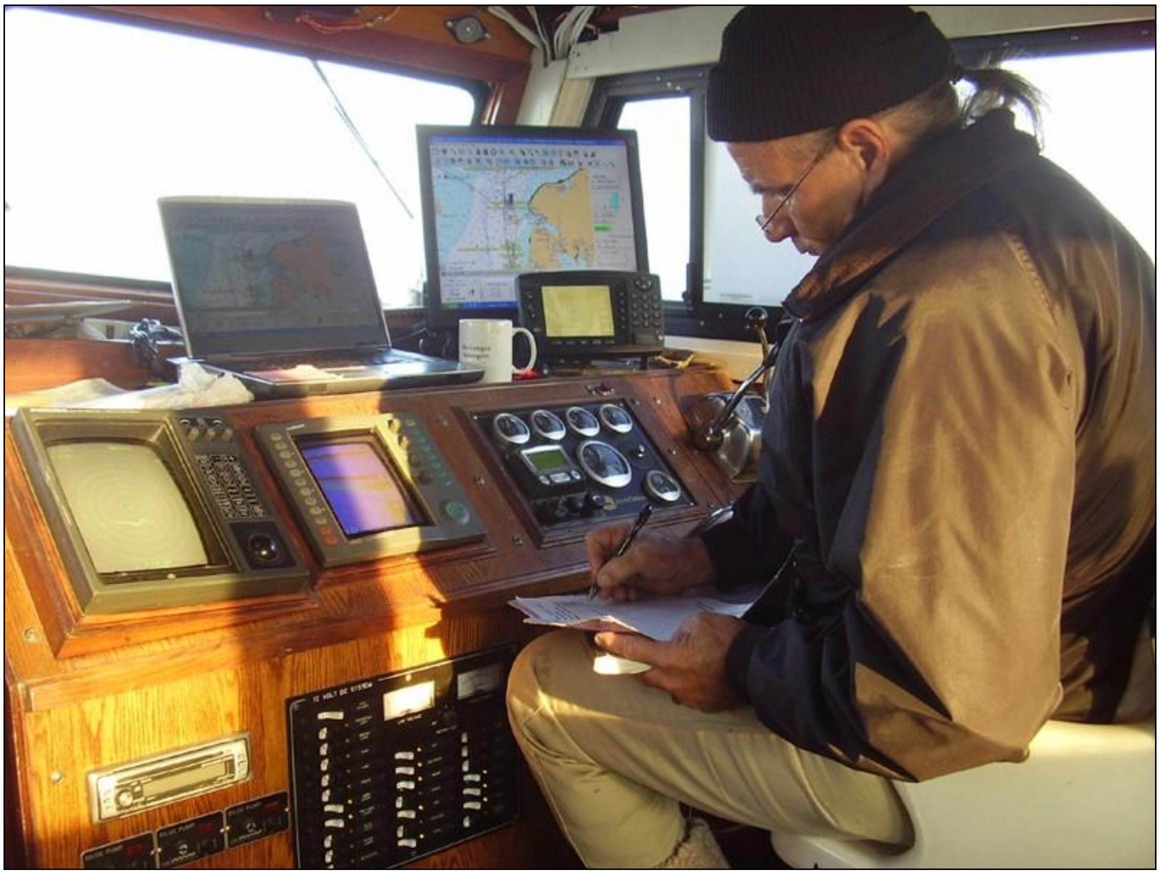
Maryland Oyster Population Status Report

2011 Fall Survey



Mitchell Tarnowski
Maryland Department of Natural Resources
Shellfish Division and Cooperative Oxford Laboratory
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FOR MORE INFORMATION PLEASE CONTACT

Maryland Department of Natural Resources
Fisheries Service
Tawes State Office Building
580 Taylor Avenue
Annapolis, MD 21401
1-800-688-FINS • 410-260-8258

MDNR GENERAL INFORMATION
1-877-620-8DNR
www.dnr.state.md.us
Fisheries Service Ext. - 8258

CONTRIBUTORS

Editor

Shellfish Division, MDNR
Mitchell Tarnowski, Shellfish Biologist

Technical Participants

Lead Scientist
Shellfish Division, MDNR
Mitchell Tarnowski, Shellfish Biologist

Field Operations
Shellfish Division, MDNR
David White, Captain R/V *Miss Kay*
Robert Bussell, Biologist
Rob Lawrence, Mate R/V *Miss Kay*

Disease Diagnostics
Cooperative Oxford Laboratory, MDNR
Joe Marcino, Pathologist
Rosalee Hamilton, Managing Histologist
Judson Blazek, Histotechnician
Stuart Lehmann, Histotechnician
Suzanne Tyler, Histotechnician

Data Management
Cooperative Oxford Laboratory, MDNR
Kelly Greenhawk, GIS Analyst

Statistical Analyses
Shellfish Division, MDNR
Dr. Mark Homer, Research Statistician

Text
Shellfish Division, MDNR
Mitchell Tarnowski, Shellfish Biologist

Reviewers

Fisheries Service, MDNR
Dr. Mark Homer
Christopher Dungan

Resource Assessment Service, MDNR
Carol B. McCollough

Acknowledgments

Field Assistance

Christopher Judy, MDNR	Carol B. McCollough, MDNR
Steven Schneider, MDNR	Maude Livings, MDNR
A.C. Carpenter, PRFC	Mark Homer, MDNR
Michael Naylor, MDNR	Carrie Kennedy, MDNR
Christopher Jones, MDNR	Elizabeth Ebersole, MDNR
Blake Hocker, MDNR	Stephanie Meredith, MDNR
Jess Crane, PWEC	Kristin Buter, PWEC
Eric Sakowski, UDel	

Cover Photo: *Capt. Dave White at the helm of the R/V* Miss Kay. *(Photo by C. McCollough)*

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EXECUTIVE SUMMARY

Since 1939, the Maryland Department of Natural Resources and its predecessor agencies have been monitoring the status of Maryland's oyster population by means of annual field surveys – one of the longest running of such programs in the world. Integral to the Fall Oyster Survey are several indices: the Spatfall Intensity Index, a measure of recruitment success and potential increase of the population obtained from a fixed subset of 53 oyster bars; indices for oyster diseases that document infection levels and rates from a fixed subset of 43 oyster bars; and the Total Observed Mortality Index, an indicator of annual mortality rates of post-spat stage oysters calculated from the 43 Disease Bar subset. A fourth index added this year, the Biomass Index, measures the number and weight of oysters from the 43 Disease Bar subset relative to the 1994 baseline.

The 2011 Fall Oyster Survey, a two-month endeavor which encompassed 263 oyster bars and 343 samples throughout the bay and its tributaries, concluded on 21 November. The results indicate that oyster populations are doing well in most parts of Maryland's Chesapeake Bay, thanks to high survivorship of yearling oysters from last year's good spat set. Disease levels were at their lowest since systematic monitoring began in 1990, resulting in the lowest oyster mortalities in over 25 years. Although high freshwater flows from heavy rains in the spring and two tropical storms in late summer impacted oysters in the Upper Bay, this represented a relatively small proportion of the total oyster population. The lower salinities proved to be beneficial to the majority of oysters in Maryland by reducing disease impacts to allow the yearling oysters to thrive. As a result, the 2011 Oyster Biomass Index increased by 44% over the previous year.

The 2011 Spatfall Index was 20.1 spat per bushel, slightly higher than the 27-year median index of 18.7 spat/bu. Although this represents a 74% drop from the previous year's spat index, this was not unexpected considering the high freshwater flows into the bay in 2011 which inhibited spatfall. The heaviest spatfall was in the southern Eastern Shore region, with a high count of 248 spat/bu. on Drum Point bar in the Manokin River. Little, if any, spat were observed north of the Honga River.

Oyster diseases appear to be in retreat. Dermo disease levels remained below the long-term average for the ninth consecutive year. The 2011 mean infection prevalence (percentage of oysters with the disease) of 38% and mean infection intensity (strength of infections) of 1.2 were the lowest since 1990, when the 43 Disease Monitoring bars were established and substantially below the record-high 2002 mean prevalence of 94% and 2001 mean intensity of 3.8. However, dermo disease continues to be widely distributed throughout Maryland waters. All but three of the standard disease monitoring sites had oysters infected with *Perkinsus marinus*, the parasite which causes dermo disease. The highest dermo disease levels were found in the more saline waters of the Eastern Shore from the Little Choptank River south. MSX disease, caused by the parasite *Haplosporidium nelsoni,* was at its lowest level since 1990. The parasite was detected at a very low prevalence at only one of the monitoring sites in Tangier Sound. This continues a decline in MSX disease that began the preceding year, due to lower salinities unfavorable to the parasite.

As a consequence of low disease pressures, oyster survivorship was the highest since 1985, before diseases put a stranglehold on the population. For the 43 disease monitoring bar subset of the 2011 Fall Survey, the survival rate was 92%. This is a remarkable turnaround from 2002 when record high disease levels devastated the Maryland population, leaving only 42% alive.

Extensive oyster mortalities were observed in the uppermost portion of the Bay, reaching 100% on the most upstream bars that were examined. The likeliest cause of these mortalities was the hyposaline conditions that existed in the Upper Bay as a result of extraordinary freshwater runoff from the Susquehanna watershed for an extended period of time during the spring and early summer and then again after Hurricane Irene and Tropical Storm Lee. However, only a relatively small proportion of the total Maryland oyster population was impacted by these events.

Despite the Upper Bay mortalities, the Maryland Oyster Biomass Index rose by 44% over the previous year. This was the first time since 2001 that it exceeded the 1994 baseline. This increase was driven by the high oyster survivorship last year, particularly of the abundant 2010 year class.

More discouraging was the commercial harvest of 124,000 bu. for the 2010-11 season, a 33% decline from the previous season. Power dredging accounted for 53% of the 2010-11 landings.

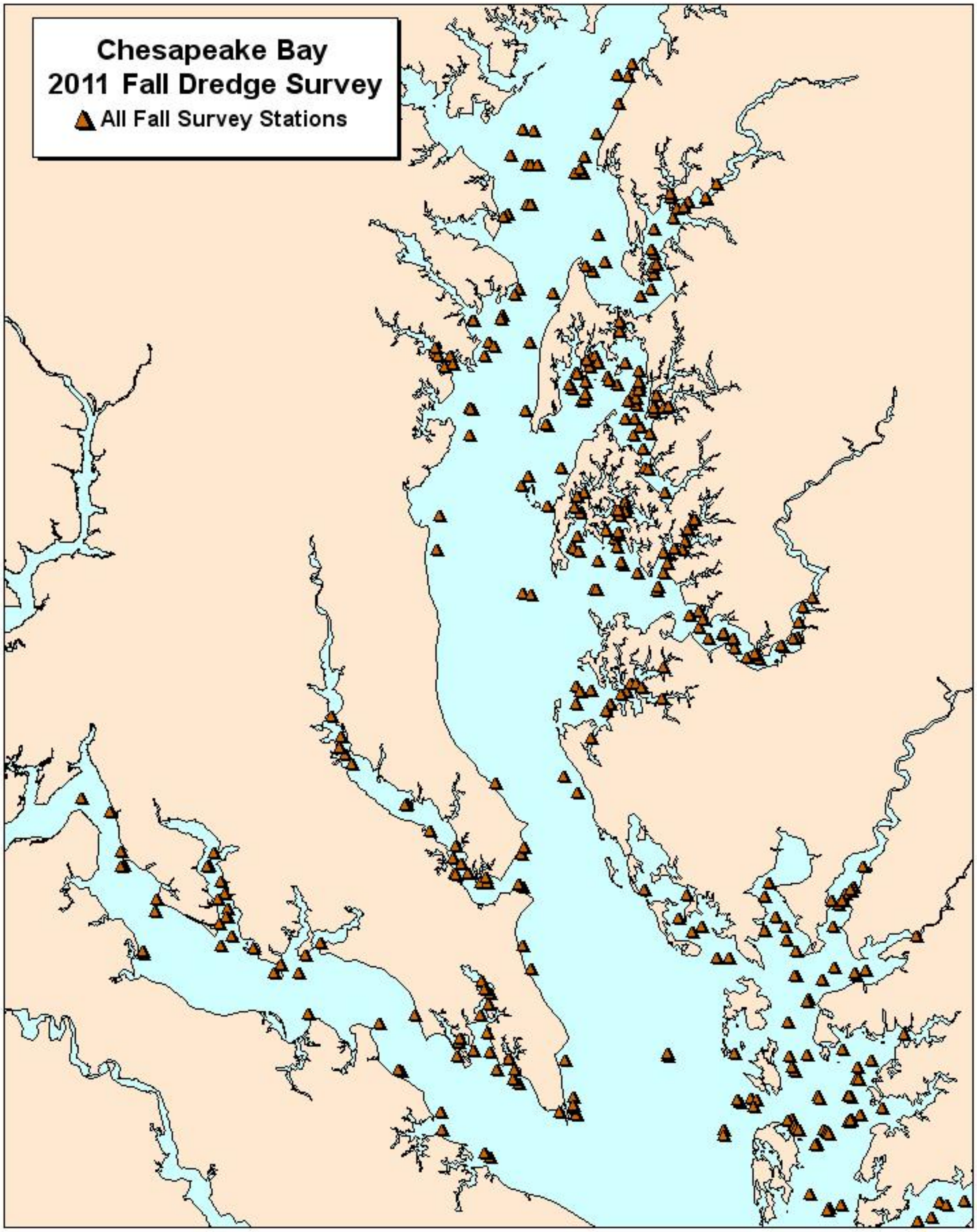

Figure 1a. 2011 Maryland Fall Oyster Survey station locations, all bar types (standard, Key, Disease, seed) included.

