Maryland Oyster Population Status Report
2014 Fall Survey

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And the Staff of the Shellfish Division and
Cooperative Oxford Laboratory

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Cover: Commemorating the 75th anniversary of the Maryland Fall Oyster Survey (Artwork by R. Bussell)

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IN MEMORIUM

Michael J. (Mickey) Astarb (1949-2015)

"It was like a kick in the gut" commented one colleague upon learning about Mickey's death at the age of 65. We were all stunned by the news. Mickey always had a youthful aspect that belied his actual age and seemed too young to have the types of medical problems he endured, especially during his all too brief retirement.

Shipboard scientific work such as the Fall Oyster Survey is punctuated by periods of intense frenetic activity when a sample is being processed. The hectic nature of sample processing is most demanding of the data recorder, where speed and accuracy are of the utmost importance. Mickey was consummate at the task, cool and quick, a model of organization in maintaining the records. He was someone you could have confidence in to get the job done properly. Yet despite the stress of the position, he was never short with his crewmates, even when they not infrequently screwed up. His good humor and discussions on music and old movies occupied the running times between stations.

Mickey's value to the MDNR Shellfish Program went well beyond the Fall Survey. During his 26 years with Shellfish he drove dump trucks and operated heavy equipment, monitored watermen contractors during the seed and shell Repletion Program, and worked in the oyster hatchery at Deal Island. His competence and dependability at all these varied activities were hallmarks of a true professional.

His retirement was a keenly felt loss to the Shellfish crew, but we thought he would be enjoying himself spinning his discs as D.J. Boomer at various nightspots along the coast and maybe even working part-time running an Ocean City street sweeper. Unfortunately, these were not to be as serious health problems intervened.

This issue of the Fall Oyster Survey report is dedicated to Mickey.

EXECUTIVE SUMMARY

The year 2014 marked the 75th anniversary of the establishment of the Fall Oyster Survey. Since 1939, the Maryland Department of Natural Resources and its predecessor agencies have been monitoring the status of Maryland's oyster population by means of annual field surveys – one of the longest running of such programs in the world.

Integral to the Fall Oyster Survey are four indices intended to take the pulse of Maryland's oyster populations: the Spatfall Intensity Index, a measure of recruitment success and potential increase of the population obtained from a subset of 53 oyster bars; the Oyster Disease Index, which documents disease infection levels and rates as derived from a subset of 43 oyster bars; the Total Observed Mortality Index, an indicator of annual mortality rates of post-spat stage oysters calculated from the 43 oyster bar Disease Index subset; and the Biomass Index, which measures the number and weight of oysters from the 43 Disease Bar subset relative to the 1993 baseline.

The 2014 Fall Oyster Survey was conducted from 14 October to 18 December throughout the Maryland portion of the Chesapeake Bay and its tributaries, including the Potomac River. A total of 305 samples were collected from 264 oyster bars. Despite a low spatset, the results were otherwise encouraging, with sustained multi-year trends of low disease pressure, below-average mortality, and elevated biomass.

This was a poor year for recruitment throughout Maryland waters. The Spatfall Intensity Index of 11.3 spat/bushel was a little over half of the 30-year median value (19.4 spat/bu.), the lowest since 2005. This appears to be a regional phenomenon, as both Virginia and New Jersey also reported poor oyster recruitment in 2014. The highest spatfall was in the southern Eastern Shore region and upper St. Marys River. Spatfall was relatively light north of the Honga River, and no spat were found above the Bay Bridge.

Oyster diseases remained below long-term average levels, a trend that began in 2003. Dermo disease levels actually declined slightly from the previous year, although it continued to be widely distributed throughout Maryland waters. Oysters at all but one of the standard disease monitoring sites were infected with *Perkinsus marinus*, the parasite which causes dermo disease. Some oyster populations, especially on bars in the southern portion of the state, had elevated intensities that may be cause for concern in the future. The highest dermo disease levels were found in the more saline waters of the Bay and tributaries from the Little Choptank River south. MSX disease showed a moderate increase while expanding its range upbay, although levels are still below the long-term mean.

Despite a slight uptick in oyster mortalities, the Mortality Index of 11.2% remained well below the 30-year mean, continuing an 11-year trend as a consequence of the low disease pressure. This is a remarkable turnaround from 2002 when record high disease levels devastated the Maryland population, killing 58% of the oysters statewide.

The 2014 Maryland Oyster Biomass Index of 2.07 was close to the previous year's record high, which more than doubled the 2010 Index. This increase was driven by the high oyster survivorship over the past few years, particularly of the strong 2010 and 2012 year classes.

The major oyster sanctuaries were sampled during the 2014 Fall Survey. Like the rest of the region, recruitment was generally poor. On a positive note, the Florida fossil shell planted in the Harris Creek caught the greatest number of spat of any of the sampling sites within that sanctuary. Mortality rates continue to be well below the long-term average, including in the Manokin River sanctuary, where there were anecdotal reports of oysters dying (a repeat survey there in January confirmed the initial low-mortality figures; the oysters appeared to be in better condition than in October). Overall, those sanctuaries that received strong spatfalls in 2010 and 2012 continue to thrive.

With reported harvests of 416,000 bushels during the 2013-14 season, commercial oyster landings were the highest since the 1998-99 harvest season, increasing by 22% from the previous year. The dockside value of \$14.1 M was the highest since 1987. Power dredging accounted for 58% of the 2013-14 landings, primarily from the Lower Eastern Shore region. In addition, almost 20% of the total harvest was reported from Broad Creek.

PREFACE

The year 2014 marks the 75th anniversary of the Maryland Fall Oyster Survey. The Survey was born of the necessity for a standardized sampling protocol to guide management strategies for conserving and enhancing the oyster resources of the Chesapeake Bay and its tributaries. Over the decades, a succession of dedicated biologists, field technicians, and boat crews have been devoted to investigating Maryland's oyster populations, creating a long-term data set of continuing value to scientists, managers, and policy makers. To honor this legacy and commemorate the occasion, we have included an article written in 2003 on the history of oyster surveys in Maryland (Appendix 3). The piece, which was intended for the general public, reaches back into the 19th century to explore the early years of scientific surveys of Maryland's oyster populations. The story continues into the early 1900s with the landmark Yates Survey, a six-year effort to legally define the oyster grounds throughout tidewater Maryland, and concludes with the management-driven origins of today's Fall Oyster Survey, along with its modifications through the years.

The article then shifts gears, describing the typical sampling routine of the Fall Survey to give readers a flavor of what a survey day is like aboard the R/V *Miss Kay*, rather than simply looking over numbers in a dry report. Also included is an account of the 2002 Fall Survey, revisiting a year significant for the devastating impacts of the millennial epizootics from which some Maryland oyster populations have only recently begun to recover.

Lastly, a photo collection of field biologists and crews who have participated on the Fall Survey over the past two decades is included to acquaint readers with many of the faces responsible for collecting the data (Appendix 4). We hope these special sections will interest the reader and provide some sense of the people behind the effort required of the Survey.

Photo by: C. Judy

Roy Scott hanging onto dredge in rough seas while Dave White transfers sample into tub.

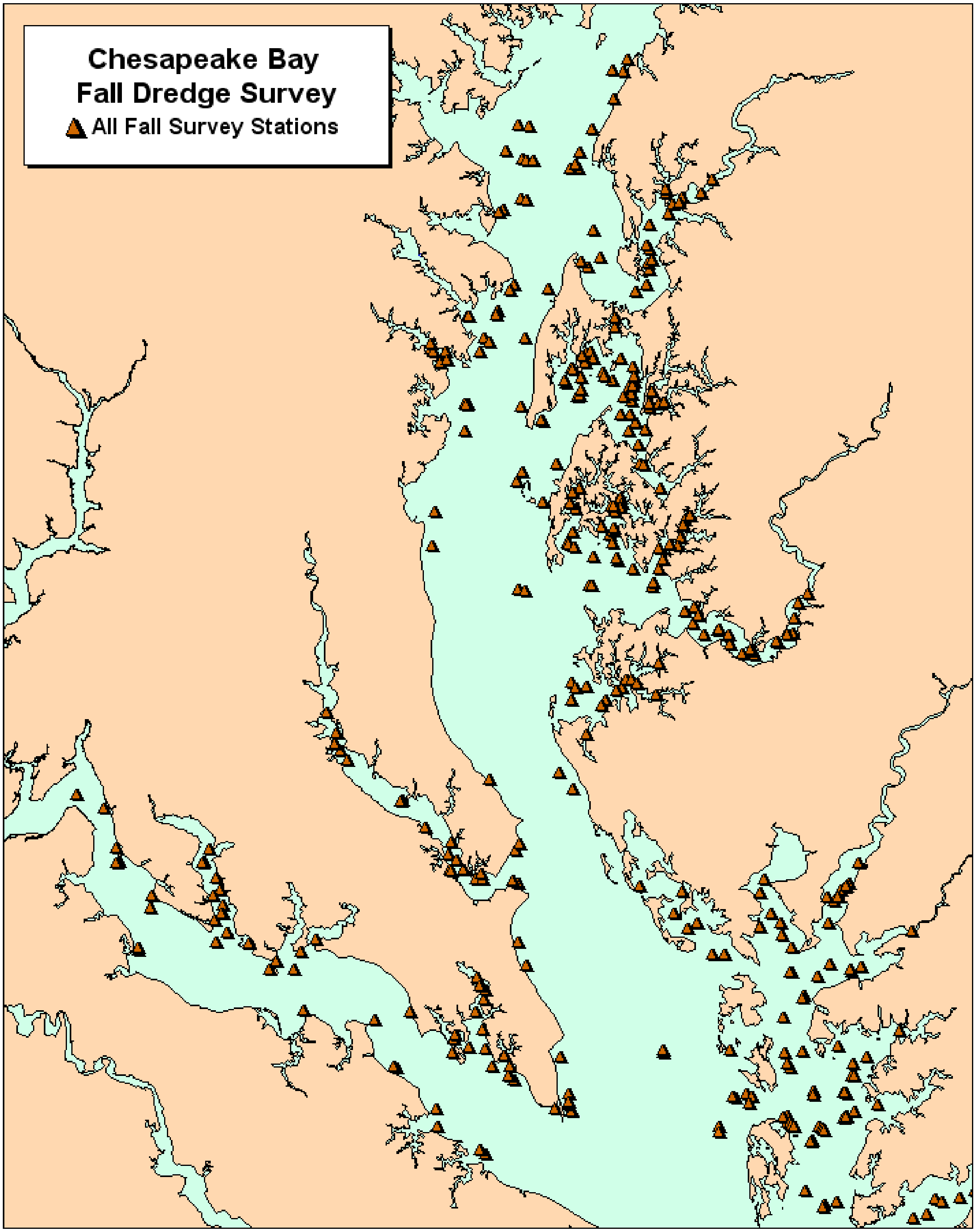

Figure 1a. 2014 Maryland Fall Oyster Survey station locations, all bar types (standard, Key, Disease, seed) included.

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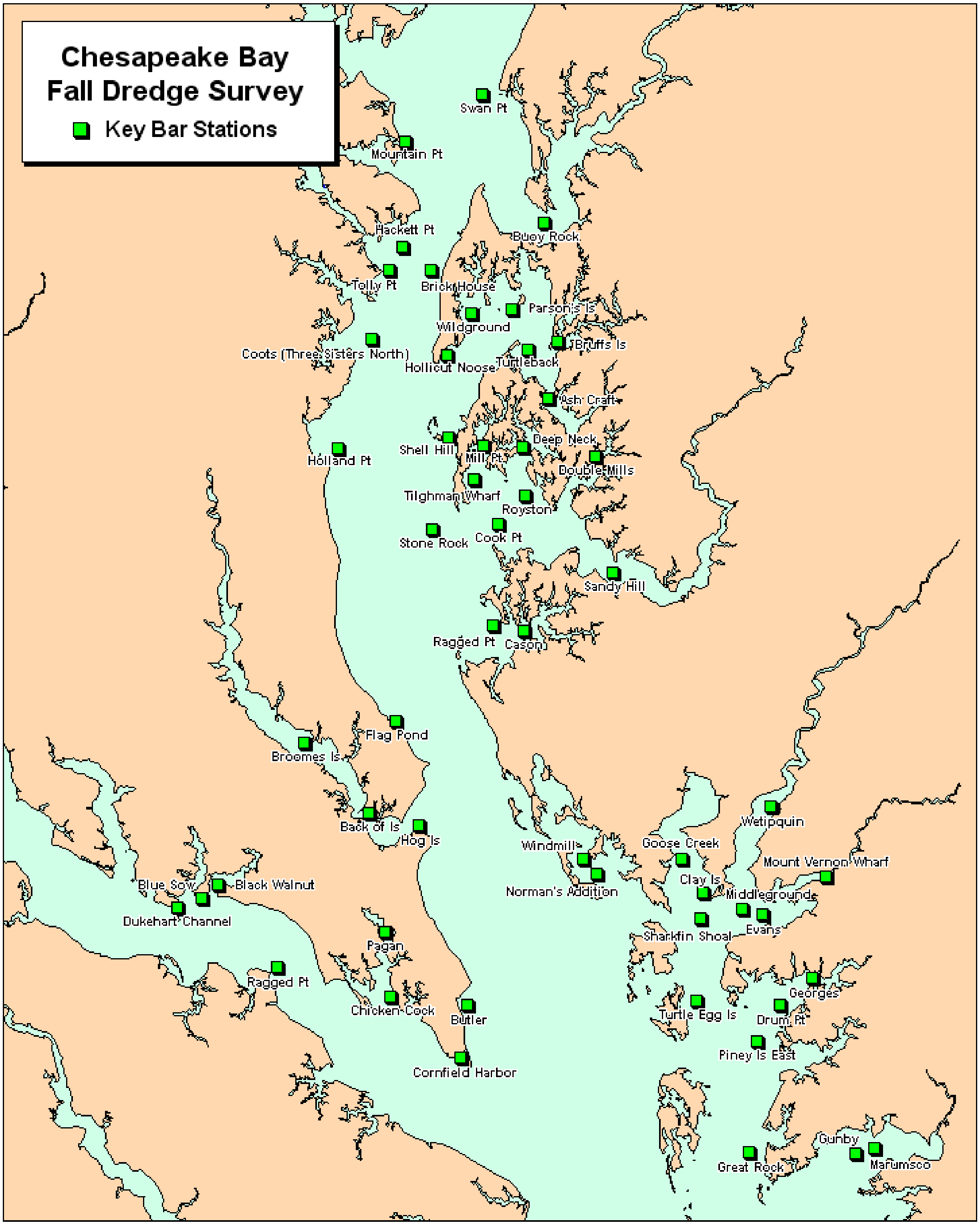

Figure 1b. Maryland Fall Oyster Survey Key Bar locations included in determining the annual Spatfall Intensity Index.

