Maryland Oyster Population Status Report

2008 Fall Survey

Mitchell Tarnowski, Editor

Prepared by the Staff of the
Maryland Department of Natural Resources
Shellfish Program and Cooperative Oxford Laboratory

MDNR Publ. No. 17-4222010-448

April 2010

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

Martin O'Malley, Governor
Anthony G. Brown, Lt. Governor
John R. Griffin, Secretary, DNR

CONTRIBUTORS

Editor

Shellfish Program, MDNR
Mitchell Tarnowski, Shellfish Biologist

Technical Participants

Lead Scientist
Shellfish Program, MDNR
Mitchell Tarnowski, Shellfish Biologist

Field Operations
Shellfish Program, MDNR
David White, Captain *R/V Miss Kay*
Mickey Astarb, Biologist
Robert Bussell, Biologist
Eugene Ramsey, Technician
Dave Perdue, Mate *R/V Miss Kay*

Parasite Diagnostic Testing
Cooperative Oxford Laboratory, MDNR
Carol B. McCollough, Pathologist
Rosalee Hamilton, Managing Histologist
Jud Blazek, Histotechnician
Stuart Lehmann, Histotechnician
Suzanne Tyler, Histotechnician

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

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

Streamflow Data
U.S. Geological Survey
Joel D. Blomquist, Hydrologist
Wendy. S. McPherson, Hydrologist

Text
Shellfish Program, MDNR
Mitchell Tarnowski, Shellfish Biologist
Christopher Judy, Shellfish Biologist

Cover Photo
Shellfish Program, MDNR
Frank Marenghi, Biologist

Reviewers

Fisheries Service, MDNR
Dr. Mark Homer, Research Statistician
Dr. Eric Weissberger, Biologist
Dr. Linda Barker, Research Statistician
Carol B. McCollough, Pathologist
Christopher Dungan, Research Scientist

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 2008 Annual Fall Oyster Survey was conducted by Shellfish Program staff from the Maryland Department of Natural Resources (MDNR) Fisheries Service from 15 October to 8 December. A total of 365 samples was collected during surveys on 282 natural oyster bars, including Key Bar and Disease Bar sites and sanctuaries, as well as contemporary seed oyster planting sites, shell planting locations, and seed production areas. Oyster parasite diagnostic tests were performed by staff of the Cooperative Oxford Laboratory (COL).

Annual streamflow during 2008 was close to normal, in contrast to the wide fluctuations between wet and dry years over the past decade and a half. However, monthly streamflows showed much greater deviation from the mean over the course of the year. Generally, flows from February through May were abnormally high, running from about 127% to 150% above average (April was the exception with 80% of mean streamflow). Beginning in June, flows dropped dramatically during a summer/fall dry spell that lasted six months, with three of the months experiencing discharges of almost 50% below the monthly mean.

Maryland oyster spatfall during 2008 was generally poor for the second consecutive year. The spat index of 13.5 was slightly lower than 2007, however, spatfall was more widely and evenly distributed among the Key Bars in 2008 compared with the previous year. Most of the spatfall occurred along the lower Eastern Shore from the Little Choptank River south, with the highest counts in the Honga River. Large areas experienced negligible if any spatfall, including the Bay north of the Choptank River on the Eastern Shore and Cove Point on the Western Shore, the upper Potomac River and tributaries, and the Eastern Bay region. The spatfall intensity index has been below the 24-year median in five of the past six years. This extended period of poor recruitment is associated with average or above average streamflows during the spring.

Oyster disease levels remained below average for the sixth consecutive year, following record highs in 2002. Although both Dermo and MSX diseases remain widely distributed, oyster disease levels and impacts remain low due to timely freshwater inputs that have inhibited the diseases. Dermo disease, caused by the parasite *Perkinsus marinus*, was found on 41 of 43 Disease Bars. The overall mean infection prevalence was 56%, well below the 19-year average and a decline from 68% in 2007. The 2008 annual mean infection intensity, still depressed relative to the drought period of 1999-2002, was comparable to the previous five years. Lethal infection intensities were detected in only 12% of sampled oysters. MSX disease has been expanding its range over the past two years, and in 2008 it was detected on 29% of the Disease Bars as far up bay as the mouth of the Choptank River. However, the disease has retreated from some areas of Tangier Sound and its tributaries where it was found in 2007.

The 2008 observed mortality of 17% remained well below the long-term average for the fifth successive year, approaching the background mortality levels of 10% or less found prior to the mid-1980's disease epizootics. These low observed mortalities are associated with the timing and magnitude of peak streamflows, maintaining a delicate balance that may have allowed MSX disease to spread while keeping it below lethal levels. Furthermore, as salinities remained unfavorable to lethal MSX impacts and less than optimal for dermo disease, the continued general reduction of dermo disease infection intensities to sub-lethal levels became the dominant factor influencing the recent decline in observed mortalities.

With reported harvests of 83,000 bushels for the 2007-08 season, commercial oyster landings plummeted to almost half of the previous year, due to the decline of the strong 2002 cohort and poor recruitment in subsequent years. Since the heyday of the Maryland oyster fishery in the 19th century, annual landings below 100,000 bushels have been reported in only four other seasons, all within the past 15 years (and four of the five in the past six years). The dockside value was $2.6 M, compared to $5.0 M in 2007. Broad Creek was again was the dominant harvest region, followed by the upper bay, Tangier Sound, and Eastern Bay. These four areas accounted for 69% of the harvest. Power dredges and hand tongs were the dominant gear types, accounting for 59% of the harvest, almost equally divided between the two.

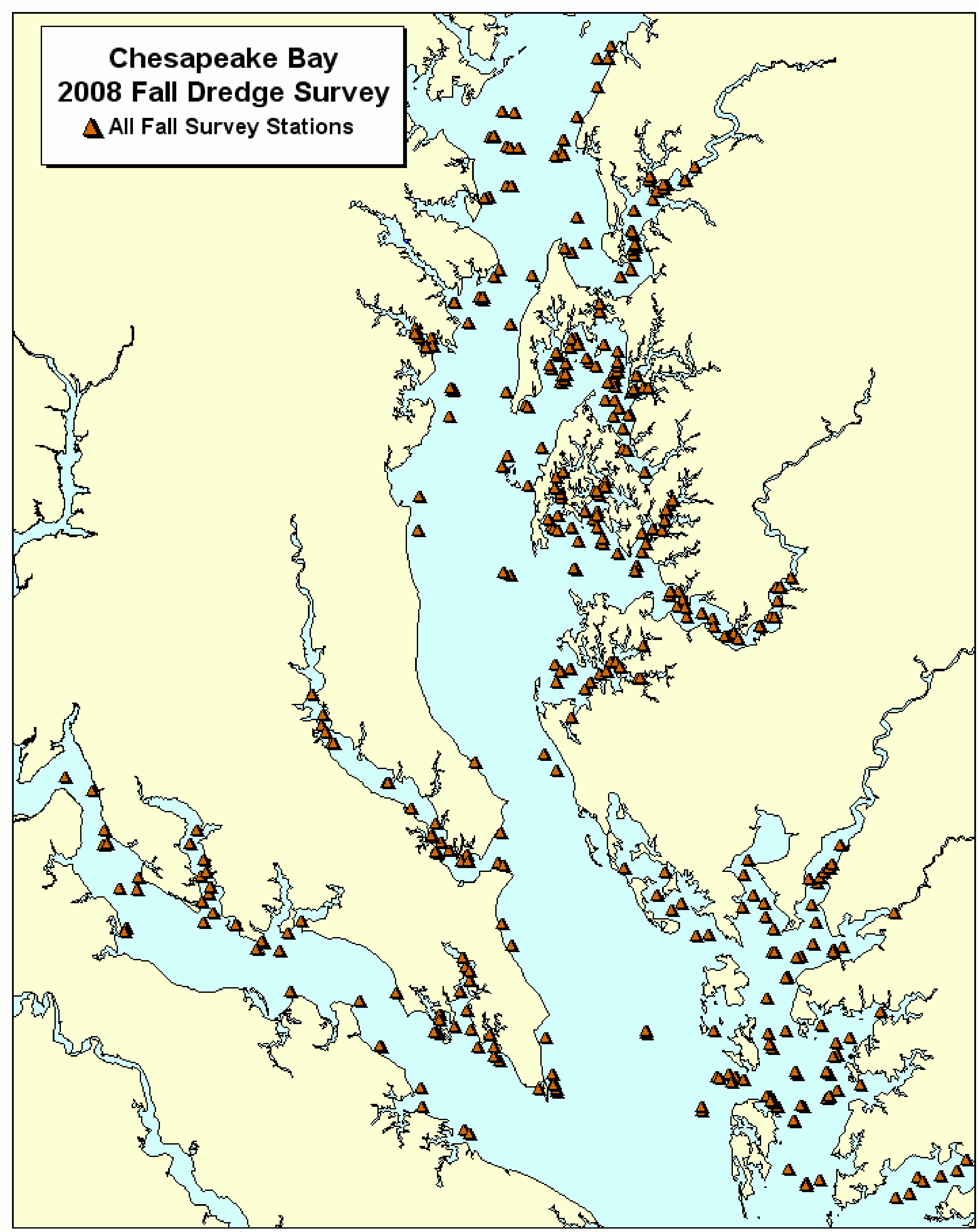

Figure 1a. 2008 Maryland Fall Oyster Survey station locations, all bar types (standard, Key, Disease, seed) included.