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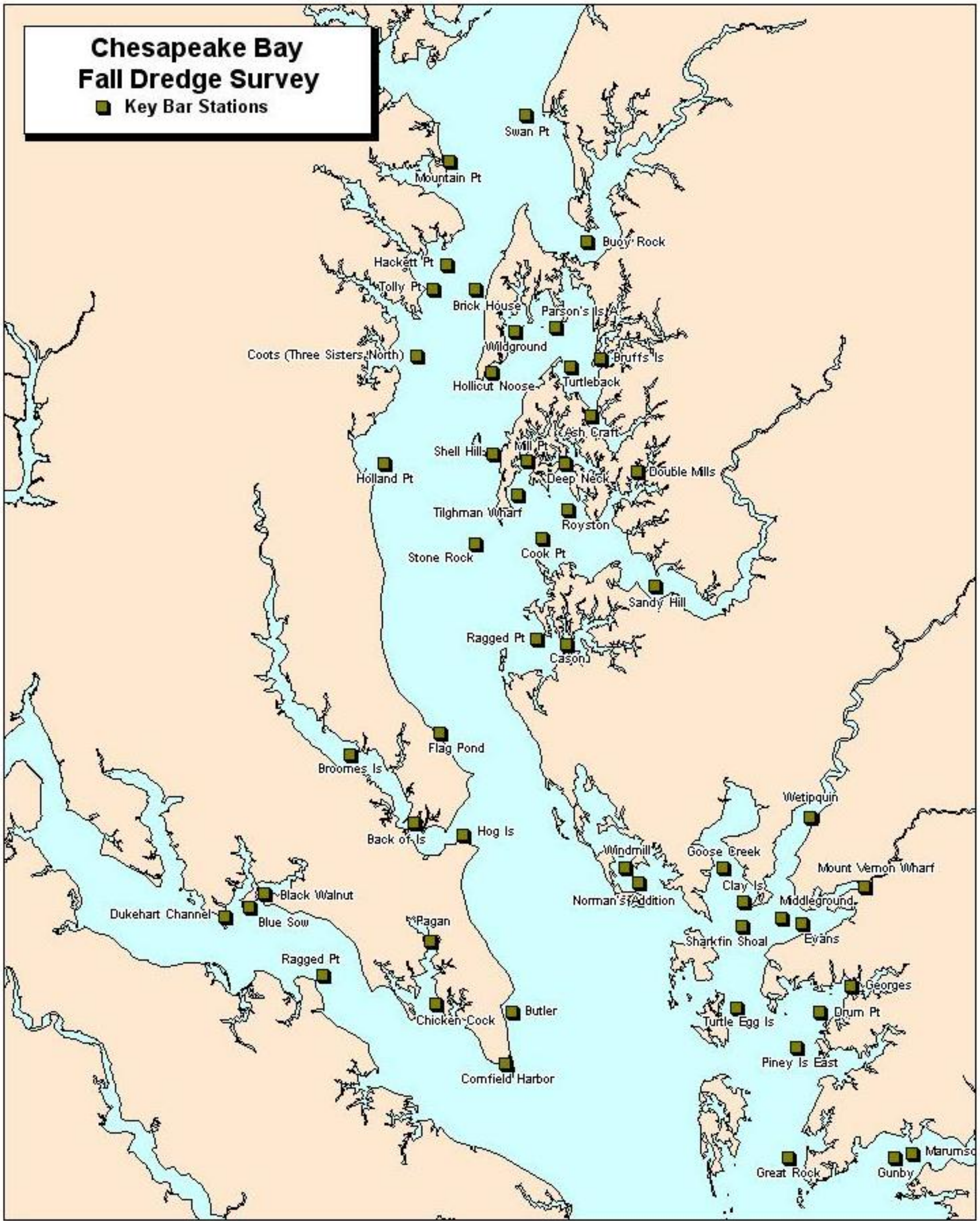

Figure 1b. Maryland Fall Oyster Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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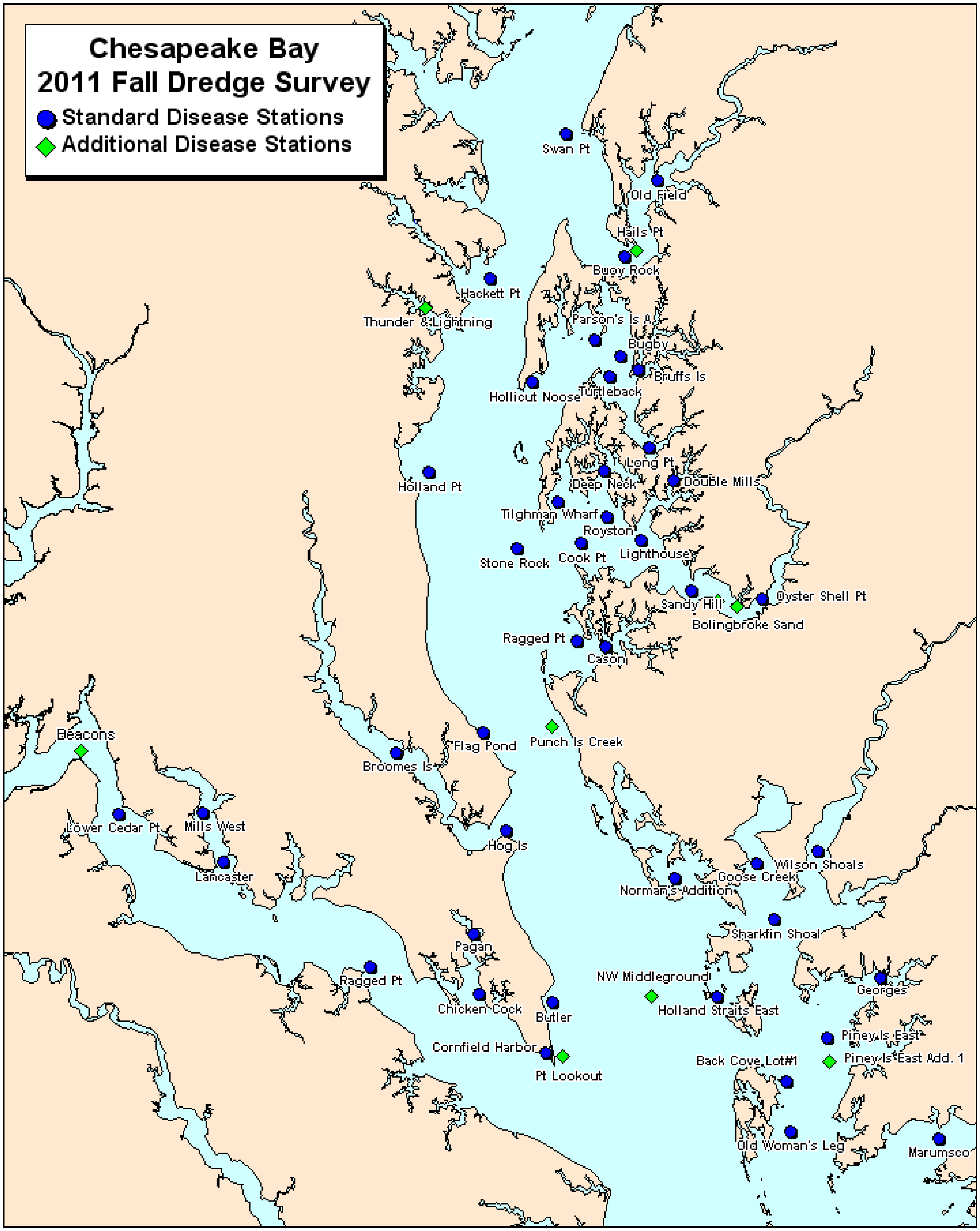

Figure 1c. Maryland Fall Oyster Survey standard Disease Bar monitoring locations and additional 2011 disease sample stations.

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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 infection status in Maryland's Chesapeake Bay. The long-term nature of the data set is a unique and valuable aspect of the survey that gives a historical perspective and reveals trends in the oyster population. Monitored sites have included natural oyster bars, seed production and planting areas, dredged and fresh shell plantings, and sanctuaries. Since this survey began, several changes and additions have been made to allow the development of structured indices and statistical frameworks while preserving the continuity of the long-term data set. In 1975, 53 sites and their alternates, referred to as the historical "Key Bar" set, were fixed to form the basis of an annual spatfall intensity index (Krantz and Webster 1980). These sites were selected to provide both adequate geographic coverage and continuity with data going back to 1939. An oyster parasite diagnosis component was added in 1958, and in 1990 a 43-bar subset (Disease Bar set) was established for obtaining standardized parasite prevalence and intensity data. Thirty-one of the Disease Bars are among the 53 spatfall index oyster bars (Key Bars).

Collaborative Studies

Throughout the years, the Fall Survey has been a source of research opportunities for scientists outside of MDNR and 2011 was no exception. A University of Delaware graduate student accompanied the Fall Survey on several trips for his dissertation work on oyster disease; additional oyster samples were collected for a collaborative VIMS/MDNR dermo disease study; a NOAA scientist investigated the distribution of dark false mussels based on several years of Fall Survey records; and Maryland Sea Grant funded a proposal by researchers from East Carolina University, University of Maryland, and MDNR to develop a predictive model of oyster spatset using the multi-decadal time series from the Fall Survey.

METHODS

Field Collection

The 2011 Annual Fall Oyster Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources (MDNR) Fisheries Service from 11 October to 21 November. A total of 343 samples was collected during surveys on 263 natural oyster bars (Figure 1a), including Key Bar (Figure 1b) and Disease Bar (Figure 1c) sites as well as sanctuaries, contemporary seed oyster planting sites, shell planting locations, and seed production areas.

A 32-inch-wide standard oyster dredge was used to obtain the samples. 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-bushel subsamples were collected from replicate dredge tows. On seed production areas, five 0.2-bushel subsamples were taken from replicate dredge tows. At all other sites, one 0.5-bushel subsample was collected. A list of data categories recorded from each sample appears in Table 1. Beginning in 2005, tow distances have been recorded for all samples (providing the dredge was not full) using the odometer function of a global positioning system unit, as well as the total volume of material in the dredge from which the subsample was taken.

Fall Oyster Survey Indices
Integral to the Fall Oyster Survey are four categories of indices used to assess Maryland's oyster populations: spatfall, disease, mortality, and biomass. The Spatfall Intensity Index is a measure of recruitment success and potential increase of the population obtained from a subset of 53 oyster bars; it is the arithmetic mean of spat/bushel counts from the 53 Key Bars. Disease infection levels are documented by Oyster Disease Prevalence (dermo and MSX disease) and Intensity (dermo disease only) as derived from a subset of 43 oyster bars (see below for methods). The Total Observed Mortality Index is an indicator of annual mortality rates of post-spat stage oysters from the 43 oyster bar Disease Index subset calculated as the number of dead oysters (boxes and gapers) divided by the sum of live and dead oysters (Appendix 2). Although keyed to the Disease Index subset established in 1990, the Total Observed Mortality Index includes 1985-1989 data. A fourth index added this year, the Biomass Index, measures the number and weight of post-spat oysters from the 43 Disease Bar subset relative to the 1994 baseline (see below for methods).

