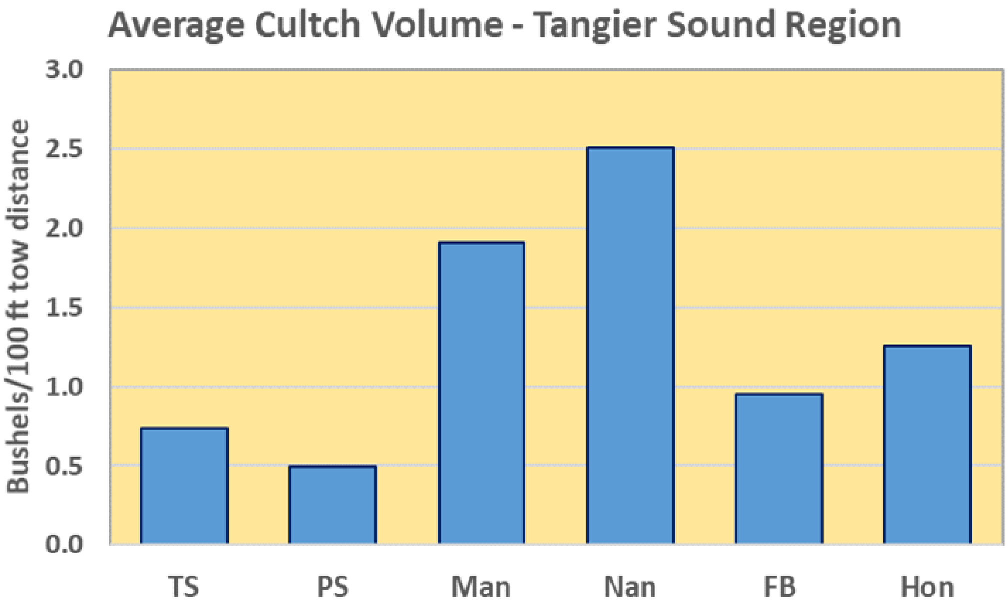

Figure 16a. Average bushels of cultch per 100 ft. tow distance for all stations by subregion within the Tangier Sound region. *TS=Tangier Sound; PS=Pocomoke Sound; Man=Manokin River; Nan=Nanticoke River; FB=Fishing Bay; Hon=Honga River*

COMMERCIAL HARVEST

Commercial oyster landings improved substantially during the 2019-20 season. With reported harvests of 270,000 bushels, oyster landings were 86% higher than the previous harvest season, reversing a five-year trend in declining landings (Table 6, Figure 17a). This was the highest harvest total of the past four years, but was 35% less than the most recent landings peak in the 2013-14 season. From the long term perspective, landings during the 2019-20 season remained below the 35-year average of 291,000 bu/yr. At an average reported price of $45.19 per bushel, the dockside value of $12.2 million was a gain of $5.6 million (85%) from the previous year (Table 7a.).

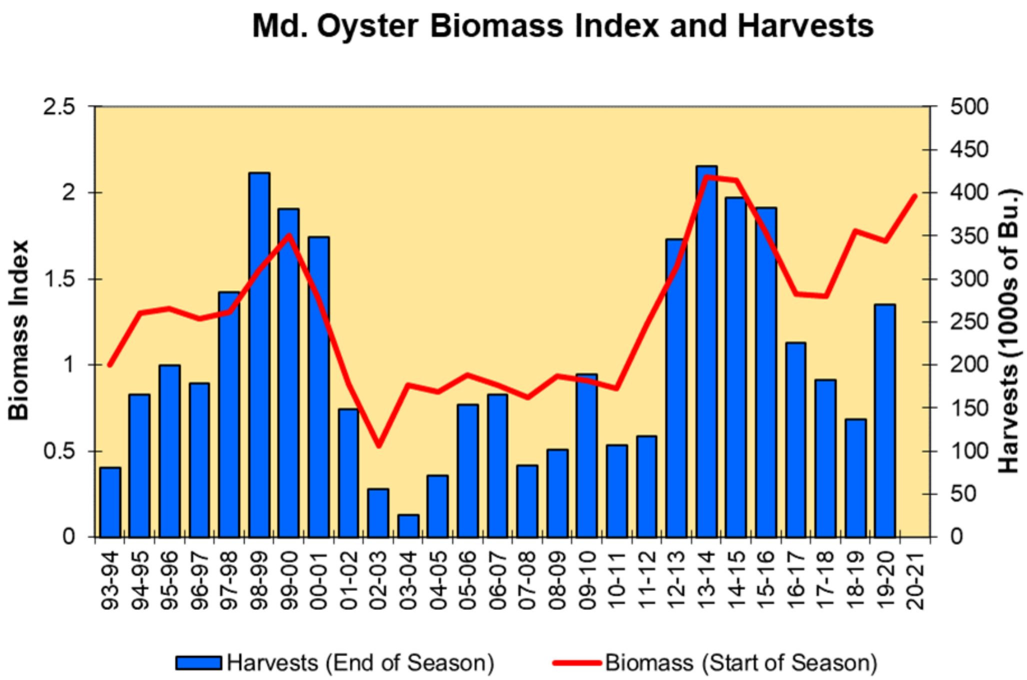

Figure 17a. Maryland oyster landings over the past 27 seasons and the relationship between the Biomass Index calculated at the start of the harvest season and total landings reported at the end of that same season. Note lag between the two metrics when abundant sublegal oysters add to the Biomass Index but have not yet entered the fishery.

Taken in the longer historical context, the average landings over the last several years remain only 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 27 years (and four of these in the most recent 18 years) following the onset of a series of disease epizootics beginning in the mid-1980s.

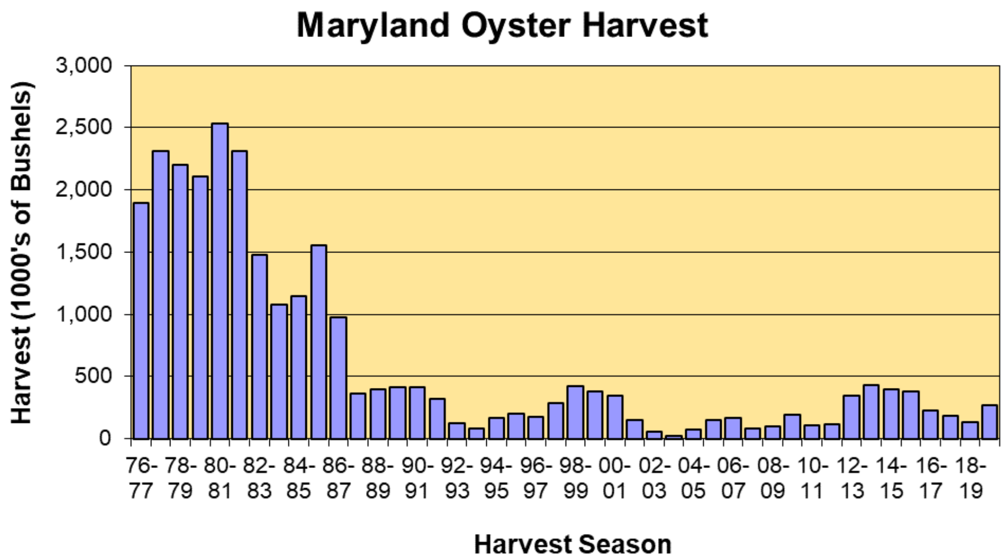

Figure 17b. Maryland seasonal oyster landings, 1976-77 to 2019-20.

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 recent seasons, following the below-average landings of the 11 years beforehand, were due to the strong 2010 and 2012 year-classes and subsequent good survivorship, allowing a larger proportion of those cohorts to attain market size. This abundance of oysters, 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 during the last three seasons. The Biomass Index did not track 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.

The Tangier Sound region, with landings of 127,000 bu, was the dominant harvest area, accounting for 47% of the 2019-20 landings. The majority of these landings came from upper Tangier Sound (82,000 bu or 30% of the Maryland harvest) (Table 6). The Choptank River region was second with 64,000 bu, providing 24% of the total harvest, primarily from Broad Creek (39,000 bu). With the exceptions of the Tred Avon and Miles rivers and a handful of other areas with minor declines, the majority of the regions experienced gains in landings to varying degrees. The most substantial changes (>4,000 bu) in Maryland landings between the 2018-19 and 2019-20 seasons are listed below:

Upper Tangier Sound
-Increased 60,164 bu (+273%)
Fishing Bay
-Increased 17,141 bu (+204%)
Patuxent River
-Increased 13,622 bu (+147%)
Little Choptank River
-Increased 9,818 bu (+4,000%)
Broad Creek
-Increased 6,933 bu (+22%)
Lower Tangier Sound
-Increased 4,458 bu (+159%)
Nanticoke River
-Increased 4,155 bu (+299%)

The combined harvests in the entire Tangier Sound region increased by 87,264 bu or 218% from 2018-19. The Choptank River region, the second most-productive area, showed a modest gain of 7,822 bu (14%), mostly from Broad Creek, despite losses in the Tred Avon River (-2,089 bu) and the upper Choptank River (-175 bu). Several regions exceeded their long-term harvest averages, including the lower bay; Broad Creek; Fishing Bay; upper Tangier Sound; and the Nanticoke, 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 2019-2020 season. For reference, the 35-year harvest average for these two regions was 32,000 bu/year, primarily sustained by numerous seed plantings from the MDNR Repletion Program. Similarly, harvests from the once-productive Eastern Bay region are about a quarter of the 35-year average.