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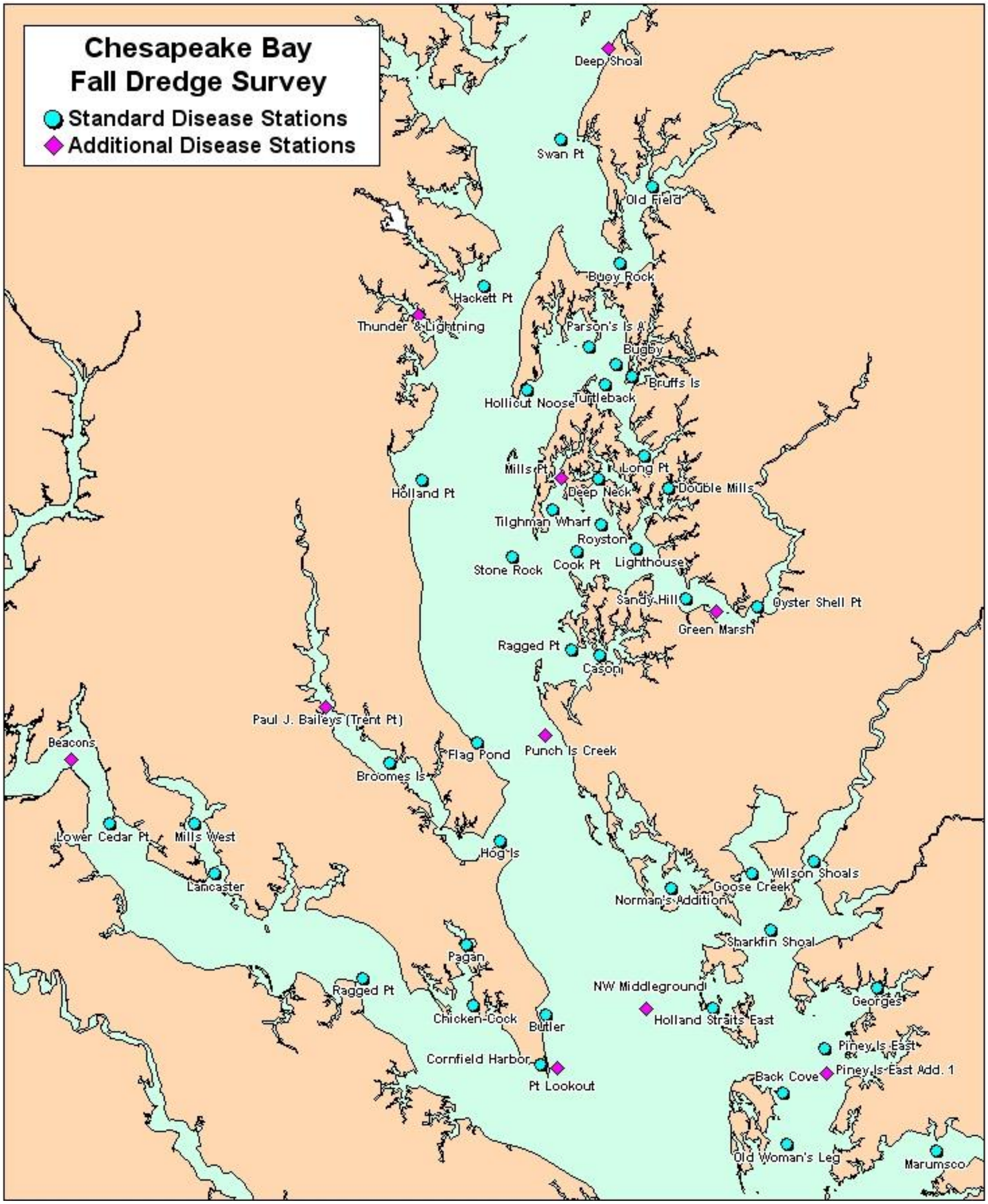

Figure 1c. Maryland Fall Oyster Survey standard Disease Bar monitoring location and additional 2014 disease sample stations.

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INTRODUCTION

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

Collaborative Studies and Outreach

Throughout the years, the Fall Survey has been a source of research opportunities for scientists within and outside of MDNR. In 2014, triploid oyster seed plantings on Ragged Point were examined for an innovative Potomac River Fisheries Commission pilot fishery program. "Spat", a documentary examining oyster issues in Maryland which included footage from the 2013 Fall Survey and interviews with Shellfish Division biologists, premiered at the Smithsonian Environmental Film Festival. In addition, reporters for two newspapers joined the Survey to observe sampling and conduct onboard interviews with Shellfish Division staff.

METHODS

Field Collection

The 2014 Annual Fall Oyster Survey was conducted by Shellfish Division staff of the Maryland Department of Natural Resources (MDNR) Fisheries Service from 14 October to 18 December. A total of 305 samples was collected during surveys on 264 natural oyster bars (Figure 1a), including Key Bar (Figure 1b) and Disease Bar (Figure 1c) sentinel sites as well as sanctuaries, contemporary seed oyster planting sites, shell planting locations, and seed production areas.

A 32-inch-wide 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. Oyster counts are reported as numbers per Maryland bushel (Appendix 2). 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 and the total volumes of dredged material per tow were noted before the subsamples were removed. For photos illustrating the process: Sample Procedures

Fall Oyster Survey Indices

Integral to the Fall Oyster Survey are four categories of indices used to assess Maryland oyster populations: spatfall, disease, mortality, and biomass. The Spatfall Intensity Index is a measure of recruitment success and potential increase of the population obtained from a subset of 53 oyster bars; it is the arithmetic mean of spat/bushel counts from the 53 Key Bars. Disease infection levels are documented by oyster disease prevalence indices (dermo and MSX disease) and the Intensity Index (dermo disease only) as derived from a subset of 43 oyster bars; these indices were established in 1990. The Total Observed Mortality Index is an indicator of annual natural mortality rates of post-spat stage oysters from the 43 oyster bar Disease Index subset, calculated for each bar as the number of dead oysters (boxes and gapers) divided by the sum of live and dead oysters, then averaging the resultant population mortality estimates from the 43 samples. Although keyed to the Disease Index subset established in 1990, the Total Observed Mortality Index also includes data from 1985-1989. The Biomass Index measures the number and weight of post-spat oysters from the 43 Disease Bar subset relative to the 1993 survey year baseline.

Oyster Disease Analyses

Representative samples of 30 oysters older than one year were taken at each of the 43 Disease Bar sites. Additional samples for disease diagnostics were collected from seed production areas, seed planting areas, and areas of special interest. Due to scarcities of oysters at four sampling sites (Old Woman's Leg, Holland Point, Parson Island, Long Point), smaller samples (n = 5, 11, 27, 29 respectively) 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 Ray's fluid thioglycollate medium (RFTM) assays of rectum tissues. Prior to 1999, less-sensitive hemolymph assays were performed. Data reported for *Haplosporidium nelsoni* (MSX disease) have been generated by 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. Infection intensity categorically ranks the relative abundance of pathogen cells in analyzed oyster tissues. Mean infection intensities are calculated for all oysters in a sample or larger group (e.g. Disease Bars set), including zeroes for uninfected oysters. A categorical infection intensity range from 0-7 is used by MDNR to rank dermo disease intensities (Calvo et al. 1996). See Gieseker (2001) for a complete description of parasite diagnostic techniques and calculations.

Biomass Index

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

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

Note that the baseline data are from the 1993 Fall Survey. In previous years the biomass index year followed the year the data were actually collected e.g. the 1994 baseline biomass index was from the 1993 Fall Survey. To avoid the confusion this caused, in this report the biomass index refers to the year the data were collected (survey year) i.e. the 2012 biomass index is derived from the 2012 Fall Survey data.

Equations

For each monitoring station:

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

For all monitoring stations:

3. (∑ dmw per1 bu station sample)/43 = annual average biomass value
4. (annual average biomass value)/(1993 average biomass value) = Biomass Index

Statistical Framework

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

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 the results to be interpreted 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 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.

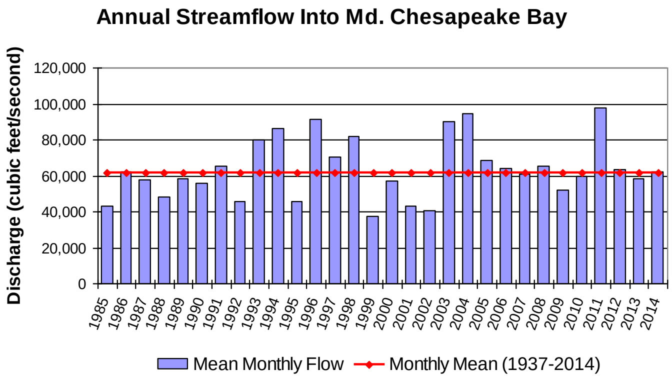

Figure 2a. Annual mean monthly freshwater flow into Chesapeake Bay, 1985-2014. USGS Section C: all Maryland tributaries and the Potomac River.

The annual streamflow into the Maryland portion of Chesapeake Bay remained at near normal levels in 2014 for the third consecutive year, following high flows during 2011 which surpassed the 75-year average by 74% (Sec. “C” in Bue 1968; USGS 2014). With the exception of 2011, annual streamflows over the past ten years were within the normal range. This is in contrast to the sometimes extreme interannual variations in streamflow witnessed during the 1990s and early 2000s, including an extended drought from 1999 to 2002 followed by near-record high flows in 2003-04 (Figure 2a).

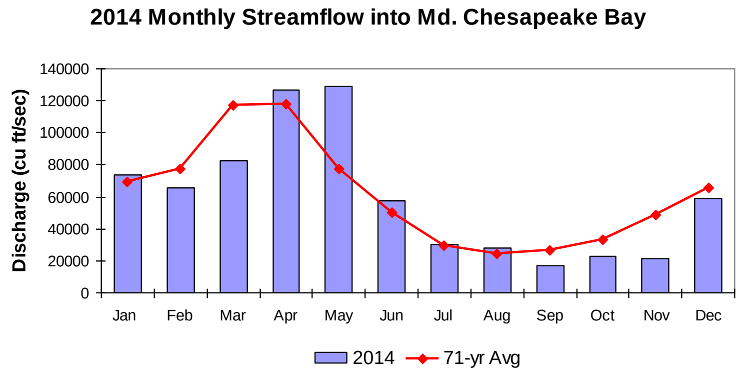

Figure 2b. Monthly average freshwater flow into Chesapeake Bay (Section C) during 2014, including the long-term monthly average.

After a relatively dry late winter, the individual monthly discharges were above average for a five month period through August; flows were well below average for the remainder of the year (Figure 2b). As a consequence, following a dry March, monthly surface salinities at a representative station in the Lower Mainstem off Point No Point were below normal from April through August (Eyes on the Bay). In comparison, salinities during 2010, a good recruitment year, were higher than average over approximately that same time period (Figure 2c).

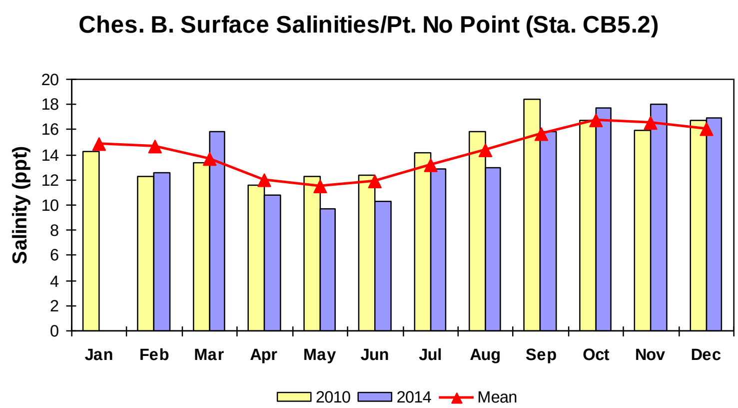

Figure 2c. Comparison between 2010 and 2014 of monthly salinities at Sta. CB5.2 in lower Chesapeake Bay off Pt. No Point.