Oyster Disease Analyses

Representative samples of 30 oysters older than one year were taken at each of the 43 Disease Bar sites. Additional samples for disease diagnostics were collected from seed production areas, seed planting areas, and areas of special interest. Due to scarcities of oysters at four sampling sites, smaller subsamples (n = 16, 23, 29, 29) were secured for disease assays. Oyster parasite diagnostic tests were performed by staff of the Cooperative Oxford Laboratory (COL). Data reported for *Perkinsus marinus* (dermo disease) are from rectal Ray's fluid thioglycollate medium (RFTM) assays. Prior to 1999, the less sensitive hemolymph assays were performed. Data reported for *Haplosporidium nelsoni* (MSX disease) have been generated from tissue histology since 1999. Before 1999, hemolymph cytology was performed, while histology samples 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, regardless of infection intensity (Appendix 2). Infection intensity refers to the mean infection stage, or relative pathogen abundance, in analyzed oyster tissues. A categorical infection intensity range from zero to seven, based on pathogen concentration in hemolymph or solid tissues, was used to classify dermo disease intensities (See Gieseker 2001 for a complete description of parasite diagnostic techniques and calculations).

Biomass Index
MDNR 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 each 5 mm grouping used in the field measurements.

For each of the 43 disease monitoring stations, the number of small and market oysters (=post-spat or 1+ year classes) in each 5 mm size class was multiplied by the average dry-meat weight for that size class to obtain the total weight for each size grouping (Eq. 1). These were summed to get the total dry-meat weight of a 1 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 1994. The Biomass Index was derived by dividing the year's average biomass value by the 1994 average biomass value (1994 biomass index = 1.0) (Eq. 4).

Note that the analyzed data actually come from the previous year's Fall Survey, i.e. the 2012 index is based on the 2011 Fall Survey. So the 1994 baseline is from the 1993 Fall Survey, etc.

Equations

For each monitoring station:

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

For all monitoring stations:

3. (∑ dmw per1 bu. station sample)/43 = annual average biomass value
4. (annual average biomass value)/(1994 average biomass value) = Biomass Index

Statistical Framework

To provide a statistical framework for some of the Annual Fall Survey data sets, a non-parametric treatment, Friedman's Two-Way Rank Sum Test, was used (Hollander and Wolfe 1973). This procedure, along with an associated multiple-range test, allowed among-year comparisons for several parameters. Additionally, mean rank data can be viewed as annual indices, thereby allowing temporal patterns to emerge. Friedman's Two-Way Rank Sum Test, an analog of the normal scores general Q statistic (Hájek and Šidák 1967), is an expansion of paired replicate tests (e.g. Wilcoxon's Signed Rank Test or Fisher's Sign Test). Friedman's Test differs substantively from a Two-Way ANOVA in that interactions between blocks and treatments are not allowed by the computational model (See Lehman 1963 for a more general model that allows such interactions). The lack of block-treatment interaction terms is crucial in the application of Friedman's Test to the various sets of Fall Survey oyster data, since it eliminates nuisance effects associated with intrinsic, site-specific characteristics. That is, since rankings are assigned across treatments (in this report - years), but rank summations are made along blocks (oyster bars), intrinsic differences among oyster bars are not an element in the test result. All Friedman's Test results in this report were evaluated at α=0.05.

To quantify annual relationships, a distribution-free multiple comparison procedure, based on Friedman's Rank Sum Test, was used to produce the "tiers" discussed in this report. Each tier consists of a set of annual mean ranks that are statistically similar to one another. This procedure (McDonald and Thompson 1967) is relatively robust, very efficient, and, unlike many multiple comparison tests, allows the results to be interpreted as hypothesis tests. Multiple comparisons were evaluated using "yardsticks" developed from experimental error rates of α=0.15.

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 throughout the Maryland oyster grounds, freshwater flow, which influences salinity, provides a more synoptic view of baywide conditions and is therefore used as a surrogate for salinity.

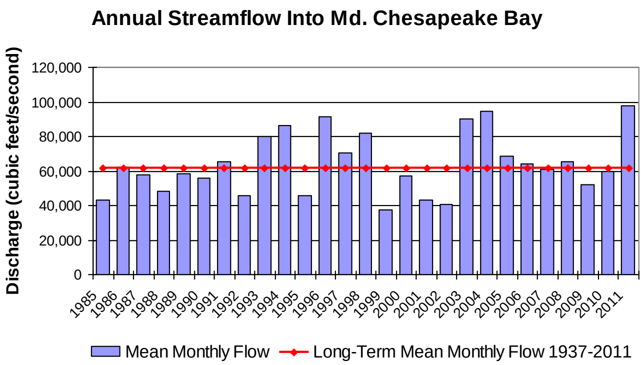

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2011. USGS Section C: all Maryland tributaries and the Potomac River.

The annual streamflow into the Maryland portion of Chesapeake Bay during 2011 was the highest since 1985 and exceeded the 75-year average by 58% (Sec. "C" in Bue 1968; USGS 2011). In contrast, flows during the six previous years were within the normal range[1] (Figure 2a).

The individual monthly discharges showed strong deviations from the monthly means from March through May (peaking at 231,000 cu ft/sec or 341% of the 71-yr mean in March) and again from September through December following Hurricane Irene and Tropical Storm Lee (peaking at 179,000 cu ft/sec or 836% of the 71-yr average in September) (Figure 2b).

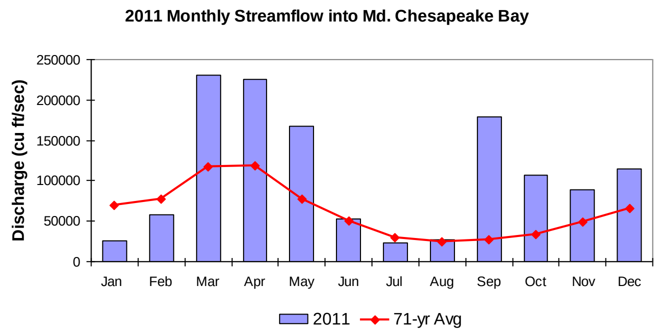

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2011, including the long-term monthly average.

As a result of the spring freshwater discharges and subsequent tropical storms, salinities plummeted throughout the Bay beginning in March and remained below normal for the rest of the year. The drop in salinity was especially dramatic in the Upper Bay, where a station near Deep Shoal oyster bar recorded extended periods of salinities below 1 ppt from March through May and again from October through December (Figure 2c).

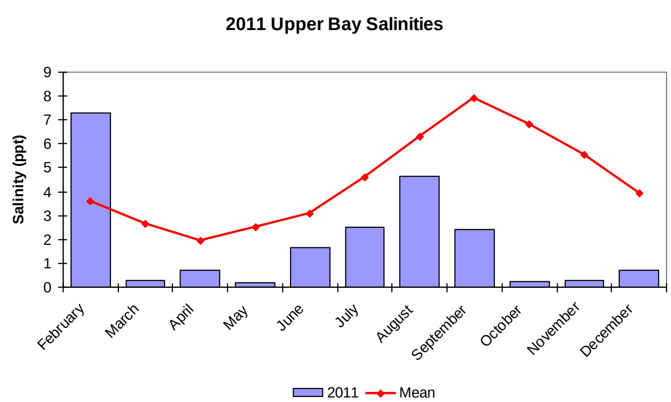

Figure 2c. Monthly Upper Bay salinities at Sta. CB3.1 near Deep Shoal oyster bar, 2011.

At the southern extreme of Maryland, lower Tangier Sound experienced below

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[1] Categorized by the U.S. Geological Survey as freshwater flows between the 75th percentile and the 25th percentile of mean monthly flows for the 1937-2011 period.

average salinities from May through December (Figure 2d). Salinities there were below the previous recorded minimums during several months (Eyes on the Bay).

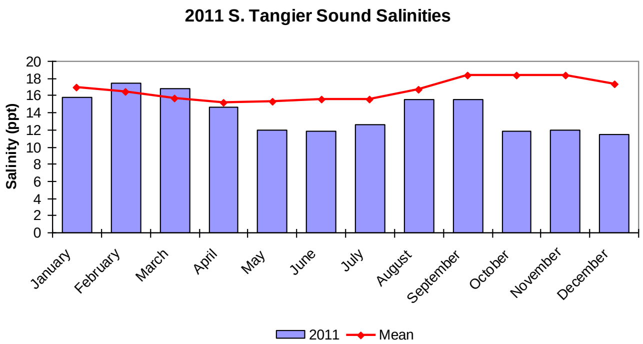

Figure 2d. Monthly southern Tangier Sound salinities at Sta. EE3.2, 2011.

SPATFALL INTENSITY

The 2011 Spatfall Index, a measure of recruitment success and potential increase of the population, was 20.1 spat per bushel, slightly higher than the 27-year median index of 18.7 spat/bu. Although this represents a 74% drop from the previous year's spat index of 78 spat/bu, this was not unexpected considering the high freshwater flows into the bay in 2011 which inhibited spatfall. As a result of the lower index and spatially confined spatfall distribution, the 2011 spat index placed in the second lowest statistical ranking out of five for the period from 1985 to 2011 (Figure 3).

Spatfall was more narrowly and unevenly distributed among the Key Bars in 2011 compared with the previous year. In 2011, spat were observed on 29 of the 53 Key Bars vs. 46 bars in 2010 (Table 2). Only five bars contributed 75% of the spat index, in contrast to 2010 when ten bars accounted for 75% of the index. The highest Key Bar spat count in 2011 was 248 spat/bu. on Drum Point in the Manokin River, accounting for 23% of the total spat index (albeit less than half the spat count of the previous year) (Table 2). In addition, four of the top-five Key Bars for spat counts were in the southern Eastern Shore region, the remaining one being Pagan in the St. Mary's River.

When considering all bars surveyed in addition to the Key Bars, most of the spatfall was distributed along the lower Eastern Shore south of the Little Choptank River, with a scattering of spat north and west of this area (Figure 4). The heaviest spatfall was in the Pocomoke/Tangier Sound region, especially around the Manokin and Big Annemessex Rivers and Hooper Strait, with a high count of 248 spat/bu at Drum Point. Although spatfall was generally light in the St. Mary's River, one station – Pagan – had over 100 spat/bu. Spatfall was virtually non-existent north of the Choptank River, the upper reaches of the Potomac, Patuxent, and Choptank Rivers and the entire Little Choptank River.

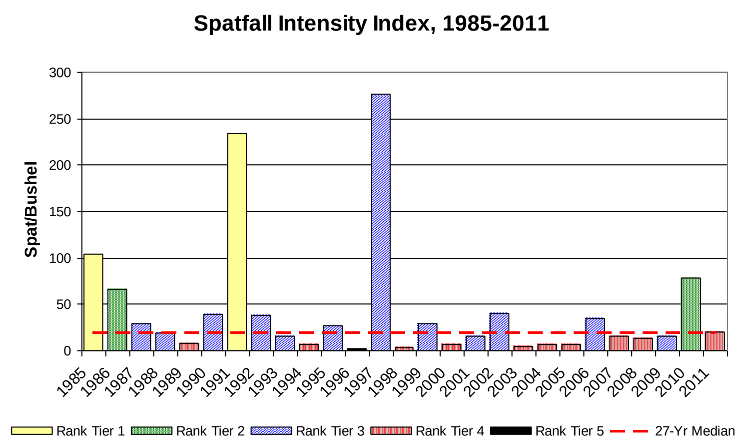

Figure 3. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including rankings of statistically similar indices.

A final comment on the annual spatfall intensity index: this index is an arithmetic mean that does not take into account geographic distribution, whereas the statistical tiers do (Figure 3). 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. Mary's Rivers (Homer & Scott 2001). Over 75% of the 1997 index was accounted for by only five of the 53 Key Bars, while ten contributed nearly 95% (Table 2). As a result, the 1997 spat index fell into the third statistical tier despite being the second highest index on record and an order of magnitude higher than other Tier 3 indexes. In contrast, the 1991 spatfall (the third highest on record) was far more widespread. Fifteen Key Bars comprised 75% of the index that year, while 28 sites were needed to attain 95% of the spatfall intensity index, placing it in the first statistical tier notwithstanding having a lower spatfall index than 1997.