All gear types showed substantial gains in harvests from the previous season. For the 13th consecutive season, power dredging was the predominant method of harvesting, accounting for 42% of the total landings (Table 7b). However, although the landings from power dredging improved by 78% from the previous year, they were less than half of those during the peak 2013-14 season (Table 7a). This activity was mainly in the lower Eastern Shore and Choptank regions. Patent tonging supplanted hand tonging in second place, producing 26% of the total harvests. Meanwhile, hand tonging slipped to 15% of the landings, primarily from Broad Creek - well below 74% of the landings during the 1996-97 season when power dredging was largely prohibited. The proportion of harvests attributable to sail dredging (skipjacks) and diving essentially remained the same.

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 2020 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 considerably above their respective Key Bar long-term averages (Table S-1). The exception was the St. Marys River, where spatset was well below average in the sanctuary and average in the harvest area. A comparison of spatset between the priority sanctuaries and adjacent harvest areas showed the sanctuaries to have consistently higher recruitment (Table S-1). Broad Creek ran counter to this generalization, having had an exceptional recruitment year. However, the difference in spatset between the Broad Creek harvest area and Harris Creek Sanctuary was proportional to their respective long-term averages, with Broad Creek about five times as high as Harris Creek both in 2020 and over the 16-year time series. 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. Cultch, the substrate required for spatset, was at lower densities in the open harvest areas than the 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.

Table S-1. 2020 average number of oysters/100 ft tow by region and size/age class (Sm=smalls, Ma=markets) and long-term Key Bar (KB) spat/100 ft tow 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 2020 Sm+Ma** (#/100 ft tow)	**Regional 2020 Spat** (#/100 ft tow)	**2020 Avg. Tow Dist.** (ft)	***KB Spat*** *16-yr Avg* (#/100 ft tow)
Harris Cr.	Sanc.	281	207	96.8	*45.8*
Harris Cr.	Open	51	100	369.6	*10.0*
Broad Cr.	Open	142	528	173.0	*51.8*[b]
Broad Cr.[a]	Open	265	1022	100.9	*240.3*
Tred Avon R.	Sanc.	140	105	71.0	*11.9*
Tred Avon R.	Open	50	48	128.2	*n/a*
L.Choptank R.	Sanc.	295	537	90.0	*61.8*
L.Choptank R	Open	114	82	171.5	*6.8*
Manokin R.	Sanc.	384	485	68.2	*187.5*[b]
Mid-Tangier S.	Open	87	166	192.1	*70.0*[b]
St. Marys R.	Sanc.	140	47	57.5	*191.6*
St. Marys R.	Open	103	24	139.5	*23.4*

[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. The Harris Creek, Little Choptank, and Manokin sanctuaries had the highest average number of adult oysters of any area in this comparison, with the highest counts in the Manokin River (Table S-1).

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 were slightly higher than the record lows of the previous year (average prevalences of 43.6% in 2020 vs. 36.1% in 2019; mean intensities of 1.4 in 2020 vs. 1.3 in 2019). Of the 13 sentinel Disease Bars within oyster sanctuaries, both dermo disease prevalences and intensities were below the 31-year site averages at all but two - Flag Pond and Cooks Point bars (Table 3). Dermo disease levels on Disease Bars in the open harvest areas were about two-thirds of those in the sanctuaries, averaging 28.4% prevalence and 0.9 mean intensity (Table S-2). The higher dermo disease levels in the sanctuaries can be attributed to the fact that they had a greater proportion of larger, older oysters than the harvest bars (Figure 18); parasite burdens tend to build up as oysters age (Ford & Tripp 1996). MSX disease was only detected at one of the supplemental disease sites within a sanctuary and one Disease Bar in an open harvest area (Table 4).

Table S-2. 2020 Dermo disease levels and observed mortality estimates for disease bars and regional averages on priority restoration sanctuaries and nearby harvest areas. MSX disease was not detected at any of these sites. Averages for all Disease Bars both within and outside sanctuaries are also presented.

Region	Disease Bar	Status	Dermo		Observed Mortality %	
			Prevalence%	Intensity	Disease Bar	Regional
Harris Cr.	Mill Pt./Rabbit I.[a,b]	Sanc.	56	1.6	4	4.6
Harris Cr.	Tilghman Wharf	Open	20	0.7	7	3.6
Tred Avon R.	Double Mills	Sanc.	63	2.2	7	9.2
Mid-Choptank R	Lighthouse	Open	0	0.0	2	3.9
Broad Cr.	Deep Neck/Royston[a]	Open	45	1.2	2	2.1
L. Choptank R.	Cason	Sanc.	50	1.7	3	4.7
L. Choptank R.	Ragged Pt.	Open	73	2.6	11	6.9
Manokin R.	Georges	Sanc.	77	2.9	7	6.8
Mid-Tangier S.	Piney I E/Back Cove[a]	Open	6	0.2	2	3.8
St. Marys R.	Pagan	Sanc.	37	1.1	49	66.6
St. Marys R.	Chicken Cock	Open	23	0.7	2	12.1
Average of all Sanctuary Disease Samples			43.6	1.4	14.7/7.1[c]	
Average of all Harvest Disease Samples			28.4	0.9	5.4	

[a] Dermo disease and mortality values are averages of the two bars. [b] Supplemental bars and not part of the Disease Index set.
[c] Average mortality with Pagan omitted.

The higher dermo disease levels in the sanctuaries did not appear to contribute to elevated observed mortalities. Mortality rates on sanctuary bars generally continue to be well below their long-term averages (Table 5). Seven of the 11 Mortality Index bars within sanctuaries had observed mortalities below the 36-year individual bar averages. For all Mortality Index bars, observed mortalities averaged higher in sanctuary bars (14.7%) than the open harvest bars (5.4%). A large proportion of the average sanctuary mortality was driven by the high mortality event at Pagan bar. If Pagan is omitted, the average mortality within sanctuaries drops to 7.1%

(Table S-2). Aside from the St. Marys Sanctuary, the Disease Bars and 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 harvests areas, with the results from 2020 exceeding their long-term averages by 61% and 49% respectively. The average biomass per index bar in 2020 was substantially higher in the sanctuaries (202.3 g/bu) than in the open harvest areas (152.2 g/bu). Most of this difference was in the larger market size classes (Figure 18). Both management categories experienced growth in the average market biomass per bar from the previous year - market biomass in the sanctuaries (174.2 g/bu, an increase of 18.9 g/bu) remained above the open harvest areas (113.6 g/bu, an increase of 32.1 g/bu). In contrast, the average biomass of sublegal oysters was lower in the sanctuaries (28.1 g/bu in the sanctuaries vs. 38.6 g/bu in the harvest areas).

The average size of adult oysters (equal to greater than one-year old) in the sanctuaries increased from the previous year (86.4 mm in 2020 vs. 81.7 mm in 2019) and was larger than on the harvest bars, which showed little change in size (76.8 mm in 2020 vs. 75.8 mm in 2019). The largest oyster observed in a sanctuary had a shell height of 187 mm, compared with 157 mm maximum shell height on a harvest bar.

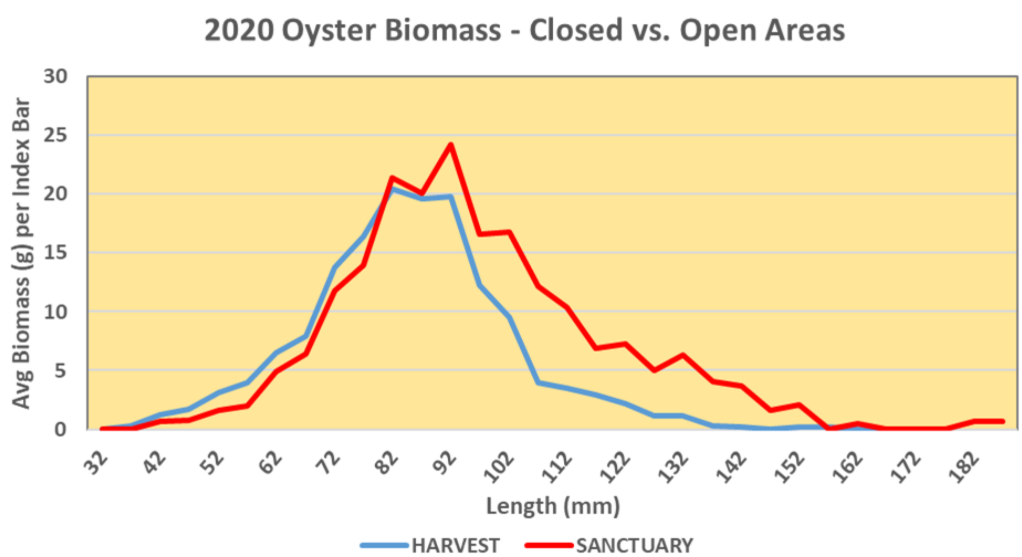

Figure 18. Average oyster biomass by 5 mm size classes on Biomass Index bars in harvest areas and sanctuaries.

