Maryland Oyster Population Status Report

2009 Fall Survey

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

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 2009 Annual Fall Oyster Survey was conducted by Shellfish Division staff from the Maryland Department of Natural Resources (MDNR) Fisheries Service from 21 October to 8 December. A total of 363 samples were collected during surveys on 269 natural oyster bars, including Key Bar and Disease Bar sites and sanctuaries, as well as contemporary seed oyster planting sites, shell planting locations, and State Seed Areas (seed production areas). Oyster parasite diagnostic tests were performed by staff of the MDNR Cooperative Oxford Laboratory (COL).

Annual streamflow for all Maryland tributaries and the Potomac River during 2009 corresponded with the median over the past 25 years. The individual monthly discharges showed strong deviations from the monthly means over two distinct periods. Streamflows from January through April were abnormally low. Beginning in May, flows were generally average or above average for the remainder of the year. Consequently, surface water salinities were below 15 ppt throughout most of Maryland for much of the summer. The magnitude and timing of these salinity declines may have strongly influenced oyster recruitment and disease impacts.

The 2009 Maryland oyster spatfall index of 15.7 spat/bu was only slightly higher than that of 2008, but the spatfall was more widespread, with the highest number of Key bars receiving spat since 2002. Most of the spatfall was distributed along the lower Eastern Shore from the Choptank River south, although the highest average count was in the St. Mary's River, followed by the Kedges Straits area of Tangier Sound. A moderate spatfall also occurred along the north shore of the lower Potomac River. Otherwise, spatfall was patchy, with a light set as far up-bay as Kent Island.

Dermo disease levels remained below average for the seventh consecutive year, following record highs in 2002. This disease, caused by the parasite *Perkinsus marinus*, was found on 40 of 43 Disease Bars. The overall mean infection prevalence was 59%, well below the 20-year average (71%) and only slightly higher than in 2008. The 2009 annual mean infection intensity (2.0) was comparable to the previous six years, but was depressed relative to the drought period of 1999-2002. Lethal infection intensities were detected in only 15% of sampled oysters. MSX disease has been expanding its range over the past three years, and in 2009 was found as far up-Bay as the Eastern Bay region. It was detected on 60% of the Disease Bars, double the frequency of occurrence in 2008 and considerably higher than the 9% frequency of 2006. MSX disease prevalences also increased, with a high of 57% of the oysters infected on Chickencock Bar in the St. Mary's River and an overall mean prevalence of 13%. Where *H. nelsoni* was prevalent, salinities during May and June, the critical months for MSX disease development, were generally between 10 and 15 ppt. The exception was a station in southern Tangier Sound, where salinities remained between 16 and 18 ppt during this period.

The 2009 observed mortality of 17% remained well below the long-term average for the sixth successive year, approaching the background mortality levels of 10% or less found prior to the mid-1980's disease epizootics. This is associated with the timing and magnitude of peak streamflows, maintaining a delicate balance that has allowed MSX disease to spread geographically while keeping it below lethal levels. Thus, although widely distributed, disease effects have been slow to rebound to lethal levels due to inhibition by timely freshwater inputs. As salinities remained unfavorable to lethal MSX impacts and less than optimal for dermo disease, a continuing widespread 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 101,000 bushels during the 2009 (2008-09) season, commercial oyster landings increased by 22% from the previous year. This increase was supported by the relatively strong year-class of 2006, in conjunction with good survivorship. The dockside value of $2.7 M was largely unchanged from 2008. As a result of the geographic redistribution of the fishery between the 2008 and 2009 seasons, there was a corresponding shift in the relative landings by gear. Power dredging landings almost doubled from the previous season, accounting for 54% of the total landings, primarily due to a threefold increase in activity in Tangier Sound and the Honga River. Conversely, hand tong harvests sharply declined, mirroring the 70% harvest drop in Broad Creek.

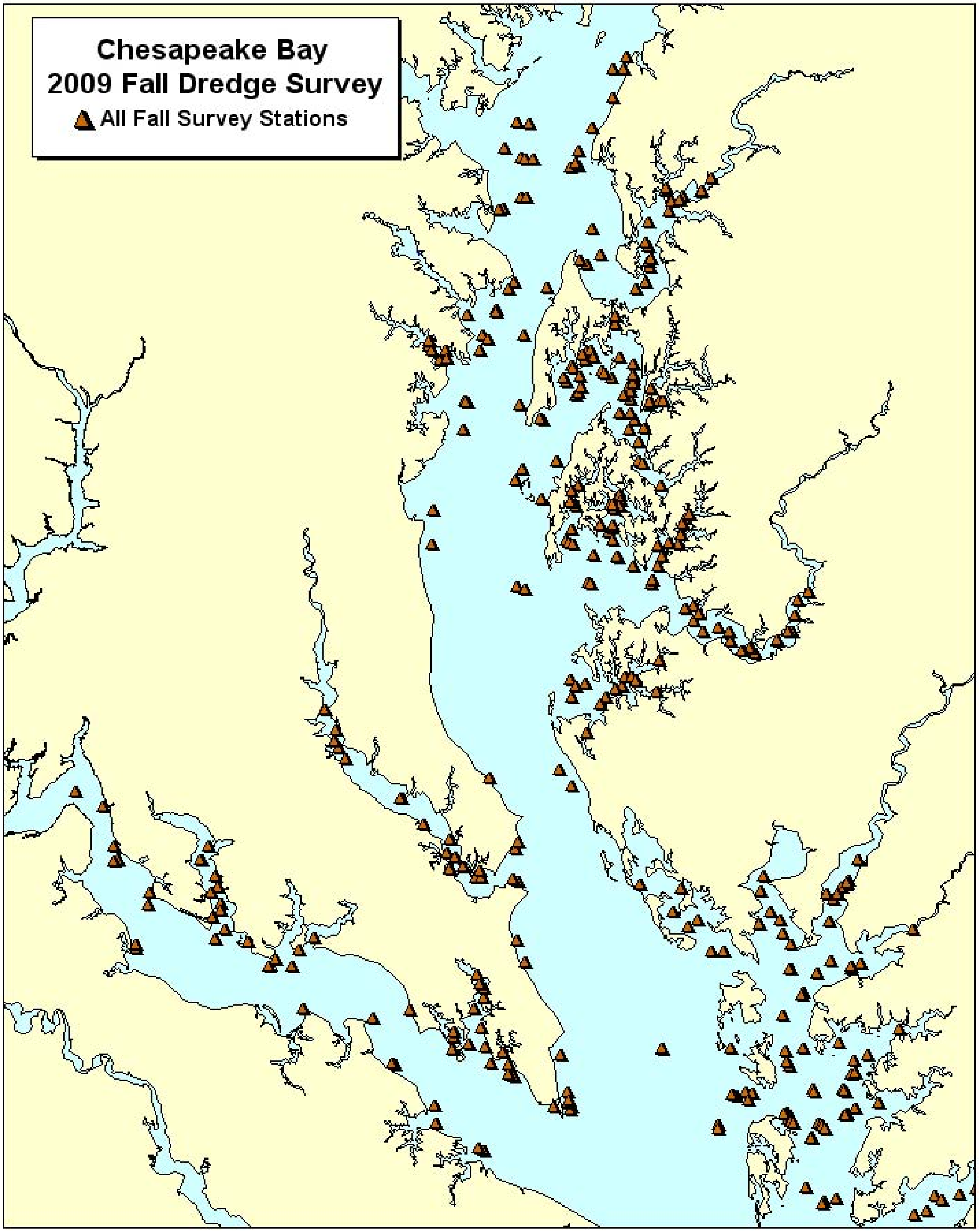

Figure 1a. 2009 Maryland Fall Oyster Survey station locations, all bar types (standard, Key, Disease, seed) included.