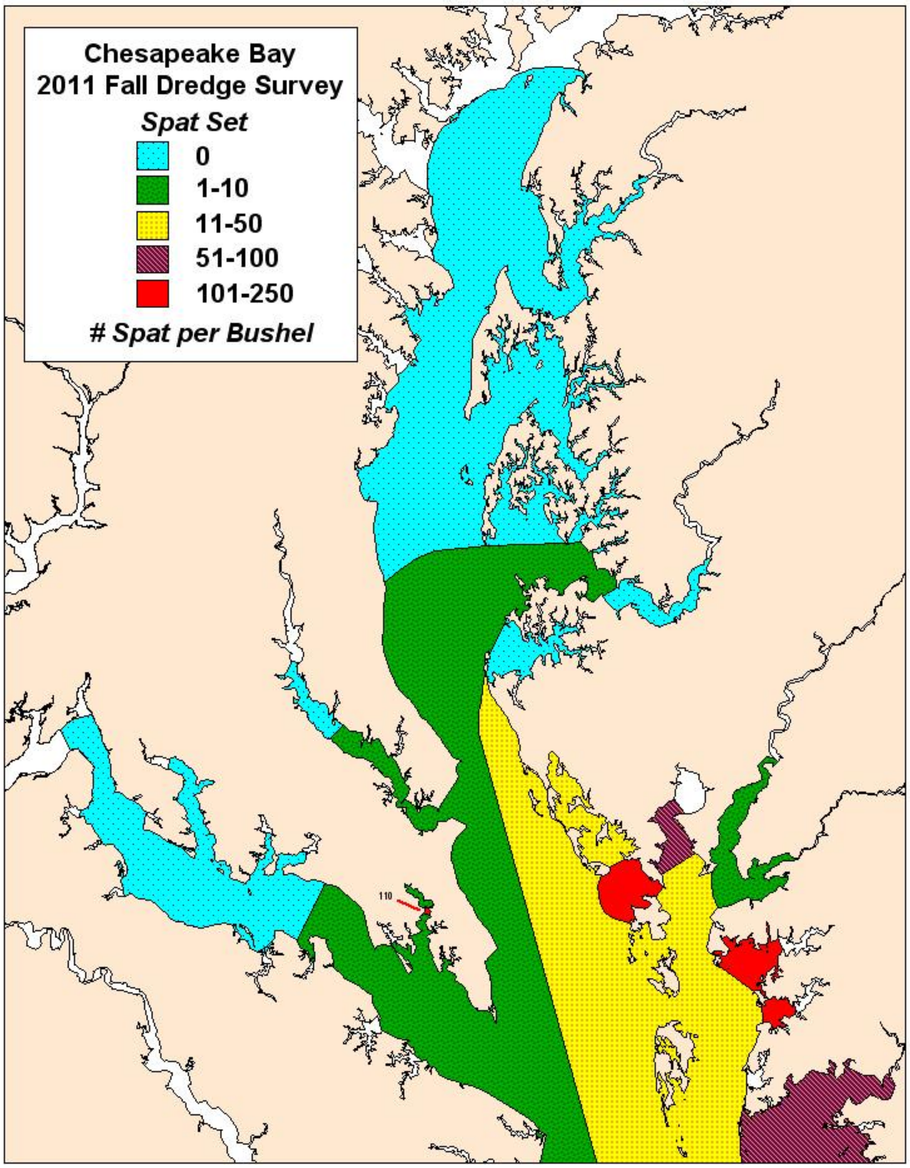

Figure 4. Oyster spatfall intensity and distribution in Maryland, 2011. Intensity ranges represent regional averages. Actual count (spat/bu) on Pagan Bar is shown.

OYSTER DISEASES

Oyster diseases continued to decline, remaining below the 21-year average for the ninth consecutive year following record highs in 2002. Although dermo disease remained widely distributed, oyster disease metrics were at their lowest since systematic monitoring began in 1990.

Dermo disease caused by the parasite *Perkinsus marinus*, infected oysters on 93% of the Disease Bars (Table 3). Because of high freshwater flows and associated mortalities, the additional sampling site at Deep Shoal in the Head-of-the-Bay could not be sampled for disease. The overall mean infection prevalence in oysters sampled on the Disease Bars was 38%, the lowest since 1990, when the 43 Disease Monitoring bars were established and substantially below the record-high 2002 mean prevalence of 94%, ranking 2011 alone in the lowest statistical grouping for prevalence (Figure 5). Eight out of the past nine years have had dermo disease prevalences below the 22-yr average.

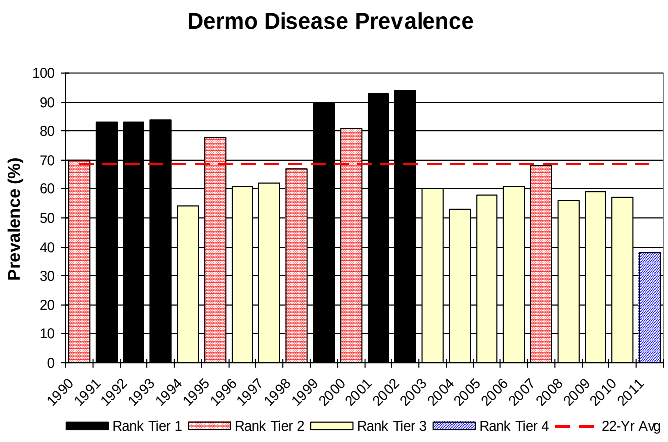

Figure 5. Annual mean P. marinus prevalences and statistical groupings from Maryland disease monitoring bars.

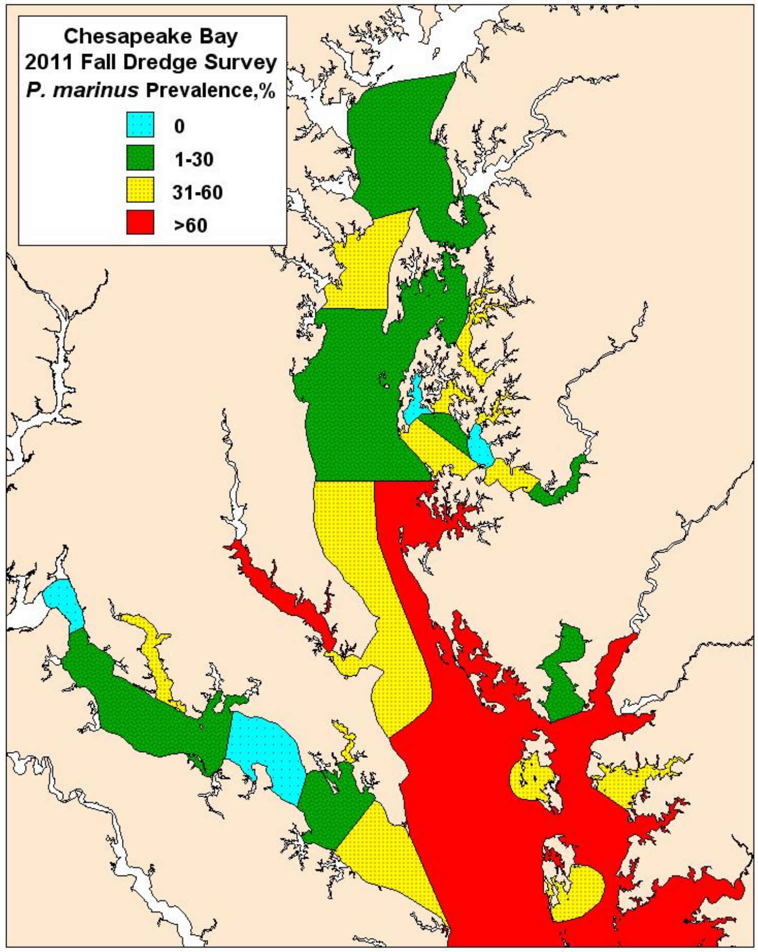

Figure 6. Geographic extent and prevalence of dermo disease in Maryland, 2011.

The geographic distribution of high prevalences (>60%) was along the lower Eastern Shore from the Little Choptank River south, as well as part of the Patuxent River (Figure 6). The remaining areas of higher prevalences were fragmented and were not necessarily associated with higher mortalities (see Observed Mortality section). *Perkinsus marinus* was not detected among tested oysters from two bars in the Choptank River and Ragged Point in the Potomac River. Also, outside of the regular disease monitoring sites, dermo disease was not detected at Beacon bar in the upper reaches of the Potomac River oyster grounds.

The 2011 annual mean infection intensity of 1.2 was the lowest in 22 years of standardized sampling, placing it within the lowest statistical grouping (of four tiers) for Disease Bar infection intensity (Figure 7). This is in contrast to the record high 2001 mean intensity of 3.8. The average intensity index over the past nine years is 1.8, similar to another extended period from 1994 to 1998 when annual mean infection intensities averaged 1.7. In comparison, the drought period of 1999-2002 had mean annual intensities that averaged 3.4.

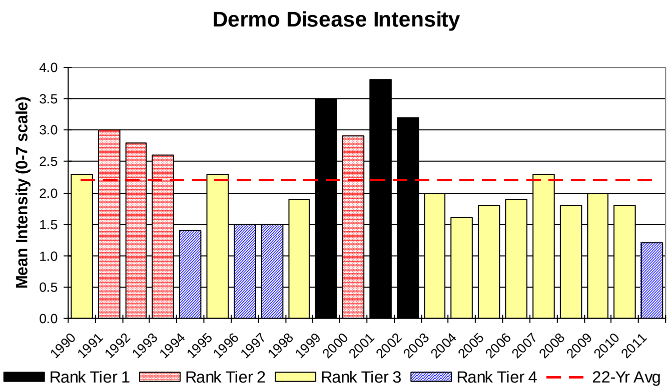

Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars. Rankings are based on statistically similar years.

The frequency distributions of sample infection intensities shifted sharply to the lower end of the range (Figure 8). In 2011, 49% of the Disease Bar samples had mean infection intensities of less than 1.0, the highest percentage of the 22-year time series, and only two bars (5%) had mean intensities of 3.0 or greater – none exceeded 4.0. In contrast, 81% of the dermo disease intensities were ≥3.0 and 51% were ≥4.0 during the peak infection intensity year of 2001. Infection intensities in individual oysters that are ≥ 5.0 on a 0 – 7 scale are considered lethal; such infection intensities were detected in only 8% of sampled oysters.

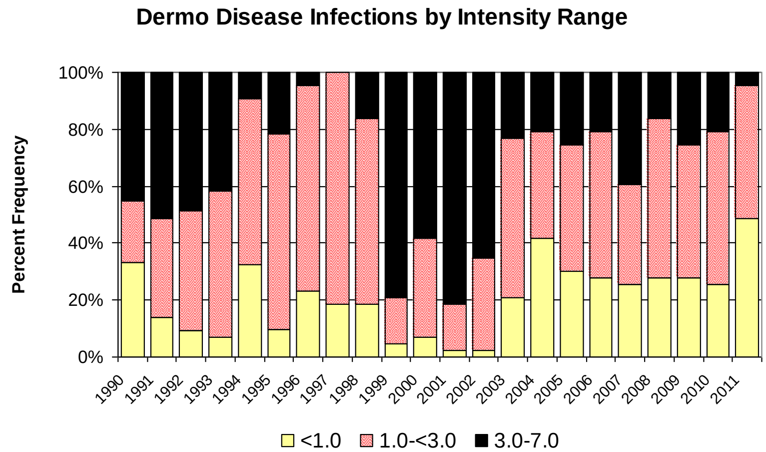

Figure 8. *Perkinsus marinus* infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.

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.

The geographic range of MSX disease contracted substantially in 2011 (Figure 9). *Haplosporidium nelsoni* was detected at only one bar at a very low prevalence (Old Woman's Leg in lower Tangier Sound), its smallest extent since 1990, when standardized disease monitoring was instituted (Table 4). In contrast, the parasite was found on 90% of these bars in 2002. For the 43 disease monitoring bars, the average percentage of oysters infected with MSX disease was 0.2%, equaling the previous low in 2004. This compares with 4% in 2010 and the record high 28% in 2002. This continues a trend of declining MSX disease that began the preceding year, due to lower salinities unfavorable to the parasite (Tarnowski 2011).