SPATFALL INTENSITY

The 2014 Spatfall Intensity Index, a measure of recruitment success and potential increase of the population, was 11.3 spat per bushel, a sharp decline from the previous year's index of 22.7 spat/bu. and only slightly more than half of the 30-year median index of 19.4 spat/bu. Two of the last five years have had strong year classes which have boosted the population; the poor 2014 spatfall may have implications for population abundance, possibly leading to lower harvests in the upcoming years (Figure 3a).

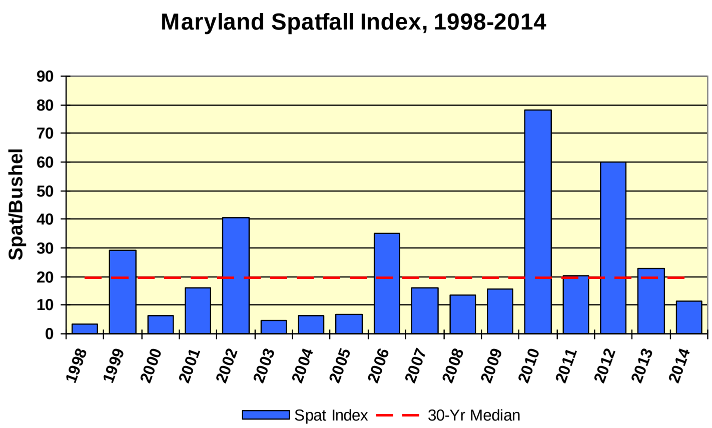

Figure 3a. Recent Maryland spatfall indices, 1998-2014.

The 2014 spat index ranked in the third lowest statistical grouping out of six for the period from 1985 to 2014 (Figure 3b).

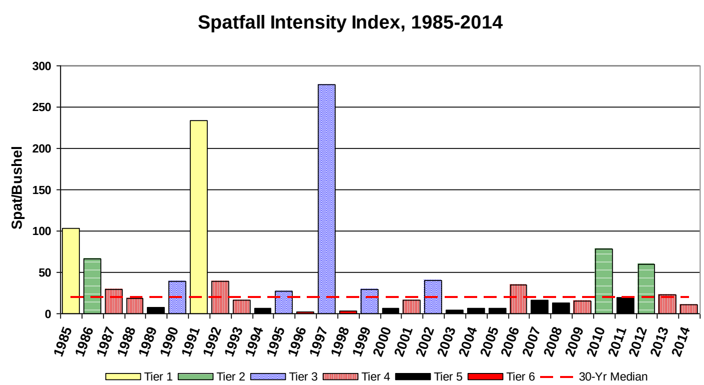

Figure 3b. Spatfall intensity (spat per bushel of cultch) on Maryland "Key Bars" for spat monitoring, including rankings of statistically similar indices.

Despite the low counts, spatfall was more widely and evenly distributed among the Key Bars in 2014 compared with the previous year. In 2014, spat were observed on 39 of the 53 Key Bars vs. 33 bars in 2013 (Table 2). Twelve bars contributed 75% of the spat index, while 22 sites were needed to reach 95% of the spat index. In contrast, only eight bars accounted for 75% of the index and 18 bars comprised 95% of the index in 2013. Three of the top-five Key Bars for spat counts in 2014 were along the Eastern Shore (Sharkfin Shoal, Deep Neck, Marumsco), although once again the highest Key Bar spat count was 64 spat/bu. on Pagan in the St. Marys River (Table 2), a tributary of the Potomac River. The Western Shore was also represented in the top-five Key Bars by Cornfield Harbor in the mouth of the Potomac.

When considering all bars surveyed in addition to the Key Bars, most of the spatfall was distributed along the Eastern Shore south from the Little Choptank River, with a scattering of spat north in the Choptank and Eastern Bay regions (Figure 4). The heaviest spatfall was in the lower portion of the Bay and adjacent tributaries, along with two Choptank River tributaries, but none of these areas reached triple digit average counts. Only three stations exceeded 100 spat/bu, the highest being 130 spat/bu on Terrapin Sands Inner bar in Tangier Sound. In comparison, the highest spat count in 2013 was 258 spat/bu, and even that was low compared to previous years. Spatfall was not detected in the Bay mainstem north of the Eastern Bay and the upper reaches of the tributaries outside of the southern part of the state.

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

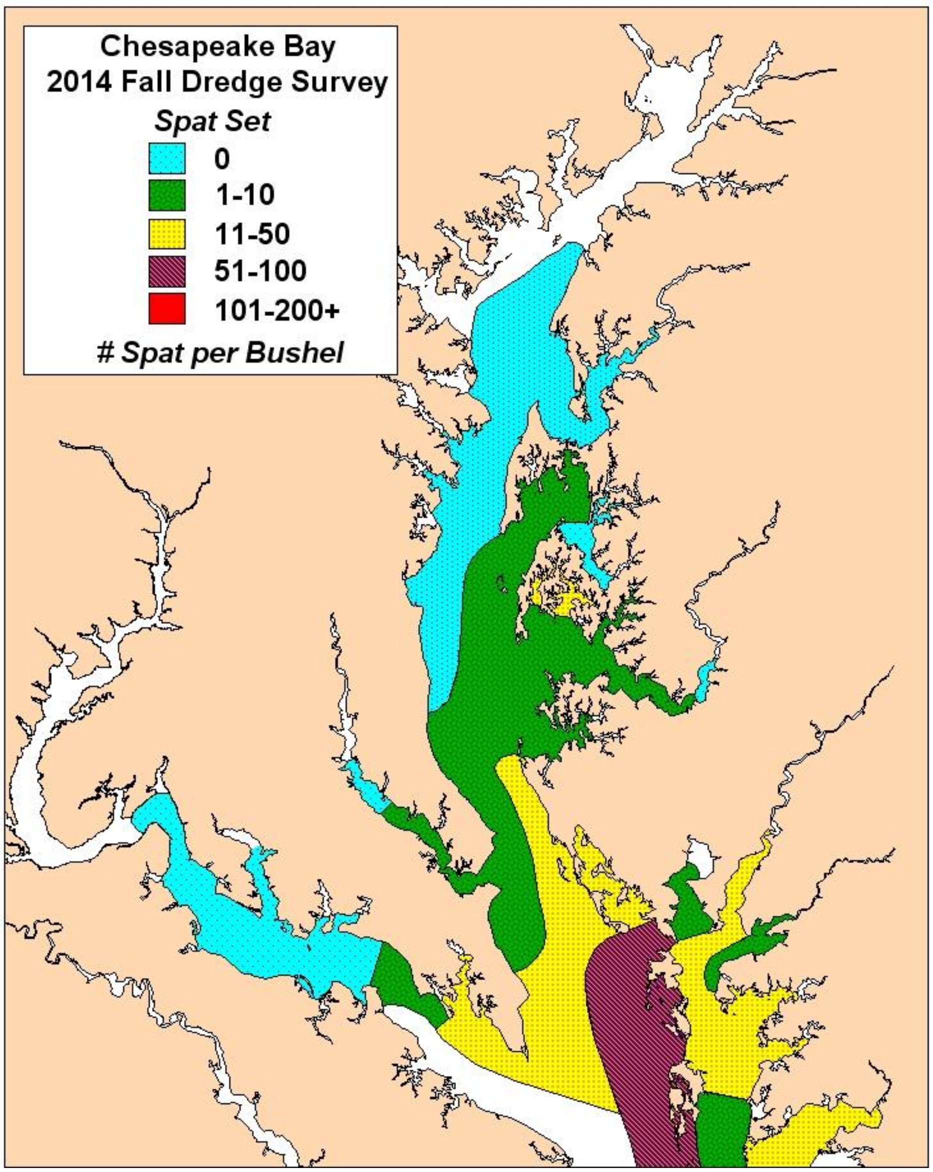

Figure 4. Oyster spatfall intensity and distribution in Maryland, 2014. Intensity ranges represent regional averages.

OYSTER DISEASES

Oyster disease levels remained below average for the eleventh year following record highs in 2002. Compared to 2013, dermo disease prevalences and intensities were largely unchanged and infections continued to be widely distributed. MSX disease showed a modest increase in mean prevalence from the previous year, and its range expanded upbay as far north as Punch Island bar just south of the Little Choptank River, albeit at low prevalences.

Dermo disease caused by the parasite *Perkinsus marinus*, infected oysters on 95% of the Disease Bars (Table 3). The overall mean infection prevalence in oysters sampled on the Disease Bars was 52%, a slight decrease from 2013 and substantially below the record-high 2002 mean prevalence of 94%, ranking 2014 in the second lowest statistical grouping for prevalence (Figure 5)**.** Eleven of the past 12 years have had dermo disease prevalences below the 25-yr average.

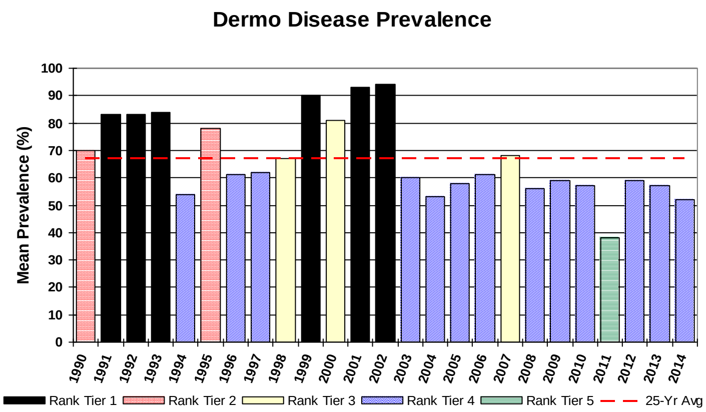

Figure 5. Annual mean *P. marinus* prevalences and statistical groupings from Maryland disease monitoring bars.

The geographic distribution of high prevalences (>60%) included the lower Bay, lower Potomac River, and the Eastern Shore from the Choptank River region southward, as well as a portion of Eastern Bay and the upper reaches of several Western Shore tributaries

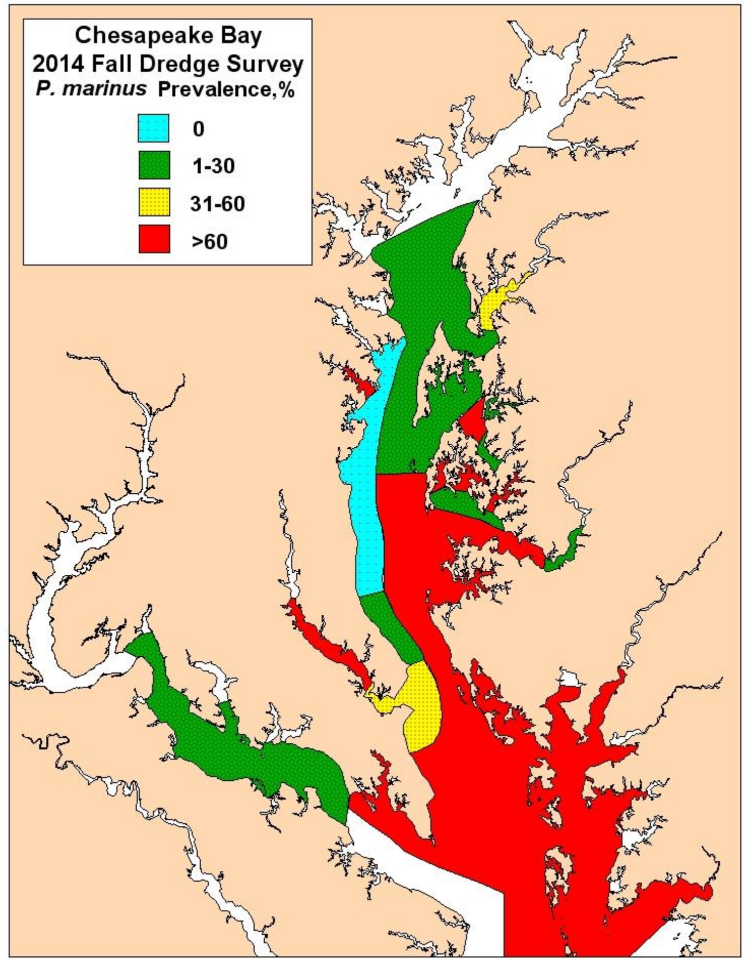

Figure 6. Geographic extent and prevalence of dermo disease in Maryland, 2013.

(Figure 6)**.** The only disease monitoring bars where dermo disease was not detected among tested oysters were Ragged Point in the Potomac River and Holland Point (n=11) on the mid-Western Shore. Outside of the regular disease monitoring sites, dermo disease was detected at extremely low levels as far north as Deep Shoal, an upper Bay bar heavily impacted by the 2011 freshets. In addition, oysters on Beacon bar in the upper reaches of the Potomac River oyster grounds have shown persistently low levels of dermo disease (3% prevalence, 0.1 intensity) over the past three years, after the disease was undetected there in 2011.

The 2014 annual mean infection intensity of 1.8 was slightly lower than in 2013 (Table 3), placing 2014 within the second lowest statistical grouping (of five tiers) for dermo disease intensity (Figure 7). This is in contrast to the record high 2001 mean intensity of 3.8. The average intensity index over the twelve years since the end of the drought is 1.8, similar to another extended period from 1994 to 1998 when annual mean infection intensities averaged 1.7. In comparison, the drought period of 1999-2002 had mean annual intensities that averaged 3.4.