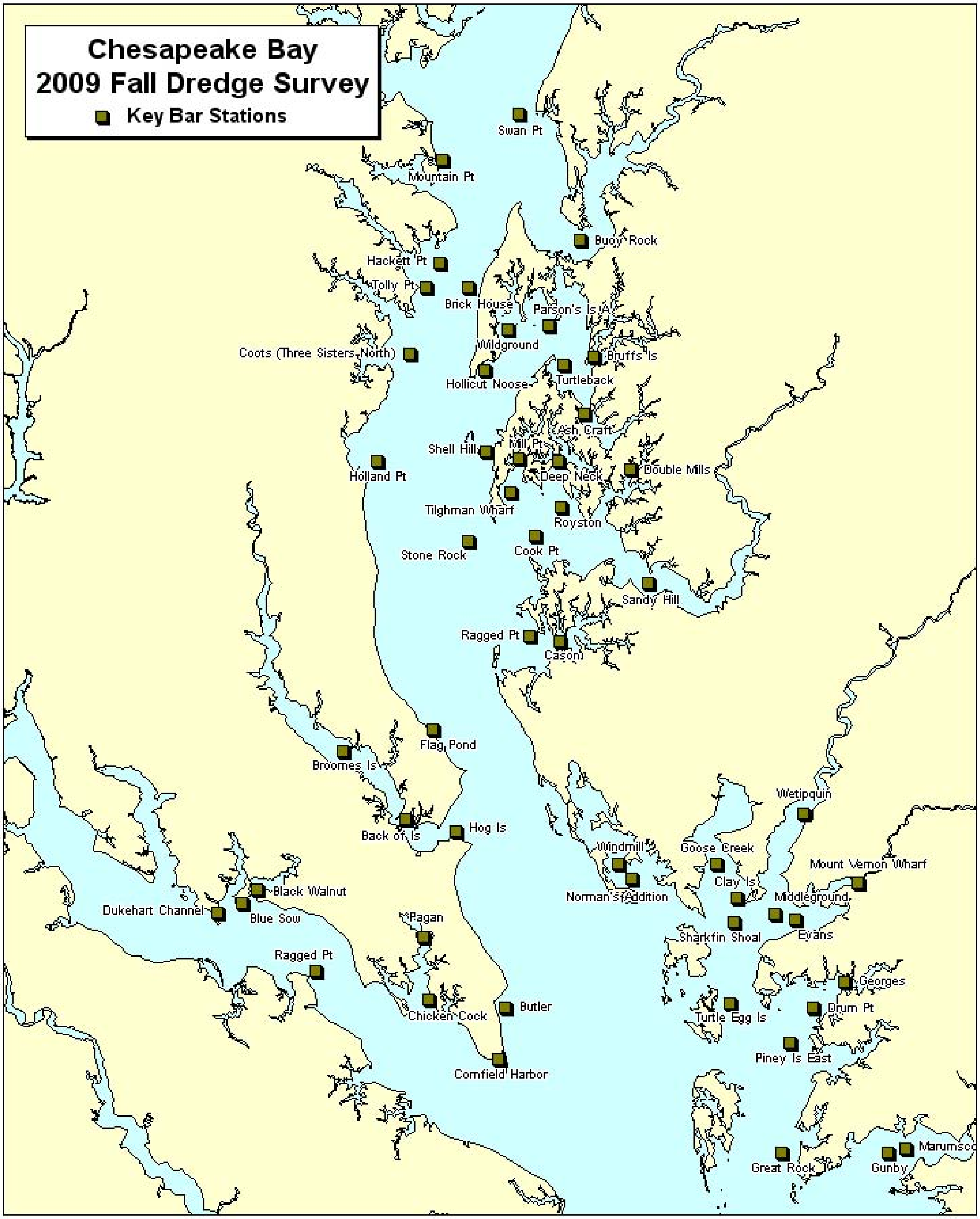

Figure 1b. Maryland Fall Oyster Survey Key Bar locations included in determining the annual Spatfall Intensity Index

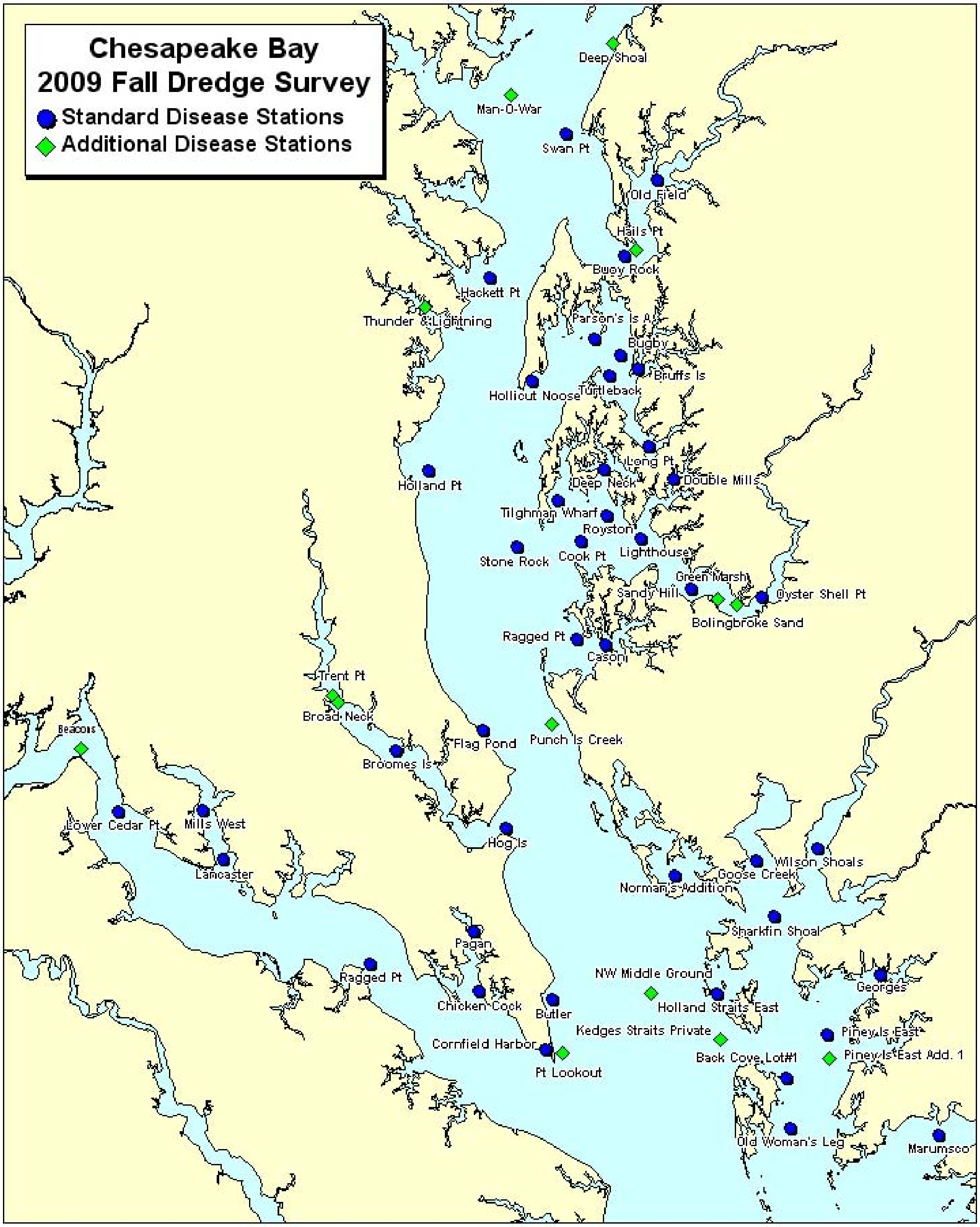

Figure 1c. Maryland Fall Oyster Survey standard Disease Bar locations and additional 2009 disease sample stations.

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 for 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 also among the 53 spatfall index oyster bars (Key Bars).

METHODS

The 2009 Annual Fall Oyster Survey was conducted by Shellfish Division staff from the Maryland Department of Natural Resources (MDNR) Fisheries Service from 21 October to 8 December. A total of 363 samples was collected during surveys on 269 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 (2009).

A 32-inch-wide standard oyster dredge was used to collect the samples, the number of which 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 State Seed 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). A brief description of the two primary oyster parasites in Maryland is in Appendix 1.

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 analysis of variance 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 i.e. since rankings are assigned across treatments (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 $\alpha = 0.05$.

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 interpretation of the results as hypothesis tests. Multiple comparisons were evaluated using "yardsticks" developed from experimental error rates of $\alpha = 0.15$.

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

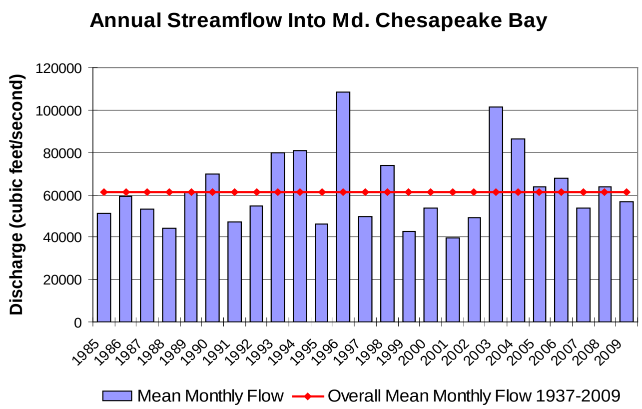

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2009. USGS Section C: all Maryland tributaries and the Potomac River.

The 2009 annual streamflow for all Maryland tributaries and the Potomac River was about 8 % below the 73-year average (Sec. “C” in Bue 1968; USGS 2009). However, 2009 flows actually corresponded with the median over the past 25 years. This marks the fifth consecutive year that freshwater discharges into the Maryland portion of Chesapeake Bay 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).

[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 1937-2009 period, respectively.

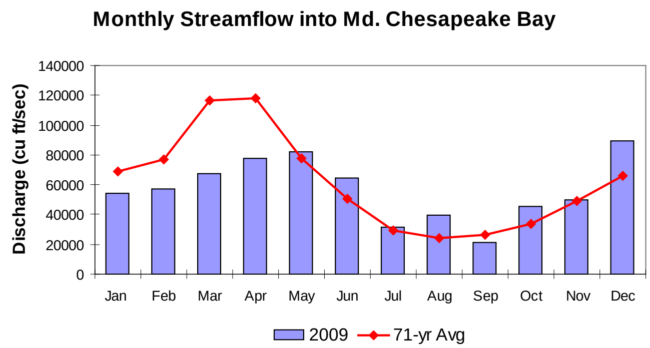

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2009, including the long-term monthly average.

The individual monthly discharges showed strong deviations from the monthly means over two distinct periods (Figure 2b). Flows from January through April were abnormally low, running from about 78% in January to a low in March of 58% of the average. Beginning in May, flows were generally average or above average for the remainder of the year. This is especially important during May/June, a critical period for seasonal proliferation of both disease parasites, when 2009 freshwater input averaged the fifth highest over the past 20 years, or 122% of the average over this period (Figure 2c).