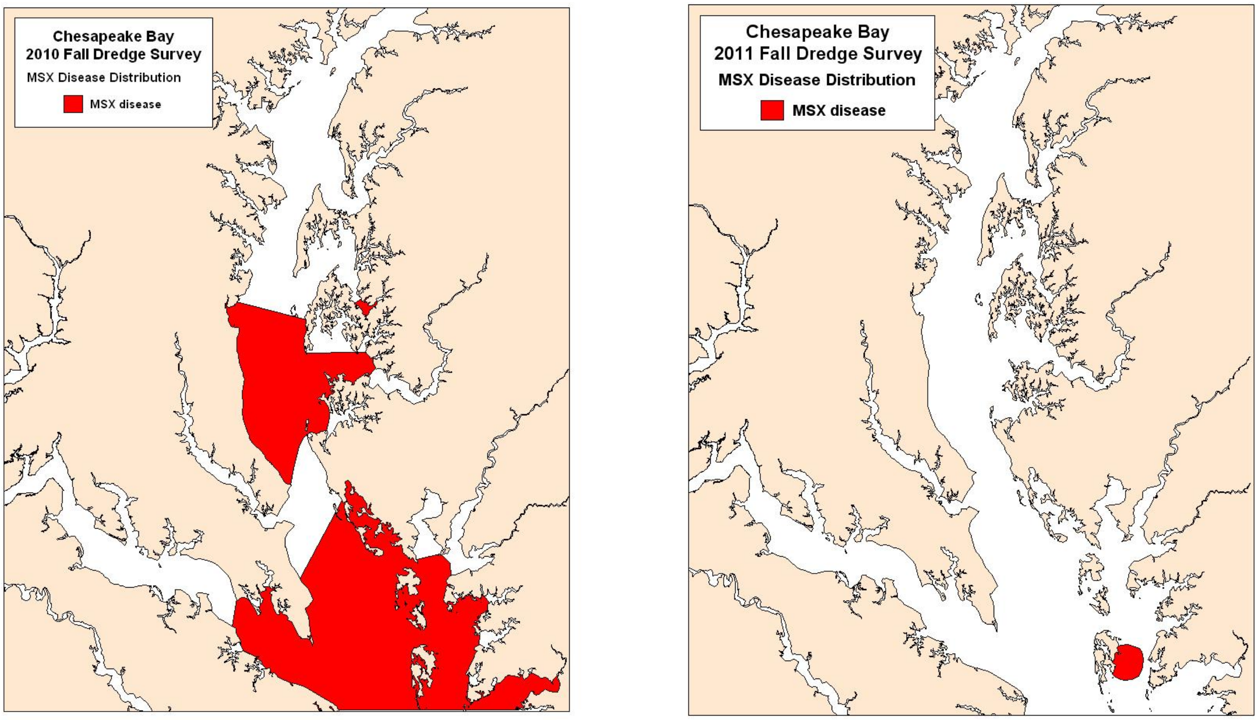

Figure 9. Change in geographic extent of MSX disease in Maryland waters between 2010 and 2011.

The abatement of MSX disease in 2003-04 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 infected disease monitoring bars (90%) and mean annual prevalence within the oyster populations (28%), leaving in its wake observed oyster mortalities approaching 60% (Figure 10).

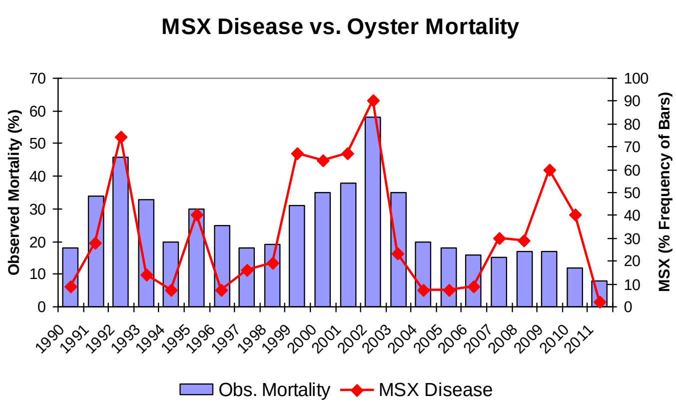

Figure 10. Percentage of Maryland disease monitoring bars with MSX disease compared to annual means for observed oyster mortalities during the period of 1990-2011.

Since 1990, there have been four *H. nelsoni* epizootics: 1991-92, 1995, 1999-2002 and 2009-10. All four of these epizootics were followed closely by periods of unusually high freshwater inputs into parts of Chesapeake Bay, which resulted in the purging of *H. nelsoni* infections from most Maryland oyster populations (Tarnowski 2005).

OBSERVED MORTALITY

Observed mortalities during 2011 were the lowest of the time series that began in 1985, before diseases put a stranglehold on the population. This marks the eighth consecutive year that observed mortalities remained well below the 27-year average of 25.3% (Table 5). For the 43 disease monitoring bar subset, the most recent eight-year average observed mortality of 15% approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (MDNR, unpubl. data). The 2011 observed mortality on the Disease Bars of 8% was ranked in the lowest statistical grouping over the same time scale (Figure 11).

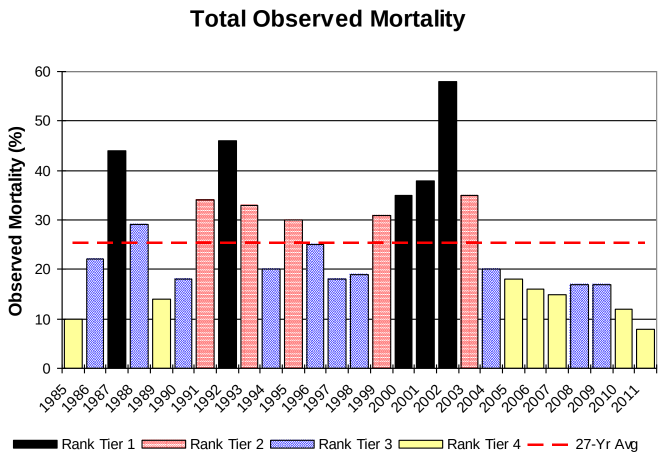

Figure 11. Mean annual observed mortality, small and market oysters combined. Ranking tiers are based on statistically similar years.

This is a remarkable turnaround from 2002 when record-high disease levels devastated Maryland populations, killing 58% of the oysters.

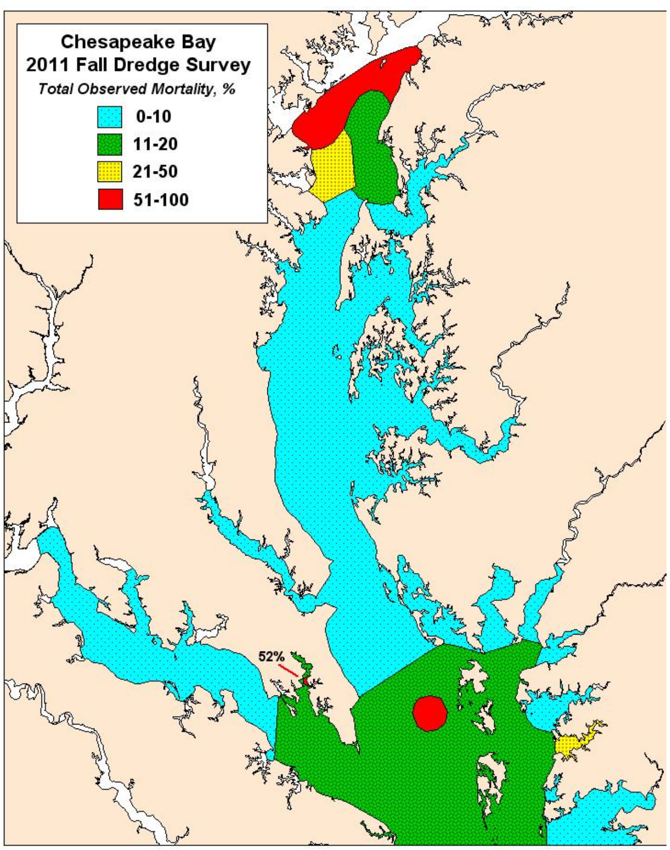

Figure 12. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2011.

As with spatfall and oyster diseases, there was a general north-south gradient in observed mortality rates, with the notable exception of the Upper Bay mortalities (see below) and low observed mortalities in Pocomoke Sound and the Tangier tributaries (Figure 12). Aside from the freshet-impacted region, higher mortalities during 2011 were in southern Maryland waters, but no major region of the bay exceeded observed mortalities of 25%.

The highest observed mortality on an individual bar was a staggering 88% at the Northwest Middleground oyster sanctuary, probably due to a low dissolved oxygen event. This bar is located in deeper water (~9 m) adjacent to the mainstem channel. Dissolved oxygen readings from a nearby monitoring station (CB5.2) showed near anoxic conditions during July up to a depth of 7 m (Figure 13). Conditions remained hypoxic in early August, then improved with the subsequent passage of two major storms. The extended period of depleted dissolved oxygen combined with high oyster metabolic activity associated with peak summer temperatures likely resulted in the high mortality observed on this bar.

Another anomalously high observed mortality occurred at Gravelly Run. Although oyster mortalities in the St. Mary’s River were relatively low (6%-12%), this bar’s observed mortalities reached 52%. The causes for this are unknown.

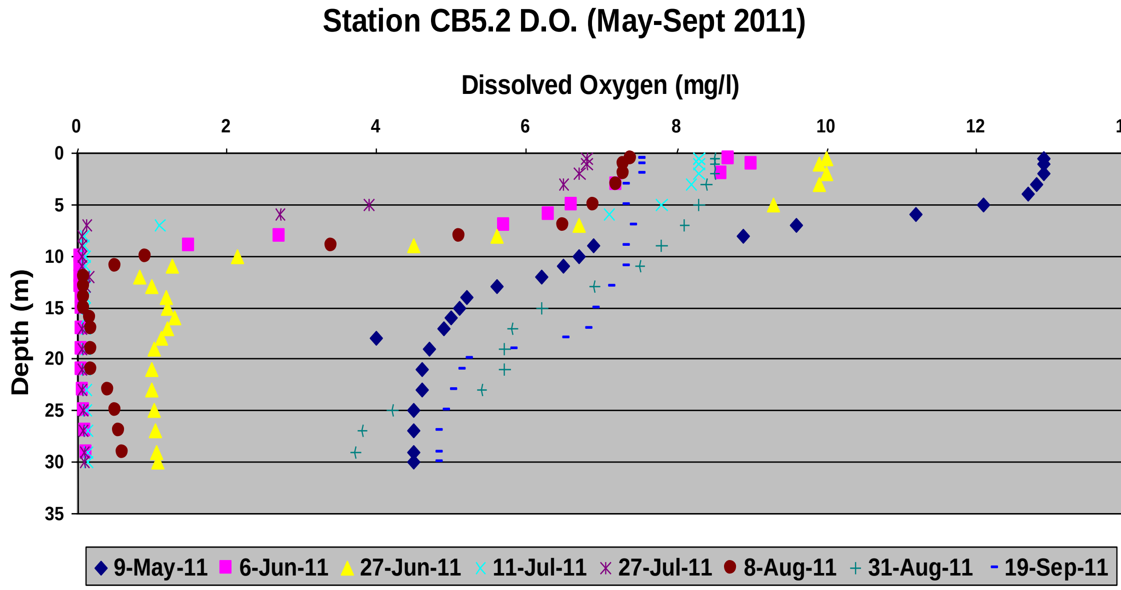

Figure 13. Water column profiles of dissolved oxygen concentrations at monitoring station CB5.2 in proximity to the Northwest Middleground oyster sanctuary, May-September 2011. *(Graph courtesy of M. Trice, MDNR/RAS)*

Upper Bay Mortalities

As part of the annual MDNR Fall Oyster Survey, the upper mainstem of the Chesapeake Bay was surveyed on 2 November 2011. A total of 21 samples from 15 individual oyster bars located north of the Bay Bridge were sampled.

Along the Eastern Shore, mortalities were comparable to those in 2010 as far north as Hodges Bar (Figure 14). The four bars from Tolchester up to Flat Rock near Pooles Island suffered a cumulative mortality of 79%, compared with 0% in 2010. No live oysters were found on the two uppermost bars. Surface salinities at these uppermost bars on this date ranged from 1.9 ppt down to 0.6 ppt (nearly fresh water). However, the bottom salinity at Deep Shoal (adjacent to the shipping channel) was 5.1 ppt.

Elevated mortalities were observed much further downbay on the Western Shore – south to Mountain Point below the mouth of the Magothy River (Figure 14). The combined observed mortality for these six bars was 74%, a sevenfold increase over 2010 (11%). The two samples from the northernmost bar, Man-O-War Shoals off the Patapsco River, had 100% observed mortalities. Surface salinities ranges from 3.5 ppt down to 1.9 ppt, with bottom salinity at one station of 4.3. The live oysters on these bars were in poor condition – bloated, watery, and translucent – and mortalities may very well continue to rise. In contrast, there were no observed mortalities at Sandy Point South (just a few miles below Mountain Pt), and the oysters looked to be in prime condition.