DISCUSSION

Trends in Oyster Population Indicators Improve

The past decade was marked by advances and setbacks for oysters in Maryland. Battered by devastating epizootics around the turn of the millennium, followed by a protracted recovery period, the oyster population finally was on the upswing, beginning with a strong recruitment event in 2010. By most measures, 2013 appeared to be a turning point for oysters in Maryland, including the highest Biomass Index in the time series. But by 2016, with the Chesapeake region in the grip of a two-year drought, conditions had begun to deteriorate. Indifferent spatsets in 2013 and 2014, followed by rising disease and mortality levels and harvesting on the abundant 2010 and 2012 year classes, contributed to a 33% drop in the Biomass Index from its 2013 peak. Oysters appeared to be at a crossroad. Would the downward trajectory continue or would environmental conditions improve and reverse the trend? Then came the record high streamflows in 2018 that devastated some regions and stunted growth in others, and resulted in a below-median spatset. At the same time, other metrics improved. Disease levels plummeted and the Biomass Index actually increased due to the 2015/16 year classes. With freshwater flows returning to normal by mid-2019, oyster populations in many parts of Maryland appear to be rebounding. The last two years have been particularly favorable to oysters, as reflected in the primary population indicators:

- Strong recruitment
- Good growth
- Record low disease levels
- Well below average mortalities
- Third-highest biomass index

Although impossible to predict what the future holds, the recent positive direction the oyster population has taken recently is a welcomed turn that is cause for cautious optimism.

Strong Recruitment

Broad Creek, historically a commercially productive tributary of the Choptank River, experienced the highest average spat count for any region since 1997, when Eastern Bay and its tributaries had among the highest average regional spatsets on record. In 2020, several bars had spat counts of over 1,000 spat/bu; Deep Neck, a Key Spat Index Bar, led with over 1,800 spat/bu, the second highest in the 82-year time series for that bar.

Equally encouraging are the two successive years of strong recruitment in the commercially important Tangier Sound region, centered in mid-Tangier Sound, with even higher counts in 2020 than the previous year. The actual source of larvae producing this robust spatset is unknown. This area is immediately outside of the Manokin River Sanctuary, which may have provided the larvae from the substantial number of broodstock oysters found there. In addition, the Nanticoke River Sanctuary, with its sizeable natural oyster population (averaging 303 adult oysters/100 ft. sample), augmented by numerous oyster aquaculture operations, sits atop Tangier Sound, an ideal location for suppling larvae to the northern reaches of the region. Other possible sources of larvae may have been Virginia, which has more consistent spatsets associated with a higher salinity regime. Alternatively, there could have been two or more independent larval sources. And, of course, the Tangier Sound oysters could have produced the larvae, although the average broodstock density (small and market oysters) standardized to a 100 ft. tow was four to five times lower in Tangier Sound proper than in the adjacent sanctuaries. Whatever the source of the larvae, the back-to-back years of successful recruitment bodes well for these oyster populations in the near term.

Adequate salinity is a necessary though not always sufficient requirement for strong recruitment. The return to normal salinities in 2020 set the stage but it is unknown what other factors, if any, contributed to such good spatsets in some areas, or conversely, why other regions such as on the lower Western Shore underperformed.

Good Growth

Like recruitment, somatic growth depends on proper salinity, as well as an adequate supply of proper nutritional sources, among other requirements. The depressed salinities during 2018/2019 inhibited growth, especially among the sublegal oysters (Tarnowski 2020). After salinities returned to normal during the second half of 2019, the average shell height of oysters on the biomass index bars in the commercial areas jumped from 69 mm in 2018 to 76 mm in 2019. As a result, many of the small oysters from the 2015/16 year classes attained the minimum legal size limit, which contributed to the 86% increase in landings during the 2019-20 season.

In 2020, growth rates in the previously established populations slowed naturally as the oysters aged. What was striking, however, was the exceptional growth of the hatchery-reared spat planted in commercial areas (Appendix 1). Although variable due to environmental conditions, the general rule of thumb for oyster growth rates in Maryland during their first three years is 1 in. (~25 mm) per year (Beavans 1952). With a mean shell height of 3 mm at time of planting, many of these seed oyster plantings averaged between 40 to 59 mm in their first year, with about a month left in their growing season at the time they were sampled. The average daily growth rate for all plantings was 0.31 mm/day. In comparison, previous studies separated by four decades reported average growth rates of 0.16-0.22 mm/day (Beavans 1952, Paynter and DeMichele 1990, Kraeuter et al. 2007).[3] The oysters in these studies had initial sizes of 5-9 mm.

Two of the samples with the largest average spat sizes as well as the biggest individuals were observed on the triploid plantings at Well Cove in Eastern Bay and Nanticoke Middleground (Appendix 1). Triploidy confers an advantage to growth as these oysters have reduced reproductive activity; less energy is diverted to gonad development, so that more goes into somatic growth (Longwell and Stiles 1996, Thompson et al. 1996). Therefore, after their first year higher growth rates would be expected to be seen in the triploids compared with the sexually maturing diploid oysters, but not necessarily in spat. In fact, the Well Cove triploid planting had only a slightly above average growth rate of the 2020 plantings; these oysters went in earlier in the year. Nevertheless, some individual oysters exhibited phenomenal growth, with the largest oyster measured at this site reaching a shell height of 85 mm, comparable to a three-year-old oyster. In contrast, the Nanticoke Middleground triploid planting had one of the highest average growth rates, similar to the diploid plantings at Howells Point and nearby Dickinson, both in the middle Choptank River. Aside from overall environmental conditions that vary annually, location as well as time of planting also play a role in spat size at time of sampling. Despite having the largest average sizes, the verdict on the growth rates of the triploid oysters is still out, pending sampling in the upcoming years.

A fundamental question arises as to whether planting triploid oysters on public oyster grounds is appropriate. A potential faster growth rate attributed with triploidy is advantageous in a mariculture setting, where the oyster growers could benefit from a rapid turnover of stock,

[3] Growth rates in the Beavans (1952) study were derived from a graph for the first four months of growth (July-October).

thereby maximizing production on their investment. In contrast, growth rate is not necessarily as critical for the public fishery, where other locations are available for harvest until the planted oysters reach legal size. Faster growth in the public fishery would be desirable if disease was an issue – the oysters could be harvested before they succumb to disease. However, disease levels and related mortalities have been low for an extended number of years, so there is little to gain in this regard at the present time. The trade-off to planting triploids for possibly quicker growth is their greater cost – about 25% higher than diploid oysters. Perhaps more importantly for a public bar is the inability of triploids to functionally reproduce, whereas diploids potentially could have two or more spawnings before being harvested, serving as broodstock for their surrounding areas. Since oysters reproduce by external fertilization, broadcasting their gametes into the water column, the often higher densities of the seed plantings compared with natural populations also help promote fertilization success. The degree to which the benefit of faster growth offsets the added expense of triploid oysters and their lack of reproductive potential merits further consideration.

Record-Low Disease Levels

Over the last three years, oyster disease levels have trended downward to record lows. Although still widespread, the geographic range of dermo disease continues to contract – in 2020, dermo was found on the fewest number of bars of the time series. Furthermore, MSX disease has been limited to small, discrete locations in the lower bay, where it was detected in only one or two oysters per year of the over 1,500 oysters examined annually during the past three years. These reduced infections are associated with the freshwater deluges of 2018 and early 2019, which likely were beneficial in suppressing disease (Ford 1985, Tarnowski 2019).

In the longer term, disease levels have generally been below average since 2003. In the case of dermo disease, it is uncertain whether this is due to resistance or tolerance developing in the oyster population, generally unfavorable environmental conditions for dermo, or a change in the parasitic organism that causes the disease. The latter possibility is not unprecedented: Carnegie et al. (2020) showed that *P. marinus* underwent a rapid phenotypic change in the 1980s and became more virulent, as evidenced by escalating mortality rates during that time. With respect to MSX disease, resistance in oysters has been amply demonstrated over the years in many regions, such as in Delaware Bay, where the first outbreaks of this disease occurred in the 1950s (Ford and Tripp 1996). The caveat is that in order to develop resistance to MSX, oyster populations must be constantly challenged by the disease, which is not always the case in the lower salinity waters of Maryland. Nonetheless, it would have been difficult to imagine during the height of the millennial epizootics that disease metrics would drop to such low levels shortly afterwards and remain consistently below average for such an extended period of time, to the point that they are the lowest in 31 years.

Below Average Mortalities

As a consequence of low disease levels, the Observed Mortality Index has also been below the long-term average for the last 17 years, with 2020 tied for the fourth lowest mortality rate in the 36-year time series. This has resulted in enhanced survivorship of the strong recruitment events such as occurred in 2010 and 2012, leading to increased harvests and allowing the sanctuaries to thrive, especially where natural spatset or restoration efforts have taken place. While dermo disease levels tend to be higher in the sanctuaries, that is because those oysters are older. Also, there is little real difference in disease-related mortalities with nearby harvest areas. These low mortality rates are a remarkable turnaround considering the devastation to the oyster populations due to disease during the early 2000s, when the baywide observed mortality index was 58% and some tributaries such as the Little Choptank River suffered mortalities of over 90%. Non-disease-related natural mortality events continue to take place, but while they can be locally devastating, they are limited in extent.

Third-Highest Biomass Index
The outcome from the improvements in all these factors – robust recruitment, good growth, low disease levels, below average mortalities – is the third-highest Biomass Index in the 28-year record. As expected, the biomass in the sanctuaries remained higher, though the commercial areas showed substantial gains. Consequently, an increase in landings can be anticipated for the 2020-21 season and beyond – further sustained by the strong 2020 year class as it attains market size should conditions remain stable.