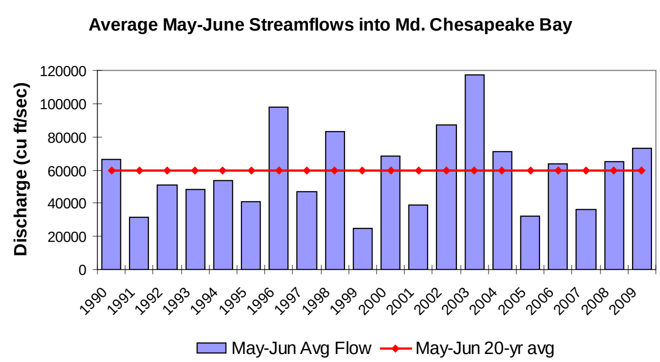

Figure 2c. Annual May-June average streamflows into Chesapeake Bay (Section C), 1990-2009, and the 20-yr mean streamflow for those months.

As a result, surface salinities dropped throughout most of Maryland from April to June by an average of 2.4 ppt (MDNR 2009). The exception was in the Tangier

Sound region, where salinities dropped an average of 1.35 ppt in May, only to rise sharply in June, averaging 1.6 ppt higher than April values. This late spring/early summer freshet was followed by additional higher streamflows in August (163% of the average) and October (136% of the average). The magnitude and timing of these salinity declines may have strongly influenced oyster recruitment and disease impacts, as described in the following sections of this report.

SPATFALL INTENSITY

Maryland oyster spatfall during 2009 was unexceptional for the third consecutive year. The spat index of 15.7 spat/bu was only slightly higher than 2008, but because the spatfall was more widespread (75% of the bars received spat in 2009 vs. 40% in 2008), it placed in the middle (Tier 2) statistical grouping for the period of 1985 through 2009 (Figure 3). The median spatfall index appears to neatly separate the Tier 2 and Tier 3 statistical groupings of the present analysis. All of the Tier 3 years were below the 25-year median spatfall, while the Tier 2 years were mostly above or just barely under it. This marks only the second year out of the past seven that the spatfall intensity index has been at or above the 25-year median, the other year being 2006 (Figure 3).

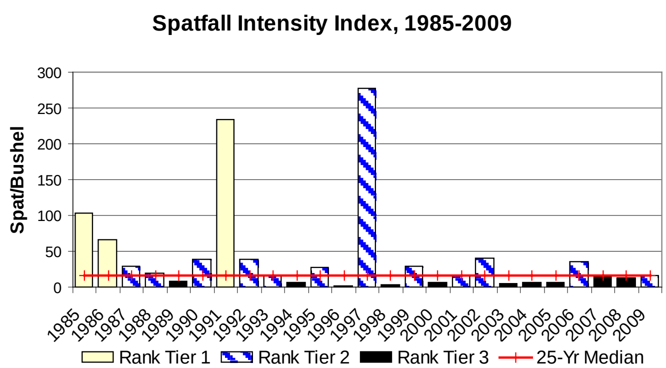

Figure 3. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, 1985-2009, including rankings of statistically similar indices.

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 (Homer & Scott 2001). Over 75% of the 1997 index was accounted for by only five of the 53 Key Bars, while ten contributed nearly 95% (Table 2). As a result, the 1997 spat index fell into the 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. Fifteen Key Bars comprised 75% of the index that year, while 28 sites were needed to attain 95% of the spatfall intensity index, placing it in the first statistical tier.

Spatfall was more widely and evenly distributed among the Key Bars in 2009 compared with recent years. In 2009, spat were observed on 40 of the 53 Key Bars vs. 21 bars in 2008 and only nine bars in 2007 (Table 2). Eleven 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 2009 was 321 spat/bu. on Pagan Bar in the St. Mary's River, accounting for 39% of the total spat index. In addition, six of the top-ten Key Bars for spat counts were in the southern Eastern Shore region and three were in the Choptank region. Furthermore, 2009 spatfall occurred on the highest total number of bars since 2002 (46 bars).

When considering all bars surveyed in addition to the Key Bars, most of the spatfall was distributed along the lower Eastern Shore from the Choptank River south, although the highest average count was in the St. Mary's River, followed by the Kedges Straits area of Tangier Sound

(Figure 4). Spatfall was also moderate along the north shore of the lower Potomac River. Otherwise, spatfall was patchy, with a light set as far up-bay as mid Kent Island.

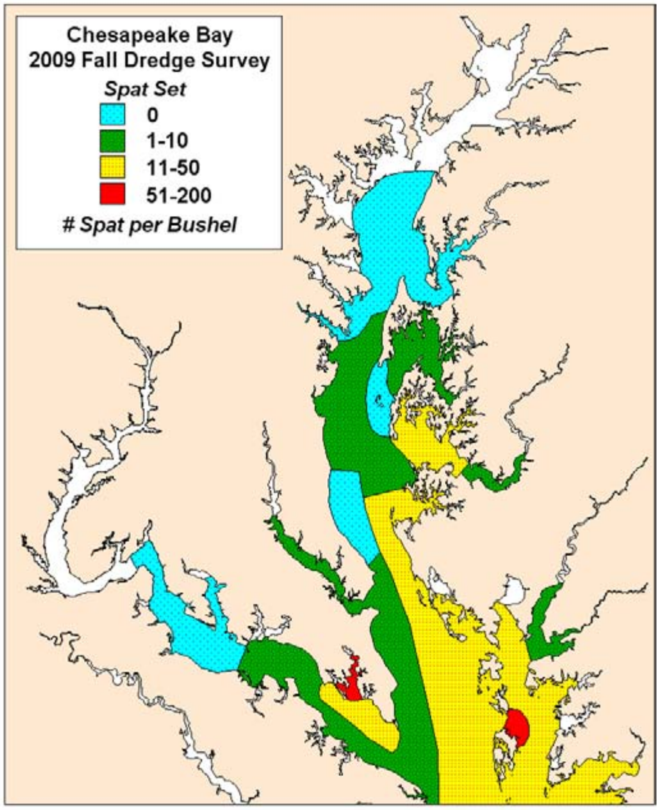

Figure 4. Spatfall intensity and distribution, 2009. Intensity range in legend represents the average for an area.

OYSTER DISEASES

Although dermo disease levels remained below average for the seventh consecutive year, MSX disease prevalences increased substantially in 2009. Although both dermo and MSX diseases remain widely distributed, oyster disease effects have been slow to rebound to lethal levels possibly due to inhibition by timely freshwater inputs. (La Peyre et al. 2003)

Dermo disease, caused by the parasite *Perkinsus marinus*, infected oysters on 40 of 43 Disease Bars (Table 3). Of two additional bars in the least saline reaches of the oyster grounds, Deep Shoal in the Head-of-the-Bay had *P. marinus* return at low levels after an absence in 2008, while the parasite was undetected at Beacon Bar in the Potomac River. The overall mean infection prevalence in oysters sampled on the Disease Bars was 59%, well below the 20-year average (71%) and only slightly higher than 2008, ranking 2009 in the lowest statistical grouping for infection prevalence (Figure 5). Six out of the past seven years have had comparably low dermo disease prevalences.

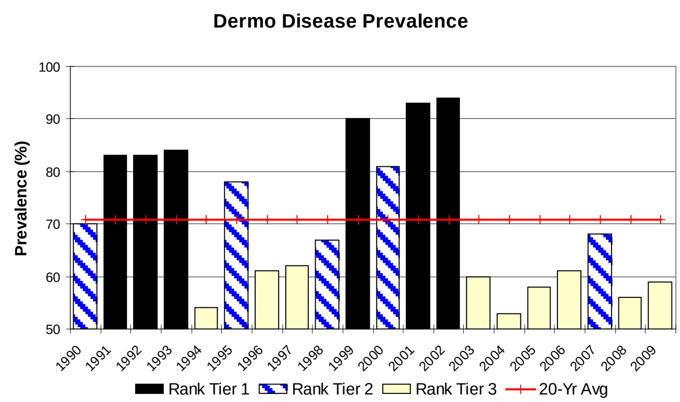

Figure 5. Annual mean *P. marinus* prevalences and rankings of statistically similar years from Maryland disease monitoring bars.

The geographic distribution of high (>60%) infection prevalences was largely the same between 2008 and 2009 (Table 3), except where elevated prevalences developed in the St. Mary's River and mouth of the Patuxent River (Figure 6). The remaining areas of highest prevalences were fragmented and included Tangier Sound, the lower and northern mid-mainstem of the Bay, the Patuxent, Chester, Tred Avon and Little Choptank Rivers, Broad Creek, and most of the Eastern Bay region. These higher prevalences were not necessarily associated with higher mortalities (see Observed Mortality section). In addition to Beacon Bar, *P. marinus* was not detected among tested oysters from the middle Potomac and upper Choptank Rivers and Fishing Bay.

The 2009 annual mean infection intensity (2.0) was comparable those of the previous

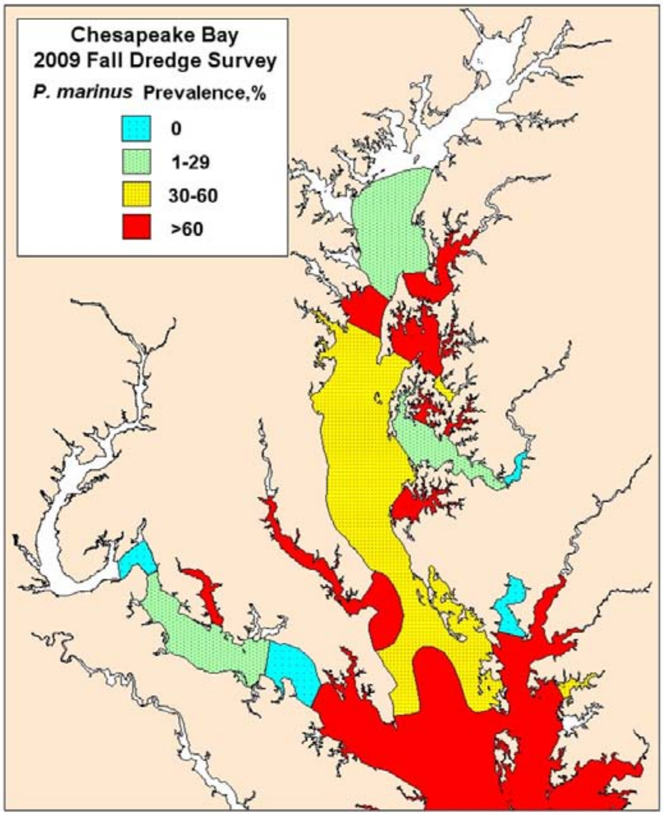

Figure 6. Geographic extent and prevalence of dermo disease, 2009.

six years, which were greatly reduced from the mean annual intensities (2.9-3.8) during the drought period of 1999-2002, and fell within the second-lowest statistical tier for Disease Bar infection intensity (Figure 7).