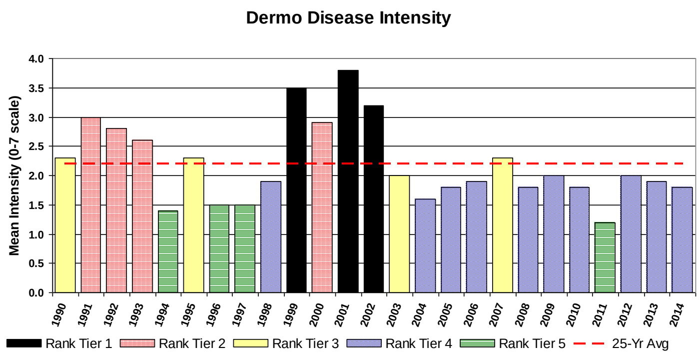

Figure 7. Annual *P. marinus* infection intensities on a scale of 0-7 in oysters from Maryland disease monitoring bars. Rankings are based on statistically similar years.

The frequency distributions of sample mean infection intensities shifted somewhat in 2014, with a reduction of the highest intensity ranges from the previous year (Figure 8).

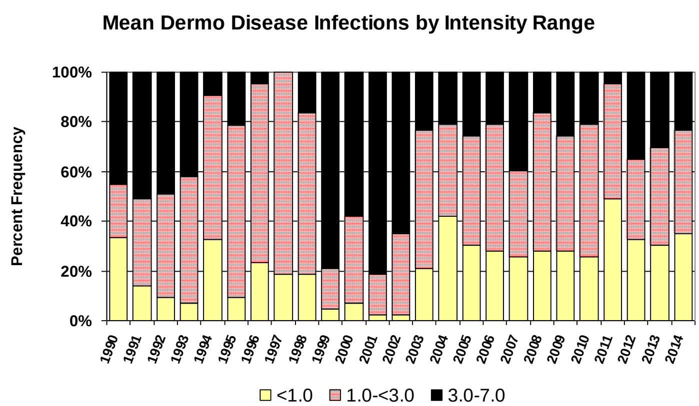

Figure 8. *Perkinsus marinus* infection intensity ranges (percent frequency by range and year) in oysters from Maryland disease monitoring bars.

In 2014, 35% of the Disease Bar samples had mean infection intensities of less than 1.0, compared with 49% in 2011, the lowest intensity year of the 25-yr time series). Only 10 bars (23%) had mean intensities of 3.0 or greater and one bar (Stone Rock) reached 4.0. In contrast, 81% of the dermo disease intensities were ≥3.0 and 51% were ≥4.0 during the peak infection intensity year of 2001. Infection intensities in individual oysters that are ≥ 5 on a 0–7 scale are considered lethal; such infection intensities were detected in 15.3% of oyster sampled in 2014, a slight increase from 2013 (14.8%). The highest mean intensities in 2014 were around the mouths of the Choptank and Potomac rivers and in the lower Eastern Shore region (Table 3).

MSX disease, resulting from the parasite *Haplosporidium nelsoni*, is another potentially devastating oyster disease. This parasite can cause rapid mortality in oysters and generally kills a wide range of year classes, including younger oysters, over a long seasonal period.

The geographic range of MSX disease expanded throughout the lower Bay in 2014, extending as far up bay as Punch Island Creek, immediately south of the Little Choptank River (Figure 9). *Haplosporidium nelsoni* was detected at nine (21%) of the Disease Bars, more than double the previous year, but at low prevalences (Table 4). In contrast, the parasite was found on 90% of the bars in 2002. For the 43 disease monitoring bars, the average percentage of oysters infected with MSX disease was 2.2%, continuing a trend of low MSX disease prevalences that began in 2010 due to lower salinities unfavorable to the parasite (Tarnowski 2011).

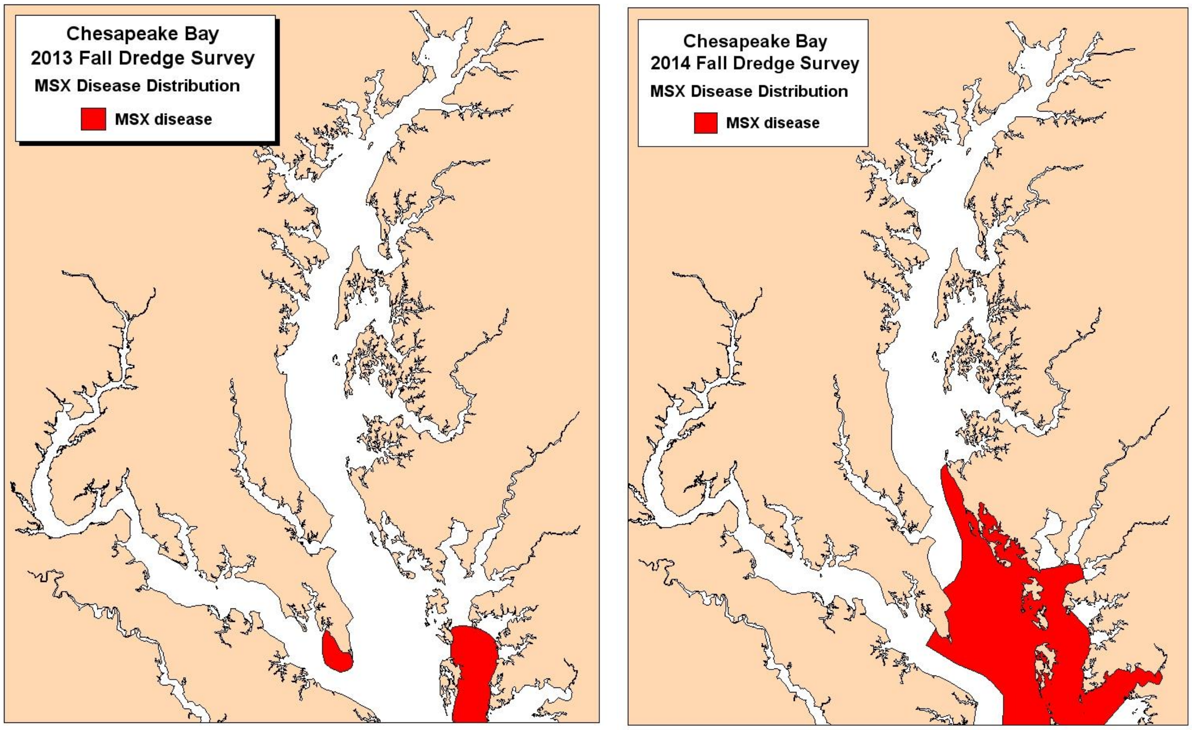

Figure 9. Geographic expansion of MSX disease in Maryland waters between 2013 and 2014.

The abatement of MSX disease in 2003-04 marked the end of the most severe *H. nelsoni* epizootic on record in Maryland waters. The 2002 epizootic set record high levels for both the frequency of affected disease monitoring bars (90%) and mean annual prevalence within the oyster populations (28%), leaving in its wake observed oyster mortalities approaching 60% (Figure 10).

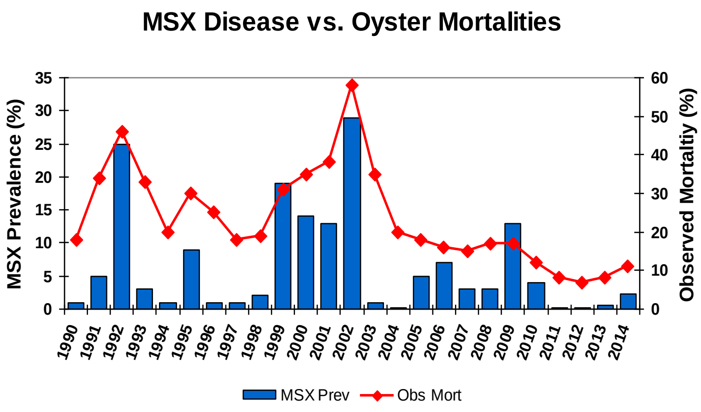

Figure 10. Percentage of Maryland oysters with MSX disease compared to annual means for observed mortalities on the disease monitoring bars from 1990-2014.

Since 1990, there have been four *H. nelsoni* epizootics: 1991-92, 1995, 1999-2002 and 2009; the first three associated with spikes in observed mortalities (Figure 10). All four of these epizootics were followed closely by periods of unusually high freshwater inputs into parts of Chesapeake Bay, which resulted in the purging of *H. nelsoni* infections from most Maryland oyster populations (Homer & Scott 2001; Tarnowski 2005, 2011).

OBSERVED MORTALITY

Although increasing to 11%, the 2014 observed mortalities remained comparable to 1985, the year before diseases seriously impacted the population. The increase was influenced by two bars with high observed mortalities but with small sample sizes (Old Woman's Leg and Holland Point). Nevertheless, this was the eleventh consecutive year that observed mortalities remained well below the 30-year average of 23.6% (Table 5). For the 43 disease monitoring bar subset, the average observed mortality of 13.5% over the last eleven years approaches the background mortality levels of 10% or less found prior to the mid-1980s disease epizootics (MDNR, unpubl. data). Despite the increase, the 2014 observed mortality on the Disease Bars was ranked in the lowest statistical grouping over the 30-year period; the past four years (out of five total) were in this lowest mortality tier (Figure 11). This is a remarkable turnaround from 2002 when record-high disease levels devastated Maryland populations, killing 58% of the oysters.

As with spatfall and oyster diseases, there was a general north-south gradient in observed mortality rates (Figure 12). Higher mortalities during 2014 generally were in southern Eastern Shore waters; the highest mortality on an individual bar with more than 50 oysters/bu was 68% on Gravelly Run in the St. Marys River.

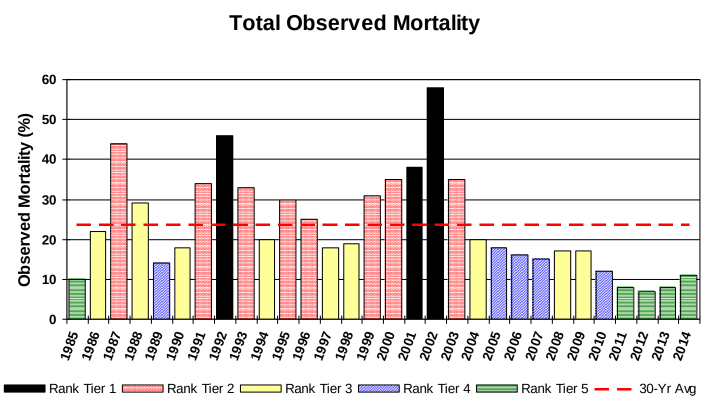

Figure 11. Mean annual observed mortality, small and market oysters combined. Ranking tiers are based on statistically similar years.

As with spatfall and oyster diseases, there was a general north-south gradient in observed mortality rates, with the notable exception of the residual boxes in the Upper Bay from the 2011 freshets (Tarnowski 2012) (Figure 12).

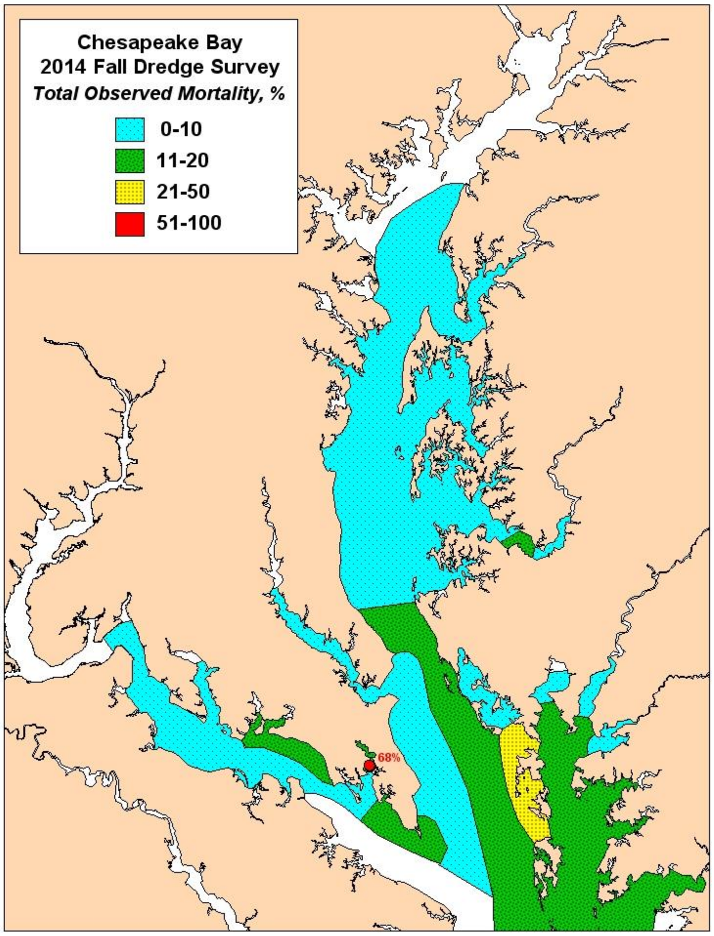

Figure 12. Geographic distribution of total observed oyster mortalities (small and market oysters) in Maryland, 2014. Mortality ranges represent regional averages.

BIOMASS INDEX

The 2014 Maryland Oyster Biomass Index of 2.07 was almost identical to 2013 (2.09), which was the highest point since the baseline index was established in 1993 (Figure 13). Since 2010, the Biomass Index has increased by 2.4 times, driven by the high oyster survivorship over the past few years and the addition of the strong 2010 and 2012 year classes.