Among the unfortunate casualties of this mortality event were the young oysters of the 2010 spatset. Although this spatset was light in the upper bay, it was widespread and was important to help sustain these populations, which receive a set once about every 10 years (the previous set was in 2002). Although spatsets in this region usually have good survivorship, they are vulnerable to freshets.

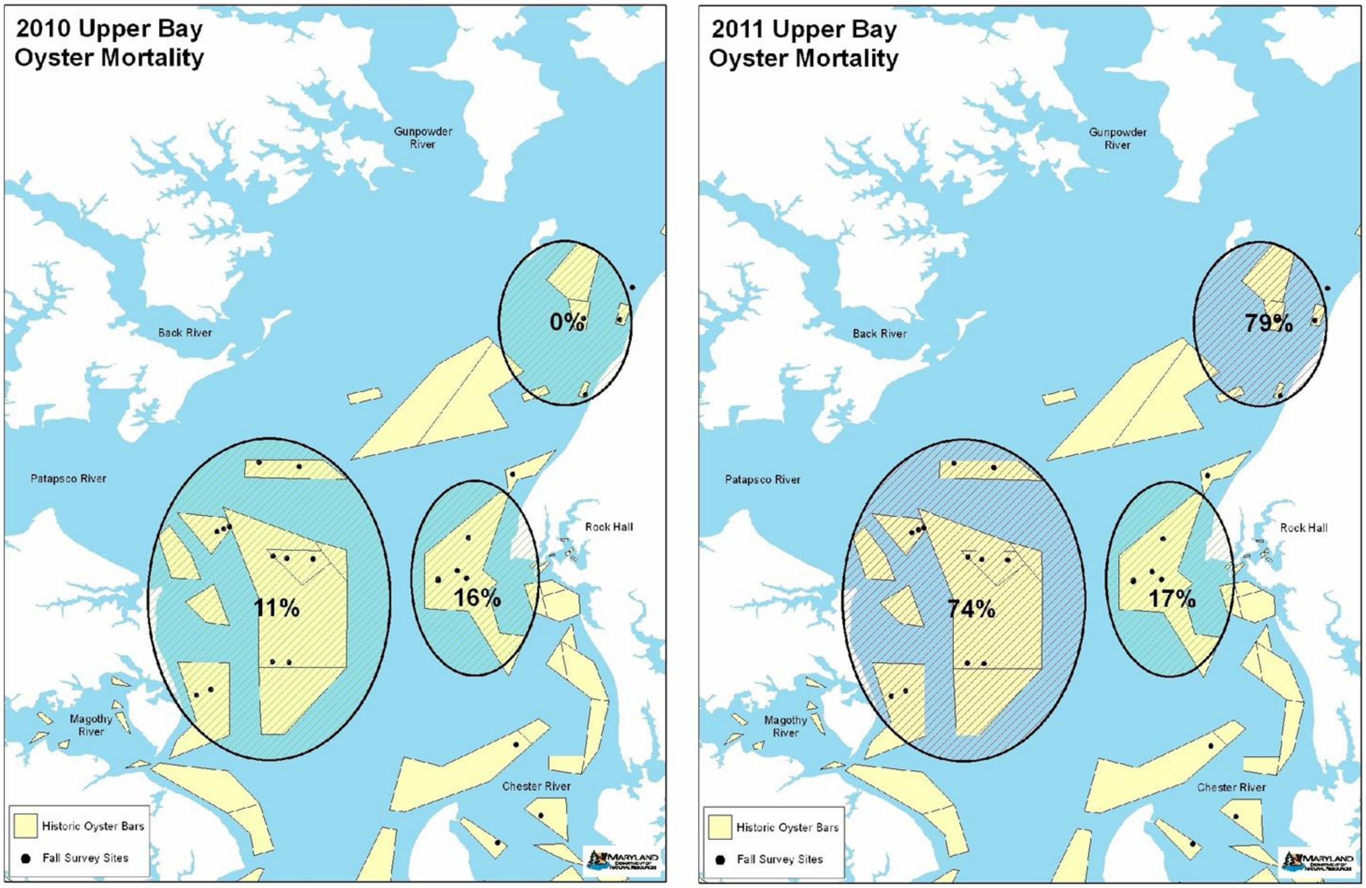

Figure 14. Comparison of observed oyster mortalities in the Upper Bay in 2010 and following the freshets of 2011.

The likeliest cause of this mortality was the hyposaline conditions that existed in the upper bay as a result of extraordinary freshwater runoff from the Susquehanna watershed (see above “Freshwater Discharge Conditions”). Salinities were well below normal for an extended period of time during the spring and early summer (March through June), and then again after Hurricane Irene and Tropical Storm Lee dumped huge quantities of rainfall on the watershed in late August - early September. It is uncertain when the oysters died. Barnacles and other fouling observed inside some of the dead oysters suggests that these may have died during the spring-early summer freshet. This could have been followed by a second bout of mortalities following the storms, as indicated by the less-fouled condition of some of the dead oysters.

Burial of the oysters due to the tremendous sediment loads in the bay after the two storms was a concern. However, this does not appear to be the primary source of mortality, since live fouling organisms such as barnacles, mussels, bryozoans, etc., were found attached to the oysters and shells on these bars. Had the oysters been smothered by sediment, these organisms would not have been able to attach to the oyster shells.

The upper bay is an important harvest area for skipjacks and patent tongers. Usually a number of boats are seen working on various bars during the Fall

Survey. However, no oystering activity was observed this year.

The elevated mortalities observed in the upper during the Fall Survey are not unprecedented. This region has a long history of oyster-killing freshets, and this event apparently is yet another chapter.

BIOMASS INDEX

Despite the Upper Bay mortalities, the Maryland Oyster Biomass Index, a measure of oyster abundance and weight, increased by 44% over the previous year. This was the first time since 2001 since it has exceeded the 1994 baseline (Figure 15). This increase was driven by the high oyster survivorship last year, particularly of the strong 2010 year class.

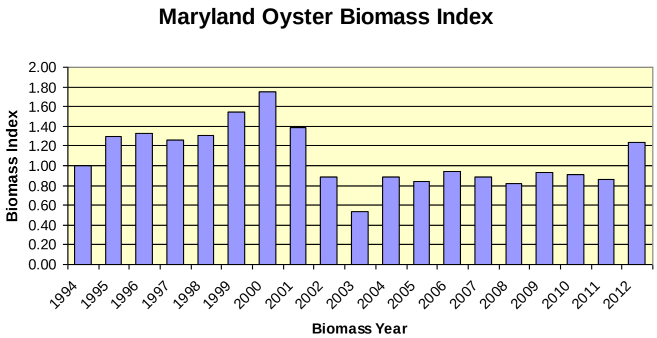

Figure 15. Maryland oyster biomass index time series for the actual survey year. The analyzed data are from the previous year's Fall Survey, i.e. the 2012 index is based on the 2011 Fall Survey.

COMMERCIAL HARVEST

With reported harvests of 124,000 bushels during the 2010-11 season, commercial oyster landings decreased by 33% from the previous year (Table 6, Figure 16). This decline was due to the depletion of the relatively strong year-class of 2006 and subsequent poor recruitment years. On the other hand, the strong 2010 year class, in conjunction with good survivorship, offers encouragement for the near future. Nonetheless, the fishery has been slow

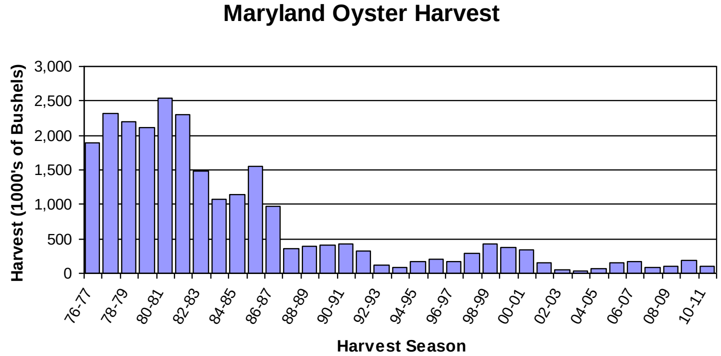

Figure 15. Maryland seasonal oyster landings, 1976-77 to 2010-11.

to recover from the devastating oyster blight of 2002. Taken in context the 2010-11 landings are only about one-third of the 2000-01 season and exponentially lower than harvests prior to the mid-1980's epizootics. 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 17 years (and four of these in the recent eight years). The dockside value of $4.3 M was a modest decrease of $0.2 M over the previous year (Table 7a.).

The Tangier Sound/Lower Mainstem region, including the Honga River and Fishing Bay, was again the dominant harvest area, accounting for 62% of the 2010-11 landings (Table 6). The most substantial changes in landings between the 2010 and 2011 seasons for this region were:

Honga River – decreased 15,000 bu.
Fishing Bay – decreased 5,000 bu
Tangier Sound – decreased 39,000 bu.
Lower Mainstem – decreased 12,000 bu.

Although most of the regions experienced declines in landings, the Nanticoke and Chester Rivers and Broad Creek had modest increase. Despite the impact of freshets in the Upper Bay, harvests there fell by only 2,400 bu. Note that both in 2010 and 2011 the

Upper Bay landings represented about 5% of the Maryland total.

There was little change in the relative landings by gear type during the 2010-11 season, (Table 7b). Power dredging continued to be the predominant method of harvesting, accounting for 53% of the total landings, primarily due to activity in the Tangier Sound region, followed by patent tonging at 23%. Hand tongs harvests increased to 11% of the total, although still well below 74% of the landings during the 1996-97 season.

DISCUSSION

The effect of environmental factors, particularly freshwater inflow, on oyster diseases and consequent oyster survivorship in Chesapeake Bay was again demonstrated in dramatic fashion by the near-record high streamflows of 2011. Oyster disease prevalences and infection intensities fell to their lowest levels since systematic monitoring began in 1990, resulting in the lowest average observed oyster mortality in over 25 years.

In contrast, drought conditions from 1999 through 2002 allowed diseases to attain record high levels both in prevalence and intensity. Dermo disease was pervasive throughout Maryland's oyster populations, while MSX disease experienced an unprecedented range expansion as far upbay as the Bay Bridge and lower portion of the Chester River. During this period, oyster populations experienced severe total observed mortality rates of nearly 60%.

Persistently high streamflows in 2003 and into 2004 effectively caused both oyster diseases to subside throughout the entire population range. By 2004, the extent of MSX disease was confined to limited areas in southern Maryland and dermo disease prevalences and intensities plummeted (Tarnowski 2005). The years since were characterized by a succession of average streamflow years – an unusual pattern when compared with the streamflow extremes of the 1990s and early 2000s. Disease levels began to creep back up during the late 2000s, notably dermo disease in 2007 and MSX disease in 2009, but timely pulses of freshwater inputs moderated disease levels and effects (Tarnowski 2010, 2011). Consequently, observed mortalities remained below the 1985-present average for eight consecutive years. In a reprise of 2003-04, the strong freshwater flows of 2011 purged MSX disease from all but one of the oyster bars examined, and drove down dermo disease to newly-established lows.

One of the major dilemmas in Maryland oyster population dynamics is that some of the same factors that have a positive effect (enhanced recruitment) can also have negative impacts (disease-related mortality). Both oyster reproduction/recruitment and the life-cycles of oyster parasites may be positively influenced by higher salinities and temperatures. Following a good spat set in 2002 - the last year of the millennial drought and record high disease levels - suboptimal freshwater flows kept recruitment below or at median values for much of the same period that disease levels were below average. The exception was 2010, when recruitment occurred throughout the bay, resulting in a strong spat index. Below average streamflows for a critical period of that year along with a sharp temperature increase may have been positive factors in this recruitment, but they also helped maintain the broad geographic range of MSX disease following its expansion in 2009 (Tarnowski 2011). Note that although adequate salinities and favorable temperatures are necessary, they are not always sufficient conditions for enhanced recruitment and other factors may need to be accounted for (Tarnowski 2010b).

The timing of the high streamflows in 2011 was particularly beneficial to the strong 2010 oyster year class, reducing disease levels to record lows and interrupting a potentially threatening situation, as had been the case with the 2003 inundation for the 2002 oyster year class. A substantial number of those yearling oysters thrived as a result, which was reflected in the 44% increase in the biomass index. This strong recruitment also provided a welcome boost to the new tributary-wide sanctuary program, allowing it to get off to a propitious start.