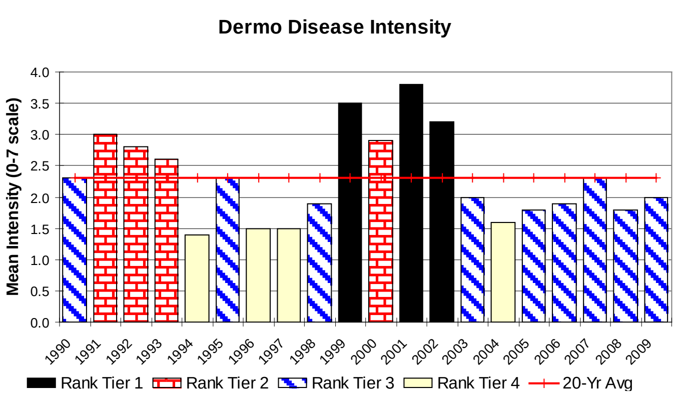

Figure 7. Annual mean *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars. Rankings are based on statistically similar years.

Over the last seven years, dermo disease infection intensities have been below the 20-year average, with one of these years ranked in the lowest statistical tier and the other six ranked in the second-lowest grouping.

The frequency distributions of sample infection intensities have also been 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 8). In 2009, 26% of the Disease Bar samples had mean infection intensities of 3.0 or greater and two (5%) 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 during 2009 such infection intensities were detected in only 15% of sampled oysters from Disease Bars. Among samples from sanctuaries and harvest reserves, 20% of individual oysters exhibited lethal infection intensities.

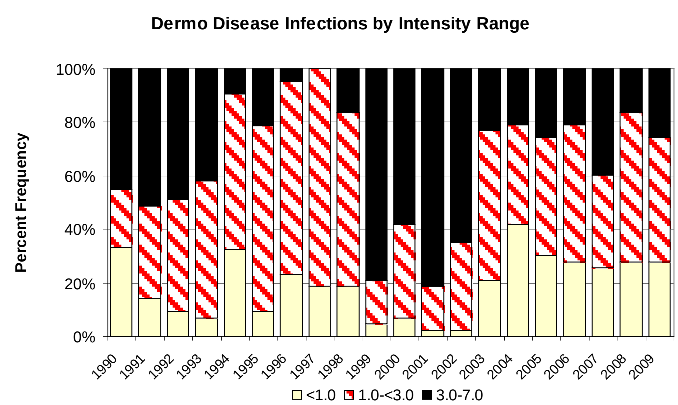

Figure 8. *P. marinus* infection intensity ranges, percent frequency by range and year.

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.

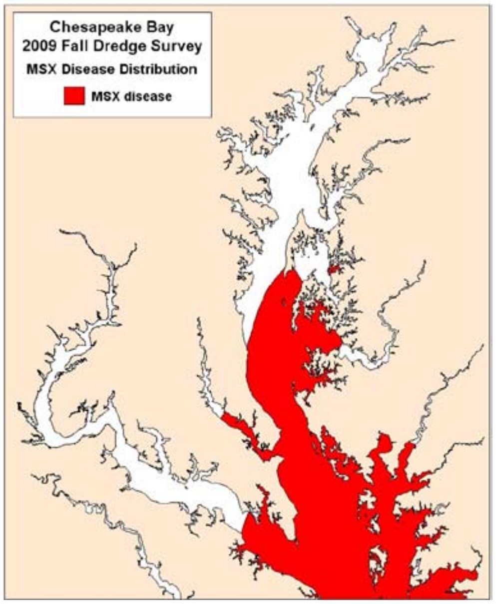

Figure 9. Geographic extent of MSX disease in Maryland waters in 2009.

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%), 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).

MSX disease has expanded its geographic distribution substantially over the past three years. In 2006 it was largely confined to Tangier Sound, but by 2009 it was detected as far up-bay as the mouth of Eastern Bay (Figure 9). Infected oysters were found on 60% of the Disease Bars, double the frequency of occurrence in 2008 and considerably higher than the 9% frequency of 2006 (Table 4). MSX disease prevalences also increased, with a high of 57% of the oysters infected on Chickencock Bar in the St. Mary's River and an overall mean of 13%.

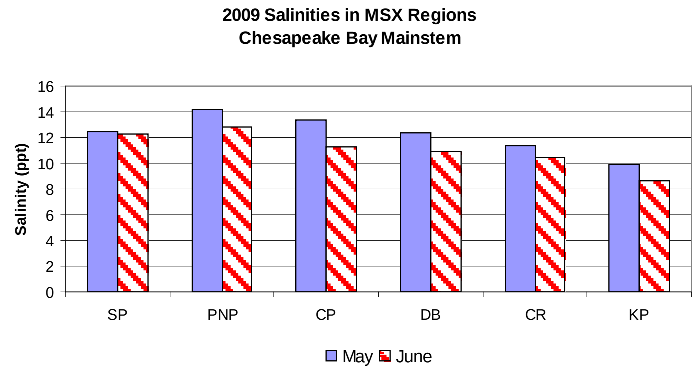

Figure 10a. May/June salinities in the MSX regions of the Chesapeake Bay mainstem, 2009. **SP = Smith Pt., PNP = Pt. No Point, CP = Cove Pt., DB = Dares Beach, CR = mouth of Choptank R., KP = Kent Pt.**

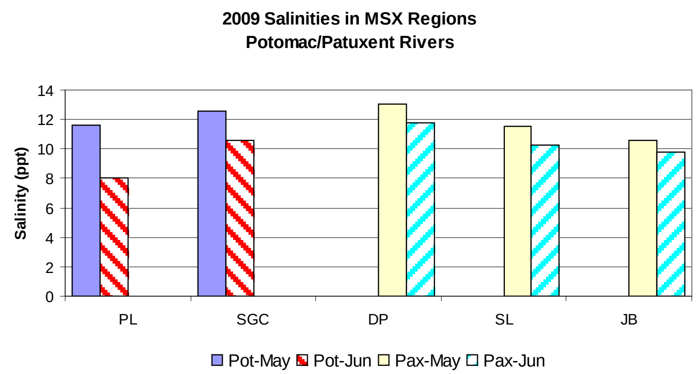

Figure 10b. May/June salinities in the MSX regions of the Potomac and Patuxent Rivers, 2009. **PL = Pt. Lookout, SGC = St. George Cr., DP = Drum Pt., SL = St. Leonard Cr., JB = Jack Bay.**

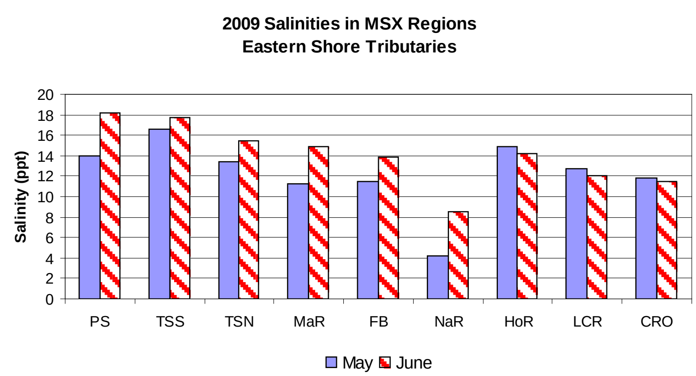

Figure 10 c. May/June salinities in the MSX regions of Eastern Shore tributaries, 2009. **PS = Pocomoke S., TSS = southern Tangier S., TSN = northern Tangier S., MaR = Manokin R., FB = Fishing Bay, NaR = Nanticoke R., HoR = Honga R., LCR = Little Choptank R., CRO = outer Choptank R.**

In regions where *H. nelsoni* was prevalent, salinities during the critical months for MSX disease development, May and June, were typically between 10 and 15 ppt (figs 10a-c), with both months averaging 11.8 ppt for all stations (MDNR 2009). The exception was a station in southern Tangier Sound, where salinities remained between 16 and 18 ppt during this period (fig 10c).

OBSERVED MORTALITY

Observed mortalities during 2009 ranged from 0-50% among oysters on Disease Bars, and the annual mean (17%) remained well below the long-term average for the sixth successive year. Observed mortalities of 15-20% during the most recent six-years approach the background mortality levels of 10% or less found prior to the mid-1980's disease epizootics (MDNR, unpubl. data), and falls well below the 25-year average of 26.5% (Table 5). The 2009 observed mortality of 17% was ranked in the second lowest statistical grouping over the same quarter-century time scale (Figure 11).