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

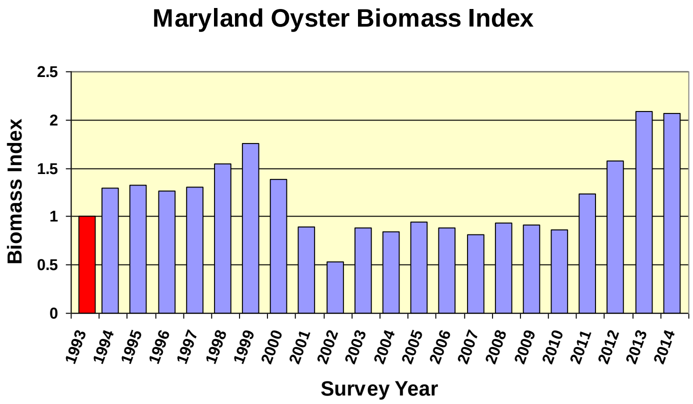

Figure 13. Maryland oyster Biomass Index. The year 1993 represents the baseline index of (1).

The oyster population had been slow to recover since its nadir in 2002, the last year of the devastating 4-yr epizootic. The Biomass Index remained below one[1] for eight consecutive years despite low disease pressure and high oyster survivorship over this period. Spatfall during this timeframe was sufficient to maintain the population at this level but not increase it. It was not until the strong recruitment event in 2010 that the population began to grow, bolstered by another good spatset in 2012.

COMMERCIAL HARVEST

With reported harvests of 416,000 bushels during the 2013-14 season, commercial oyster landings were the highest since the 1998-99 harvest season, increasing by 22% from the previous year. (Table 6, Figure 14a). The dockside value of $14.1 M was an increase of $3.2 M over the previous year and the highest since 1987 (Table 7a).

Prior to the 2012-13 season, the fishery had been slow to recover from the devastating oyster blight of 2002, with a record low of 26,000 bu. taken in 2003-03. The substantial harvest increases during the last two seasons over the average landings of the previous eight years were due to the strong 2010 year-class and subsequent good survivorship, allowing a large proportion of the cohort to attain market size. This abundance of oysters led to an increase in harvesters and fishing effort, resulting in higher landings.

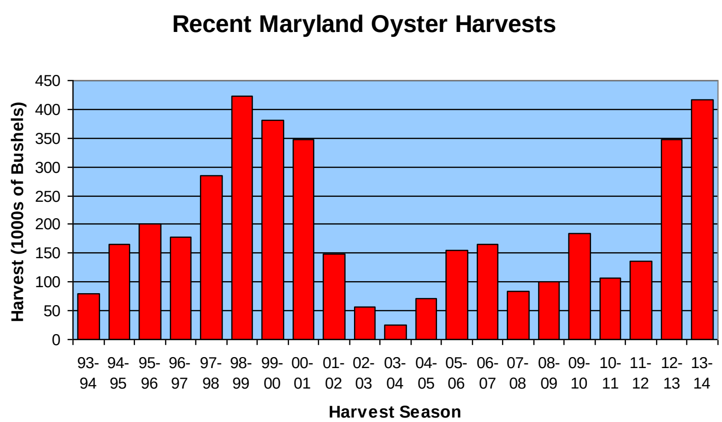

Figure 14a. Maryland oyster landings over the most recent 21 seasons.

Taken in context, the 2013-14 landings remain only a fraction of the harvests prior to the mid-1980s epizootics (Figure 14b). 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 21 years (and four of these in the most recent twelve years). Nevertheless, the recent spikes in harvests are a welcome improvement from the dismal landings of the past decade.

[1] The baseline (Biomass Index = 1) year of 1993 was chosen because it had the lowest harvest on record up to that point.

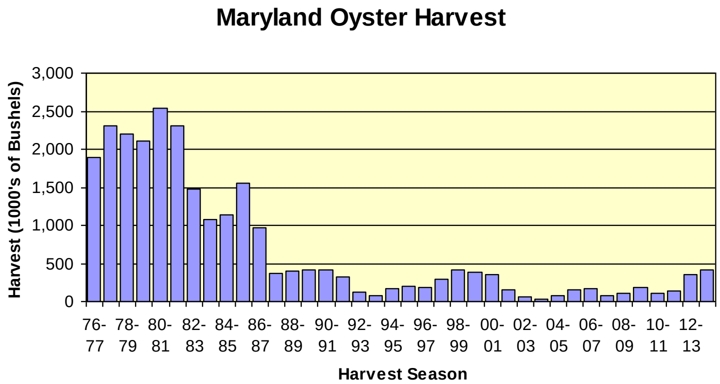

Figure 14b. Maryland seasonal oyster landings, 1976-77 to 2013-14.

The Tangier Sound/Lower Mainstem region, including the Nanticoke, Wicomico and Honga rivers, Pocomoke Sound and Fishing Bay, was again the dominant harvest area, accounting for 61% of the 2013-14 landings (Table 6). Outside of Tangier Sound proper the highest percentage of the harvests (18.5%) came from Broad Creek, a tributary of the Choptank River with a much smaller area. Almost all regions experienced harvest increases of varying degrees, with the notable exception of the St. Marys River, which declined by 30.3%. The most substantial changes in landings between the 2012-13 and 2013-14 seasons in Maryland were:

Tangier Sound	+ 24,200 bu	(+31%)
Fishing Bay	+ 10,900 bu	(+21%)
Eastern Bay	+ 10,700 bu	(+215%)
Patuxent River	+ 6,200 bu	(+45%)
St. Marys River	- 3,436 bu	(-30%)

The combined harvests in the Tangier Sound region increased by 42,483 bu. or 12.6%. In contrast, the total landings from the upper Bay and Chester River, which in some years accounted for over half of Maryland's total landings, was a mere 480 bu. (Table 6).

For the sixth consecutive season, power dredging was the predominant method of harvesting, accounting for 58% of the total landings, a slight decline from the previous year (Table 7b). This activity was mainly in the Tangier Sound region. Hand tonging remained at 16% of the total harvests, primarily from Broad Creek, though still well below 74% of the landings during the 1996-97 season. Patent tonging showed a modest increase to 18% of the total, while sail dredging and diving trailed with single-digit percentages.

OYSTER SANCTUARIES

A total of 89 oyster bars within 33 sanctuaries were sampled during 2014 the Fall Survey (Table 8). Like the rest of the region, recruitment was generally poor. On a positive note, the Florida fossil shell planted in the Harris Creek caught the greatest number of spat (76 spat/bu) of any of the sampling sites within that sanctuary, which had an overall average of 19 spat/bu. With a few exceptions, dermo disease levels in most of the sanctuaries declined somewhat from 2013 (Table 3). Of the 14 Disease Bars within oyster sanctuaries, dermo disease prevalences declined at 11 bars; intensities dropped at 10 bars while two bars were unchanged. MSX disease was detected at only one of the sanctuary sites, Piney Island East Addition in Tangier Sound (17% prevalence), which is not a standard Disease Bar. Mortality rates continue to be well below the long-term average, including in the Manokin River sanctuary, where there were anecdotal reports of many oysters dying. A repeat survey there in January found an average observed mortality of 10.3%, corroborating the original low-mortality estimate of 12.1%, and the oysters appeared to be in better condition than in October. Overall, oysters in sanctuaries that received strong spatfalls in 2010 and 2012 - including Harris Creek, Little Choptank, Manokin, and St. Marys - continued to thrive.

DISCUSSION

Implications of the Recent Poor Oyster Recruitment for Future Harvests

Ever since people have been observing oysters, it has been recognized that good spatsets and survivorship are needed for future bountiful harvests. This relationship was again demonstrated by the strong recruitment year of 2010, which, coupled with subsequent improved survivorship, above average growth rates, and elevated market prices, have led to the highest landings in fifteen years with a dockside value of $14.1 million for the 2013-14 season. The 2010 cohort was bolstered by another successful year class in 2012 which has not yet fully entered into the fishery. The 2012 cohort is expected to carry harvests through the next couple of years, barring a significant mortality event. Consequently, during the past four years the number of surcharges paid by watermen who wished to harvest oysters has nearly doubled to over 1,100.

The recruitment/harvest relationship is dependent on good survivorship of spat to market size. Beginning in the 1980s, disease epizootics disrupted this relationship by killing oysters before they could reach market (Krantz 1996). For example, the exceptional 1997 cohort was just entering the fishery when a four-year epizootic, the worst on record, struck Maryland's oyster populations. By 2002, almost 60% of the oysters throughout state waters were dead and landings plummeted.

Market forces and regulatory changes can also affect landings and their relationship with spatset. Despite a decrease in recruitment during the 1970s, oyster harvests actually increased, driven by higher demand and prices. This was a result of severe oyster losses to disease in Virginia and a change in law to permit Maryland watermen to fish in any county rather than just their county of residence, resulting in localized overexploitation of the resource as boats converged on a confined area from around the Bay (Krantz 1996). In recent years reduced production from the Gulf Coast states has placed a premium on Maryland oysters, leading to an increase in the number of watermen participating in the fishery and greater fishing pressure. The spike in harvests during the 2012-13 season was so abrupt that dealers could not handle the volume, resulting in industry imposed restrictions on harvesting days from five to three days a week (F. Marenghi, MDNR, pers. comm.).

The high spat-production years of 2010/2012 have been followed by two successive years of mediocre to low recruitment. This is characteristic of Maryland oyster populations, where above-median recruitment can be expected roughly once every four years. Potential factors influencing the highly variable and generally poor recruitment in Maryland were discussed in Tarnowski (2010a,b). Spat set was particularly poor in 2014, with the Spat Index at slightly over half of the 30-year median.

Past experience has proven that without successive spatsets, harvests will decline after a strong year class has played out, as evidenced by the strong recruitment years of 2002 and 2006. As a consequence of a spat set in 2002 that was double the long-term median, harvests had a slight uptick two years later, followed by a sharp increase in the 2005-06 and 2006-07 seasons. During this period, however, recruitment was well below the median. Thus, these elevated harvests were sustained by the 2002 year class for only two years before crashing in 2007-08.

Meanwhile, most of the 2006 year class reached market size in 2009, resulting in another spike in landings. However, this lasted for only one season before a sharp decline occurred in 2010-11 for lack of oysters due to depressed recruitment from 2007 to 2009.

A similar pattern is developing for the current period. A dominant recruitment event in 2010 was followed by steep increases in landings two to three years later (this year class seemed to be faster growing than usual, so began entering the fishery in larger numbers a full season earlier than expected). In this case, however, another strong year class followed in 2012. If natural mortalities remain low, the fishery should be sustained through the 2015-16 season, after which it can be expected to seriously decline due to the poor recruitment years of 2013-14, especially if the elevated fishing pressure of the past couple of years continues.

To reduce the severity of the next crash, the 2012 year class should be conserved to extend its harvest for at least another season. With the collaboration of the industry, this could be accomplished by reducing the fishing effort during the 2015-16 season using various measures such as a cap on licenses/surcharges, a reduction in the daily harvest limit and/or permitted times, and the introduction of areal management schemes such as rotational harvests.

Even with such conservation actions, the harvests should be expected to fall somewhat, then precipitously by the 2017-18 season. Should a strong year class occur in 2015, it would start entering the fishery that season, ameliorating the downslide, but recruitment levels won't be known until the 2015 Fall Survey. However, in anticipation of a decline, harvest restraints applied now would help to bridge a projected harvest gap between the 2012 year class and the next dominant recruitment event.

A key role of the Fall Survey and reports such as this is to gather and disseminate data about Maryland's oyster populations for informed and proactive management decisions. Based on the findings from the 2014 Survey, the Shellfish Division urges discussion and action on this important issue facing the harvestable stocks and the oyster industry.

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TABLES

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

Physical Parameters

-Latitude and longitude (deg., min., decmin.)

-Depth (ft.)

-Temperature (°C; surface at all stations, 1 ft. above bottom at Key & Disease Bars)

-Salinity (ppt; surface at all stations, 1 ft. above bottom at Key & Disease Bars)

-Tow distance (ft.) (2005-present)

Biological Parameters

-Total volume of material in dredge (Md. bu.) (2005-present)

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

-Stage of oyster boxes (recent, old)

-Observed (estimated) average and range of shell heights of live and dead oysters by age/size classes (mm)

-Shell heights of oysters grouped into 5-mm intervals (Disease Bars, 1990-2009) or 1-mm intervals (Disease Bars and other locations totaling about 30% of all surveyed bars, 2010-present)

-Oyster condition index and meat quality

-Type and relative index of fouling and other associated organisms

-Type of sample and year of activity (e.g. 1997 seed planting, natural oyster bar, 1990 fresh shell planting, etc.)

(Return to Text)

Table 2. Spatfall intensity (spat per bushel of cultch) from the 53 “Key” spat monitoring bars, 1985-2014.

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 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)							
	1991	1992	1993	1994	1995	1996	1997	1998
Mountain Point	0	0	3	0	0	0	1	0
Swan Point	1	0	3	0	0	0	0	0
Brick House	0	0	0	0	5	0	0	0
Hackett Point	0	0	0	0	0	0	0	0
Tolly Point	0	0	0	0	0	0	0	0
Three Sisters	0	0	0	0	0	0	0	0
Holland Point	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 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)							
	1999	2000	2001	2002	2003	2004	2005	2006
Mountain Point	0	0	0	1	0	0	0	0
Swan Point	0	0	0	0	0	0	0	0
Brick House	1	1	3	97	0	0	0	0
Hackett Point	0	1	0	13	0	0	0	0
Tolly Point	2	2	1	10	0	0	0	0
Three Sisters	0	0	1	0	0	0	0	0
Holland Point	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 - Spat (continued).