[(Return to Text)]

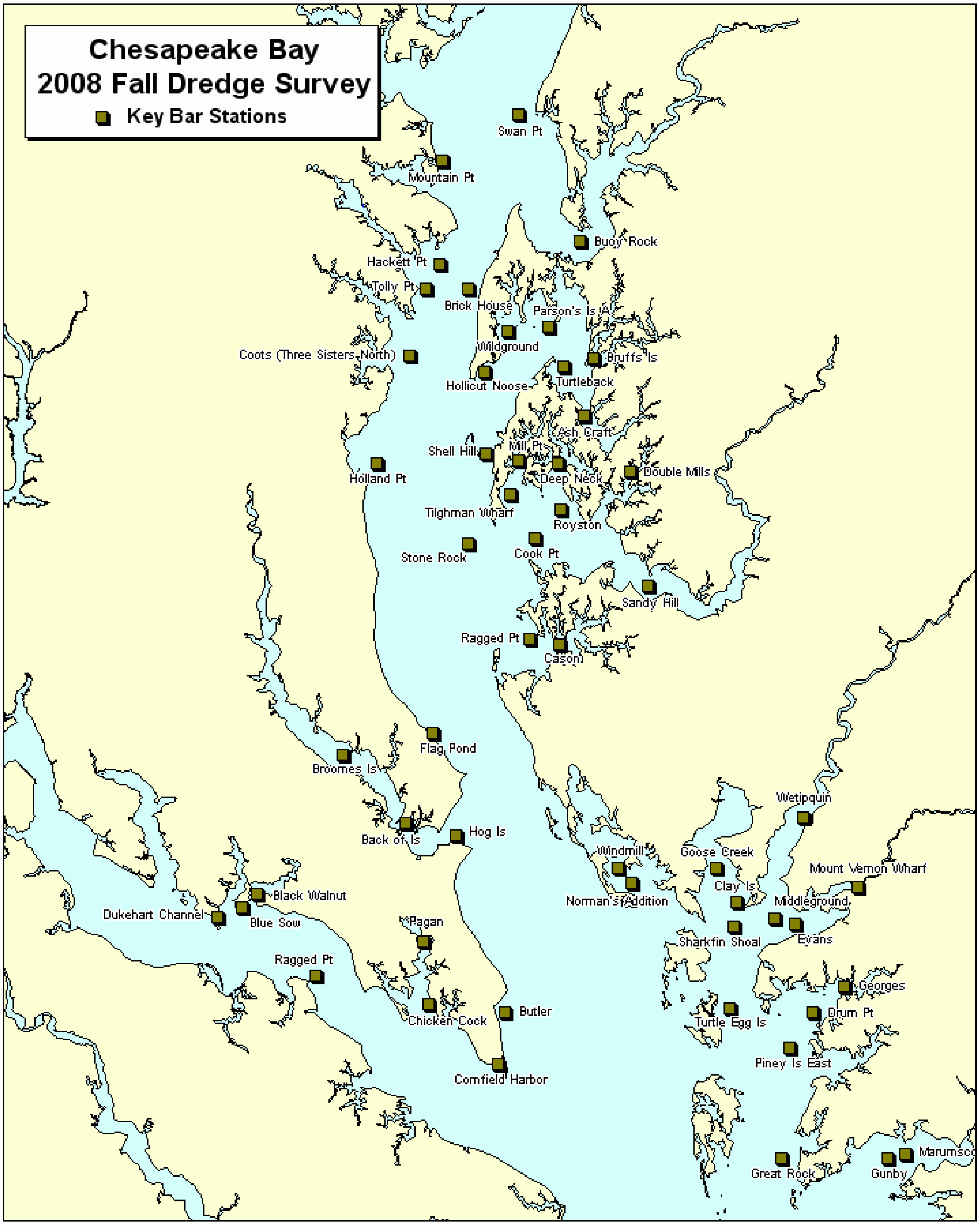

Figure 1b. Maryland Fall Oyster Survey Key Bar locations included in determining the annual Spat Intensity Index.

(Return to Text)

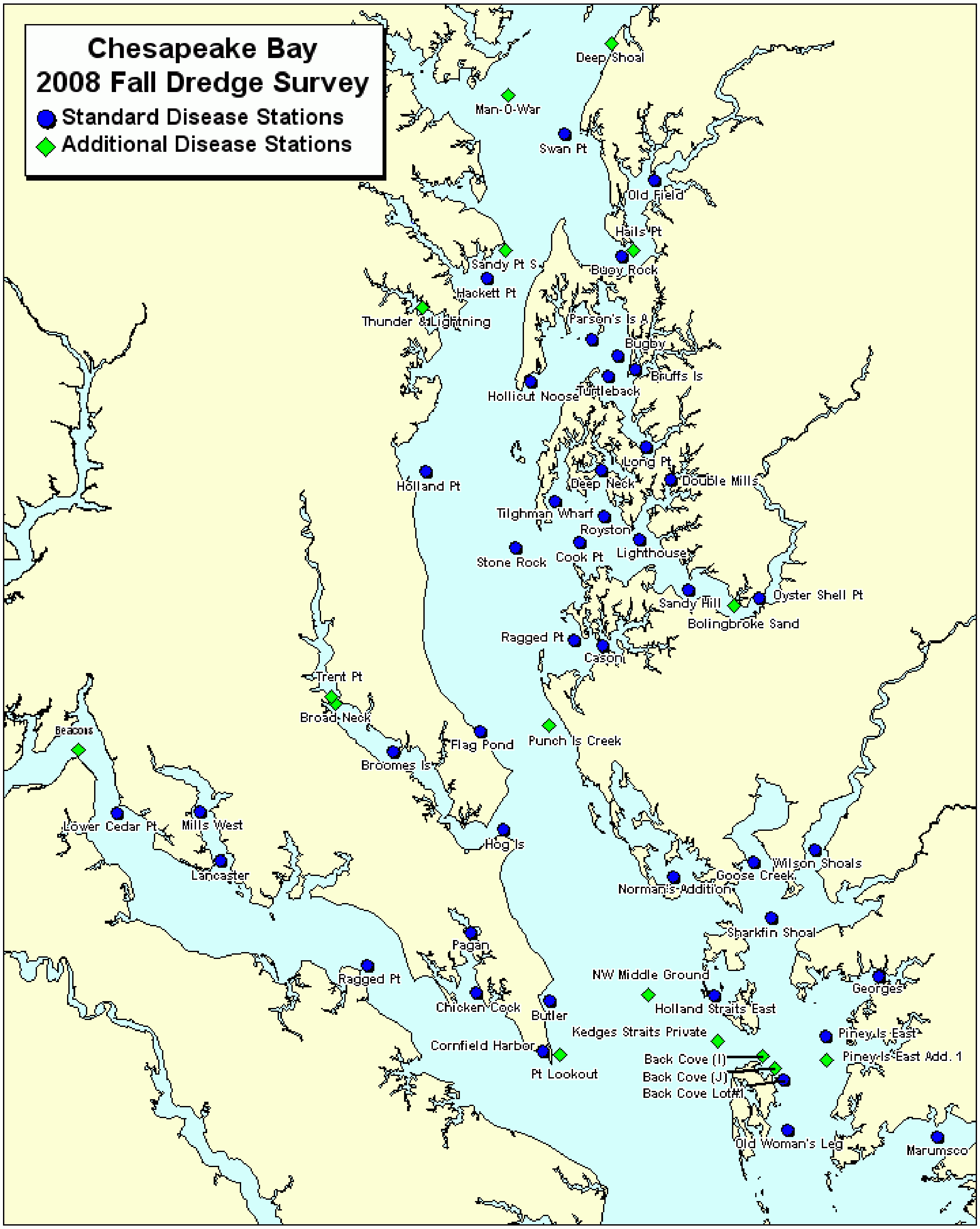

Figure 1c. Maryland Fall Oyster Survey standard Disease Bar locations and additional 2008 disease sample stations.

[(Return to Text)]

INTRODUCTION

Since 1939, a succession of Maryland state agencies has conducted annual dredge-based surveys of oyster bars. These assessments have provided biologists and managers with information on oyster 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 allows the discernment of 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).

METHODS

The 2008 Annual Fall Oyster Survey was conducted by Shellfish Program staff from the Maryland Department of Natural Resources (MDNR) Fisheries Service from 15 October to 8 December. A total of 365 samples was collected during surveys on 282 natural oyster bars (Figure 1a), including Key Bar (Figure 1b) and Disease Bar (Figure 1c) sites and sanctuaries, as well as contemporary seed oyster planting sites, shell planting locations, and seed production areas. Data on seed and shell plantings are provided in Astarb (2008).

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 is taken.

The spatfall intensity index is the arithmetic mean of spat/bushel counts from the 53 Key Bars.

Total observed mortality (small and market oysters combined) was calculated as the number of dead oysters (boxes and gapers) divided by the sum of live and dead oysters (Appendix 2).

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 two sampling sites, smaller subsamples (n = 12, 28) 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).

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.

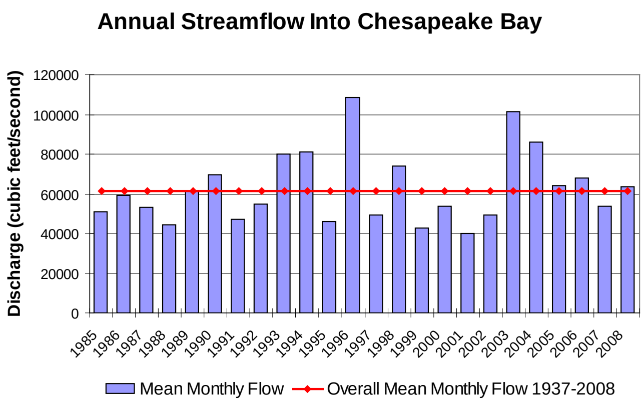

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay. USGS Section C: all Maryland tributaries and the Potomac River.