Persistent Issues
The paucity of spatset over large areas of the bay is the result of the convergence of three problems: a salinity regime that is often too low for gametogenesis and recruitment, the dearth of substrate for larval attachment, and a shortage of broodstock in those areas. The first is in the hands of nature with little of the physical environment that can be controlled. One possible approach might be a selective breeding program to develop oysters that can reproduce and recruit in lower salinity conditions. Then again, even areas that have suitable salinity during some years are lacking either or both of the other two factors, resulting in recruitment failure. The broodstock issue can be somewhat mitigated with plantings in sanctuaries, but in places such as the upper bay it becomes perhaps a decadal-scale wait for a drought to elevate salinities. Adequate habitat is another issue for successful recruitment. Even if competent oyster larvae are present – whether during a dry period or transported from outside the area or by means of genetic selection – the lack of substrate is a major obstacle to recruitment (Tarnowski 2018). These low recruitment regions, in particular the mainstem of the bay, had the lowest Cultch Index of the bay (Figure 16). Essentially a negative feedback loop has been established:

no cultch = no recruitment = no oysters = no cultch.

Localized non-disease-related natural mortality events, especially due to freshets, have always been a fact of oyster life in low salinity regions (Beavan 1947, Tarnowski 2010, 2012, 2019). The results can be extreme, such as the total loss of oysters from several of the uppermost bars in the Potomac River during the record freshwater streamflows in 2018/19. As with reproduction, perhaps a selective breeding program can develop an oyster that tolerates lower salinities. This would be of benefit not only to restoring oyster populations in these lower salinity regions, but could expand the potential areas for raising oysters in an aquaculture setting.

Anoxic or hypoxic conditions fueled by algal blooms can also result in oyster mortality events. The tighter confines of many tributaries, which often have limited tidal flushing as well as higher ratios of impervious surfaces that can result in greater runoff and nutrient input, are particularly vulnerable to the development of low dissolved oxygen situations.

The upper St. Marys River is an example of a region with recurring elevated oyster mortalities, usually of a highly localized nature centered on Gravelly Run bar. Little if any evidence exists as to the cause(s) of these deaths. This past year, however, there was a much larger mortality event that spread upriver into the oyster sanctuary – Horseshoe bar lost 95% of its oysters. Anecdotal reports indicated that a mahogany tide bloom had occurred, coincident with a hypoxic event that had been documented with a dissolved oxygen meter. The St. Marys River historically has been a productive oyster recruitment tributary. It is considered a trap estuary, where the configuration of the river and associated water currents tend to hold the free-swimming oyster larvae within the system (Manning and Whaley 1954, Kennedy 1996). It seems reasonable that these same water circulation patterns could also retain an algal bloom, with fatal consequences as was evident in 2020. This is not to say that the mortality events in previous years were the result of anoxic conditions – there simply is no information to determine causality – but a low dissolved oxygen issue and/or toxic algal blooms are certainly candidates (Wolny et al. 2020).

"Whereto Tends All This"[4]

With the positive direction in oyster population indexes over the last two years, the immediate future in general looks promising for both the commercial fishery and sanctuaries. These improvements continue a trend that started in 2010 with the most substantial spatset since the onset of the millennial epizootics and continued with another strong spatset in 2012, resulting in the highest recorded biomass indexes in 2013 and 2014. These advances were set back for a few years in the middle of the decade by often indifferent spatsets that could not adequately support subsequent harvests, as well as rising disease and mortality levels, all leading to declining biomass. Nevertheless, the past 11 years has seen a net gain for oysters in Maryland, especially when compared with the devastated post-epizootics populations of the previous decade. Five of the last 11 years had spat indexes well above the long-term median, four to six years (depending on the metric) during this period had the lowest disease levels of the 31-year time series, the average observed mortality for this period was lower than any but one year[5] of the 25 mortality index years prior to 2010, and the five highest annual biomass indexes of the 28-year time series occurred during this decade. Whether these trends will continue remains to be seen. Given the vagaries of environmental conditions, which control so many aspects of oyster population dynamics, it is impossible to predict what the long-range prospects will be for oysters, but all present indicators clearly point to an increasing and sustainable oyster population, albeit incrementally.

[4] Shakespeare, Wm. – *A Midsummer's Night Dream*

[5] 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 in paper files.

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Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 Key spat monitoring bars, 1985-2020. (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	*36-Yr Avg*
Mountain Point	0	0	0	0	0	0	*0.3*
Swan Point	0	0	0	0	0	0	*0.4*
Brick House	0	0	0	0	0	0	*6.1*
Hackett Point	0	0	0	0	0	0	*0.7*
Tolly Point	0	2	0	0	1	0	*0.8*
Three Sisters	0	0	0	0	1	0	*0.7*
Holland Point (S)	0	0	0	0	0	1	*0.5*
Stone Rock	2	17	0	4	6	7	*23.4*
Flag Pond (S)	10	12	28	0	2	0	*22.0*
Hog Island	9	22	1	0	19	8	*17.5*
Butler	68	90	2	1	42	34	*39.6*
Buoy Rock	0	0	0	0	0	0	*1.3*
Parsons Island	8	0	0	0	2	0	*103.5*
Wild Ground	15	0	0	0	1	2	*38.8*
Hollicutt Noose	1	0	0	0	0	2	*4.7*
Bruffs Island (S)	0	0	0	0	0	0	*25.3*
Ash Craft	0	0	0	0	0	1	*67.4*
Turtle Back	13	4	0	0	0	5	*124.1*
Shell Hill	4	2	1	5	2	0	*7.0*
Sandy Hill (S)	0	3	1	0	2	5	*11.3*
Royston	21	13	23	22	0	231	*55.1*
Cook Point (S)	1	21	2	4	7	68	*18.1*
Eagle Pt./Mill Pt. (S	34	68	55	28	0	187	*42.9*
Tilghman Wharf	45	58	13	40	5	247	*69.7*
Deep Neck	83	91	205	119	17	1838	*163.1*
Double Mills (S)	9	12	3	1	1	74	*19.2*
Ragged Point	19	125	35	2	1	18	*55.1*
Cason (S)	11	60	67	9	4	613	*102.4*
Windmill	16	9	9	4	12	62	*50.6*
Norman Addition	34	60	44	13	24	227	*81.4*
Goose Creek	11	44	27	23	18	448	*42.7*
Clay Island	43	68	41	43	14	43	*46.9*
Wetipquin (S)	2	6	0	21	33	15	*5.8*
Middleground	12	32	66	49	138	100	*31.1*
Evans	14	18	1	7	37	52	*13.4*
Mt. Vernon Wharf	1	3	1	10	7	42	*4.0*
Georges (S)	29	61	137	40	78	185	*72.4*
Drum Point (S)	59	172	78	110	160	445	*108.2*
Sharkfin Shoal	57	53	32	23	14	17	*27.8*
Turtle Egg Island	64	57	15	69	88	122	*90.3*
Piney Island East	3	0	2	0	68	196	*100.4*
Great Rock	13	4	14	93	151	258	*42.7*
Gunby	95	73	34	25	46	18	*57.3*
Marumsco	141	69	31	8	61	53	*41.0*
Broome Island	6	21	6	1	12	1	*6.6*
Back of Island	18	42	5	5	13	7	*13.9*
Chicken Cock	712	33	19	5	10	37	*78.7*
Pagan (S)	24	91	247	7	15	53	*162.2*
Black Walnut (S)	3	4	0	0	0	0	*1.5*
Blue Sow (S)	0	10	0	0	0	1	*4.4*
Dukehart Channel	0	3	0	0	0	0	*1.6*
Ragged Point	1	11	2	2	0	4	*5.3*
Cornfield Harbor	100	92	6	6	108	55	*72.8*
Spat Index	**34.2**	**30.9**	**23.6**	**15.0**	**23.0**	**109.1**	***41.3***
Median	**10**	**12**	**2**	**2**	**5**	**17**	***10.9***