Oyster Bar	Spatfall Intensity (Number per Bushel)							
	2007	2008	2009	2010	2011	2012	2013	2014
Mountain Point	0	0	0	0	0	0	0	0
Swan Point	0	0	0	0	0	1	0	0
Brick House	0	0	6	4	1	7	0	0
Hackett Point	0	0	0	5	0	0	0	1
Tolly Point	0	0	0	2	0	1	0	0
Three Sisters	0	0	0	3	0	0	0	0
Holland Point	0	0	0	1	0	0	0	0
Stone Rock	0	1	4	22	1	46	2	1
Flag Pond	0	0	0	15	4	8	2	6
Hog Island	1	1	4	4	8	42	11	3
Butler	1	8	1	15	3	7	0	14
Buoy Rock	0	0	0	3	0	1	0	0
Parsons Island	0	0	8	2	0	13	0	1
Wild Ground	0	1	1	3	0	7	0	2
Hollicutt Noose	0	0	0	5	0	8	0	0
Bruffs Island	0	0	0	3	0	18	0	0
Ash Craft	0	0	2	39	0	1	3	0
Turtle Back	0	0	13	13	0	16	1	1
Shell Hill	0	0	0	1	0	4	0	0
Sandy Hill	3	1	5	5	0	6	1	1
Royston	2	5	20	27	0	46	9	19
Cook Point	1	10	18	37	2	41	6	1
Eagle Pt./Mill Pt.	0	2	17	44	0	29	4	1
Tilghman Wharf	0	6	15	72	0	183	20	46
Deep Neck	1	23	100	144	1	331	14	9
Double Mills	1	3	11	4	0	5	2	1
Ragged Point	0	2	12	33	0	14	5	2
Cason	0	13	9	50	0	65	14	4
Windmill	4	79	7	85	12	88	114	19
Norman Addition	0	102	6	155	27	138	145	38
Goose Creek	0	35	20	75	83	98	128	8
Clay Island	1	94	29	342	26	103	56	6
Wetipquin	0	2	2	8	4	8	5	22
Middleground	0	21	6	92	23	78	59	7
Evans	0	14	9	27	10	98	3	1
Mt. Vernon Wharf	0	0	8	2	4	16	0	9
Georges	5	28	22	753	243	133	117	35
Drum Point	56	124	34	524	248	219	92	58
Sharkfin Shoal	1	16	14	169	23	65	46	24
Turtle Egg Island	7	32	17	202	23	153	47	24
Piney Island East	44	23	0	160	109	199	6	14
Great Rock	64	38	5	12	5	111	0	2
Gunby	4	5	24	317	25	251	20	43
Marumsco	14	12	24	261	44	81	43	19
Broome Island	0	3	5	52	2	8	4	2
Back of Island	2	7	8	47	7	70	6	3
Chicken Cock	9	1	16	37	11	27	15	38
Pagan	616	0	321	227	110	325	196	64
Black Walnut	0	0	0	1	0	0	0	0
Blue Sow	0	0	3	0	0	0	0	0
Dukehart Channel	0	0	1	0	0	1	0	0
Ragged Point	2	1	2	0	1	0	0	2
Cornfield Harbor	7	1	1	28	3	7	7	46
Spat Index	**15.9**	**13.5**	**15.7**	**78.0**	**20.1**	**59.9**	**22.7**	**11.3**

(Return to Text)

Table 3. *Perkinsus marinus* prevalence and intensity (scale of 0-7) in oysters from the 43 disease monitoring bars, 1990-2014. NA = insufficient quantity of oysters for analytical sample. (S) = bar within an oyster sanctuary.

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

Table 3 - Dermo (continued).

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

Table 3 - Dermo (continued).

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

Table 3 - Dermo (continued).

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

Table 3 - Dermo (continued).

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

(Return to Text)

Table 4. Prevalence of *Haplosporidium nelsoni* in oysters from the 43 disease monitoring bars, 1990-2014. NA=insufficient quantity of oysters for analytical sample. ND= sample collected but diagnostics not performed; prevalence assumed to be 0. (S) = bar within an oyster sanctuary.

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

Table 4 – MSX (continued).

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

Table 4 - MSX (continued).

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

(Return to Text)

Table 5. Oyster population mortality estimates from the 43 disease monitoring bars, 1985-2014. NA=unable to obtain a sufficient sample size. (S) = bar within an oyster sanctuary.

Region	Oyster Bar	Total Observed Mortality (%)							
		1985	1986	1987	1988	1989	1990	1991	1992
Upper Bay	Swan Point	14	1	2	1	9	4	4	3
Middle Bay	Hackett Point	7	0	10	9	5	2	2	12
	Holland Point (S)	4	21	19	3	19	3	14	45
	Stone Rock	6	NA	NA	NA	NA	2	9	45
	Flag Pond (S)	NA	48	30	39	37	10	35	77
Lower Bay	Hog Island	NA	26	47	25	6	19	73	85
	Butler	NA	23	84	15	7	30	58	84
Chester River	Buoy Rock (S)	10	0	0	1	10	5	11	16
	Old Field (S)	8	3	3	4	2	7	3	9
Eastern Bay	Bugby	8	25	46	33	25	39	53	18
	Parsons Island	19	1	26	13	2	7	43	27
	Hollicutt Noose	2	32	42	25	14	1	7	9
Wye River	Bruffs Island (S)	2	1	45	12	9	12	50	77
Miles River	Turtle Back	NA	1	19	27	15	27	51	23
	Long Point (S)	17	8	23	8	12	11	53	73
Choptank River	Cook Point (S)	40	20	45	63	6	11	2	88
	Royston	4	21	19	11	14	14	33	43
	Lighthouse	3	14	59	14	8	8	45	52
	Sandy Hill (S)	12	6	29	34	7	11	75	48
	Oyster Shell Pt. (S)	9	0	1	2	2	3	2	19
Harris Creek	Tilghman Wharf	2	36	57	NA	20	30	34	26
Broad Creek	Deep Neck	2	25	37	32	47	66	48	40
Tred Avon River	Double Mills (S)	4	7	13	9	6	28	82	50
Little Choptank R.	Cason (S)	4	22	60	37	40	63	25	48
	Ragged Point	5	31	84	38	7	23	53	49
Honga River	Norman Addition	15	53	82	NA	11	11	48	49
Fishing Bay	Goose Creek	6	26	84	59	19	7	23	63
Nanticoke River	Wilson Shoals (S)	23	65	51	41	38	10	29	60
Manokin River	Georges (S)	5	24	84	55	23	31	50	55
Holland Straits	Holland Straits	19	51	85	90	15	27	35	71
Tangier Sound	Sharkfin Shoal	25	61	94	80	8	0	10	63
	Back Cove	NA	NA	NA	NA	NA	11	49	88
	Piney Island East	21	16	88	11	5	23	57	55
	Old Woman's Leg	4	17	79	21	8	5	50	80
Pocomoke Sound	Marumsco	3	27	77	NA	20	8	31	44
Patuxent River	Broome Island	10	29	31	6	4	24	53	70
St. Mary's River	Chicken Cock	18	43	63	43	24	27	31	51
	Pagan (S)	9	30	27	13	20	39	24	19
Wicomico R. (west)	Lancaster	13	6	4	4	6	28	20	8
	Mills West	18	0	2	1	1	2	11	9
Potomac River	Cornfield Harbor	17	59	92	51	11	16	29	77
	Ragged Point	10	14	29	79	54	63	34	63
	Lower Cedar Point	6	9	2	1	6	6	7	5
Annual Means		**10**	**22**	**44**	**29**	**14**	**18**	**34**	**46**

Table 5 - Mortality (continued).

Oyster Bar	Total Observed Mortality (%)									
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Swan Point	5	35	18	43	20	3	7	13	12	14
Hackett Point	18	30	30	16	10	26	22	13	30	60
Holland Point (S)	43	42	35	49	36	36	8	33	42	67
Stone Rock	30	29	40	25	15	33	46	66	30	86
Flag Pond (S)	43	28	24	16	13	33	50	NA	NA	23
Hog Island	76	16	45	20	16	33	67	67	14	31
Butler	66	37	63	17	20	20	48	67	32	11
Buoy Rock (S)	51	33	22	17	7	7	6	25	43	61
Old Field (S)	8	12	8	17	8	5	8	21	36	47
Bugby	29	18	18	27	15	8	5	29	48	63
Parsons Island	29	18	36	22	25	8	16	29	60	59
Hollicutt Noose	29	32	30	13	15	14	13	38	55	85
Bruffs Island (S)	47	47	33	6	6	11	16	33	44	50
Turtle Back	24	40	51	21	9	9	26	38	48	54
Long Point (S)	44	8	28	8	3	9	14	33	34	66
Cook Point (S)	63	40	22	16	11	20	35	63	28	100
Royston	37	10	17	9	9	6	32	31	51	91
Lighthouse	57	27	18	15	5	6	20	33	44	92
Sandy Hill (S)	45	36	29	23	22	4	15	27	50	77
Oyster Shell Pt. (S)	20	14	18	25	6	2	1	15	28	55
Tilghman Wharf	36	6	10	9	15	6	12	19	34	85
Deep Neck	32	1	23	14	8	13	37	23	37	85
Double Mills (S)	24	10	20	9	8	10	38	40	50	85
Cason (S)	53	6	7	12	11	18	28	32	62	98
Ragged Point	71	17	16	12	13	19	34	37	70	94
Norman Addition	51	28	39	55	31	54	35	38	29	29
Goose Creek	38	7	38	69	64	20	64	63	81	85
Wilson Shoals (S)	23	10	17	11	11	9	29	25	26	52
Georges (S)	16	0	55	33	36	12	32	60	50	44
Holland Straits	18	16	45	43	20	18	35	35	17	12
Sharkfin Shoal	16	7	66	59	47	28	62	61	39	61
Back Cove	4	6	46	33	29	50	59	20	46	38
Piney Island East	13	20	65	56	49	67	38	27	12	20
Old Woman’s Leg	15	25	63	46	33	38	42	15	53	27
Marumsco	21	8	78	53	49	26	40	22	35	45
Broome Island	53	27	8	0	13	11	44	25	59	72
Chicken Cock	33	28	15	10	7	24	82	63	28	63
Pagan (S)	17	11	9	27	15	3	14	35	51	84
Lancaster	7	4	19	25	8	8	18	48	58	52
Mills West	2	4	21	18	17	16	24	36	40	75
Cornfield Harbor	47	25	56	24	7	27	78	62	44	33
Ragged Point	28	35	8	11	4	25	10	8	33	NA
Lower Cedar Point	47	28	5	23	3	26	8	0	3	44
Annual Means	**33**	**20**	**30**	**25**	**18**	**19**	**31**	**35**	**38**	**58**

Table 5 - Mortality (continued).

Oyster Bar	Total Observed Mortality (%)									
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Swan Point	13	10	11	8	10	9	33	20	27	1
Hackett Point	17	10	2	5	11	26	15	14	0	13
Holland Point (S)	50	29	5	0	0	11	0	8	50	7
Stone Rock	13	5	5	20	5	25	16	8	2	2
Flag Pond (S)	0	0	2	4	0	14	26	20	11	0
Hog Island	11	6	12	25	42	14	18	12	8	14
Butler	9	2	3	23	0	9	8	8	12	4
Buoy Rock (S)	41	28	6	21	20	24	43	8	4	2
Old Field (S)	34	10	38	12	12	17	17	11	21	12
Bugby	50	14	2	20	52	42	50	12	4	9
Parsons Island	37	11	8	35	50	34	36	16	10	4
Hollicutt Noose	25	3	6	48	43	27	12	23	0	0
Bruffs Island (S)	50	12	5	4	12	36	33	28	0	7
Turtle Back	43	11	12	51	57	55	34	5	11	4
Long Point (S)	54	10	10	14	38	46	17	33	0	33
Cook Point (S)	21	0	0	0	12	22	7	8	6	5
Royston	69	14	0	0	9	5	10	0	1	3
Lighthouse	89	47	0	0	0	0	4	1	3	4
Sandy Hill (S)	88	59	44	24	4	5	5	0	8	6
Oyster Shell Pt. (S)	48	20	0	4	0	4	4	2	1	3
Tilghman Wharf	62	17	0	1	10	14	2	2	3	0
Deep Neck	54	14	1	3	8	9	3	6	4	3
Double Mills (S)	59	23	8	0	7	4	19	6	4	14
Cason (S)	57	4	0	2	4	16	17	33	10	13
Ragged Point	52	5	4	13	13	2	22	15	4	2
Norman Addition	9	14	40	5	3	2	6	15	9	10
Goose Creek	53	59	50	50	1	2	6	0	3	1
Wilson Shoals (S)	19	27	7	21	7	30	10	3	5	8
Georges (S)	4	24	44	76	16	48	10	12	2	11
Holland Straits	11	18	43	48	17	27	12	14	5	7
Sharkfin Shoal	23	32	54	22	10	3	18	20	12	13
Back Cove	22	23	32	12	5	8	6	15	4	10
Piney Island East	28	48	50	23	6	18	20	26	17	11
Old Woman's Leg	35	56	26	0	12	14	37	38	26	0
Marumsco	4	11	29	20	10	21	7	13	4	15
Broome Island	14	19	6	6	20	20	11	14	3	6
Chicken Cock	2	38	50	20	20	7	27	22	11	1
Pagan (S)	7	29	66	9	4	11	29	13	5	11
Lancaster	35	27	14	7	31	17	24	0	0	0
Mills West	48	11	0	7	33	0	16	10	11	12
Cornfield Harbor	1	7	20	2	9	25	44	16	9	8
Ragged Point	76	NA	NA	NA	0	0	0	0	0	10
Lower Cedar Point	55	22	17	3	11	5	4	7	14	10
Annual Means	**35**	**20**	**17**	**16**	**15**	**17**	**17**	**12**	**8**	**7**

Table 5 - Mortality (continued).