The annual streamflow was only slightly below average during 2008 (Sec. "C" in Bue 1968; USGS 2008), marking the fourth consecutive year flows were within the normal range, in contrast to the wide fluctuations between wet and dry years[1] over the previous decade and a half (Figure 2a). However, the individual monthly discharges showed strong deviations from the monthly means over two distinct periods (Figure 2b). Generally, flows from February through May were abnormally high,

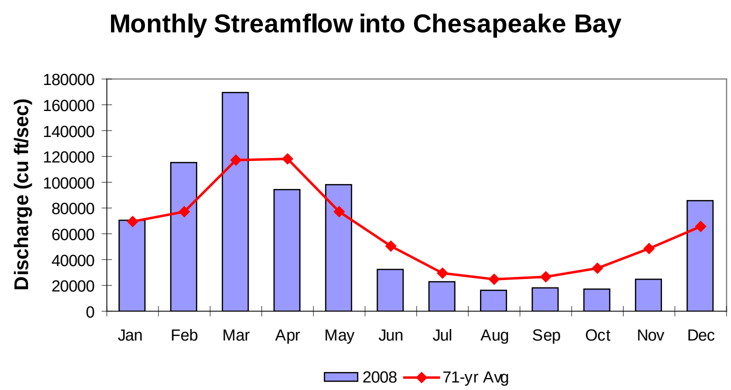

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2006, including the long-term monthly average.

running from about 127% to a peak in March of 150% above average (April was the exception with 80% of mean streamflow). Beginning in June, flows dropped dramatically during a summer/fall dry spell that lasted six months, with three of the months experiencing discharges of almost 50% below the monthly mean.

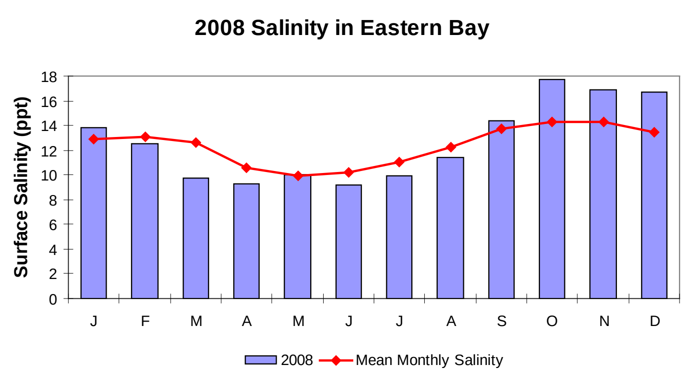

Figure 2c. Monthly surface salinities and monthly long-term average in Eastern Bay.

A representative station in Eastern Bay illustrates the influence of streamflows on salinity (Figure 2c). Whereas monthly shifts in freshwater discharges can be volatile and extreme, the changes in salinity are more subdued. There was also a time lag in salinity shifts, so that

[1] Categorized by the U.S. Geological Survey as freshwater flows above the 75th percentile or below the 25th percentile of mean monthly flows for the 1937-2006 period, respectively.

below average salinities persisted until September, three months after streamflows had dropped below normal. Below average salinities during the spring and early summer of 2008 was typical for most areas throughout the bay in Maryland, with 71% of the Disease Bars sites experiencing salinities of 10 ppt or less in June. The magnitude and timing of these depressed salinities may have strongly influenced oyster recruitment and disease impacts, as described in the following sections of this report.

SPATFALL INTENSITY

Maryland oyster spatfall during 2008 was generally poor for the second consecutive year. The spat index of 13.5 was slightly lower than 2007, placing it in the lowest statistical grouping for the period of 1985 through 2008 (Figure 3).

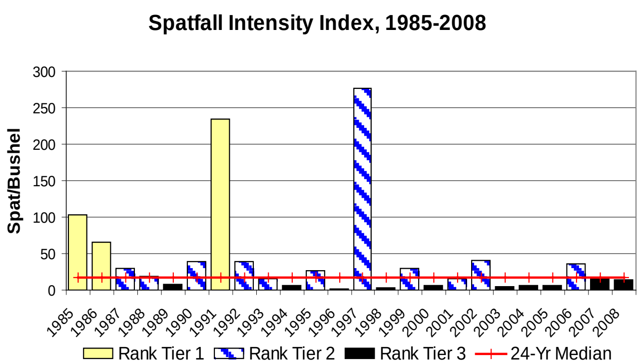

Figure 3. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including rankings of statistically similar indices.

Note that the annual spatfall intensity index is an arithmetic mean that does not take into account geographic distribution. 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 (MDNR 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 second statistical tier despite being the second highest index on record and an order of magnitude higher than other Tier 2 indexes. In contrast, the 1991 spatfall (the third highest on record) was far more widespread, with 15 Key Bars totaling 75% of the index, and 28 sites were needed to attain 95% of the spatfall intensity index, placing it in the first statistical tier.

Spatfall was more widely distributed among the Key Bars in 2008 compared with the previous year: in 2008 spat were observed on 21 of the 53 Key Bars vs. nine bars in 2007 (Table 2). Also, spatfall was somewhat more evenly dispersed in 2008, when nine bars contributed 75% of the spat index, in contrast to 2007 when only one bar accounted for nearly 75% of the index. The highest Key Bar spat count in 2008 was 124 spat/bu. on Drum Point in the Manokin River, accounting for 17% of the total spat index. The nine highest-count Key Bars were all in the southern Eastern Shore region.

When considering all bars surveyed in addition to the Key Bars, most of the spatfall was distributed along the lower Eastern Shore from the Little Choptank River south, with the highest counts in the Honga River (Figure 4). Spatfall was light in the Choptank, lower Potomac and Patuxent Rivers, and the St. Mary's County shore of the mainstem. Large areas experienced negligible if any spatfall, including

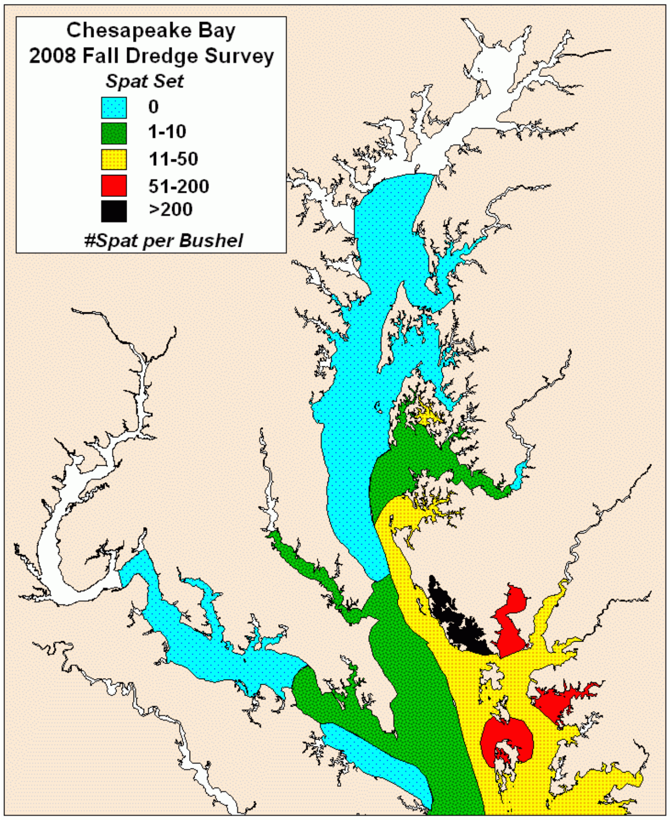

Figure 4. Spatfall intensity ranges and distribution, 2008.

the Bay north of the Choptank River on the Eastern Shore and Cove Point on the Western Shore, the upper Potomac River and tributaries, and the Eastern Bay region.

In a departure from previous reports, the *median* of the annual spatfall indices from 1985 to present was used as a benchmark for comparison against individual years, rather than the *arithmetic mean* of the annual spatfall indices for this time period. The average was severely skewed by two extraordinary spatfall years (1991 and 1997) which created an unrealistically high point of reference. Nonetheless, although these exceptional recruitment events are rare, they are a feature of oyster population dynamics in Maryland

The median spatfall index appears to neatly separate the Tier 2 and Tier 3 statistical groupings of the present analysis (Figure 3). All of the Tier 3 years were below the 24-year median spatfall, while the Tier 2 years were mostly above or just barely under it.

The spatfall intensity index has been below the 24-year median in five of the past six years, the exception being 2006 (Figure 3). This extended period of poor recruitment was coincident with average or above average streamflows during the spring (97% - 137% of the historical mean flow), specifically March through May (Figure 5). Conversely, higher spatfalls during the period from 1998 through 2008 were associated with streamflows well below the 70-year average (45% - 78% of the mean flow). A statistically significant negative relationship existed between the annual spatfall intensity index and March through May streamflow over the last 11 years ($r = -0.83$, $p < 0.01$; Figure 6). Both parameters have associated variances which have not been taken into account due to the scale of the question i.e. a baywide general relationship.

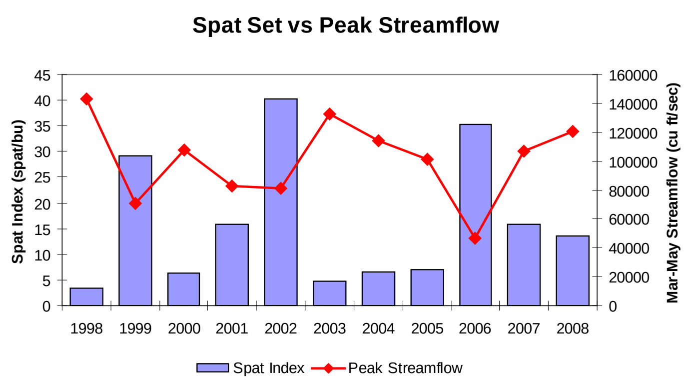

Figure 5. Oyster recruitment compared with peak streamflow for the period 1998-2008. Peak streamflow is the average for March – May, except in 2006 when peak flows were during June-July.