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Table 3. *Perkinsus marinus* prevalence and mean intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2020. 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		*31-Yr Avg*	
	%	I	%	I	*%*	*I*
Swan Point	3	0.1	0	0.0	*26.9*	*0.7*
Hackett Point	10	0.5	30	0.9	*49.1*	*1.5*
Holland Point (S)	0	0.0	0	0.0	*39.6*	*1.2*
Stone Rock	23	1.0	23	0.6	*71.2*	*2.4*
Flag Pond (S)	13	0.5	87	3.0	*46.0*	*1.5*
Hog Island	27	1.0	30	1.0	*72.4*	*2.7*
Butler	60	2.0	60	2.0	*66.9*	*2.1*
Buoy Rock	3	0.1	0	0.0	*50.4*	*1.6*
Old Field (S)	17	0.4	20	0.7	*56.8*	*1.7*
Bugby	90	2.8	57	1.6	*81.0*	*2.7*
Parsons Island	7	0.4	23	0.5	*70.6*	*2.4*
Hollicutt Noose	13	0.5	13	0.4	*59.4*	*1.9*
Bruffs Island (S)	70	2.3	33	0.8	*73.0*	*2.3*
Turtle Back	73	2.9	67	2.2	*84.1*	*2.9*
Long Point (S)	3	0.03	13	0.3	*63.3*	*2.1*
Cook Point (S)	37	1.2	80	2.6	*58.2*	*1.9*
Royston	20	0.6	60	1.5	*54.2*	*1.9*
Lighthouse	3	0.2	0	0.0	*43.9*	*1.4*
Sandy Hill (S)	53	2.4	67	2.1	*74.7*	*2.8*
Oyster Shell Pt. (S)	3	0.1	20	0.5	*40.1*	*1.2*
Tilghman Wharf	23	0.9	20	0.7	*52.0*	*1.5*
Deep Neck	33	1.2	30	0.9	*78.5*	*2.7*
Double Mills (S)	47	1.8	63	2.2	*78.9*	*2.8*
Cason (S)	60	2.0	50	1.7	*79.1*	*2.6*
Ragged Point	60	1.4	73	2.6	*79.7*	*2.6*
Norman Addition	37	1.5	23	0.8	*78.0*	*2.8*
Goose Creek	27	1.1	53	2.0	*66.2*	*2.3*
Wilson Shoals (S)	30	1.0	47	1.2	*82.6*	*2.6*
Georges (S)	77	3.1	77	2.9	*81.3*	*2.9*
Holland Straits	0	0.0	0	0.0	*62.7*	*2.1*
Sharkfin Shoal	63	2.4	67	2.7	*82.0*	*2.9*
Back Cove	3	0.2	10	0.3	*77.4*	*2.8*
Piney Island East	17	0.5	3	0.1	*75.7*	*2.5*
Old Woman's Leg	0	0.0	0	0.0	*70.9*	*2.5*
Marumsco	30	1.0	7	0.3	*81.1*	*2.9*
Broome Island	13	0.5	27	0.8	*74.5*	*2.6*
Chicken Cock	27	1.2	23	0.7	*71.7*	*2.4*
Pagan (S)	17	0.4	37	1.1	*78.5*	*2.4*
Lancaster	7	0.2	47	1.5	*56.0*	*1.7*
Mills West	0	0.0	3	0.2	*55.6*	*1.7*
Cornfield Harbor	40	1.3	53	2.0	*78.0*	*2.5*
Ragged Point	0	0.0	0	0.0	*19.4*	*0.5*
Lower Cedar Point	NA	NA	10	0.4	*22.3*	*0.6*
Annual Means	**27**	**1.0**	**33**	**1.1**	***63.5***	***2.1***
Bar Freq. (%)	**88**		**84**		***96.4***	

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2020. 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	*31-yr Avg*
Swan Point	0	0	*0.0*
Hackett Point	0	0	*0.6*
Holland Point (S)	0	0	*2.3*
Stone Rock	0	0	*8.5*
Flag Pond (S)	0	0	*5.2*
Hog Island	0	0	*8.6*
Butler	0	0	*10.9*
Buoy Rock	0	0	*0.0*
Old Field (S)	0	0	*0.0*
Bugby	0	0	*1.4*
Parsons Island	0	0	*1.1*
Hollicutt Noose	0	0	*3.6*
Bruffs Island (S)	0	0	*0.8*
Turtle Back	0	0	*2.4*
Long Point (S)	0	0	*0.2*
Cook Point (S)	0	0	*9.5*
Royston	0	0	*4.7*
Lighthouse	0	0	*6.3*
Sandy Hill (S)	0	0	*2.5*
Oyster Shell Pt. (S)	0	0	*1.2*
Tilghman Wharf	0	0	*5.6*
Deep Neck	0	0	*3.8*
Double Mills (S)	0	0	*1.7*
Cason (S)	0	0	*6.8*
Ragged Point	0	0	*8.9*
Norman Addition	0	0	*10.6*
Goose Creek	0	0	*7.5*
Wilson Shoals (S)	0	0	*4.4*
Georges (S)	0	0	*6.3*
Holland Straits	0	0	*14.4*
Sharkfin Shoal	0	0	*12.6*
Back Cove	0	0	*12.7*
Piney Island East	0	3	*14.6*
Old Woman's Leg	0	0	*15.6*
Marumsco	3	0	*8.1*
Broome Island	0	0	*2.1*
Chicken Cock	0	0	*12.1*
Pagan (S)	0	0	*3.2*
Lancaster	0	0	*0.3*
Mills West	0	0	*1.5*
Cornfield Harbor	0	0	*13.0*
Ragged Point	0	0	*3.3*
Lower Cedar Point	NA	0	*0.0*
Avg. Prev. (%)	**0.1**	**0.1**	***5.6***
Pos. Bars (%)	**2**	**2**	***28.9***

(Return to Text)

Table 5. Oyster population mortality estimates from the 43 disease monitoring bars, 1985-2020.
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	*36-yr Avg*
Swan Point	4	0	3	0	0	8	12	3	*10.6*
Hackett Point	0	0	0	3	19	3	5	21	*12.9*
Holland Point (S)	12	40	29	0	0	50	nd	nd	*23.8*
Stone Rock	2	5	31	36	30	9	5	4	*21.4*
Flag Pond (S)	15	13	5	6	50	3	1	7	*20.7*
Hog Island	2	2	12	38	27	18	0	5	*26.6*
Butler	7	7	10	11	4	5	7	14	*23.6*
Buoy Rock	5	9	3	12	4	12	9	13	*16.4*
Old Field (S)	0	3	0	5	33	10	31	33	*14.1*
Bugby	8	31	21	21	13	12	17	18	*25.1*
Parsons Island	2	4	15	2	10	14	0	5	*20.4*
Hollicutt Noose	1	9	6	7	29	30	8	2	*20.4*
Bruffs Island (S)	0	4	5	16	20	41	38	25	*23.3*
Turtle Back	0	8	14	18	3	15	8	3	*23.9*
Long Point (S)	20	0	0	17	0	0	37	nd	*22.3*
Cook Point (S)	9	12	16	48	45	24	13	12	*25.9*
Royston	1	6	9	16	4	2	4	3	*16.9*
Lighthouse	1	1	2	9	7	0	4	2	*19.3*
Sandy Hill (S)	3	13	11	15	15	11	11	4	*24.3*
Oyster Shell Pt. (S)	2	5	2	11	11	18	24	12	*10.9*
Tilghman Wharf	5	1	5	11	1	7	4	6	*16.8*
Deep Neck	5	7	16	8	2	3	3	2	*20.0*
Double Mills (S)	11	12	10	20	13	11	2	7	*20.1*
Cason (S)	11	8	17	26	33	8	4	2	*24.8*
Ragged Point	15	13	21	45	14	6	3	11	*25.9*
Norman Addition	9	7	13	14	15	8	2	2	*24.0*
Goose Creek	5	15	22	27	6	10	3	4	*31.5*
Wilson Shoals (S)	5	4	7	17	6	4	4	6	*20.0*
Georges (S)	15	5	8	23	15	9	5	7	*27.8*
Holland Straits	9	48	71	18	4	17	4	1	*28.5*
Sharkfin Shoal	16	18	24	19	3	7	4	5	*30.3*
Back Cove	11	19	14	1	2	8	1	1	*21.7*
Piney Island East	7	10	9	21	25	38	33	4	*28.8*
Old Woman's Leg	50	75	15	0	50	25	10	5	*30.4*
Marumsco	13	13	17	13	20	34	36	4	*24.9*
Broome Island	7	8	14	21	3	4	0	4	*20.0*
Chicken Cock	1	7	16	32	20	17	20	2	*26.8*
Pagan (S)	4	13	22	28	6	4	4	49	*21.1*
Lancaster	13	0	3	1	1	10	5	2	*14.6*
Mills West	20	9	5	14	0	5	15	21	*14.8*
Cornfield Harbor	10	16	10	36	8	3	5	2	*27.4*
Ragged Point	0	0	50	10	8	4	33	0	*21.8*
Lower Cedar Point	0	0	6	8	27	96	100	100	*19.8*
Annual Means	**8**	**11**	**14**	**16**	**14**	**14**	**13**	**10**	***21.9***

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland from buy tickets, 1985-86 through 2019-20 seasons.