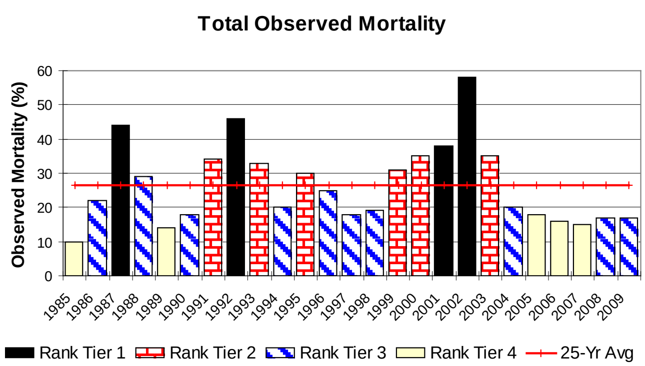

Figure 11. Mean annual observed mortality, small and market oysters combined. Rankings are based on statistically similar years.

Regions with the highest observed mortalities were Eastern Bay and its tributaries, the St. Mary's River, lower Potomac River and adjacent bay mainstem, lower Tangier Sound and part of Pocomoke Sound (Figure 12). With the exception of Eastern Bay, these areas are in the higher salinity zone of southern Maryland. No region exceeded an average total observed mortality of 50%. Likewise, none of the individual Disease Bars had observed mortalities greater than 50% (Table 5).

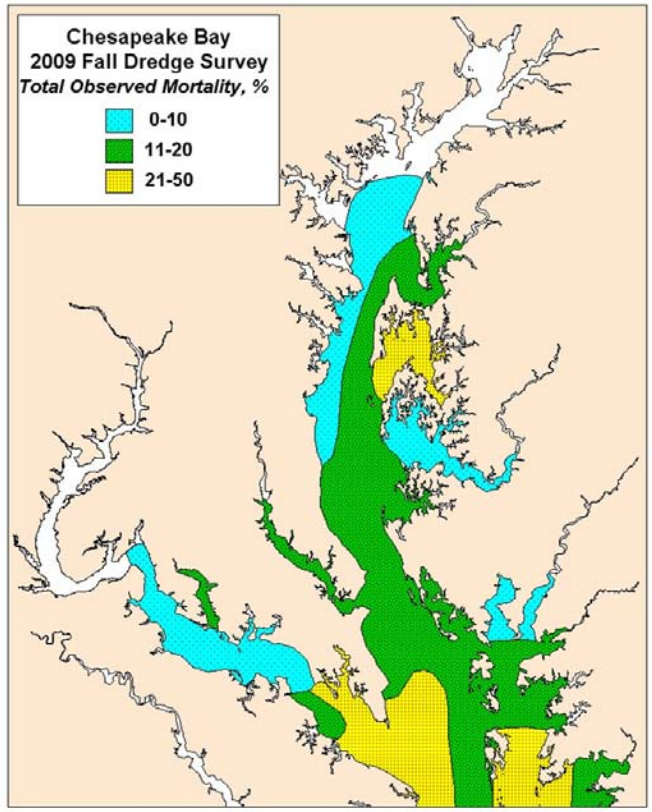

Figure 12. Total observed mortalities of small and market oysters in Maryland, 2009.

A strong correlation exists between observed mortalities and the percentage of Disease Bars with MSX disease during the period from 1990-2009 ($r^2 = 0.52$, $p < 0.001$) (Figure 13). Likewise, there is a good correlation between observed mortalities and dermo disease intensities during 1990-2009 ($r^2 = 0.49$, $p < 0.001$) (Figure 14). 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 and with the decline in the annual mean intensities of dermo disease. However, the relationship between observed mortalities and MSX disease has not been as robust over the past three years, with low observed mortalities persisting despite an increased frequency of bars with MSX disease, particularly in 2009. This could be due to the timing and magnitude of peak streamflows, maintaining a delicate balance that may have allowed MSX disease to spread geographically while keeping infection intensities below lethal levels. The general reduction of dermo disease infection intensities, a consequence of sub-optimal salinity conditions for *P. marinus* that coincided with reduced impacts from MSX disease, may have been a factor that limited observed mortalities during 2009 to well below the 24-year average (Figure 11). The relative contribution of each disease to the observed mortalities varies with environmental conditions, with MSX disease intensifying during droughts (Tarnowski 2010).

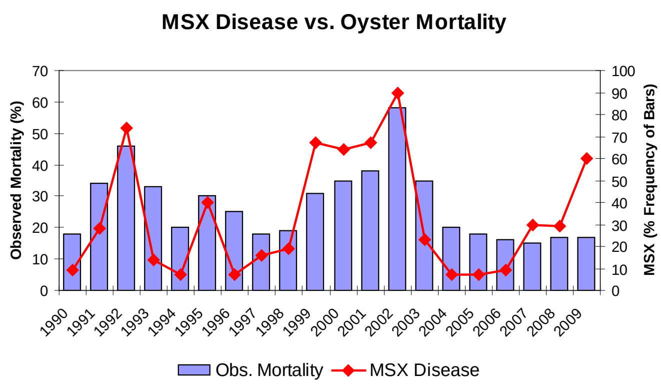

Figure 13. Percentage of Disease Bars with MSX disease compared to annual means for observed oyster mortalities during the period from 1990-2009.

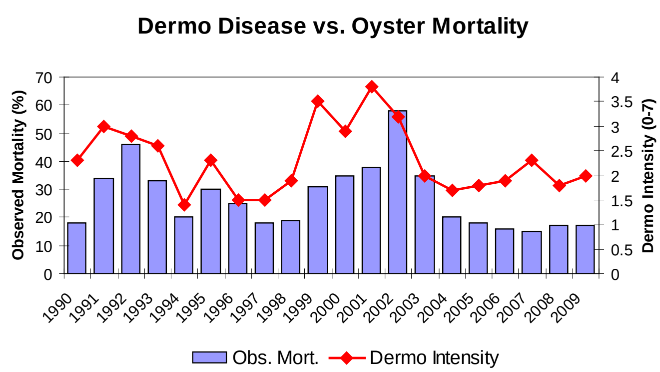

Figure 14. Mean annual dermo disease intensities compared to annual means for observed oyster mortalities during the period 1990-2009.

COMMERCIAL HARVEST

With reported harvests of 101,000 bushels during the 2008-09 season, commercial oyster landings increased by 22% from the previous year (Table 6, Figure 15).

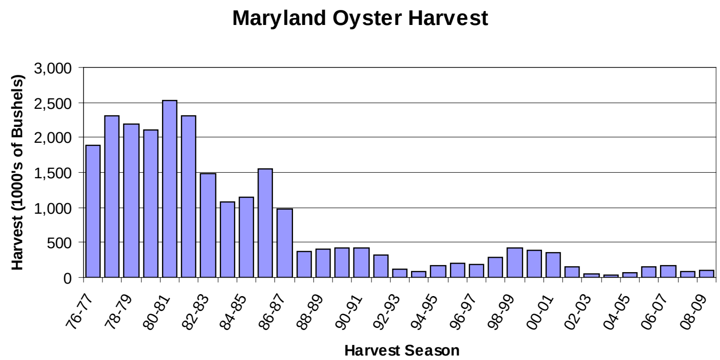

Figure 15. Maryland seasonal oyster landings, 1976-77 to 2008-09.

This increase was supported by the relatively strong year-class of 2006, in conjunction with good survivorship. Since the heyday of the Maryland oyster fishery in the 19th century, annual landings below 100,000 bushels have been reported in only five seasons, all within the past 15 years (and four of the five in the past six years). The dockside value was $2.7 M was largely unchanged from 2008 (Table 7a.).

Tangier Sound and the Honga River were the dominant harvest regions, followed by the upper Bay and Eastern Bay (Table 6). These four areas accounted for 64% of the harvest. The changes in landings between 2008 and 2009 for these regions were:

Honga River – increased 16,000 bu.
Upper Bay – decreased 7,000 bu.
Tangier Sound – increased 18,000 bu.
Eastern Bay – decreased 1,000 bu.

Broad Creek, the leading harvest area during the previous two seasons, experienced another steep drop in landings, from 54,000 bu. in 2007 to 6,000 bu. in 2009. Other regions had similar landings reported as the previous season. Of note was a modest 3,000 bu. harvest increase in Fishing Bay, which had its highest landings since the 1997-98 season.

As a result of the change in geographic distribution of the fishery during the 2009 season, there was a corresponding shift in the relative landings by gear type (Table 7b). Power dredging landings almost doubled from the previous season, accounting for 54% of the total landings, primarily due to the increased activity in Tangier Sound. Conversely, hand tongs harvests sharply declined, mirroring the harvest drop in Broad Creek.

DISCUSSION

THE INFLUENCE OF SALINITY ON OYSTER POPULATIONS

One of the most critical physical factors influencing oyster populations, both directly and indirectly, is salinity. Salinity, as a function of freshwater flow, varies seasonally, annually, and spatially depending on weather patterns such as rainfall and snow pack. Changes in freshwater discharges into the Bay can alter salinity regimes sufficiently to affect recruitment patterns, predation, disease pressure, and mortality rates. Even slight shifts in salinities can have profound consequences for oysters in a given area. Low salinities can inhibit recruitment and, taken to the extreme, have devastating effects on upstream oyster populations in normally marginal salinity habitats. Higher salinities enable good spatfall, but may foster oyster diseases and associated mortalities.

Oyster populations can be directly impacted by deluges of freshwater, which, depending on the timing and duration, can cause mass mortalities on vulnerable bars. A long record of oyster-killing freshets exists in Maryland, the most famous occurring in 1972 during Tropical Storm Agnes (Beaven 1947, CRC 1976). More recent freshet-related oyster mortalities were documented during 1993, 1994, and 1996 variously in the Potomac, western Wicomico, Chester and Choptank Rivers as well as the upper Bay (Homer & Scott 2001).