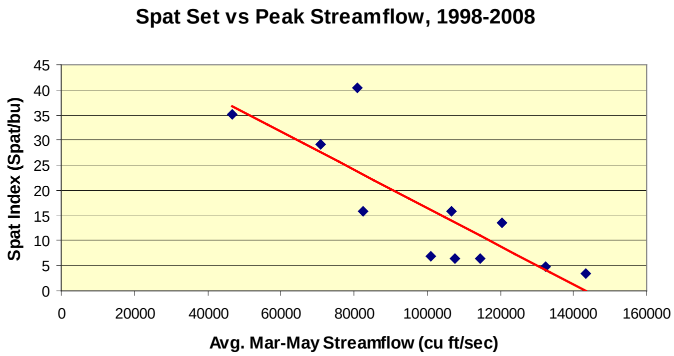

Figure 6. Relationship between recruitment and peak streamflow from 1998 through 2008 (r=-0.83, p<0.01).

Reduced streamflow, hence higher salinity, is a necessary but not always sufficient condition for higher oyster recruitment. The 2001 spat index was less than half of the 2002 index, even though the March through May streamflows were similar (Figure 5) and the 2001 annual streamflow was actually 20% lower than in 2002 (Figure 2a). Alternatively, the spatfall indices in 2001 and 2007 were identical, despite the much lower flows in 2001. Nor can streamflow predict an exceptional spatfall. Flows during March through May 1997 were no lower than succeeding years with recruitment peaks (i.e. 1999, 2002, 2006), yet the 1997 index was an order of magnitude higher (Table 2).

OYSTER DISEASES

Oyster disease levels remained below average for the sixth consecutive year, following record highs in 2002. Although both Dermo and MSX diseases remain widely distributed, oyster disease levels and effects remain low due to timely freshwater inputs that have inhibited both diseases.

Dermo disease, caused by the parasite *Perkinsus marinus*, infected oysters on 41 of 43 Disease Bars (Table 3). Two additional bars in the least saline reaches of the oyster grounds, Deep Shoal in the Head-of-the-Bay and Beacons in the Potomac River, were purged of *P. marinus* from the previous year. The overall mean infection prevalence was 56%, well below the 19-year average and a decline from 68% in 2007, ranking 2008 in the lowest statistical grouping for prevalence (Figure 7).

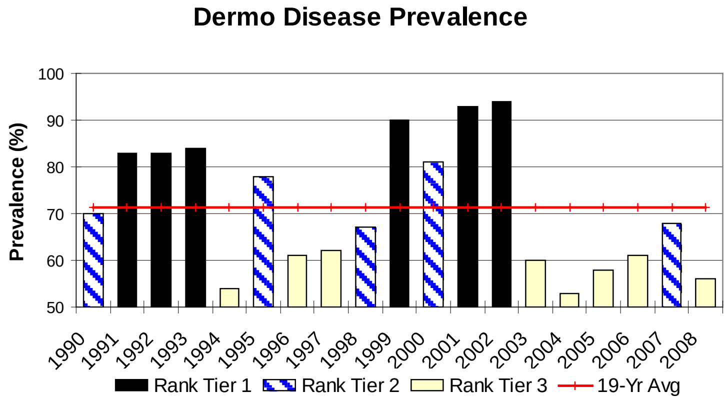

Figure 7. Annual mean *P. marinus* prevalences and rankings of statistically similar years from Maryland disease monitoring bars.

The geographic distribution of high prevalences (>60%) contracted between 2007 and 2008 (Table 3), with major declines in the mid-mainstem of the Bay, Fishing Bay, Potomac, Choptank, and Manokin Rivers, as well as the mouth of the Little Choptank River (Figure 8). In addition to the aforementioned upper Bay and upper Potomac bars, *P. marinus* was not detected among tested oysters from the upper Choptank and a station in the middle Choptank River. The remaining areas of highest prevalences were fragmented and included Tangier Sound, the lower mainstem, the northern mid-mainstem, the Chester, Patuxent and upper Little Choptank Rivers, the Choptank tributaries, and the entire Eastern Bay region. These higher

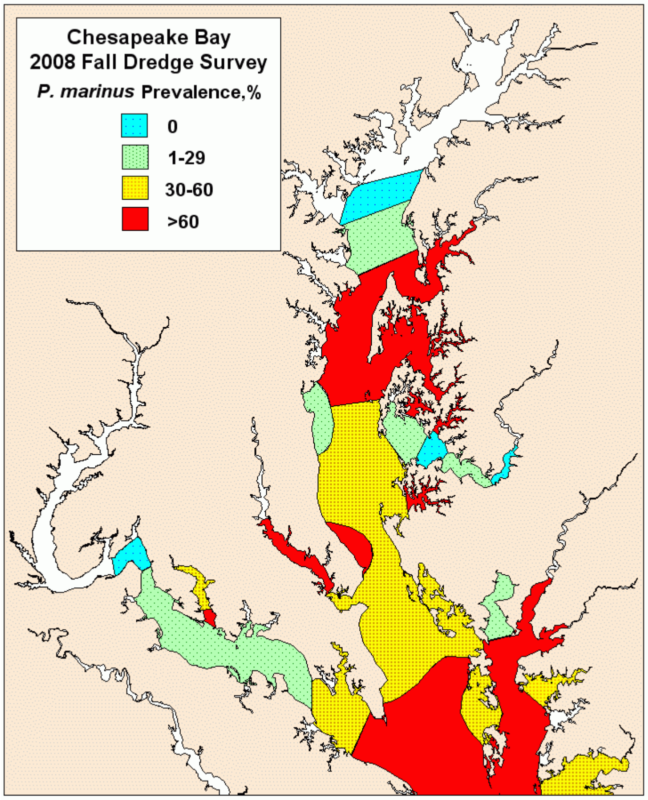

Figure 8. Geographic extent and prevalence of Dermo disease, 2008.

prevalences were not necessarily associated with higher mortalities (see Observed Mortality section).

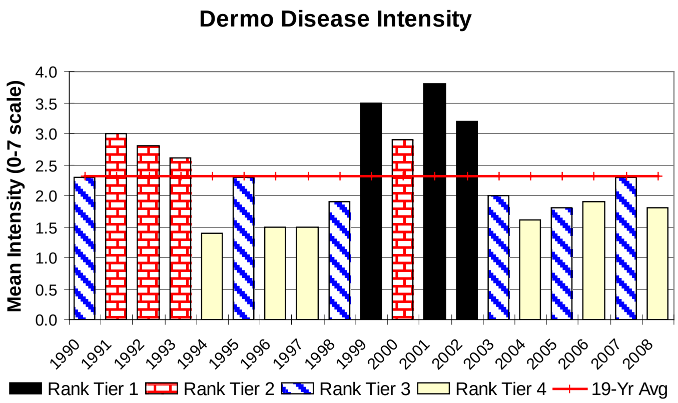

Figure 9. Annual mean *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars. Rankings are based on statistically similar years.

The 2008 annual mean infection intensity, fell within the lowest statistical grouping for Disease Bar infection intensity (Figure 9).Over the last six years, Dermo disease infection intensities have been below the 19-year average; three of the years ranked in the lowest statistical tier and the other three bars ranked in the second-lowest tier.

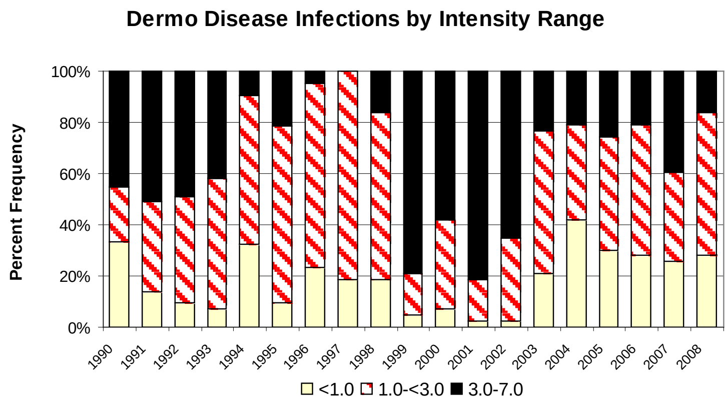

Figure 10. *P. marinus* infection intensity ranges, percent frequency by year and range.

The frequency distributions of sample infection intensities were also similar over the past six years, with the possible exception of 2007 when nearly 40% of the bars were in the highest intensity category (Figure 10). In 2008, only 16% of the Disease Bar samples had mean infection intensities of 3.0 or greater and none of these bars had mean intensities of 4.0 or greater, in contrast to 81% and 51%, respectively in the peak infection intensity year of 2001. Infection intensities in individual oysters that are ≥ 5 on a 0 – 7 scale are considered lethal, and such infection intensities were detected in only 12% of sampled oysters. Younger oysters sampled from natural seed production areas exhibited fewer lethal infection intensities (3.5%). Among samples from sanctuaries and harvest reserves, 21% of individual oysters exhibited lethal infection intensities.