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

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

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

Maryland Oyster Harvests (bu)						
Region/Tributary	2015-16	2016-17	2017-18	2018-19	2019-20	*35-yr Avg*
Upper Bay	3,648	4,693	2,580	747	48	*11,938*
Middle Bay	13,019	11,072	5,134	3,005	4,715	*14,836*
Middle Bay Tributaries	2,409	1,876	1,169	184	804	*1,288*
Lower Bay	4,285	4,314	9,112	11,083	13,380	*6,226*
Total Bay Mainstem	*23,360*	*21,955*	*17,995*	*15,019*	*18,947*	*32,772*
Chester R.	1,547	569	5,135	613	690	*20,470*
Eastern Bay	13,091	15,576	9,663	8,566	9,553	*27,983*
Miles R.	3,335	1,666	527	962	180	*5,001*
Wye R.	18	17	21	0	0	*1,772*
Total Eastern Bay Region	*16,444*	*17,259*	*10,211*	*9,528*	9,733	*34,755*
Upper Choptank R.	192	42	129	183	8	*8,974*
Middle Choptank R.	8,420	5,749	6,563	3,930	4,395	*17,557*
Lower Choptank R.	22,141	10,979	6,458	11,849	13,235	*14,863*
Tred Avon R.	4,007	2,403	889	2,704	616	*10,302*
Broad Cr.	67,375	32,063	32,516	32,295	39,228	*22,325*
Harris Cr.	7,072	2,704	3,901	5,240	6,542	*7,788*
Total Choptank R. Region	*109,207*	*53,940*	*50,456*	*56,201*	64,023	*81,809*
Little Choptank R.	2,027	2,048	453	246	10,063	*11,107*
Upper Tangier Sound	64,305	35,521	33,322	22,060	82,224	*19,595*
Lower Tangier Sound	28,269	9,471	7,244	2,806	7,264	*13,810*
Honga R.	13,241	11,114	2,051	925	2,811	*7,507*
Fishing Bay	20,195	13,608	7,441	5,728	22,869	*14,683*
Nanticoke R.	7,095	7,430	8,017	4,201	8,355	*7,278*
Wicomico R.	10,122	4,735	1,044	939	1,177	*1,371*
Manokin R.	1,431	1,128	1,914	1,045	430	*3,288*
Big Annemessex R.	4,037	473	90	74	24	*234*
Pocomoke Sound	10,261	6,131	5,269	2,166	2,054	*5,177*
Total Tangier Sound Region	*158,956*	*89,611*	*66,392*	*39,943*	*127,207*	*72,941*
Patuxent R.	50,048	22,669	9,446	9,290	22,912	*12,794*
Wicomico R., St. Clement and Breton bays	5,596	5,130	891	1,160	356	*9,779*
St. Mary's R. and Smith Cr.	10,537	8,716	18,759	12,371	11,564	*8,840*
Total Potomac Md. Tribs.	*16,133*	*13,846*	*19,650*	*13,531*	*11,920*	*18,599*
Total Maryland (bu.)[1]	**383,534**	**224,758**	**182,310**	**145,161**	**270,043**	***290,527***

[1] Includes harvests from unidentified regions.

(Return to Text)

Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2019-20 seasons. Dockside value is in millions of dollars.

Season	Hand Tongs	Diver	Patent Tongs	Power Dredge	Skipjack	*Total Harvest*[1]	*Dockside Value*
1989-90	309,723	47,861	31,307	11,424	14,007	*414,445*	*$ 9.9 M*
1990-91	219,510	74,333	105,825	4,080	14,555	*418,393*	*$ 9.4 M*
1991-92	124,038	53,232	108,123	6,344	31,165	*323,189*	*$ 6.4 M*
1992-93	71,929	24,968	18,074	1,997	8,821	*123,618*	*$ 2.6 M*
1993-94	47,309	19,589	11,644	787	133	*79,618*	*$ 1.4 M*
1994-95	99,853	29,073	31,388	1,816	2,410	*164,641*	*$ 3.2 M*
1995-96	115,677	25,657	46,040	6,347	7,630	*199,798*	*$ 3.2 M*
1996-97	130,861	16,780	15,716	8,448	6,088	*177,600*	*$ 3.8 M*
1997-98	191,079	37,477	30,340	14,937	10,543	*284,980*	*$ 5.7 M*
1998-99	294,342	58,837	36,151	25,541	8,773	*423,219*	*$ 7.8 M*
1999-2000	237,892	60,547	44,524	18,131	12,194	*380,675*	*$ 7.2 M*
2000-01	193,259	75,535	43,233	18,336	8,820	*347,968*	*$ 6.8 M*
2001-02	62,358	30,284	26,848	17,574	8,322	*148,155*	*$ 2.9 M*
2002-03	11,508	9,745	18,627	12,386	2,432	*55,840*	*$ 1.6 M*
2003-04	1,561	5,422	3,867	13,436	1,728	*26,471*	*$ 0.7 M*
2004-05	5,438	14,258	6,548	37,641	4,000	*72,218*	*$ 1.1 M*
2005-06	28,098	38,460	49,227	30,824	3,576	*154,436*	*$ 4.7 M*
2006-07	55,906	36,271	31,535	35,125	3,250	*165,059*	*$ 5.0 M*
2007-08	24,175	11,745	15,997	25,324	4,243	*82,958*	*$ 2.6 M*
2008-09	11,274	9,941	15,833	50,628	5,370	*101,141*	*$ 2.7 M*
2009-10	7,697	6,609	48,969	107,952	12,479	*185,245*	*$4.5 M*
2010-11	13,234	5,927	27,780	65,445	10,550	*123,613*	*$4.3 M*
2011-12	4,885	12,382	22,675	84,950	11,305	*137,317*	*$4.6M*
2012-13	53,622	8,107	48,095	212,837	18,471	*341,132*	*$10.9 M*
2013-14	67,093	21,510	75,937	242,964	9,074	*416,578*	*$14.1 M*
2014-15	57,289	25,126	98,187	154,716	33,518	*388,658*	*$17.1 M*
2015-16	71,296	31,110	91,852	107,781	32,815	*383,534*	*$14.9 M*
2016-17	45,929	24,434	52,740	80,586	17,724	*224,758*	*$10.6 M*
2017-18	35,717	14,787	26,673	61,882	19,161	*182,310*	*$8.7 M*
2018-19	35,574	11,461	21,532	64,073	12,487	*145,161*	*$6.6 M*
2019-20	44,522	18,724	69,089	113,707	25,051	270,043	*$12.2 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 2019-20 seasons. Some years may not total 100% due to incomplete data.

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

(Return to Text)

Table 8. Oyster bars within sanctuaries sampled during the 2020 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 2020, the Fall Survey sampled 34 hatchery seed plantings located throughout the Maryland portion of the bay (Figure A1-1). Most of these were entirely new locations (27), but a few were taken on previously established sampling sites. Approximately 260 million hatchery seed were planted at these locations (Table A1-1), covering 155 acres. The mean density of these plantings was 1.7 million spat per acre. All areas received diploid spat except Well Cove in Eastern Bay and Nanticoke Middleground, where triploid spat were planted. Nanticoke Middleground also received the highest number of spat planted and was also one of the highest in number of acres planted. The highest planting density occurred on Coots bar, in the Mid-Bay West region, followed by Punch Island Creek, in the lower bay.

Table A1-1. Hatchery seed plantings for 2020, including number of acres planted, total number of seed planted and planting density.

2020 Hatchery Seed Plantings				
Region	**Bar Name**	**Acres**	**# Seed (million)**	**Density (million/acre)**
Chester River	Durdin	3.9	5.83	1.5
	Piney Point	8.8	11.89	1.4
Choptank River	Dickinson	3.0	9.32	3.1
	Howells Point	2.7	4.95	1.9
	Howells Point Add 2	2.3	4.95	2.2
Eastern Bay	Bald Eagle Add 2	3.7	4.02	1.1
	Bugby	6.6	10.13	1.5
	Bugby	1.7	2.0	1.2
	Crab Alley Lumps	2.5	6.96	2.8
	Well Cove	1.2	3.48	3.0
Lower Bay East	Punch Island Creek	4.02	16.67	4.1
Mid-Bay East	Stone	5.7	10.45	1.8
Mid-Bay West	Coots	3.6	18.16	5.1
	Hackett Point	3.9	4.43	1.1
	Tolly Point	7.0	11.35	1.6
Nanticoke	Nanticoke Middleground	14.9	25.42	1.7
South River	Outer Round Point	5.2	13.99	2.7
Tred Avon River	Mares Point	5.5	13.95	2.5
	Town Point	2.7	4.74	1.7
Upper Bay East	Swan Point	2.4	2.16	0.9
	Swan Point (Peach Orchard)	16.3	10.23	0.6
	Swan Point (Peach Orchard S.)	12.9	11.11	0.9
Upper Bay West	Man O War Shoals	6.2	12.6	2.0
Wicomico River East	Evans	7.7	8.75	1.1
Wicomico River West	Lancaster	5.1	8.07	1.6
	White Point	7.3	14.4	1.9
	Wicomico Lumps	2.3	7.16	3.2
	Wicomico Middleground	4.5	7.03	1.6
	Windmill	2.0	1.77	0.9