Oyster recruitment is also affected by salinity, both directly and indirectly (Kimmel & Newell 2007). If salinity is below a critical threshold, a spatfall failure is assured. The timing and volume of streamflows (which modulate salinities) is important; the March – May period appears to be a good indicator of recruitment potential (Tarnowski 2010). However, proper salinity is a necessary but not always sufficient condition to ensure a good spatfall. For example, 1999 and 2001 had similar streamflow volumes, but a twofold difference in recruitment (Figure 2a, Table 2). Factors accounting for successful recruitment when salinities are adequate may include, but are not limited to, availability of clean substrate, 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. Species that can modify oyster recruitment have their own cycles of abundance, and the timing and magnitude of their occurrence in relation to the timing of the oyster reproductive/recruitment cycle form an intricate web of interactions. As salinity affects the physiology of oyster reproduction, it also influences those populations of species that can interfere with spat settlement.

Salinity can indirectly affect oyster populations by influencing the distribution of oyster predators and competitors. For example, in 2002, the fourth consecutive year of drought conditions, salinities had been elevated for such a prolonged period that oyster drills, which require salinities above 15 ppt, were found well up Tangier Sound in areas not normally inhabited by them. Consequently, during the spring of

2002 a large percentage of oyster spat boxes had tell-tale drill holes, indicating they had been consumed by these carnivorous gastropods (MDNR unpubl. data).

Similarly, oyster diseases are controlled by salinity. Oyster parasites are salinity sensitive, particularly *H. nelsoni* (Ford 1985, Ragone & Burreson 1993). This was dramatically illustrated in 2004, when persistently-high freshwater runoff pushed back MSX disease from its record high levels throughout much of Maryland waters during 2002 to relatively small areas in Tangier Sound and the lower mainstem (Tarnowski 2005). Since that freshet, salinities have moderated and over the past three years MSX disease has expanded geographically, but there has been no concomitant increase in the baywide average observed mortality.

Since the end of a prolonged drought in the fall of 2002 (Tarnowski 2005), a string of environmental conditions unfavorable to diseases has been documented during these seven years of below average observed mortalities. Exceptionally high annual freshwater inflows characterized 2003 and 2004 (the second and third highest over the past 25 years) (Figure 2a), and three of the subsequent five years had above average inputs. Even as annual streamflows moderated in the second half of this decade, peak spring/summer streamflows generally were still above average (Figure 2c). The timing and magnitude of these peak streamflows were such that a delicate balance may have been maintained between salinities that allowed the geographic spread of MSX disease, yet were low enough to prevent the development of lethal infections, resulting in reduced observed mortalities. Furthermore, dermo disease prevalences and infection intensities have remained below average for the past seven years. Even if the oysters were tolerant of dermo disease they would still carry infections of *P. marinus*, but the below average prevalence levels suggest that other factors are affecting dermo disease transmission and acquisition.

Disease-related oyster mortality is not the only oyster population dynamic to have been inhibited by the pattern of seasonal above-average freshwater pulses in recent years. A parallel situation exists with oyster recruitment, where high streamflows (i.e. below average salinities) result in recruitment failures (Tarnowski 2010). Spatfall has been below the 25-year median in six of the last seven years. There are a number of other factors than can affect recruitment, but the strong numerical correlation between freshwater inputs and recruitment implicates high streamflows in the spate of recent poor spatfall years (Tarnowski 2010).

On an annual, Baywide (Maryland and Virginia) basis, 2009 was considered a dry year by the USGS (2009). However, as in the previous four years (excluding 2003 and 2004 because of their extended high streamflows throughout the year), a timely pulse of above average freshwater flow in May and June drove down salinities. By mid-June, most of the water quality stations in Maryland were reporting surface salinities below 15 ppt, (MDNR 2009). This was followed by additional pulses of higher streamflows in August (163% of the average) and October (136% of the average), which kept salinities in most of Maryland waters below 15 ppt throughout much of the summer. The Tangier Sound region was the exception, with salinities remaining above 15 ppt, and coincidentally was one of the areas with the highest observed mortalities.

Haplosporidium nelsoni can tolerate salinities as low as 10 ppt, but MSX disease becomes substantially more pathogenic in salinities greater than 15 ppt and temperatures greater than 20°C (Ford 1985, Sprague et al. 1969), conditions which in Maryland generally develop during May. Thus, in 2009 during the critical months for the development of MSX disease infections and consequent mortalities (Ford & Tripp 1996), salinities throughout most of

Maryland were within the window that allows *H. nelsoni* to survive but at sub-lethal levels.

Although the generalized picture is one of an extended period of lower observed mortalities, when localized conditions become favorable to disease, mortality events continue to occur. For example, the Paul Bailey Oyster Sanctuary in the Patuxent River received disease-free hatchery seed in 2002. These oysters experienced excellent survivorship during the first few years (MDNR unpubl. data), but by 2006 dermo disease was detected (83% prevalence, 2.8 infection intensity, 20% lethal infections), although observed mortalities were only about 7%. The following year the salinity in the area increased substantially (Fall Survey salinities were 15.7 ppt in 2007 vs. 10.7 ppt in 2006) and *P. marinus* flourished (97% prevalence, 4.6 infection intensity, 60% lethal infections), resulting in observed mortalities of 43%, despite a baywide Disease Bar average observed mortality of 15%.

The development of disease tolerance or resistance among Maryland oyster populations cannot be discounted. In higher salinity waters such as Delaware Bay and the Virginia portion of Chesapeake Bay, native oyster populations have demonstrated greater survivorship in the face of MSX disease (Ford & Tripp 1996, Burreson & Ford 2004). Furthermore, selective breeding has produced oyster strains with genetically enhanced resistance/tolerance to both MSX and dermo diseases (Ford & Tripp 1996, Ragone Calvo et al. 2003).

In Maryland, however, developing resistance or tolerance to MSX disease is problematic since most of the oyster populations are not consistently challenged by *H. nelsoni* except during dry years. Consequently, susceptible individuals are only intermittently and incompletely removed from the population. Surviving and newly recruited susceptible individuals can dilute the pool of tolerant or resistant stocks by either reproducing with them directly or by providing larvae from more remote low disease areas which may recruit, grow, and reproduce with the selected oysters. Such a scenario could have occurred in 2002, when salinities were high enough to promote recruitment throughout most of Maryland, producing the highest spat index in 12 years (Table 2). This was followed by successive years of good survivorship to reproductive age with little challenge by disease due to favorable salinity conditions. Even during an epizootic outbreak, the susceptible individuals generally would be capable of reproducing before succumbing to disease. Nonetheless, during the high freshwater flow years of 2003 and 2004, a pocket of MSX disease remained in Tangier Sound to challenge the oysters of that region. It would not be surprising if tolerant or resistant oysters developed there, although definitive, empirical evidence is not yet available to support this contention.

The host-parasite relationship as affected by salinity between oysters and *P. marinus* is considerably more involved than that described for MSX. Until the late 1980's - early 1990's, dermo disease epizootics would occur in the higher salinity Bay regions and penetrate up-Bay only during low freshwater flow periods. Since the early 1990's, however, this disease has entrenched itself in the Bay's oyster population; it is now an enzootic condition found almost everywhere oysters are present. Salinity patterns and resultant infection levels observed prior to the onset of chronic dermo disease no longer apply to oyster populations. As described here, the last seven years have seen a remarkable abatement of dermo disease, on a Baywide basis, measured by both prevalence and intensity. Although environmental conditions can adequately account for what has been observed in recent years, the apparent evolving relationship between oyster and *P. marinus* populations is not fully understood. Dermo disease appears to remain strongly influenced by salinity, but evidence for modulating effects of enhanced dermo disease resistance among oysters from chronically selected wild populations is only circumstantial to date.

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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, 1985-2009.

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	2009
Mountain Point	0	0	0
Swan Point	0	0	0
Brick House	0	0	6
Hackett Point	0	0	0
Tolly Point	0	0	0
Three Sisters	0	0	0
Holland Point	0	0	0
Stone Rock	0	1	4
Flag Pond	0	0	0
Hog Island	1	1	4
Butler	1	8	1
Buoy Rock	0	0	0
Parsons Island	0	0	8
Wild Ground	0	1	1
Hollicutt Noose	0	0	0
Bruffs Island	0	0	0
Ash Craft	0	0	2
Turtle Back	0	0	13
Shell Hill	0	0	0
Sandy Hill	3	1	5
Royston	1/3	5	20
Cook Point	1	10	18
Eagle Pt./Mill Pt.	0	2	17
Tilghman Wharf	0	6	15
Deep Neck	1	23	100
Double Mills	1	3	11
Ragged Point	0	2	12
Cason	0	13	9
Windmill	4	79	7
Norman Addition	0	102	6
Goose Creek	0	35	20
Clay Island	1	94	29
Wetipquin	0	2	2
Middleground	0	21	6
Evans	0	14	9
Mt. Vernon Wharf	0	0	8
Georges	5	28	22
Drum Point	56	124	34
Sharkfin Shoal	1	16	14
Turtle Egg Island	7	32	17
Piney Island East	44	23	0
Great Rock	64	38	5
Gunby	4	5	24
Marumsco	14	12	24
Broome Island	0	3	5
Back of Island	2	7	8
Chicken Cock	9	1	16
Pagan	616	0	321
Black Walnut	0	0	0
Blue Sow	0	0	3
Dukehart Channel	0	0	1
Ragged Point	2	1	2
Cornfield Harbor	7	1	1
Spat Index	**15.9**	**13.5**	**15.7**