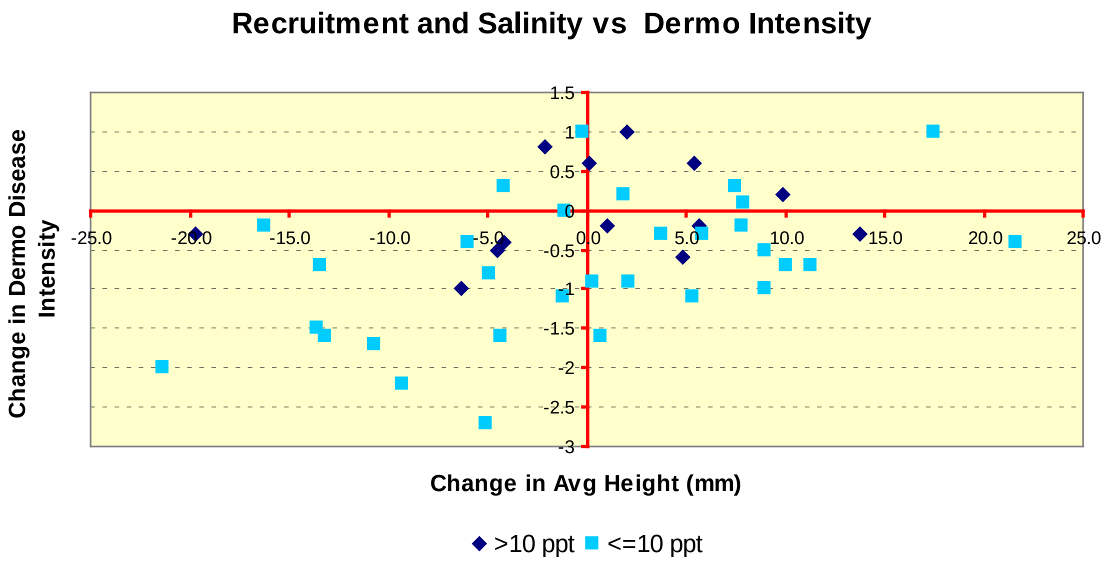

Fig. 11. Relationship of Δ Dermo disease intensity to Δ average oyster height in disease samples from different salinity regimes. Each marker represents these changes from 2007 to 2008 at the same Disease Bar location. Salinities were during June 2008.

One factor contributing to the decline in Dermo disease in 2008 may have been a shift in oyster demographics. Good recruitment in 2006 (Figure 3) resulted in a higher proportion of smaller, younger oysters in many of the disease samples (the 2006 cohort was too small in size to be included in the 2007 disease samples). The average shell height in 19 of 44 disease samples dropped between 2007 and 2008. Of these, 16 samples had a decline in infection intensity (lower left quadrant of Figure 11), while only two showed an increase (upper left quadrant of Figure 11). Conversely, seven of the 11 samples with increases in Dermo infection intensity also had increases in the average shell height of the samples (upper right quadrant of Figure 11), while two samples had decreases and two showed no change.

However, a large proportion of the decline in intensity cannot be accounted for by a shift in demographics - 36% of the samples had lower Dermo disease infection intensities than the previous year despite increases or no change in the average shell height (lower right quadrant of Figure 11). Of these, 75% experienced salinities ≤ 10 ppt during June 2008. The remaining four samples had relatively small decreases in intensities. In fact, 75% of the samples with decreases in Dermo disease infection intensities were exposed to June salinities ≤ 10 ppt, confounding to a certain extent the effects of demographics. When samples with younger oysters and samples exposed to lower salinities are considered together, the two factors account for 88% of the samples with lower Dermo disease infection intensities.

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.

MSX disease has expanded its range over the past two years, and in 2008 it was detected as far up bay as the mouth of the Choptank River (Figure 12). However, the disease has retreated from some areas of Tangier Sound and its tributaries where it had been detected in 2007. Infected oysters were found on 29% of the Disease Bars, similar to the frequency of occurrence in 2007 but substantially higher than the 9% frequency of 2006 (Table 4). MSX disease prevalences continue to be low, even in the affected areas, with a high of 17% on Sharkfin Shoal and an overall mean of 2.7%.

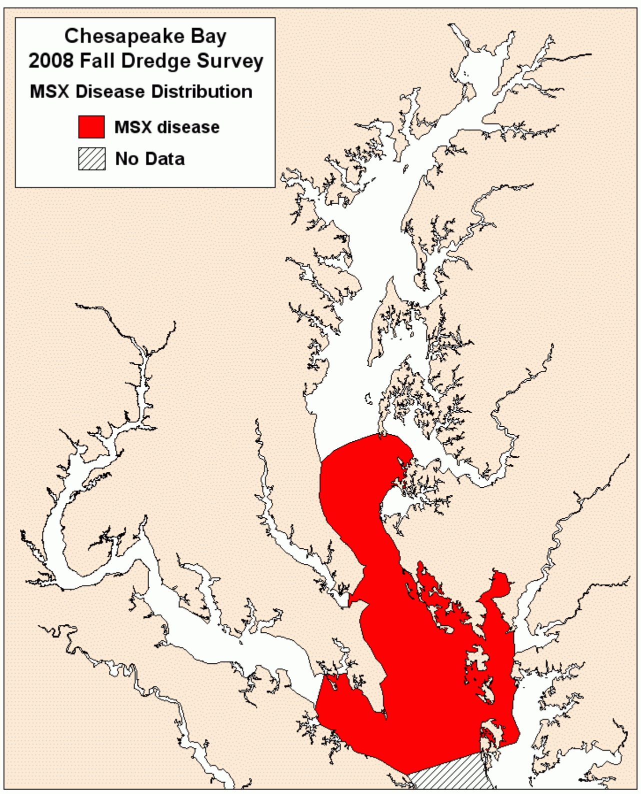

Figure 12. Geographic extent of MSX disease in Maryland waters, 2008.

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 occurrence (88%) and mean annual prevalence (28%), leaving in its wake observed oyster mortalities approaching 60% (see following section). Since 1990, there have been three *H. nelsoni* epizootics: 1991-92, 1995, and 1999-2002. 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 remained well below the long-term average for the fifth successive year. The most recent 5-year average observed mortality of 17% approaches the background mortality levels of 10% or less found prior to the mid-1980's disease epizootics (MDNR, unpubl. data) and well below the 24-year average of 27% (Table 5). The 2008 observed mortality of 17% was ranked in the second lowest statistical grouping (Figure 13).

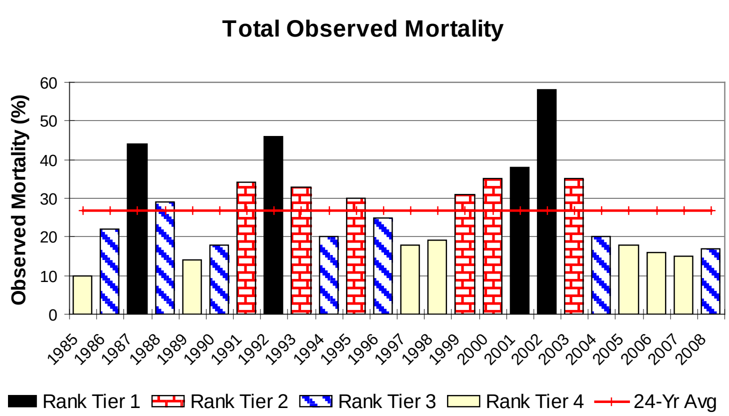

Figure 13. Mean annual observed mortality, small and market oysters combined. Rankings are based on statistically similar years.

Regions with the highest observed mortalities were Eastern Bay and its tributaries, the middle Chester, lower Potomac, and Manokin Rivers, and the lower Dorchester County shore of the bay mainstem (Figure 14). No region exceeded an average total observed mortality of 50% and the only Disease Bar that was over 50% was Turtle Back in the Miles River (for the third consecutive year) (Table 5).

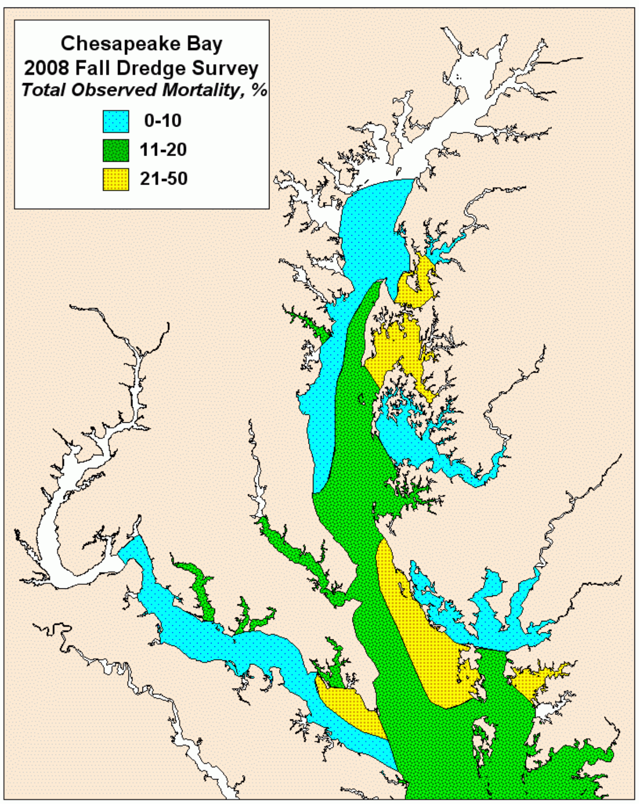

Figure 14.Total observed oyster mortality in Maryland, 2008.

There is a strong relationship between observed mortalities and the percentage of Disease Bars with MSX disease during the period from 1990-2008 (r^2 = 0.66, $p < 0.001$). The steep decline in total observed mortalities in recent years from the record high levels of 2002 is associated with the abatement of MSX disease (Figure 15). This relationship has not been as strong over the past two years, with low observed mortalities persisting despite an increased frequency of bars with MSX disease. This could be due to the timing and magnitude of peak streamflows, maintaining a delicate balance that allowed MSX disease to spread while keeping infection intensities below lethal levels. The general reduction of Dermo disease infection intensities that coincided with reduced impacts from MSX disease under low salinity conditions became a dominant factor limiting observed mortalities during 2008 to well below the 24-year average (Figure 13).