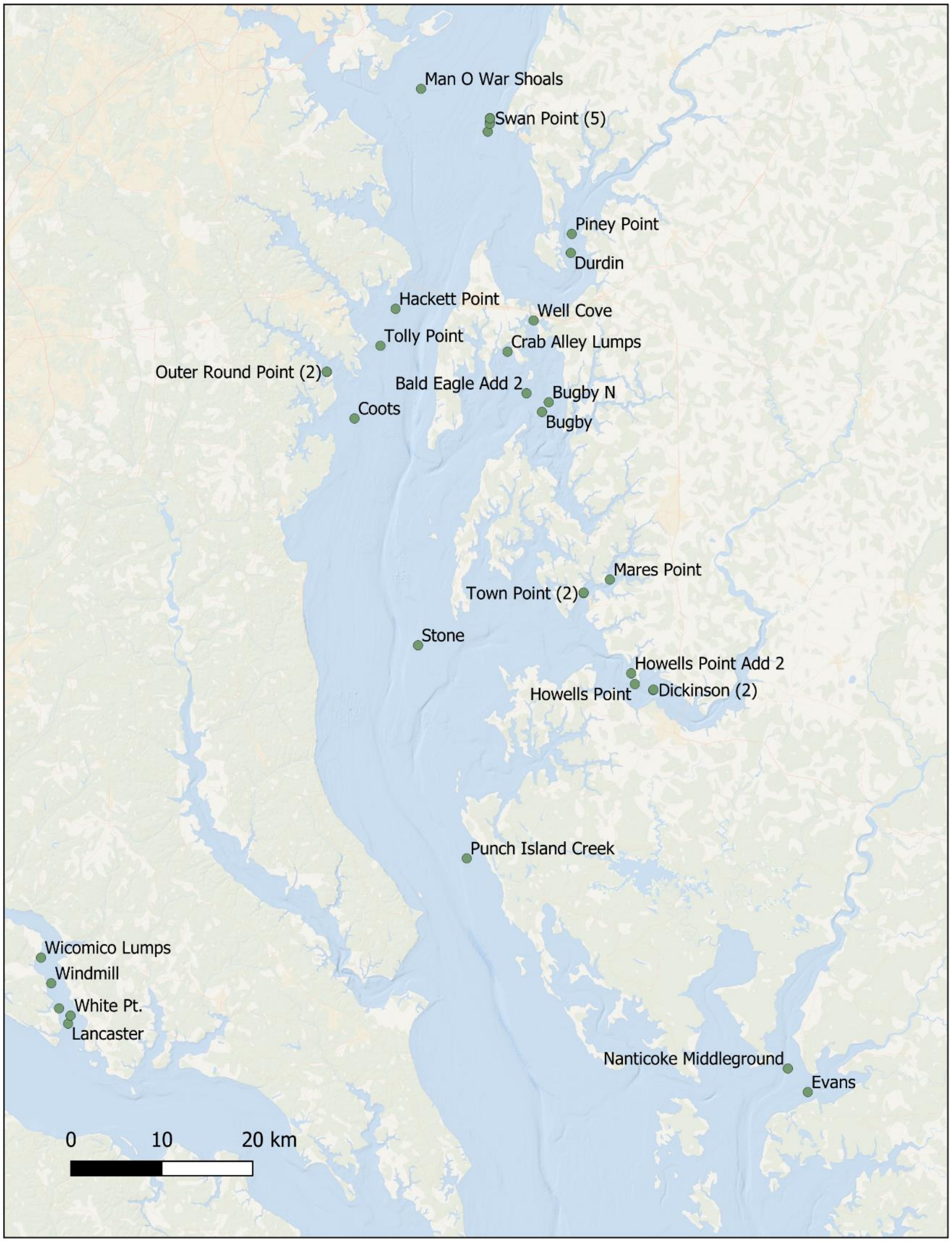

Figure A1-1. Location of 2020 hatchery seed plantings sampled during the Fall Survey. Well Cove and Nanticoke Middleground received triploid spat. Numbers in parentheses () indicate the number of plantings at a location; all other sites received one planting.

For most of the new stations, spat were counted and measured and the number of spat per shell was enumerated (Table A1-2). The number of spat per bushel on these sites ranged from 26 to 1288, with a mean of 300 spat per bushel. One of the most notable aspects of these sites (particularly for the sites that were new to the survey) was the size of the spat. Spat sizes ranged from 11 to 85 mm shell height, with a mean of 41.2 mm. The maximum sizes from all plantings averaged an impressive 60 mm, and included spat that were close to or above market size (76.2 mm). There was no doubt that these were spat, based on their morphological characteristics and considering the spat were planted in high densities, often in areas of little or no spatset with few, if any, natural oysters of any size.

There was considerable variation in sizes across sites (Figure A1-2), with the triploid oysters from Well Cove and Nanticoke Middleground ranked first and second respectively in terms of average and maximum sizes, followed closely by Howells Point.

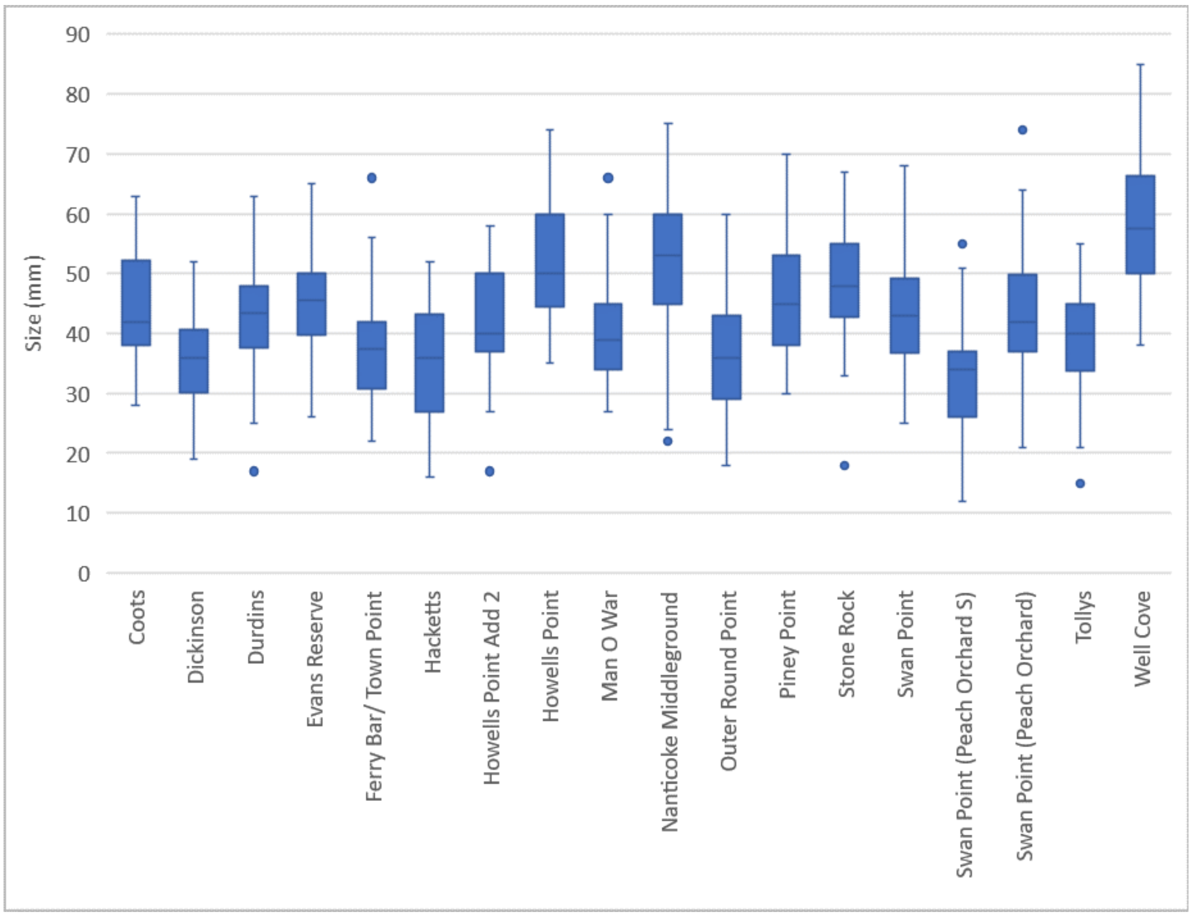

Figure A1-2. Box plots of shell heights from hatchery seed oysters planted during 2020.

The Fall Survey did not begin until October, but most of the plantings occurred in spring to early summer. The elapsed times between plantings and the Fall Survey ranged from 72 to 180 days (Figure A1-3). The lengthy time between planting and measuring accounted in part to the larger sizes of these spat. Well Cove had the highest average size of oysters (Figure A1-2), but also had one of the longest elapsed times (Figure A1-3). Thus, the daily growth rate ranked only eleventh of the 34 plantings examined (Figure A1-4). Nevertheless, some individual oysters at this site exhibited phenomenal growth, with the largest oyster measured reaching a shell height of 85 mm

(Table A1-2), comparable to a three-year-old oyster. Furthermore, the sizes observed from many of the other 2020 plantings are typical of one- or two-year-old oysters. Hatchery spat usually average about 3 mm at the time of planting (MDNR, unpublished data), which speaks to the extraordinary growth they experienced, even considering the longer elapsed times. The areas with the slowest average daily oyster growth were the Western Shore tributaries South and Wicomico rivers (Table A1-2). In addition, the Fall Survey found that 2020 had strong recruitment in several regions of the bay; the hatchery spat may have also benefitted from the same conditions that enabled natural spat to survive. No attempt was made to compare sizes between hatchery and natural spat, as the timing and duration of the natural spatset were unknown.