(Return to Text)

Table 3. *Perkinsus marinus* prevalence and intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2009. 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		2009	
	%	I	%	I	%	I
Swan Point	17	0.4	20	0.6	23	0.4
Hackett Point	87	2.9	80	2.7	73	1.9
Holland Point	33	0.6	23	0.8	33	0.8
Stone Rock	93	3.5	47	1.3	30	0.9
Flag Pond	87	2.0	67	2.3	57	2.1
Hog Island	80	3.1	50	2.0	67	2.7
Butler	77	1.7	43	1.2	43	1.3
Buoy Rock	80	3.2	70	2.2	64	1.5
Old Field	100	4.0	90	3.3	87	3.3
Bugby	100	3.9	93	2.9	100	3.8
Parsons Island	97	4.0	87	3.1	100	2.5
Hollicutt Noose	87	3.0	93	3.3	43	1.4
Bruffs Island	100	3.8	93	3.0	83	2.6
Turtle Back	100	4.4	100	4.1	97	2.9
Long Point	93	3.8	87	3.1	46	1.6
Cook Point	17	0.3	13	0.4	7	0.1
Royston	23	0.7	17	0.4	27	0.7
Lighthouse	0	0.0	0	0.0	10	0.1
Sandy Hill	87	2.5	17	0.5	13	0.2
Oyster Shell Point	27	0.7	0	0.0	0	0.0
Tilghman Wharf	23	0.5	3	0.1	10	0.2
Deep Neck	90	2.7	67	2.2	70	2.4
Double Mills	87	2.9	67	2.2	80	2.1
Cason	60	1.9	100	2.9	100	3.2
Ragged Point	93	2.7	37	1.0	80	2.5
Norman Addition	23	0.9	37	0.7	57	1.8
Goose Creek	0	0.0	20	0.2	0	0.0
Wilson Shoals	93	2.7	80	2.3	87	2.9
Georges	83	3.8	57	2.2	57	1.6
Holland Straits	80	3.0	50	2.0	47	1.5
Sharkfin Shoal	70	1.9	70	1.7	90	3.6
Back Cove	93	3.2	80	2.6	87	3.3
Piney Island East	67	2.5	90	3.3	90	3.4
Old Woman's Leg	73	2.2	90	2.8	97	4.7
Marumsco	37	1.1	57	1.7	90	3.0
Broome Island	97	3.6	93	2.5	100	4.2
Chicken Cock	90	4.0	40	1.3	90	3.5
Pagan	90	2.5	57	1.8	93	2.7
Lancaster	97	4.2	77	2.1	73	2.4
Mills West	47	1.6	57	1.9	50	1.3
Cornfield Harbor	97	3.5	73	2.6	87	3.7
Ragged Point	0	0.0	8	0.1	0	0.0
Lower Cedar Point	30	0.6	7	0.1	10	0.3
Annual Means	**68**	**2.3**	**56**	**1.8**	**59**	**2.0**

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2009. NA=insufficient quantity of oysters for analytical sample. ND= sample collected but not analyzed because prevalence was assumed to be 0.

Region	Oyster Bar	*Haplosporidium nelsoni* Prevalence (%)							
		1990	1991	1992	1993	1994	1995	1996	1997
Upper Bay	Swan Point	0	0	0	0	ND	0	0	0
Middle Bay	Hackett Point	0	0	3	0	0	0	0	0
	Holland Point	0	3	13	0	0	0	0	0
	Stone Rock	0	0	43	0	0	3	0	0
	Flag Pond	0	0	53	0	0	27	0	0
Lower Bay	Hog Island	0	0	43	0	0	14	0	0
	Butler	0	0	50	0	0	23	0	7
Chester River	Buoy Rock	ND	0	0	0	ND	0	0	0
	Old Field	ND	0	0	0	ND	0	0	0
Eastern Bay	Bugby	0	7	3	0	0	0	0	0
	Parsons Island	ND	0	7	0	0	0	0	0
	Hollicutt Noose	0	0	17	0	0	0	0	0
Wye River	Bruffs Island	0	0	0	0	0	0	0	0
Miles River	Turtle Back	0	0	0	0	0	23	0	0
	Long Point	0	0	0	0	0	0	0	0
Choptank River	Cook Point	0	7	73	0	0	NA	0	3
	Royston	NA	0	33	0	0	0	0	0
	Lighthouse	0	0	53	0	0	0	0	0
	Sandy Hill	0	0	13	0	ND	0	0	0
	Oyster Shell Point	0	0	30	0	ND	0	0	0
Harris Creek	Tilghman Wharf	0	0	40	0	0	0	0	0
Broad Creek	Deep Neck	0	0	30	0	0	0	0	0
Tred Avon River	Double Mills	0	0	17	0	0	0	0	0
Little Choptank R.	Cason	0	0	43	0	0	0	0	0
	Ragged Point	0	20	57	0	0	0	0	0
Honga River	Norman Addition	3	0	53	0	0	33	0	0
Fishing Bay	Goose Creek	0	10	27	7	0	20	0	0
Nanticoke River	Wilson Shoals	0	0	57	0	ND	7	0	0
Manokin River	Georges	10	7	23	0	0	33	0	0
Holland Straits	Holland Straits	0	20	13	13	0	52	0	10
Tangier Sound	Sharkfin Shoal	20	43	40	17	0	33	0	0
	Back Cove	0	17	27	33	7	20	3	3
	Piney Island East	7	23	17	20	13	10	7	13
	Old Woman's Leg	0	33	23	30	10	43	20	4
Pocomoke Sound	Marumsco	0	20	20	0	0	20	0	11
Patuxent River	Broome Island	0	ND	20	0	0	0	0	0
St. Mary's River	Chicken Cock	0	0	57	0	ND	0	0	0
	Pagan	0	0	0	0	ND	0	0	0
Wicomico R. (west)	Lancaster	0	0	0	0	ND	0	0	0
	Mills West	0	0	0	0	ND	0	0	0
Potomac River	Cornfield Harbor	0	0	57	0	0	37	0	0
	Ragged Point	0	0	0	0	0	0	0	0
	Lower Cedar Point	ND	ND	0	0	ND	0	0	0
Annual Means		**1.1**	**5.1**	**24.5**	**2.8**	**0.9**	**9.5**	**0.7**	**1.2**
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
Annual Means	**2.1**	**19.2**	**14.9**	**13.0**	**29.0**	**1.4**	**0.2**	**0.5**	**0.7**	**3.1**
% Frequency	**19**	**67**	**64**	**67**	**90**	**23**	**7**	**7**	**9**	**30**

Table 4 (continued).

Oyster Bar	*Haplosporidium nelsoni* Prevalence (%)	
	2008	2009
Swan Point	0	0
Hackett Point	0	0
Holland Point	0	0
Stone Rock	10	23
Flag Pond	3	13
Hog Island	7	17
Butler	7	37
Buoy Rock	0	0
Old Field	0	0
Bugby	0	0
Parsons Island	0	0
Hollicutt Noose	0	13
Bruffs Island	0	3
Turtle Back	0	0
Long Point	0	0
Cook Point	7	43
Royston	0	0
Lighthouse	0	13
Sandy Hill	0	0
Oyster Shell Point	0	0
Tilghman Wharf	0	3
Deep Neck	0	13
Double Mills	0	0
Cason	0	20
Ragged Point	0	13
Norman Addition	10	33
Goose Creek	7	27
Wilson Shoals	0	7
Georges	0	10
Holland Straits	7	33
Sharkfin Shoal	17	17
Back Cove	13	27
Piney Island East	0	33
Old Woman's Leg	0	27
Marumsco	0	17
Broome Island	0	3
Chicken Cock	13	57
Pagan	0	30
Lancaster	0	0
Mills West	0	0
Cornfield Harbor	10	30
Ragged Point	0	0
Lower Cedar Point	0	0
Annual Means	**2.6**	**13.1**
% Frequency	**30**	**60**

(Return to Text)

Table 5. Oyster population observed mortality estimates from the 43 disease monitoring bars, 1985-2009. NS=not sampled. 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	NS	NS	NA	2	9	45
	Flag Pond	10	48	30	39	37	10	35	77
Lower Bay	Hog Island	12	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	NS	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	NS	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	NS	NS	NS	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	NS	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	2009
Swan Point	13	10	11	8	10	9	33
Hackett Point	17	10	2	5	11	26	15
Holland Point	50	29	5	0	0	11	0
Stone Rock	13	5	5	20	5	25	16
Flag Pond	0	0	2	4	0	14	26
Hog Island	11	6	12	25	42	14	18
Butler	9	2	3	23	0	9	8
Buoy Rock	41	28	6	21	20	24	43
Old Field	34	10	38	12	12	17	17
Bugby	50	14	2	20	52	42	50
Parsons Island	37	11	8	35	50	34	36
Hollicutt Noose	25	3	6	48	43	27	12
Bruffs Island	50	12	5	4	12	36	33
Turtle Back	43	11	12	51	57	55	34
Long Point	54	10	10	14	38	46	17
Cook Point	21	0	0	0	12	22	7
Royston	69	14	0	0	9	5	10
Lighthouse	89	47	0	0	0	0	4
Sandy Hill	88	59	44	24	4	5	5
Oyster Shell Point	48	20	0	4	0	4	4
Tilghman Wharf	62	17	0	1	10	14	2
Deep Neck	54	14	1	3	8	9	3
Double Mills	59	23	8	0	7	4	19
Cason	57	4	0	2	4	16	17
Ragged Point	52	5	4	13	13	2	22
Norman Addition	9	14	40	5	3	2	6
Goose Creek	53	59	50	50	1	2	6
Wilson Shoals	19	27	7	21	7	30	10
Georges	4	24	44	76	16	48	10
Holland Straits	11	18	43	48	17	27	12
Sharkfin Shoal	23	32	54	22	10	3	18
Back Cove	22	23	32	12	5	8	6
Piney Island East	28	48	50	23	6	18	20
Old Woman's Leg	35	56	26	0	12	14	37
Marumsco	4	11	29	20	10	21	7
Broome Island	14	19	6	6	20	20	11
Chicken Cock	2	38	50	20	20	7	27
Pagan	7	29	66	9	4	11	29
Lancaster	35	27	14	7	31	17	24
Mills West	48	11	0	7	33	0	16
Cornfield Harbor	1	7	20	2	9	25	44
Ragged Point	76	NA	NA	NA	0	0	0
Lower Cedar Point	55	22	17	3	11	5	4
Annual Means	**35**	**20**	**17**	**16**	**15**	**17**	**17**