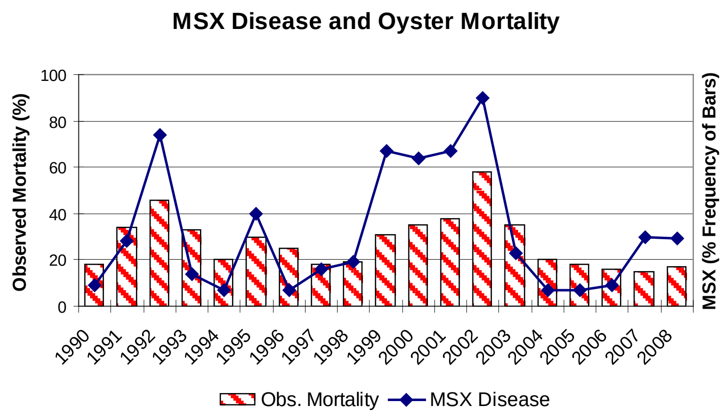

Figure 15. Changes in frequency of occurrence of bars with *H. nelsoni* and total observed oyster mortalities.

COMMERCIAL HARVEST

With reported harvests of 83,000 bushels during the 2008 (2007-08) season, commercial oyster landings plummeted to about half of the previous year (Table 6, Figure 16). The substantial falloff in harvest was related to the decline of the strong 2002 cohort and poor recruitment in subsequent years. Oysters from the next relatively strong year-class of 2006 were mostly still too small to be legally harvested. Since the heyday of the Maryland oyster fishery in the 19th century, annual landings below 100,000 bushels have been reported in only four other seasons, all within the past 15 years (and four of the five in the past six years). The dockside value was $2.6 M, compared to $5.0 M in 2007 (Table 7a.).

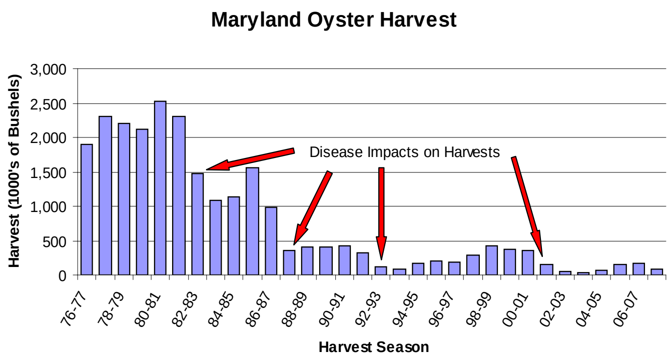

Figure 16. Maryland seasonal oyster landings, 1976-77 to 2007-08.

Broad Creek was again was the dominant harvest region, followed by the upper bay, Tangier Sound, and Eastern Bay (Table 6). These four areas accounted for 69% of the harvest. The changes in landings between 2007 and 2008 for these regions were:

Broad Creek – decreased 33,000 bu.
Upper Bay – no change
Tangier Sound – increased 8,000 bu.
Eastern Bay – decreased 28,000 bu.

While harvest declines occurred among most of the regions, 75% of the total loss took place in Broad Creek and Eastern Bay. The middle bay region also showed a sharp decline of 13,000 bushels. Landings in the Chester and Choptank Rivers, two mainstay areas of the fishery during the 1980's and 1990's, suffered losses of 35% and 44%, keeping them at the low levels recorded for recent seasons. In contrast, after a steep drop in the oyster harvest during the 2007 season, Tangier Sound experienced a modest rebound in 2008.

As a result of the change in geographic distribution of the fishery during the 2008 season, there was a corresponding shift in the relative landings by gear type (Table 7b). Power dredging picked up, reflecting the increased harvest in Tangier Sound. Conversely, hand tongs and especially diving declined, mirroring the harvest drops in Broad Creek and Eastern Bay, respectively.

Absolute changes in landings illustrate the correlations between gear type and region (Table 7a). The relative changes do not indicate the extent of the absolute changes, where all gear types except skipjacks had declines. Although patent tongs still maintained a 19% share of the harvest (Table 7b), the actual landings dropped almost by half (Table 7a), reflecting the decline in the middle Bay harvests.

DISCUSSION

FACTORS INFLUENCING RECRUITMENT

One of the most critical factors for successful oyster recruitment is adequate salinity (Kimmel & Newell 2007). If salinity is below some critical threshold the likelihood of a spatfall failure is assured. The timing and volume of streamflows (which modulate salinities) are important; freshwater discharge during the March – May period appears to be a good indicator of recruitment potential. However, proper salinity is a necessary but not always sufficient condition to ensure a good spatfall. For example, 2001 and 2002 had similar spring streamflow volumes, but a twofold difference in recruitment.

Clean substrate is another important factor. Shell plantings in good recruitment areas to produce seed oysters have been the basis of the Maryland Repletion Program for many decades. The restoration activities on the Piney Island East Sanctuary illustrate the importance of clean substrate as well as the timing of the planting. This sanctuary received two distinct shell plantings separated by two years, while maintaining a portion in its natural, unimproved state. In 2000, good spat sets occurred on shells planted that year, outperforming the unimproved natural area by a factor of almost thirty to one. In contrast, the 2002 planting initially performed extremely poorly (4 spat/bu) and was bested that year by both the 2000 planting (140 spat/bu) and the natural bar (70 spat/bu), most likely because the late July planting date missed the primary spatfall. This is supported by the average size of the spat during the Fall Survey - 25 mm at both the 2000 planting and natural site vs. 10 mm at the 2002 planting, indicating the latter area missed an earlier spat set. By 2004, all three sites were roughly equivalent in term of spatfall, except in 2006 when the natural bar lagged behind the two shell plantings. The 2006 set demonstrated that even after several years, shell plantings can still receive decent spatfalls – 214 spat/bu on the 2000 planting and 293 spat/bu on the 2002 planting, in contrast to the natural bar with 95 spat/bu. These numbers are modest in comparison to a 12-year old shell planting in Eastern Bay, where in 1997 2,000 spat/bu were recorded. Thus, although clean, newly-planted shell can greatly enhance spatfall, under the right circumstances older shell plantings can continue to catch spat providing they aren’t buried or heavily fouled.

Other factors accounting for successful recruitment when salinities are adequate are a matter of conjecture. These may include, but are not limited to, broodstock densities, the physiological condition of the broodstock including the impact of diseases, adequate food in the phytoplankton assemblage, competition for settlement space with other epibenthic species (e.g. tunicates, barnacles), predator abundance, variations in physical determinants such as temperature, wind and currents, and undoubtedly other factors. Abundances of species that can impact oyster recruitment (prey, predators, competitors) and the timing of their occurrence in relation to the timing of the oyster reproductive/recruitment cycle may vary annually. This myriad of factors plays into an intricate web of interactions that is poorly understood. The multiplicity and variability of these interactions confound ready analyses.

SPRING STREAMFLOWS, DISEASES, and OBSERVED MORTALITIES

Disease levels and consequent observed mortalities in 2008 were below the 19-year average for the sixth year in a row. This extended period of reduced disease impacts has led to speculation that Maryland oysters have developed a tolerance for Dermo disease. However, our analyses suggest that there are alternative or additional reasons accounting for these observations.

The weather pattern during this period has resulted in some wetter than normal springs. Streamflows during 2003 and 2004 were exceptionally high throughout those years, knocking back record-high Dermo (Figure 17) and MSX (Figure 18) disease intensities and prevalences to current levels. Although streamflows during 2005 were near-average, they apparently were high enough that, in combination with reduced disease levels during the previous year, did not allow disease to gain traction.

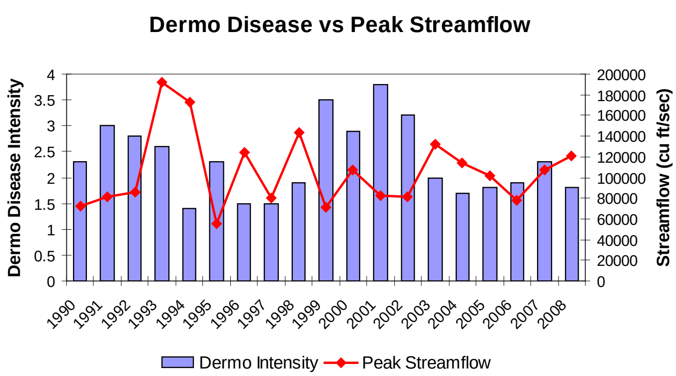

Figure 17. Dermo disease intensity (0-7 scale) compared with peak streamflow, 1990-2008. Peak streamflow is the average for March – May, except in 2006 when peak flows were delayed until June-July.

An apparent exception to this pattern was 2006, which experienced drought

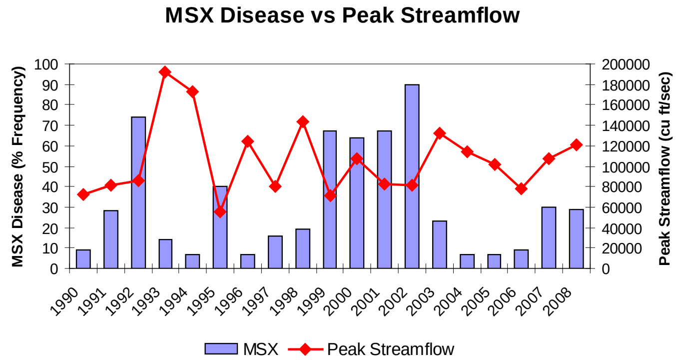

Figure 18. Frequency of bars with MSX disease compared with peak streamflows, 1990-2008. Peak streamflow is the average for March – May, except in 2006 when peak flows were delayed until June-July.

conditions during the spring. Actually, the wet weather was delayed until June; streamflows during June-July and September were 195% of average. The timing of this elevated flow occurred at a critical juncture of the *P. marinus* epizootiological cycle, inhibiting its proliferation at warm summer temperatures, when under favorable salinities the parasite normally begins to proliferate (Burreson & Ragone Calvo 1996).