Oyster Bar	Total Observed Mortality (%)	
	2013	2014
Swan Point	4	0
Hackett Point	0	0
Holland Point (S)	12	40
Stone Rock	2	5
Flag Pond (S)	15	13
Hog Island	2	2
Butler	7	7
Buoy Rock (S)	5	9
Old Field (S)	0	3
Bugby	8	31
Parsons Island	2	4
Hollicutt Noose	1	9
Bruffs Island (S)	0	4
Turtle Back	0	8
Long Point (S)	20	0
Cook Point (S)	9	12
Royston	1	6
Lighthouse	1	1
Sandy Hill (S)	3	13
Oyster Shell Pt. (S)	2	5
Tilghman Wharf	5	1
Deep Neck	5	7
Double Mills (S)	11	12
Cason (S)	11	8
Ragged Point	15	13
Norman Addition	9	7
Goose Creek	5	15
Wilson Shoals (S)	5	4
Georges (S)	15	5
Holland Straits	9	48
Sharkfin Shoal	16	18
Back Cove	11	19
Piney Island East	7	10
Old Woman's Leg	50	75
Marumsco	13	13
Broome Island	7	8
Chicken Cock	1	7
Pagan (S)	4	13
Lancaster	13	0
Mills West	20	9
Cornfield Harbor	10	16
Ragged Point	0	0
Lower Cedar Point	0	0
Annual Means	**7.7**	**11.2**

(Return to Text)

Table 6. Regional summary of oyster harvests (bu.) in Maryland, 1985-86 through 2011-14 seasons.

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

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

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

Table 6 - Landings (continued).

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

[1] Includes harvests from unidentified regions.

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Table 7a. Bushels of oyster harvest by gear type in Maryland, 1989-90 through 2013-14 seasons. Dockside value is in millions of dollars.

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

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

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Table 7b. Percent of oyster harvest by gear type in Maryland, 1989-90 through 2013-14 seasons. Some years may not total 100% due to incomplete data.

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

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Table 8. Oyster bars within sanctuaries sampled during the 2014 Fall Survey.

Region	Oyster Sanctuary	Surveyed Bars Within Sanctuary
Upper Bay	Man O War/Gales Lump	Man O War Shoals
Middle Bay	Poplar Island	Poplar I.
	Herring Bay	Holland Pt.[1,2]
	Calvert Shore	Flag Pond[1,2]
Lower Bay	Lower Mainstem East	Northwest Middleground
	Cedar Point	Cedar Point Hollow
	Point Lookout	Pt. Lookout
Chester River	Lower Chester River	Love Pt., Strong Bay, Wickes Beach, Buoy Rock[1,2]
	Upper Chester River	Boathouse, Cliff, Drum Pt., Ebb Pt., Emory Hollow, Old Field[2], Sheep
	Chester ORA Zone A	Shippen Creek
Eastern Bay	Mill Hill	Mill Hill
	Cox Creek	Ringold Middleground
Wye River	Wye River	Bruffs I. [1,2], Mills, Race Horse, Whetstone, Wye River Middleground
Miles River	Miles River	Long Pt. [2]
Choptank River	Cook Point	Cook Pt. [1,2]
	Lower Choptank River	Chlora Pt.
	Sandy Hill	Hambrooks, Sandy Hill[1,2]
	Howell Point - Beacons	Beacons
	States Bank	Green Marsh, Shoal Creek
	Upper Choptank River	Bolingbroke Sand, The Black Buoy, Oyster Shell Pt. [2]
	Choptank ORA Zone A	Dixon, Mill Dam, Tanners Patch, Cabin Creek, Drum Pt.
Harris Creek	Harris Creek	Tilghman Wharf[1,2], Change, Mill Pt. [1], Seths Pt., Walnut, Little Neck, Rabbit I.
Tred Avon River	Tred Avon River	Pecks Pt., Mares Pt., Louis Cove, Orem, Double Mills[1,2], Maxmore Add. 1
Little Choptank River	Little Choptank River	Susquehanna, Cason[1,2], Butterpot, McKeils Pt., Grapevine, Town, Pattison
Hooper Straits	Hooper Straits	Applegarth, Lighthouse
Nanticoke River	Nanticoke River	Roaring Pt. East, Wilson Shoals[2], Bean Shoal, Cherry Tree, Cedar Shoal, Old Woman's Patch, Hickory Nut, Wetipquin[1]
Manokin River	Manokin River	Piney I. Swash, Mine Creek, Marshy I., Drum Pt. [1], Georges[1,2]
Tangier Sound	Somerset	Piney I. East Add. 1
Severn River	Severn River	Chinks Pt.
Patuxent River	Upper Patuxent	Thomas, Broad Neck, Trent Hall, Buzzard I., Holland Pt.
	Neal Addition	Neale
St. Marys River	St. Marys River	Pagan[1,2], Horseshoe
Breton Bay	Breton Bay	Black Walnut[1], Blue Sow[1]

[1] Key Spat Bar [2] Disease Bar

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APPENDIX 1

OYSTER HOST & OYSTER PATHOGENS

C. Dungan

Oysters

The eastern oyster *Crassostrea virginica* is found in waters with temperatures of -2° to 36°C (28 to 97°F) and sustained salinities of 4 to 40 ‰ (ppt) for indefinite survival, where ocean water has 35 ‰ salinity. Oysters reproduce when both sexes simultaneously spawn their gametes into Chesapeake Bay waters. Spawning occurs from May through September, and peaks during June and July. Externally fertilized eggs develop into swimming planktonic larvae that are transported by water currents for two to three weeks, while feeding on phytoplankton as they grow and develop. Mature larvae seek solid benthic substrates, preferably oyster shells (valves), to which they attach as they metamorphose to become sessile juvenile oysters. Unlike fishes and other vertebrates, oysters do not regulate the salt content of their tissues; instead, the salt content of 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 environmental waters, as wells as while infecting oysters in low-salinity waters. After death, an oyster's valves spring open passively, exposing its tissues to 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 proportions of natural mortalities among oyster populations.

Dermo disease

Although the protozoan parasite that causes dermo disease is now known as *Perkinsus marinus*, it was first described as *Dermocystidium marinum* in Gulf of Mexico oysters (Mackin, Owen, & Collier 1950), and its name was colloquially abbreviated as 'dermo'. Almost immediately, dermo disease was also reported in Chesapeake Bay oysters (Mackin 1951). *Perkinsus marinus* is transmitted through the water to uninfected oysters in as few as three days, and such infections may prove fatal in as few as 18 days. Heavily infected oysters are emaciated, showing reduced growth and reproduction (Ray & Chandler 1955). Although *P. marinus* survives low temperatures and low salinities, its proliferation is highest in the broad range of temperatures (15 to 35°C) and salinities (10 to 30 ‰) that are typical of Chesapeake Bay waters during oyster dermo disease mortality peaks (Dungan & Hamilton 1995). Over several years of drought during the 1980s, *P. marinus* expanded its Chesapeake Bay distribution into upstream areas where it had been rare or absent (Burreson & Ragone Calvo 1996). Since 1990, at least some oysters in 93 to100% of all regularly tested Maryland populations have been infected, and mean annual prevalences for dermo disease have ranged from 38 to 94% of tested oysters.

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 also infected oysters in lower Chesapeake Bay during 1959 (Andrews 1968). Although the common location of the lightest *H. nelsoni* infections in oyster gill tissues suggests waterborne transmission of infectious pathogen cells, the complete life cycle and actual infection mechanism of this parasite remain unknown. Despite numerous experimental attempts, MSX disease has rarely been transmitted to uninfected oysters in laboratories. However, captive experimental oysters reared in enzootic waters above 14 ‰ salinity are frequently infected, and die within 3 to 6 weeks. In Chesapeake Bay, MSX disease is most active in higher salinity waters with temperatures of 5 to 20°C (Ewart & Ford 1993). MSX disease prevalences typically peak during June, and deaths from such infections peak during August. Since MSX disease is rare in oysters from waters below 9 ‰ salinity, the distribution of *H. nelsoni* in Chesapeake Bay varies as salinities change with variable freshwater inflows. During a recent 1999-2002 drought, consistently low freshwater inflows raised salinities of Chesapeake Bay waters to foster upstream range extensions by MSX disease during each successive drought year (Tarnowski 2003). The geographic range for MSX disease also expanded widely during a recent 2009 epizootic. During 2003-2008 and 2010-2012, freshwater inflows near or above historic averages, reduced salinities of upstream Chesapeake Bay waters to dramatically limit the geographic ranges and effects of MSX disease (Tarnowski 2012). Since 1990, mean annual prevalences for MSX disease have ranged between 0.1% and 28% of oysters at regular Maryland sample sites.

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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**). **Recent boxes** are those with no or little fouling or sedimentation inside the shells, generally considered to have died within the previous two to four weeks. **Old boxes** have heavier fouling or sedimentation inside the shells and the hinge ligament is generally weaker.

bushel — Unit of volume used to measure oyster catches. The official Maryland bushel is equal to 2,800.9 cu. in., or 1.0194 times the U.S. standard bushel (heaped) and 1.3025 times the U.S. standard bushel (level).

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cultch — Hard substrate, such as oyster shells, spread on oyster grounds for the attachment of spat.

dermo disease — The oyster disease caused by the protozoan pathogen *Perkinsus marinus.*

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

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

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

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

infection intensity, individual — *Perkinsus* sp. parasite burdens of individual oysters, estimated by RFTM assays and categorized on an eight-point scale. Uninfected oysters are ranked 0, heaviest infections are ranked 7, and intermediate-intensity infections are ranked 1-6. Oysters with infection intensities of 5 or greater are predicted to die imminently.

infection intensity, mean sample — Averaged categorical infection intensity for all oysters in a sample:

sum of all categorical infection intensities (0-7) ÷ number of sample oysters

Oyster populations whose samples show mean infection intensities of 3.0 or greater are predicted to experience significant near-term mortalities.

infection intensity, mean annual — Average of mean intensities for annual survey samples from constant sites:

sum of all sample mean intensities ÷ number of annual samples

intensity index, sample — Categorical infection intensities averaged only for infected oysters:

sum of individual infection intensities(1-7) ÷ number of infected oysters

intensity index, annual Categorical infection intensities averaged for all infected survey oysters:
sum of all sample intensity indices ÷ number of annual samples

market oyster An oyster measuring 3 inches or more from hinge to mouth (ventral margin).

mortality (observed), sample Percent proportion of annual, natural oyster population mortality estimated by dividing the number of dead oysters (boxes and gapers) by the sum of live and dead oysters in a sample:
100 x [number of boxes and gapers ÷
(number of boxes and gapers + number of live)]

mortality (observed), annual Percent proportion of annual, bay-wide, natural oyster mortality estimated by averaging population mortality estimates from the 43 Disease Bar (DB) samples collected during an annual survey:
sum of sample mortality estimates ÷ 43 DB samples

MSX disease The oyster disease caused by the protozoan pathogen *Haplosporidium nelsoni.*

MSX % frequency, annual Percent proportion of sampled populations infected by *H. nelsoni* (MSX):
100 x (number of sample with MSX infections ÷ total sample number)

Perkinsus marinus The protozoan oyster parasite that causes dermo disease.

prevalence, sample Percent proportion of infected oysters in a sample:
100 x (number infected ÷ number examined)

prevalence, mean annual Percent proportion of infected oysters in an annual survey:
sum of sample percent prevalences ÷ number of samples

RFTM assay Ray's fluid thioglycollate medium assay. Method for enlargement, detection, and enumeration of *Perkinsus marinus* cells in oyster tissue samples. This diagnostic assay for dermo disease has been widely used and refined for over fifty years to date.

seed oysters Young oysters produced by planting shell as a substrate for oyster larvae to settle on in historically productive areas. If the spatfall is adequate, the seed oysters are subsequently transplanted to growout (seed planting) areas, generally during the following spring.

small oyster An oyster equal to or greater than one year old but less than 3 inches (see market oyster, spat).

spat Oysters younger than one year old.

spatfall, spatset, set The process by which swimming oyster larvae attach to a hard substrate such as oyster shell. During this process the larvae undergo metamorphosis, adopting the adult form and habit.

spatfall intensity, sample site The number of spat per bushel of cultch. This is a relative measure of density used to calculate the spat index.

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

sum of Key Bar spatfall intensities ÷ number of Key Bars

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The R/V *Miss Kay* at rest at Deal Island.