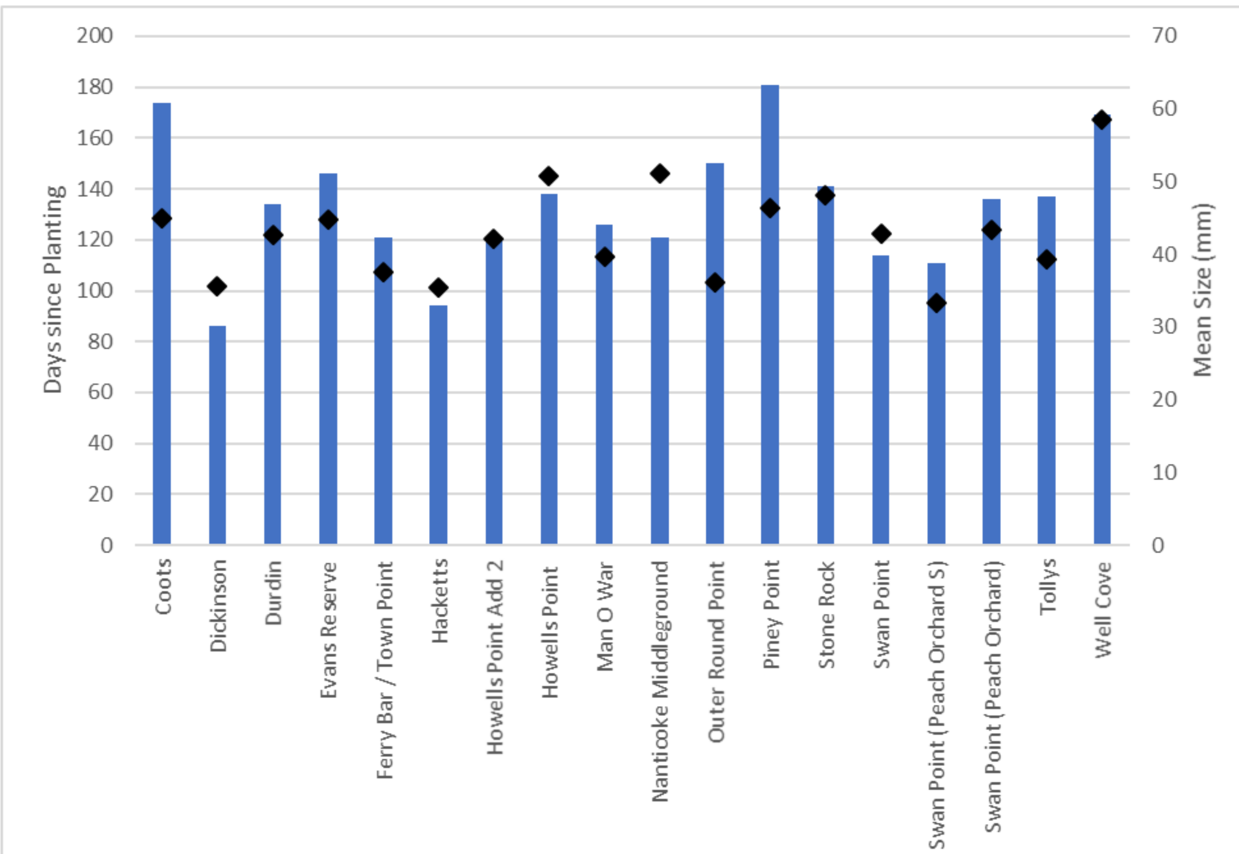

Figure A1-3. The elapsed time in days from planting of hatchery seed to measuring the oysters during the Fall Survey and the mean shell height (black points) for each of the bars.

Table A1-2. Fall Survey sites on hatchery seed plantings for 2020, including counts, sizes, elapsed time since planting, daily growth rates, and averages for those values. "Old" sites are previously established Fall Survey sites replanted in 2020.

2020 Hatchery Seed Plantings-New Sites								
Region	Bar Name	Spat #/bu	Spat/shell	Min mm	Mean mm	Max mm	Max. Days since planting	Growth mm/day
Chester River	Durdin	52	1.30	17	43	63	134	0.32
	Piney Point	54	1.59	30	46	70	181	0.25
Choptank River	Dickinson	290	2.84	19	36	52	86	0.42
	Howells Point	286	2.86	35	51	74	120	0.43
	Howells Point Add 2	358	6.88	17	42	58	138	0.30
Eastern Bay	Bald Eagle Add 2	658	8.44	24	43	53	122	0.35
	Bugby	84	2.80	20	38	54	122	0.31
	Bugby	152	2.11	10	27	31	72	0.38
	Crab Alley Lumps	52	1.53	23	43	50	107	0.40
	Well Cove	110	1.57	38	59	85	169	0.35
Mid-Bay East	Stone	304	NA	18	48	67	141	0.34
Mid-Bay West	Coots	226	1.66	28	45	63	174	0.26
	Hackett Point	856	8.56	16	35	52	94	0.37
	Tolly Point	368	2.36	15	39	55	137	0.28
Nanticoke	Nanticoke Middleground	282	NA	22	51	75	121	0.42
South River	Outer Round Point	550	4.74	18	36	60	150	0.24
Tred Avon River	Town Point	194	2.20	22	38	66	121	0.31
Upper Bay East	Swan Point	270	2.81	25	43	68	114	0.38
	Swan Point (Peach Orchard)	254	3.53	21	43	74	111	0.39
	Swan Point (Peach Orchard S.)	94	1.74	12	33	55	136	0.24
Upper Bay West	Man O War Shoals	168	6.46	27	40	66	126	0.32
Wicomico R. East	Evans	100	4.17	26	45	65	146	0.31
Wicomico R. West	Lancaster	170	2.43	28	35	57	181	0.19
	White Point	226	2.63	22	35	44	153	0.23
	Wicomico Lumps	476	5.41	11	40	53	157	0.25
	Wicomico Middleground	134	2.68	21	33	47	133	0.25
	Windmill	126	2.86	30	45	61	132	0.34
	Averages	255	3.5	22	41	60	132	0.31
2020 Hatchery Seed Plantings- Old Sites								
Choptank River	Dickinson	26	NA	30	36	45	121	0.30
Lower Bay East	Punch Island Creek	1288	NA	17	36	58	91	0.40
South River	Outer Round Point	92	NA	26	38	50	150	0.25
Tred Avon River	Mares Point	1150	NA	21	45	65	136	0.33
	Town Point	130	NA	20	35	52	121	0.29
Upper Bay East	Swan Point	520	NA	21	45	66	136	0.33
	Swan Point (KB/DB)	59	NA	22	38	51	111	0.34
	Averages	399		22	39	55	124	0.31

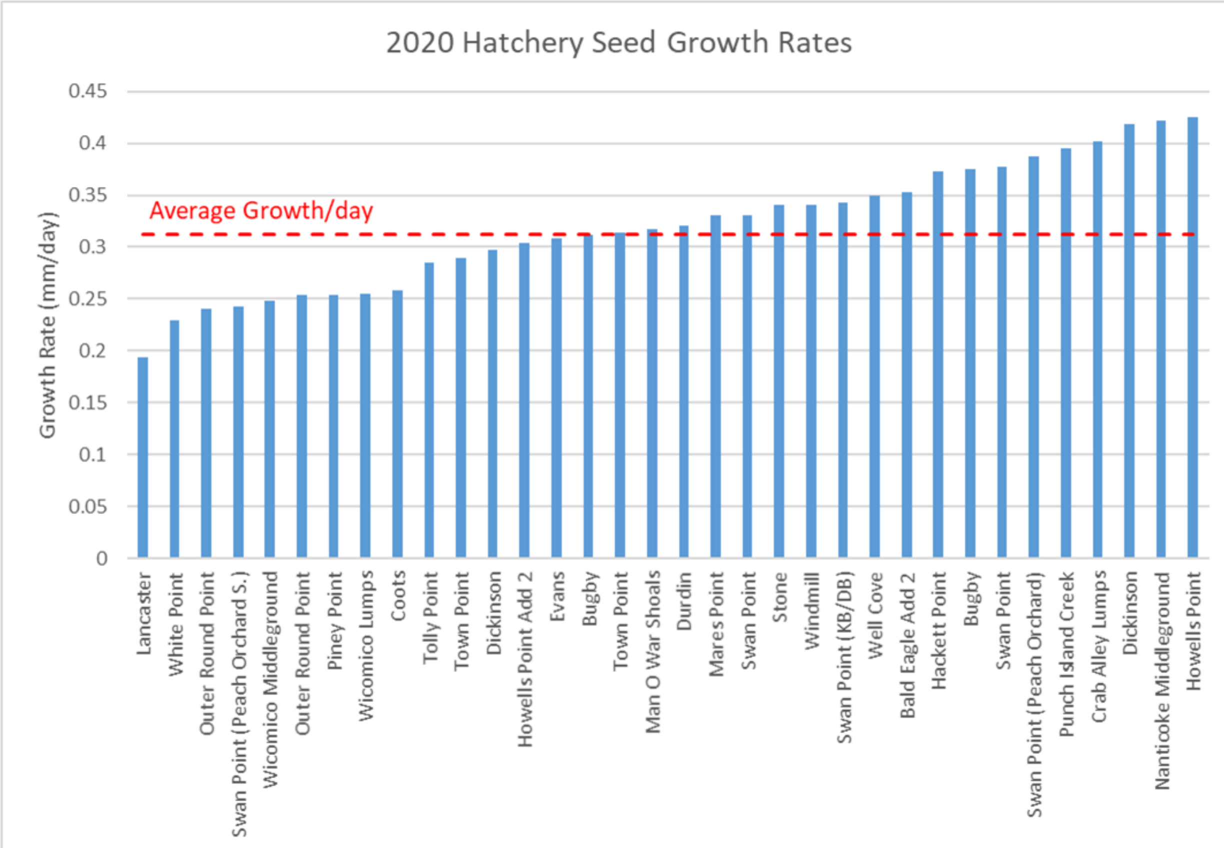

Figure A1-4. Average daily growth rate of seed oysters from plantings made in 2020. The average growth/day is the average of all 34 plantings.

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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, — Infection intensities averaged only for infected oysters:

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

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

sum of Key Bar spatfall intensities ÷ number of Key Bars

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

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

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