There were downsides, however, to the elevated 2011 streamflows. Lowered salinities inhibited oyster recruitment, resulting in a 74% decline from the previous year. More striking, several oyster bars located in the Upper Bay suffered remarkably high mortality rates. Included in these were a scattering of 2010 year-class oysters in a region that receives spatsets on a decadal scale. Ordinarily, these yearlings would have been expected to have a high survival rate over a prolonged period since these lower-salinity waters ordinarily provide a refuge from the effects of oyster diseases. It should be remembered, however, that freshet-related mortalities occasionally occur in the Upper Bay. During the 20th century eight major mortality events were documented in this region – in 1908/9, 1916, 1928, 1936, 1943, 1945/46, 1972, and 1996 (Beavan 1947, Engle 1947, CRC 1976, Homer & Scott 2001). Fortunately, the oysters lost to the 2011 freshet represent only a small percentage of the total Maryland oyster population. Regrettably, this offers small solace for the oyster harvesters who work in this region.

In summary, the results from the 2011 Fall Oyster Survey indicate that oyster populations are doing well in most parts of Maryland's Chesapeake Bay, thanks to high survivorship of yearling oysters from the good spat set of 2010. Disease levels were at their lowest since systematic monitoring began in 1990, resulting in oyster natural mortality rates comparable to the years prior to the disease epizootics of the mid-1980s. Although high freshwater flows from heavy rains in the spring and two tropical storms in late summer impacted oysters in the Upper Bay, this represented a relatively small proportion of the total oyster population. The lower salinities proved to be beneficial to the majority of oysters in Maryland by limiting disease, allowing the yearling oysters to thrive. As a result, the 2011 Oyster Biomass Index, a measure of oyster abundance and weight, increased by 44% over the previous year.

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TABLES

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

Physical Parameters

-Latitude and longitude

-Bottom type

-Depth

-Temperature

-Salinity

-Tow distance (2005-present)

Biological Parameters

-Total volume of material in dredge (2005-present)

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

-Stage of oyster boxes (recent, old)

-Average and range of shell heights of live and dead oysters by age/size classes

-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.)

(Return to Text)

Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 “Key” spat monitoring bars, 1985-2011.

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	6	5	0	0	0	0
	Stone Rock	136	20	0	50	22	37
	Flag Pond	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	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	74	16	2	0	0	28
	Royston	440	8	8	0	0	57
	Cook Point	66	82	4	28	0	17
Harris Creek	Eagle Pt./Mill Pt.	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	332	24	2	0	0	1
Little Choptank R.	Ragged Point	134	82	34	112	0	65
	Cason	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	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	26	98	14	4	16	4
	Drum Point	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	140	34	52	36	6	613
Breton Bay	Black Walnut	16	12	0	0	0	1
	Blue Sow	55	40	0	0	0	1
St. Clement Bay	Dukehart Channel	20	7	0	0	0	1
Potomac River	Ragged Point	69	35	4	0	0	2
	Cornfield Harbor	383	908	362	28	14	36
	Spat Index	**103.8**	**66.1**	**29.1**	**18.7**	**7.8**	**39.0**

Table 2. Spatfall (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	0	0	0	0	0	0	0	0
Stone Rock	355	9	4	4	16	0	18	0
Flag Pond	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	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	179	2	0	0	4	0	55	0
Royston	595	20	10	0	10	0	289	0
Cook Point	171	1	0	2	14	0	20	0
Eagle Pt./Mill Pt.	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	129	0	13	0	15	0	40	0
Ragged Point	1036	53	9	1	25	0	106	0
Cason	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	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	52	42	19	9	5	0	8	6
Drum Point	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	190	62	15	7	54	0	1390	6
Black Walnut	6	0	1	0	1	0	2	0
Blue Sow	22	0	1	0	7	0	0	0
Dukehart Channel	19	0	3	0	0	0	0	0
Ragged Point	26	0	2	0	19	0	2	0
Cornfield Harbor	212	2	29	0	49	0	4	11
Spat Index	**233.6**	**38.6**	**16.0**	**6.3**	**26.8**	**2.0**	**276.7**	**3.5**

Table 2. Spatfall (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	0	0	1	4	0	0	0	0
Stone Rock	3	34	2	17	1	0	0	3
Flag Pond	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	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	4	0	1	1	0	2	0	5
Royston	39	0	3	10	0	14	0	44
Cook Point	1	5	5	3	1	4	0	9
Eagle Pt./Mill Pt.	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	1	0	0	0	0	3	0	3
Ragged Point	43	3	5	0	1	2	0	6
Cason	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	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	50	6	1	280	15	4	5	75
Drum Point	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	95	42	117	535	9	6	10	125
Black Walnut	3	0	1	2	0	0	0	0
Blue Sow	11	0	2	4	1	0	0	0
Dukehart Channel	1	0	0	1	0	0	0	1
Ragged Point	1	1	0	1	0	0	0	1
Cornfield Harbor	25	5	35	31	9	0	8	6
Spat Index	**29.1**	**6.4**	**15.9**	**40.3**	**4.8**	**6.5**	**6.9**	**35.2**

Table 2. Spatfall (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)				
	2007	2008	2009	2010	2011
Mountain Point	0	0	0	0	0
Swan Point	0	0	0	0	0
Brick House	0	0	6	4	1
Hackett Point	0	0	0	5	0
Tolly Point	0	0	0	2	0
Three Sisters	0	0	0	3	0
Holland Point	0	0	0	1	0
Stone Rock	0	1	4	22	1
Flag Pond	0	0	0	15	4
Hog Island	1	1	4	4	8
Butler	1	8	1	15	3
Buoy Rock	0	0	0	3	0
Parsons Island	0	0	8	2	0
Wild Ground	0	1	1	3	0
Hollicutt Noose	0	0	0	5	0
Bruffs Island	0	0	0	3	0
Ash Craft	0	0	2	39	0
Turtle Back	0	0	13	13	0
Shell Hill	0	0	0	1	0
Sandy Hill	3	1	5	5	0
Royston	2	5	20	27	0
Cook Point	1	10	18	37	2
Eagle Pt./Mill Pt.	0	2	17	44	0
Tilghman Wharf	0	6	15	72	0
Deep Neck	1	23	100	144	1
Double Mills	1	3	11	4	0
Ragged Point	0	2	12	33	0
Cason	0	13	9	50	0
Windmill	4	79	7	85	12
Norman Addition	0	102	6	155	27
Goose Creek	0	35	20	75	83
Clay Island	1	94	29	342	26
Wetipquin	0	2	2	8	4
Middleground	0	21	6	92	23
Evans	0	14	9	27	10
Mt. Vernon Wharf	0	0	8	2	4
Georges	5	28	22	753	243
Drum Point	56	124	34	524	248
Sharkfin Shoal	1	16	14	169	23
Turtle Egg Island	7	32	17	202	23
Piney Island East	44	23	0	160	109
Great Rock	64	38	5	12	5
Gunby	4	5	24	317	25
Marumsco	14	12	24	261	44
Broome Island	0	3	5	52	2
Back of Island	2	7	8	47	7
Chicken Cock	9	1	16	37	11
Pagan	616	0	321	227	110
Black Walnut	0	0	0	1	0
Blue Sow	0	0	3	0	0
Dukehart Channel	0	0	1	0	0
Ragged Point	2	1	2	0	1
Cornfield Harbor	7	1	1	28	3
Spat Index	**15.9**	**13.5**	**15.7**	**78.0**	**20.1**

(Return to Text)

Table 3. *Perkinsus marinus* prevalence and intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2011. NA=insufficient quantity of oysters for analytical sample.

Region	Oyster Bar	***Perkinsus marinus* Prevalence (%) and 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	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	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	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	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	73	2.3	94	4.3	86	3.0	77	2.6	60	2.0
Choptank River	Cook Point	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	100	5.0	100	5.7	100	4.2	100	3.8	83	2.3
	Oyster Shell Point	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	97	3.6	100	4.9	100	4.1	100	3.8	90	2.0
Little Choptank R.	Cason	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	93	2.9	100	2.8	90	2.5	83	1.6	40	0.9
Manokin River	Georges	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	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	**70**	**2.3**	**83**	**3.0**	**83**	**2.8**	**84**	**2.6**	**54**	**1.4**

Table 3. Dermo disease (continued).

Oyster Bar	*Perkinsus marinus* Prevalence (%) and 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	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	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	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	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	67	2.2	20	0.4	23	0.6	100	2.7	100	3.6	97	3.3
Cook Point	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	89	3.4	30	0.7	60	1.3	40	1.0	97	3.4	87	3.6
Oyster Shell Point	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	75	2.5	70	1.2	83	2.0	100	3.0	100	4.8	100	4.7
Cason	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	63	1.1	83	1.8	80	1.9	70	1.6	100	4.3	70	2.1
Georges	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	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**

Table 3. Dermo disease (continued).

Oyster Bar	*Perkinsus marinus* Prevalence (%) and 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	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	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	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	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	100	4.2	100	3.1	97	2.8	97	3.2	90	2.7	80	2.1
Cook Point	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	100	4.5	100	5.0	93	3.5	87	3.3	80	2.5	70	2.3
Oyster Shell Point	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	100	5.5	97	2.9	53	1.7	53	2.1	53	1.6	40	1.1
Cason	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	100	4.0	100	3.6	83	2.3	97	2.3	90	3.0	93	3.7
Georges	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	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**

Table 3. Dermo disease (continued).

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

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2011. NA=insufficient quantity of oysters for analytical sample. ND= sample collected but diagnostics not performed; prevalence assumed to be 0.

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	0	3	13	0	0	0	0	0
	Stone Rock	0	0	43	0	0	3	0	0
	Flag Pond	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	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	0	0	0	0	0	0	0	0
Miles River	Turtle Back	0	0	0	0	0	23	0	0
	Long Point	0	0	0	0	0	0	0	0
Choptank River	Cook Point	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	0	0	13	0	ND	0	0	0
	Oyster Shell Point	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	0	0	17	0	0	0	0	0
Little Choptank R.	Cason	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	0	0	57	0	ND	7	0	0
Manokin River	Georges	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	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
Frequency of Positive Bars (%)		**9**	**28**	**74**	**14**	**7**	**40**	**7**	**16**
Average Prevalence (%)		**1.1**	**5.1**	**24.5**	**2.8**	**0.9**	**9.5**	**0.7**	**1.2**

Table 4. MSX disease (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	0	0	3	7	40	0	0	0	0	0
Stone Rock	0	30	47	40	30	3	0	0	0	0
Flag Pond	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	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	0	0	0	3	17	0	0	0	0	0
Turtle Back	0	0	0	7	33	0	0	0	0	0
Long Point	0	0	0	0	3	0	0	0	0	0
Cook Point	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	0	0	0	10	53	0	0	0	0	0
Oyster Shell Point	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	0	3	0	0	33	0	0	0	0	0
Cason	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	0	4	10	10	27	0	0	0	0	7
Georges	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	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
Pos. Bars (%)	**19**	**67**	**64**	**67**	**90**	**23**	**7**	**7**	**9**	**30**
Avg. Prev. (%)	**2.1**	**19.2**	**14.9**	**13.0**	**29.0**	**1.4**	**0.2**	**0.5**	**0.7**	**3.1**

Table 4. MSX disease (continued).

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

(Return to Text)

Table 5. Oyster population mortality estimates from the 43 disease monitoring bars, 1985-2011. NA=unable to obtain a sufficient sample size.