The spike in Dermo disease intensity occurred in 2007 despite seemingly average streamflows that spring. In fact, March experienced high streamflows (133% of average), which subsequently tailed off. From May through September streamflows dried up to only 56% of the 70-year average for those months. The March-April pulse of freshwater likely was sufficient to dampen dermo to sublethal levels until the waters cooled in autumn. Another factor may have been the lower initial *P. marinus* population following four successive years of reduced Dermo disease levels. In contrast, the record high mortalities of 2002 were preceded by three years of elevated Dermo disease intensities

[(Figure 9)](#) and high MSX disease levels [(Figure 15)](#). The population was essentially primed for the devastating mortalities observed in 2002.

Another wet spring occurred during 2008 which suppressed disease. June salinities were ≤ 10 ppt at 75 % of the disease bars. This is a critical threshold for Dermo disease (Ragone & Burreson 1993) and below the threshold for MSX disease (Ford & Tripp 1996). In addition, the large proportion of 2006 year-class oysters in the disease bar samples, especially those from higher salinity disease-prone areas, reduced mean Dermo disease intensities in those samples. Dermo disease-related mortality rates are somewhat influenced by the age of the oysters; older oysters are generally more likely to have higher infection intensities and mortality rates than younger oysters (Ford & Tripp 1996). The relatively young oyster population in 2008, along with the wet spring, suggests that Dermo disease did not have sufficient time to attain lethal levels before water temperatures cooled in the fall.

When examining the entire disease data set from 1990 to present, a statistically significant negative relationship between streamflow and Dermo disease intensity was absent ($r^2 = 0.14$, $p = 0.11$), although the trend was apparent (Figure 19). The 1990's were characterized by alternating years of dry and wet conditions, including freshets in three of those years. Diseases never had the opportunity to get fully entrenched or purged during this period. The buildup

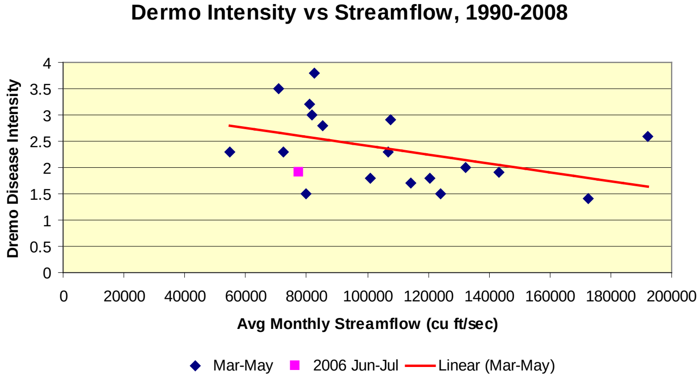

Figure 19. Relationship between Dermo disease intensity (0-7 scale) and peak streamflow, 1990 to 2008. Peak streamflow is the average for March – May, except in 2006 when peak flows were delayed until June-July.

of diseases to lethal levels may require successive dry years or at least an exceptionally dry year (Figure 20). To dislodge disease takes extraordinary freshwater flows such as in 2003 and 2004, which, in combination with timely streamflow increases in succeeding years, appears to have restrained disease impacts to sub-lethal levels during the last six years.

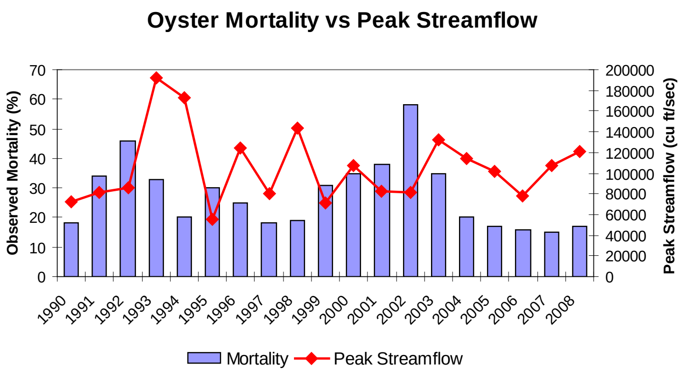

Figure 20. Observed oyster mortalities compared with peak streamflows, 1990-2008. Peak streamflow is the average for March – May, except in 2006 when peak flows were delayed until June-July.

COMMERCIAL HARVEST TRENDS

Following the long decline from peak unsustainable harvests in the late 1800's, Maryland oyster landings enjoyed an extended period of relative stability during the middle of the 20th century. After bottoming out in the mid-1920's – in association with a typhoid outbreak attributed to eating raw oysters which shriveled up demand (Tarnowski 1999) – annual oyster harvests of between one and three million bushels were maintained for the next 60 years, despite a host of external factors impacting landings over that long time span (e.g. economic depression, world war, changes in market preferences, bad weather, etc.) (Tarnowski 1999).

The MSX epizootic and entrenchment of Dermo disease during the mid-1980's had a devastating effect on the Maryland oyster population (Figure 16). Between 1986 and 1988 landings plummeted almost 75%, with harvests dropping below the one million bushel mark for the first time in well over a century. During the late 1980's and through the 1990's the population stabilized at a new, lower level with landings in the vicinity of 400,000 bu. Even after another epizootic in the early 1990's, the population slowly built back up so that landings returned to the 400,000 bu. plateau. The four-year epizootic over the turn of the millennium knocked harvests back to two successive record lows. Although landings have rebounded somewhat they are still at less than half the peak of the previous decade, despite low observed mortalities over the past six years. Perhaps it is too early to tell, but the oyster population may have been pushed to an even lower stable state by the 1999-2002 epizootic. For a discussion of stable states in oyster populations, see Powell et al. (2009a, 2009b).

LITERATURE CITED

Astarb, M. 2008. Seed oyster and shell activity reports. MDNR, Shellfish Program, Annapolis, Md.

Bue, C.D. 1968. Monthly surface-water inflow to Chesapeake Bay: U.S. Geological Survey Open-File Report, Arlington, Va., October 1968, 45 pp.

Burreson, E.M. and L.M. Ragone Calvo. 1996. Epizootiology of Perkinsus marinus disease of oysters in Chesapeake Bay, with emphasis on data since 1985. J. Shellfish Res. 15: 17-34.

Dungan, C.F. and R.M. Hamilton. 1995. Use of a tetrazolium-based cell proliferation assay to measure effects of *in vitro* conditions on *Perkinsus marinus* (Apicomplexa) proliferation. J. Eukaryot. Microbiol. **42**: 379-388.

Ford, S. and M.R. Tripp. 1996. Chapter 17. Diseases and defense mechanisms. *In:* V.S. Kennedy, R.I.E. Newell, and A.F. Eble (eds.). The Eastern Oyster, *Crassostrea virginica*, p. 581-660. Md. Sea Grant Publ. UM-SG-TS-96-01. College Park, Md.

Gieseker, C.M. 2001. Year 2000 Maryland Oyster Disease Status Report. MDNR, Fish. Serv., Sarbanes Cooperative Oxford Lab. FS-SCOL-01-1. Oxford, Md.

Hájek, J. and Z. Šidák. 1967. Theory of Rank Tests. Academic Press, New York.

Kimmel, D. G., and R. I. E. Newell. 2007. The influence of climate variation on eastern oyster (*Crassostrea virginica*) juvenile abundance in Chesapeake Bay. *Limnology and Oceanography*. 52: 959-965.

Powell, E.N., J.M. Klinck, K.A. Ashton-Alcox, and J.M. Kraeuter. 2009a. Multiple stable reference points in oyster populations: biological relationships for the eastern oyster (Crassostrea virginica) in Delaware Bay. Fish. Bull. 107: 109-132.

Powell, E.N., J.M. Klinck, K.A. Ashton-Alcox, and J.M. Kraeuter. 2009b. Multiple stable reference points in oyster populations: implications for reference point-based management. Fish. Bull. 107: 133-147.

Ragone, L.M. and E.M. Burreson. 1993. Effect of salinity on infection progression and pathogenicity of *Perkinsus marinus* in the eastern oyster, *Crassostrea virginica* (Gmelin). J. Shellfish Res. 12: 1-7.

Tarnowski, M. 1999. A historical background for oyster landings in Maryland 1916-1998. http://mddnr.chesapeakebay.net/mdcomfish/oyster/OYSFACT.cfm?which=oyster

Tarnowski, M. (ed.). 2005. Maryland Oyster Population Status Report: 2003 and 2004 Fall Surveys. MDNR Shellfish Prog. and Coop. Oxford Lab., MDNR Publ. No. 17-1072005-62. Annapolis, Md.

LIST OF TABLES

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 Bar sites, 1990-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, 1985-2008.

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 (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 (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 (continued).

Oyster Bar	Spatfall Intensity, Number per Bushel	
	2007	2008
Mountain Point	0	0
Swan Point	0	0
Brick House	0	0
Hackett Point	0	0
Tolly Point	0	0
Three Sisters	0	0
Holland Point	0	0
Stone Rock	0	1
Flag Pond	0	0
Hog Island	1	1
Butler	1	8
Buoy Rock	0	0
Parsons Island	0	0
Wild Ground	0	1
Hollicutt Noose	0	0
Bruffs Island	0	0
Ash Craft	0	0
Turtle Back	0	0
Shell Hill	0	0
Sandy Hill	3	1
Royston	1/3	5
Cook Point	1	10
Eagle Pt./Mill Pt.	0	2
Tilghman Wharf	0	6
Deep Neck	1	23
Double Mills	1	3
Ragged Point	0	2
Cason	0	13
Windmill	4	79
Norman Addition	0	102
Goose Creek	0	35
Clay Island	1	94
Wetipquin	0	2
Middleground	0	21
Evans	0	14
Mt. Vernon Wharf	0	0
Georges	5	28
Drum Point	56	124
Sharkfin Shoal	1	16
Turtle Egg Island	7	32
Piney Island East	44	23
Great Rock	64	38
Gunby	4	5
Marumsco	14	12
Broome Island	0	3
Back of Island	2	7
Chicken Cock	9	1
Pagan	616	0
Black Walnut	0	0
Blue Sow	0	0
Dukehart Channel	0	0
Ragged Point	2	1
Cornfield Harbor	7	1
Spat Index	**15.9**	**13.5**

(Return to Text)

Table 3. *Perkinsus marinus* prevalence and intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2008. 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	--	---	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 (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 (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 (continued).