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland, 1985-86 through 2008-09 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	2008-09
Upper Bay	2,210	1,632	17,420	14,052	13,601	7,020
Middle Bay	750	295	17,346	17,004	3,728	1,870
Lower Bay	187	1,801	269	642	2,077	5,554
Total Bay Mainstem	*3,147*	*3,728*	*35,035*	*31,698*	*19,406*	*14.444*
Chester R.	557	3,239	4,385	7,201	4,685	4,826
Eastern Bay	5,446	16,767	49,120	36,268	8,582	7,390
Miles R.	56	353	3,660	1,133	27	910
Wye R.	0	173	122	0	0	12
Total Eastern Bay Region	*5,502*	*17,293*	*52,902*	*37,401*	*8,609*	*8,312*
Upper Choptank R.	0	78	591	11	95	15
Middle Choptank R.	30	67	967	2,510	597	597
Lower Choptank R.	0	267	1,250	3,037	2,426	2,535
Tred Avon R.	0	139	149	157	61	112
Broad Cr.	954	1,342	14,006	53,577	20,413	6,097
Harris Cr.	12	71	4,429	5,342	3,308	1,900
Total Choptank R. Region	*996*	*1,964*	*21,392*	*64,634*	*26,900*	*11,256*
Little Choptank R.	1,150	144	3,534	4,218	1,516	*1,163*
Upper Tangier Sound	7,630	13,658	2,874	3,856	4,614	12,454
Lower Tangier Sound	5,162	15,648	5,828	1,996	8,970	19,600
Honga R.	378	2,744	270	154	860	17,305
Fishing Bay	24	106	6	0	197	3,320
Nanticoke R.	57	965	387	97	97	134
Wicomico R.	0	0	0	30	11	118
Manokin R.	1,638	2,816	737	91	364	184
Annemessex R.	0	5	108	17	5	13
Pocomoke Sound	0	2,676	1,071	277	1,051	765
Total Tangier Sound Region	*14,889*	*38,618*	*11,281*	*6,518*	*16,169*	*53,893*
Patuxent R.	0	466	17,808	7,316	831	1,258
Wicomico R., St. Clement and Breton Bays	13	18	1,414	80	698	808
St. Mary's R. and Smith Cr.	0	91	1,863	2,069	1,252	1,643
Total Potomac Md. Tribs	*13*	*109*	*3,277*	*2,149*	*1,950*	*2,451*
Total Maryland (bu.)[1]	**26,000**	**72,000**	**154,000**	**165,000**	**83,000**	**101,000**

[1] Including regions not listed.

(Return to Text)

Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2008-09 seasons. Dockside value is in millions of dollars.

Season	Hand Tongs	Diver	Patent Tongs	Power Dredge	Skipjack	*Total Harvest*	*Dockside Value*
1989-90	309,723	47,861	31,307	11,424	14,007	*414,445*	*$ 9.9 M*
1990-91	219,510	74,333	105,825	4,080	14,555	*418,393*	*$ 9.4 M*
1991-92	124,038	53,232	108,123	6,344	31,165	*323,189*	*$ 6.4 M*
1992-93	71,929	24,968	18,074	1,997	8,821	*123,618*	*$ 2.6 M*
1993-94	47,309	19,589	11,644	787	133	*79,618*	*$ 1.4 M*
1994-95	99,853	29,073	31,388	1,816	2,410	*164,641*	*$ 3.2 M*
1995-96	115,677	25,657	46,040	6,347	7,630	*199,798*	*$ 3.2 M*
1996-97	130,861	16,780	15,716	8,448	6,088	*177,600*	*$ 3.8 M*
1997-98	191,079	37,477	30,340	14,937	10,543	*284,980*	*$ 5.7 M*
1998-99	294,342	58,837	36,151	25,541	8,773	*423,219*	*$ 7.8 M*
1999-2000	237,892	60,547	44,524	18,131	12,194	*380,675*	*$ 7.2 M*
2000-01	193,259	75,535	43,233	18,336	8,820	*347,968*	*$ 6.8 M*
2001-02	62,358	30,284	26,848	17,574	8,322	*148,155*	*$ 2.9 M*
2002-03	11,508	9,745	18,627	12,386	2,432	*55,840*	*$ 1.6 M*
2003-04	1,561	5,422	3,867	13,436	1,728	*26,471*	*$ 0.7 M*
2004-05	5,438	14,258	6,548	37,641	4,000	*72,218*	*$ 1.1 M*
2005-06	28,098	38,460	49,227	30,824	3,576	*154,436*	*$ 4.7 M*
2006-07	55,906	36,271	31,535	35,125	3,250	*165,059*	*$ 5.0 M*
2007-08	24,175	11,745	15,997	25,324	4,243	*82,958*	*$ 2.6 M*
2008-09	11,274	9,941	15,833	50,628	5,370	*101,141*	*$ 2.7 M*

(Return to Text)

Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2008-09 seasons. Some years may not total 100% due to incomplete data.

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

(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 (32 to 97°F) and salinities of 3 to 40 ppt, where ocean water has 35 ppt salinity. Oysters reproduce when both sexes simultaneously spawn their gametes into Chesapeake Bay waters, which occurs 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 regulate the salt content of their tissues; instead, the salt content of functioning oyster tissues conforms to the broad and variable range of salinities in oyster habitats. Thus, oyster parasites with narrow salinity requirements may be exposed to low environmental salinities when shed into the environment, as wells as while infecting oysters in low-salinity waters. Upon its death, an oyster's valves spring open passively, exposing its tissues to consumption by predators and scavengers. However, the resilient hinge ligament holds the articulated valves together for months after death. Vacant, articulated oyster shells (boxes) in our samples are interpreted to represent oysters that died during the previous year, and their relative numbers along with those of dead and moribund oysters with tissues still present (gapers), are used to estimate annual natural mortalities among oyster populations (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 as 'dermo', 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 in as few as 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 - 35°C) and salinities (10 - 30 ppt) that are typical of Chesapeake Bay waters during oyster dermo disease mortality peaks (Dungan and Hamilton 1995). Over several years of drought during the 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, at least some oysters in 93 - 100% of all regularly tested Maryland populations have been infected.

MSX disease
The high-salinity, protozoan oyster pathogen *Haplosporidium nelsoni* was first detected and described as a *multinucleated sphere unknown* (MSX) from diseased and dying Delaware Bay oysters during 1957 (Haskin et al. 1966), and was found to also infect oysters from lower Chesapeake Bay during 1959 (Andrews 1968). Although the tissue

location of early *H. nelsoni* infections in oyster gill tissues suggests waterborne transmission of infectious pathogen cells, the complete life cycle and actual infection mechanism of this parasite remain unknown. Despite many attempts by scientists, MSX disease has rarely been experimentally transmitted in the laboratory, although experimental oysters that are reared in endemic waters above 14 ppt salinity may acquire infections and die within three to five weeks. In Chesapeake Bay, MSX disease is most active at water temperatures of 5° to 20°C (Ewart and Ford 1993), *H. nelsoni* infection rates typically peak during June, and deaths from *H. nelsoni* infections peak during August. Since MSX disease is rare in oysters from waters below 9 ppt salinity, the distribution of *H. nelsoni* in Chesapeake Bay varies as salinities change with variable freshwater inflows. During 1999 - 2002, consistently low freshwater inflows raised salinities of Chesapeake Bay waters, fostering upstream range extensions by *H. nelsoni* and MSX disease during each successive drought year (Tarnowski 2003). During the subsequent years of 2003 - 2008, freshwater inflows that were consistently at- or above-average have reduced salinities of upstream Chesapeake Bay waters, and dramatically reduced the geographic range and effects of MSX disease (Tarnowski 2010).

(Return to Text)

Appendix 1 References

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APPENDIX 2
GLOSSARY

box oyster	Pairs of empty shells joined together by their hinge ligaments. These remain articulated for months after the death of an oyster, providing a durable estimator of recent oyster mortality (see gaper).
bushel	Unit of volume used to measure oyster catches. The official Maryland bushel is equal to 2,800.9 cu. in., or 1.0194 times the U.S. standard bushel (heaped) and 1.3025 times the U.S. standard bushel (level).
cultch	Hard substrate, such as oyster shells, spread on oyster grounds for the attachment of spat.
dermo disease	The oyster disease caused by the protozoan pathogen, *Perkinsus marinus.*
dredged shell	Oyster shell dredged from buried ancient (3000+ years old) shell deposits. Since 1960 this shell has been the backbone of the Maryland shell planting 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	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 older than one year old but less than 3 inches (see market oyster, spat).
spat	Oysters younger than one year old.

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