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	4	21	19	3	19	3	14	45
	Stone Rock	6	NA	NA	NA	NA	2	9	45
	Flag Pond	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	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	2	1	45	12	9	12	50	77
Miles River	Turtle Back	NA	1	19	27	15	27	51	23
	Long Point	17	8	23	8	12	11	53	73
Choptank River	Cook Point	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	12	6	29	34	7	11	75	48
	Oyster Shell Point	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	4	7	13	9	6	28	82	50
Little Choptank R.	Cason	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	23	65	51	41	38	10	29	60
Manokin River	Georges	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	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	43	42	35	49	36	36	8	33	42	67
Stone Rock	30	29	40	25	15	33	46	66	30	86
Flag Pond	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	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	47	47	33	6	6	11	16	33	44	50
Turtle Back	24	40	51	21	9	9	26	38	48	54
Long Point	44	8	28	8	3	9	14	33	34	66
Cook Point	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	45	36	29	23	22	4	15	27	50	77
Oyster Shell Point	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	24	10	20	9	8	10	38	40	50	85
Cason	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	23	10	17	11	11	9	29	25	26	52
Georges	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	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
Swan Point	13	10	11	8	10	9	33	20	27
Hackett Point	17	10	2	5	11	26	15	14	0
Holland Point	50	29	5	0	0	11	0	8	50
Stone Rock	13	5	5	20	5	25	16	8	2
Flag Pond	0	0	2	4	0	14	26	20	11
Hog Island	11	6	12	25	42	14	18	12	8
Butler	9	2	3	23	0	9	8	8	12
Buoy Rock	41	28	6	21	20	24	43	8	4
Old Field	34	10	38	12	12	17	17	11	21
Bugby	50	14	2	20	52	42	50	12	4
Parsons Island	37	11	8	35	50	34	36	16	10
Hollicutt Noose	25	3	6	48	43	27	12	23	0
Bruffs Island	50	12	5	4	12	36	33	28	0
Turtle Back	43	11	12	51	57	55	34	5	11
Long Point	54	10	10	14	38	46	17	33	0
Cook Point	21	0	0	0	12	22	7	8	6
Royston	69	14	0	0	9	5	10	0	1
Lighthouse	89	47	0	0	0	0	4	1	3
Sandy Hill	88	59	44	24	4	5	5	0	8
Oyster Shell Point	48	20	0	4	0	4	4	2	1
Tilghman Wharf	62	17	0	1	10	14	2	2	3
Deep Neck	54	14	1	3	8	9	3	6	4
Double Mills	59	23	8	0	7	4	19	6	4
Cason	57	4	0	2	4	16	17	33	10
Ragged Point	52	5	4	13	13	2	22	15	4
Norman Addition	9	14	40	5	3	2	6	15	9
Goose Creek	53	59	50	50	1	2	6	0	3
Wilson Shoals	19	27	7	21	7	30	10	3	5
Georges	4	24	44	76	16	48	10	12	2
Holland Straits	11	18	43	48	17	27	12	14	5
Sharkfin Shoal	23	32	54	22	10	3	18	20	12
Back Cove	22	23	32	12	5	8	6	15	4
Piney Island East	28	48	50	23	6	18	20	26	17
Old Woman's Leg	35	56	26	0	12	14	37	38	26
Marumsco	4	11	29	20	10	21	7	13	4
Broome Island	14	19	6	6	20	20	11	14	3
Chicken Cock	2	38	50	20	20	7	27	22	11
Pagan	7	29	66	9	4	11	29	13	5
Lancaster	35	27	14	7	31	17	24	0	0
Mills West	48	11	0	7	33	0	16	10	11
Cornfield Harbor	1	7	20	2	9	25	44	16	9
Ragged Point	76	NA	NA	NA	0	0	0	0	0
Lower Cedar Point	55	22	17	3	11	5	4	7	14
Annual Means	**35**	**20**	**17**	**16**	**15**	**17**	**17**	**12**	**8**

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Table 6. Regional summary of oyster harvests (bu.) in Maryland, 1985-86 through 2010-11 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
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**	**1,000,000**	**360,000**	**390,000**	**414,000**	**418,000**

[1] Including regions not listed.

Table 6. Regional 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
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] Including regions not listed.

Table 6. Regional 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
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] Including regions not listed.

Table 6. Regional 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
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] Including regions not listed.

Table 6. Regional landings (continued).

Maryland Oyster Harvests (bu)		
Region/Tributary	2009-10	2010-11
Upper Bay	8,723	6,310
Middle Bay	4,012	2,054
Lower Bay	14,927	2,759
Total Bay Mainstem	*27,662*	*11,123*
Chester R.	2,874	5,290
Eastern Bay	2,662	1,957
Miles R.	11	12
Wye R.	227	0
Total Eastern Bay Region	*2,900*	*1,969*
Upper Choptank R.	42	412
Middle Choptank R.	661	523
Lower Choptank R.	3,424	3,534
Tred Avon R.	0	68
Broad Cr.	5,328	7,646
Harris Cr.	1,227	191
Total Choptank R. Region	*10,682*	*12,374*
Little Choptank R.	923	0
Upper Tangier Sound	24,553	19,098
Lower Tangier Sound	61,771	27,849
Honga R.	24,696	10,213
Fishing Bay	14,949	10,174
Nanticoke R.	2,168	5,300
Wicomico R.	109	1,140
Manokin R.	888	1,477
Annemessex R.	0	1,036
Pocomoke Sound	1,165	855
Total Tangier Sound Region	*130,299*	*77,142*
Patuxent R.	3,456	6,535
Wicomico R., St. Clement and Breton Bays	712	2,132
St. Mary's R. and Smith Cr.	3,186	2,275
Total Potomac Md. Tribs	*3,898*	*4,407*
Total Maryland (bu.)[1]	**185,245**	**123,613**

[1] Including regions not listed. Not all harvest reports had region information, but were included in the Md. total.

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Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2010-11 seasons. Dockside value is in millions of dollars.

Season	Hand Tongs	Diver	Patent Tongs	Power Dredge	Skipjack	*Total Harvest*	*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*

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

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Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2010-11 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

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APPENDIX 1
OYSTER HOST and OYSTER PARASITES
C. Dungan

Oysters

The eastern oyster *Crassostrea virginica* tolerates water temperatures of 0-36°C (32-97°F) and salinities of 3 to 40 ppt, where ocean water has 35 ppt salinity. Oysters reproduce when both sexes simultaneously spawn their gametes into Chesapeake Bay waters. Spawning occurs from May through September and peaks during June and July. Externally fertilized eggs develop into swimming planktonic larvae that are transported by water currents for two to three weeks while feeding on phytoplankton as they grow and develop. Mature larvae seek solid benthic substrates, preferably oyster shells (valves), to which they attach as they metamorphose to become sessile juvenile oysters. Unlike fishes and other vertebrates, oysters do not regulate the salt content of their tissues; instead, the salt content of functioning oyster tissues conforms to the broad and variable range of salinities in oyster habitats. Thus, oyster parasites with narrow salinity requirements may be exposed to low environmental salinities when shed into the environment, as wells as while infecting oysters in low-salinity waters. Upon its death, an oyster's valves spring open passively, exposing its tissues to consumption by predators and scavengers. However, the resilient hinge ligament holds the articulated valves together for months after death. Vacant, articulated oyster shells (boxes) in our samples are interpreted to represent oysters that died during the previous year, and their relative numbers along with those of dead and moribund oysters with tissues still present (gapers), are used to estimate annual natural mortalities among oyster populations.

Dermo disease

Although the protozoan parasite that causes dermo disease is now known as *Perkinsus marinus*, it was first described as *Dermocystidium marinum* in Gulf of Mexico oysters (Mackin, Owen, and Collier 1950), and its name was colloquially abbreviated as 'dermo'. Almost immediately, dermo disease was also reported in Chesapeake Bay oysters (Mackin 1951). *Perkinsus marinus* is transmitted through the water to uninfected oysters in as few as three days, and such infections may prove fatal in as few as 18 days. Heavily infected oysters are emaciated, showing reduced growth and reproduction (Ray and Chandler 1955). Although *P. marinus* survives low temperatures and low salinities, its proliferation is highest in the broad range of temperatures (15-35°C) and salinities (10-30 ppt) that are typical of Chesapeake Bay waters during oyster dermo disease mortality peaks (Dungan and Hamilton 1995). Over several years of drought during the 1980s, *P. marinus* expanded its Chesapeake Bay distribution into upstream areas where it had been rare or absent, and became prevalent in newly infected oyster populations (Burreson and Ragone Calvo 1996). Since 1990, at least some oysters in 93-100% of all regularly tested Maryland populations have been infected.

MSX disease

The high-salinity, protozoan oyster pathogen *Haplosporidium nelsoni* was first detected and described as a *multinucleated sphere unknown* (MSX) from diseased and dying Delaware Bay oysters during 1957 (Haskin et al. 1966), and was found to also infect oysters from lower Chesapeake Bay during 1959 (Andrews 1968). Although the common location of the lightest *H. nelsoni* infections in oyster gill tissues suggests waterborne transmission of infectious pathogen cells, the complete life cycle and actual infection mechanism of this parasite remain unknown. Despite many attempts by scientists, MSX disease has rarely been experimentally transmitted in the laboratory, although captive experimental oysters that are reared in endemic waters above 14 ppt salinity may acquire infections and die within three to five weeks. In Chesapeake Bay, MSX disease is most active at water temperatures of 5-20°C (Ewart and Ford 1993), *H. nelsoni* infection rates typically peak during June, and deaths from *H. nelsoni* infections peak during August. Since MSX disease is rare in oysters from waters below 9 ppt salinity, the distribution of *H. nelsoni* in Chesapeake Bay varies as salinities change with variable freshwater inflows. During a recent 1999-2002 drought, consistently low freshwater inflows raised salinities of Chesapeake Bay waters to foster upstream range extensions by *H. nelsoni* and MSX disease during each successive drought year (Tarnowski 2003). The geographic range for MSX disease also expanded widely during a 2009 epizootic. During 2003-2009, freshwater inflows near historic averages reduced salinities of upstream Chesapeake Bay waters, to dramatically reduce the geographic ranges and effects of MSX disease (Tarnowski 2010).

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APPENDIX 2
GLOSSARY

box oyster	Pairs of empty shells joined together by their hinge ligaments. These remain articulated for months after the death of an oyster, providing a durable estimator of recent oyster mortality (see gaper).
bushel	Unit of volume used to measure oyster catches. The official Maryland bushel is equal to 2,800.9 cu. in., or 1.0194 times the U.S. standard bushel (heaped) and 1.3025 times the U.S. standard bushel (level).
cultch	Hard substrate, such as oyster shells, spread on oyster grounds for the attachment of spat.
dermo disease	The oyster disease caused by the protozoan pathogen *Perkinsus marinus.*
dredged shell	Oyster shell dredged from buried ancient (3000+ years old) shell deposits. Since 1960 this shell has been the backbone of the Maryland shell planting efforts to produce seed oysters and restore oyster bars.
fresh shell	Oyster shells from shucked oysters. It is used to supplement the dredged shell plantings.
gaper	Dead or moribund oyster with gaping valves and tissue still present (see box oyster).
Haplosporidium nelsoni	The protozoan oyster parasite that causes MSX disease.
infection intensity, individual	*Perkinsus* sp. parasite burdens of individual oysters, estimated by RFTM assays and categorized on an eight-point scale. Uninfected oysters are ranked 0, heaviest infections are ranked 7, and intermediate-intensity infections are ranked 1-6. Oysters with infection intensities of 5 or greater are predicted to die imminently.
infection intensity, mean sample	Averaged categorical infection intensity for all oysters in a sample: *sum of all categorical infection intensities (0-7) ÷ number of sample oysters* Oyster populations whose samples show mean infection intensities of 3.0 or greater are predicted to experience significant near-term mortalities.
infection intensity, mean annual	Averaged categorical infection intensities for all annual survey oysters: *sum of all sample mean intensities ÷ number of annual samples*
intensity index, sample	Categorical infection intensities averaged only for infected oysters: *sum of individual infection intensities(1-7) ÷ number of infected oysters*

intensity index, annual	Categorical infection intensities averaged for all infected survey oysters: *sum of all sample intensity indices ÷ number of annual samples*
market oyster	An oyster measuring 3 inches or more from hinge to mouth (ventral margin).
mortality (observed), 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)]*
mortality (observed), annual	Percent proportion of annual, bay-wide, natural oyster mortality estimated by averaging population mortality estimates from all samples collected during an annual survey: *sum of sample mortality estimates ÷ number of survey samples*
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)*
Perkinsus marinus	The protozoan oyster parasite that causes dermo disease.
prevalence, sample	Percent proportion of infected oysters in a sample: *100 x (number infected ÷ number examined)*
prevalence, mean annual	Percent proportion of infected oysters in an annual survey: *sum of sample percent prevalences ÷ number of samples*
RFTM assay	Ray’s fluid thioglycollate medium assay. Method for enlargement, detection, and enumeration of *Perkinsus marinus* cells in oyster tissue samples. This diagnostic assay for dermo disease has been widely used and refined for over fifty years to date.
seed oysters	Young oysters produced by planting shell as a substrate for oyster larvae to settle on in historically productive areas. If the spatfall is adequate, the seed oysters are subsequently transplanted to growout (seed planting) areas, generally during the following spring.
small oyster	An oyster equal to or greater than one year old but less than 3 inches (see market oyster, spat).
spat	Oysters younger than one year old.

spatfall, spatset, set	The process by which swimming oyster larvae attach to a hard substrate such as oyster shell. During this process the larvae undergo metamorphosis, adopting the adult form and habit.
spatfall intensity, sample site	The number of spat per bushel of cultch. This is a relative measure of density used to calculate the spat 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*

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