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

(Return to Text)

Table 4. Prevalence of Haplosporidium nelsoni in oysters from the 43 disease monitoring bars, 1990-2008. NA=insufficient quantity of oysters for analytical sample. ND= no diagnostic sample collected; 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	ND	0	3
	Royston	ND	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
Percent Frequency		**9**	**28**	**74**	**14**	**7**	**40**	**7**	**16**

Table 4 (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	0
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
% Frequency	**19**	**67**	**64**	**67**	**90**	**23**	**7**	**7**	**9**	**30**

Table 4 (continued).

Oyster Bar	*Haplosporidium nelsoni* Prevalence (%)
	2008
Swan Point	0
Hackett Point	0
Holland Point	0
Stone Rock	10
Flag Pond	3
Hog Island	7
Butler	7
Buoy Rock	0
Old Field	0
Bugby	0
Parsons Island	0
Hollicutt Noose	0
Bruffs Island	0
Turtle Back	0
Long Point	0
Cook Point	7
Royston	0
Lighthouse	0
Sandy Hill	0
Oyster Shell Point	0
Tilghman Wharf	0
Deep Neck	0
Double Mills	0
Cason	0
Ragged Point	0
Norman Addition	10
Goose Creek	7
Wilson Shoals	0
Georges	0
Holland Straits	7
Sharkfin Shoal	17
Back Cove	13
Piney Island East	0
Old Woman's Leg	0
Marumsco	0
Broome Island	0
Chicken Cock	13
Pagan	0
Lancaster	0
Mills West	0
Cornfield Harbor	10
Ragged Point	0
Lower Cedar Point	0
% Frequency	**30**

(Return to Text)

Table 5. Oyster population mortality estimates from the 43 disease monitoring bars, 1985-2008. 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 (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 (continued).

Oyster Bar	Total Observed Mortality (%)					
	2003	2004	2005	2006	2007	2008
Swan Point	13	10	11	8	10	9
Hackett Point	17	10	2	5	11	26
Holland Point	50	29	5	0	0	11
Stone Rock	13	5	5	20	5	25
Flag Pond	0	0	2	4	0	14
Hog Island	11	6	12	25	42	14
Butler	9	2	3	23	0	9
Buoy Rock	41	28	6	21	20	24
Old Field	34	10	38	12	12	17
Bugby	50	14	2	20	52	42
Parsons Island	37	11	8	35	50	34
Hollicutt Noose	25	3	6	48	43	27
Bruffs Island	50	12	5	4	12	36
Turtle Back	43	11	12	51	57	55
Long Point	54	10	10	14	38	46
Cook Point	21	0	0	0	12	22
Royston	69	14	0	0	9	5
Lighthouse	89	47	0	0	0	0
Sandy Hill	88	59	44	24	4	5
Oyster Shell Point	48	20	0	4	0	4
Tilghman Wharf	62	17	0	1	10	14
Deep Neck	54	14	1	3	8	9
Double Mills	59	23	8	0	7	4
Cason	57	4	0	2	4	16
Ragged Point	52	5	4	13	13	2
Norman Addition	9	14	40	5	3	2
Goose Creek	53	59	50	50	1	2
Wilson Shoals	19	27	7	21	7	30
Georges	4	24	44	76	16	48
Holland Straits	11	18	43	48	17	27
Sharkfin Shoal	23	32	54	22	10	3
Back Cove	22	23	32	12	5	8
Piney Island East	28	48	50	23	6	18
Old Woman's Leg	35	56	26	0	12	14
Marumsco	4	11	29	20	10	21
Broome Island	14	19	6	6	20	20
Chicken Cock	2	38	50	20	20	7
Pagan	7	29	66	9	4	11
Lancaster	35	27	14	7	31	17
Mills West	48	11	0	7	33	0
Cornfield Harbor	1	7	20	2	9	25
Ragged Point	76	NA	NA	NA	0	0
Lower Cedar Point	55	22	17	3	11	5
Annual Means	**35**	**20**	**17**	**16**	**15**	**17**

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland, 1985-86 through 2007-08 seasons.

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 (continued).

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 (continued).

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 (continued).

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

[1] Including regions not listed.

(Return to Text)

Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2007-08 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*

(Return to Text)

Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2007-08 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

(Return to Text)

APPENDIX 1
OYSTER HOST and OYSTER PARASITES
C. Dungan

Oysters

The eastern oyster, *Crassostrea virginica*, tolerates water temperatures of -2° to 36°C and salinities of 3 to 40 ppt, where ocean water has 35 ppt salinity. Oysters reproduce when sexes simultaneously spawn their gametes into Chesapeake Bay waters, which can occur from May through September and peaks during June and July. Externally fertilized eggs develop into planktonic larvae, which 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 strictly 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 high or narrow salinity requirements may be exposed to low environmental salinities when shed into the environment, and while infecting oysters whose habitat salinity is diluted by precipitation. 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. 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 dead and moribund oysters with tissue still present (gapers) are used to estimate annual natural mortality (observed mortality).

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 accordingly. 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 by 18 days. Heavily infected oysters are emaciated, showing reduced growth and reproduction (Ray and Chandler 1955). Although *P. marinus* survives both low temperatures and low salinities, its proliferation is high in the broad range of temperatures (15° to 35°C) and salinities (10 to 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 1980's, *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, some oysters in most Maryland populations have been infected.

MSX disease

The high-salinity, protozoan oyster pathogen *Haplosporidium nelsoni* was first detected and described as a *multinucleated sphere X* (MSX) from diseased and dying Delaware Bay oysters during 1957 (Haskin et al. 1966) and was found infecting oysters from lower

Chesapeake Bay during 1959 (Andrews 1968). Although the location of early *H. nelsoni* infections in oyster gill tissues suggests waterborne transmission, the complete life cycle and infection mechanism of this parasite remain unknown. Despite many attempts, MSX has rarely been experimentally transmitted in the laboratory, although experimental oysters deployed 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° to 20°C (Ewart and Ford 1993), H. nelsoni infection rates typically peak during May, 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 freshwater inflows. During 1999 through 2002, consistently low freshwater inflows to Chesapeake Bay fostered upstream range extensions by *H. nelsoni* and MSX disease during each successive drought years (Tarnowski 2003). During the subsequent years of 2003 and 2004, consistent above-average freshwater inflows have reduced salinities of upstream Chesapeake Bay waters and dramatically reduced the geographic range and effects of MSX disease to Tangier Sound waters (Tarnowski 2005).

(Return to Text)

Appendix 1 References

Andrews, J.D. 1968. Oyster mortalitiy studies in Virginia VII. Review of epizootiology and origin of *Minchinia nelsoni*. Proc. Natl. Shellfish. Assn. **58:** 23-36.

Burreson, E.M. and L.M. Ragone Calvo. 1996. Epizootiology of *Perkinsus marinus* disease in Chesapeake Bay, with emphasis on data since 1985. J. Shellfish Res. **15:** 17-34.

Dungan, C.F. and R.M. Hamilton. 1995. Use of a tetrazolium-based cell proliferation assay to measure effects of in vitro conditions on *Perkinsus marinus* (Apicomplexa) proliferation. J. Eukaryot. Microbiol. **42**: 379-388.

Ewart, J.W. and S.E. Ford. 1993. History and impact of MSX and dermo diseases on oyster stocks in the Northeast region. NRAC Fact Sheet No. 200, 8 pp. Univ. of Massachusetts, North Dartmouth, Ma.

Haskin, H.H., L.A. Stauber, and J.G. Mackin. 1966. *Minchinia nelsoni* n. sp. (Haplosporida, Haplosporidiidae): causative agent of the Delaware Bay oyster epizootic. Science **153:** 1414-1416.

Ray, S.M. and A.C. Chandler. 1955. Parasitological reviews: *Dermocystidium marinum*, a parasite of oysters. Exp. Parasitol. **4:** 172-200.

Mackin, J.G., H.M. Owen, and A. Collier. 1950. Preliminary note on the occurrence of a new protistan parasite, *Dermocystidium marinum* n. sp. in *Crassostrea virginica* (Gmelin). Science **111:** 328-329.

Mackin, J.G. 1951. Histopathology of infection of *Crassostrea virginica* (Gmelin) by *Dermocystidium marinum* Mackin, Owen, and Collier. Bull Mar. Sci. Gulf and Caribbean **1:** 72-87.

Tarnowski, M. 2003. Maryland Oyster Population Status Report: 2002 Fall Survey. Maryland Department of Natural Resources, Annapolis, Md. 32 pp.

Tarnowski, M. 2005. Maryland Oyster Population Status Report: 2003 and 2004 Fall surveys. Maryland Department of Natural Resources Publ. No. 17-1072005-62. Annapolis, Md. 33 pp.

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 effort 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, non-fishing 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, non-fishing 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 infection — 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 over one year old but less than 3 inches (see market oyster, spat).

spat — Oysters less than one year old.

spatfall, spatset, — The process by which swimming oyster larvae attach to a hard

set	substrate such as oyster shell. During this process the larvae undergo metamorphosis, adopting the adult form and habit.
spatfall intensity	The number of spat per bushel of cultch. This is a relative measure of 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*

(Return to Text)