APPENDIX 3

A BRIEF HISTORY of OYSTER POPULATION SURVEYS in MARYLAND INCLUDING a SUMMARY of the 2002 SURVEY RESULTS

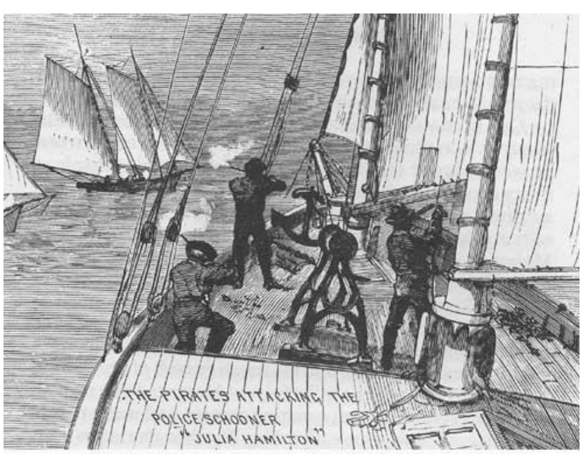
Mitchell Tarnowski
MDNR Shellfish Program
March 2003

Introduction

"How are the oysters doing?" As a shellfish biologist for the Maryland Department of Natural Resources, this is probably the most common question asked of me, particularly at the start of the oyster season in October. The topic is a great icebreaker at social gatherings (providing the subject is changed before the listener's eyes glaze over). Oysters have a mystique all their own, and not just for the watermen who depend on the bivalve for their livelihood. The general populace around the Chesapeake never seems to tire of news about oysters, as evidenced by the myriad of newspaper articles that crop up about the same time that the leaves start turning colors. Television news crews endure rough conditions on the bay for a few minutes of footage aboard the survey boat, all for the consumption of the expectant public. This fascination with oysters goes well beyond the merely gustatory, however, or their ecological role as reef builders and filter feeders; even beyond the history and tradition of oystering and the romance of earning a living on the water. At best resembling a mud-covered rock, an oyster is not warm or cuddly such as some Pooh-like creature, or aesthetically appealing like many of its molluscan relatives with their beautiful shells. Yet there is something inherently charismatic about the oyster itself that defies explanation. Perhaps this is a topic better left for poets and philosophers rather than biologists.

History of Oyster Population Surveys in Maryland

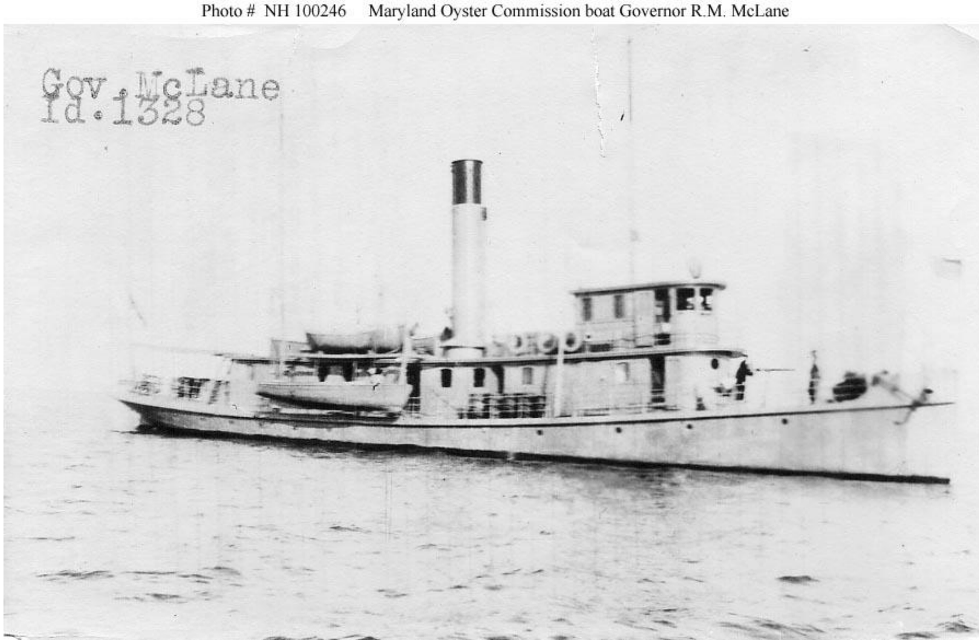
The opening question is an age old one. Aside from metaphysical inquiry or casual curiosity, however, the need for obtaining the answer has been driven by economic and (more recently) ecological considerations, stemming from the oyster's importance in commerce and in nature. Thus, the basic objective of an oyster population survey is to provide information for the conservation and enhancement of this valuable natural resource. In Maryland, the approximately 200,000 acres of natural oyster bars belong to the public domain. Because stewardship of these oyster grounds is the responsibility of the state, these surveys are inevitably undertaken with government sponsorship.



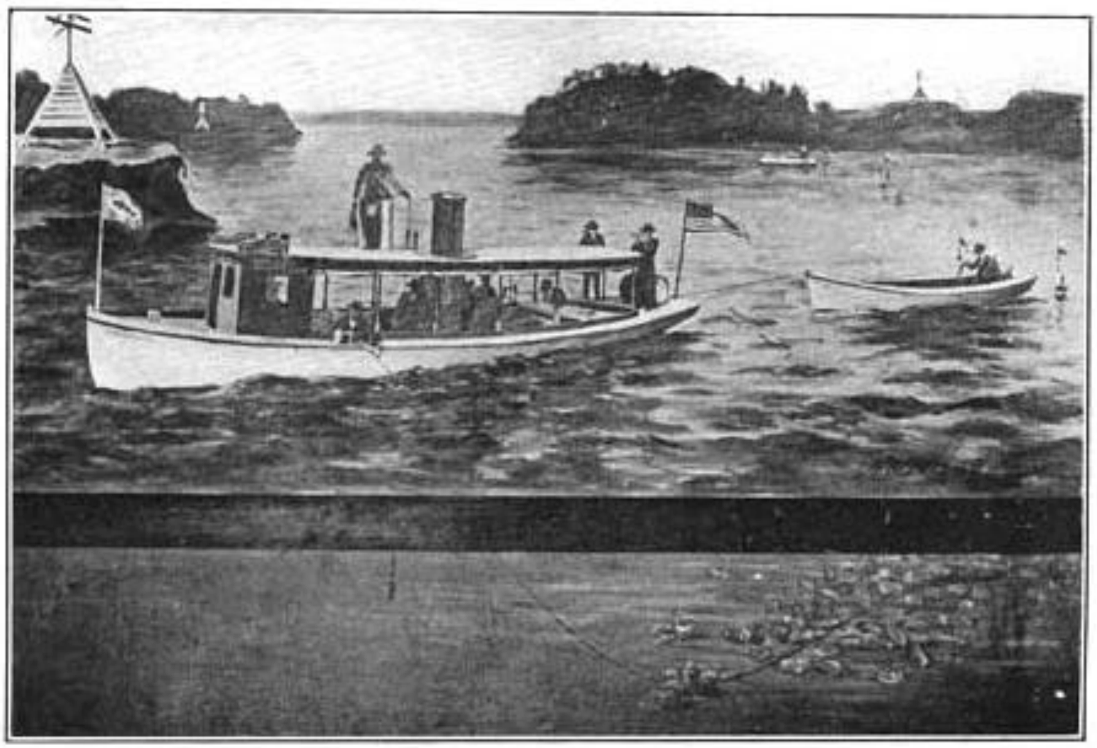
Violent encounters often occurred while dredging for oysters in the 19th century. Illustration from an 1884 edition of *Harper's Weekly.*

Scientific inquiry into the status of Maryland oyster populations has a rich history dating back 125 years, when Lt. Francis Winslow of the United States Navy braved the notoriously violent oyster dredgers of Somerset County to survey the oyster bars in Tangier Sound. This was a period when oysters were a principle source of inexpensive protein for the urban masses of the east coast, before the railroads brought in cheap western beef. In 1880, the Maryland oyster industry, valued at nearly $4 million per year (when a penny could buy a loaf of bread), supported some 24,000 workers. The tremendous demand for oysters during the mid-1870's increased harvesting pressure to the point where landings began to slip and people became concerned. Commissioned by the Maryland General Assembly, the Winslow survey was conducted in 1878-79 without incident, the Tangier Sound dredgers being merely curious and amused about the strange activities entailed in survey work. This was followed up by a Maryland-wide survey in 1882 at the behest of the newly formed Oyster Commission. Both surveys found the bars to be in a deteriorated state, mirroring the decline in harvests that prompted the surveys in the first place. Unfortunately, the release of the Commission’s report two years afterwards coincided with the all time high harvest of 15 million bushels. The survey findings, along with the warnings and recommendations that resulted from them (including instituting an annual survey), went largely ignored. The principle exception was the establishment of a minimum size limit for keeping oysters, legislated in 1890. In hindsight, 1884 was the high water mark for landings after which they began a steady decline that wasn’t stanched until some 40 years later, when harvests leveled out at about 20% of the record total.

Photo # NH 100246 Maryland Oyster Commission boat Governor R.M. McLane



During the early 1900's, the Progressive Era of American politics developed as a response to the excesses of the previous century, a sentiment which even carried down to oyster management in Maryland. The Haman Oyster Culture Law was intended to increase oyster production by encouraging private aquaculture and providing for a Shell Fish Commission to oversee the process, including a survey of the oyster bars. The primary objective of the survey was to delineate the legal boundaries of the oyster bars so as to facilitate leasing grounds outside of the bars for oyster farming. The resulting Yates survey of 1906-1912 was possibly the apotheosis of oyster assessments in terms of thoroughness and sheer magnitude of the undertaking. Great care and objectivity were required since this was a high profile, politically charged issue, given the fierce opposition to leasing in the state. Using primitive equipment, the survey painstakingly examined 350,000 acres of bay bottom and mapped 780 bars covering 216,000 acres over a six year period. The results were presented in a series of 43 charts showing the precise locations of all of the legally defined oyster bars in Maryland and the often whimsical names for them (e.g. Old Woman's Leg, Butterpot, Blue Sow, Helsinki, and Pagan), along with several accompanying reports. Unfortunately, the biological underpinnings for these boundaries have been lost to time, although abbreviated tabular summaries of the results are still available in the old reports.



SKETCH ILLUSTRATING METHODS OF CONDUCTING THE SURVEY OF THE OYSTER GROUNDS OF MARYLAND

From a 1912 report on the Yates Survey.

The Haman Oyster Culture Law ultimately failed to increase private oyster farming due to overwhelming political opposition, so the emphasis in improving oyster production had to be shifted back to the public fishery. The Maryland Conservation Commission was created in 1916 from four disparate natural resources organizations including the Shell Fish Commission and State Fisheries Force. Confronted with the daunting task of stemming a 30 year decline in oyster harvests, the Commission began looking into innovative techniques for rehabilitating depleted bars. Experimental methods included transplanting stunted "seed" oysters from overcrowded bars to growout areas and planting shell to provide clean substrate for baby oysters (spat) to attach onto and grow.

As an aside, although oyster harvests never returned to 19th century levels, they did stabilize for a period of about 60 years from the mid-1920's to the mid-1980's, after which diseases decimated the oyster populations. In effect, the efforts initiated by the Conservation Commission and that were expanded and refined through the years by its successor organizations helped to provide sustainable livelihoods for a couple of generations of watermen.

Without knowing the condition of the bars over time, there was no way of evaluating the effectiveness of the management efforts. The Winslow, Oyster Commission, and Yates surveys were essentially one time affairs; they gave a snapshot of the condition of the oyster population at a single point in time. As acknowledged in the Oyster Commission's 1884 report, to get an idea of trends in the population for management purposes, the oyster bars needed to be looked at more frequently. So it came about that a Maryland-wide dredge survey of the oyster bars was initiated by the Conservation Commission in 1919. In principle, this was the immediate precursor of today's Fall Survey.

The scientist in charge was a young biologist for the U.S. Bureau of Fisheries named Reginald Truitt. He was a native of Boxiron, Maryland on the shores of Chincoteague Bay, where his family planted oysters. Truitt attended the University of Maryland (where he played lacrosse against the legendary Jim Thorpe) and flew rickety biplanes in World War I before succumbing to the siren call of the oyster. To further his investigations on oysters, in the mid-1920's he established what became the Chesapeake Biological Laboratory (CBL) in Solomons, an institution which he headed for nearly 30 years. Truitt was to become the most respected and influential scientist of his era in the Bay region and a tireless advocate for scientific inquiry into the Chesapeake. As CBL grew, its investigations diversified to encompass a wide range of scientific topics, but Truitt maintained a passion for oysters. His research had a strong practical bent and he constantly urged the application of scientific management to the oyster resource.

The 1919 survey visited most of the Maryland oyster growing waters, including Chincoteague Bay. Towing a dredge from various Oyster Police (as the State Fishery Force was called) boats provided by the Conservation Commission, a number of oyster bar characteristics were looked at, including the abundance of market (harvestable) oysters, the condition and reproductive state of the oysters, the presence of spat, and descriptions of the bottom. In addition, water was sieved through a very fine mesh net to capture the microscopic oyster larvae and diatom abundance was noted. The results were presented in largely descriptive form with little in the way of hard numbers. A number of management recommendations emerged from the findings, the most important of which was to plant shell to revitalize depleted bars. In addition, with modifications the survey served as a template for those that followed.

The next 20 years was a period of increased conservation efforts (not only of oysters but other living resources such as finfish and blue crabs) and innovative methods for increasing oyster production, fueled in part by the synergy of a progressive Conservation Commissioner (Swepson Earle, 1924-35, who had served on the Yates survey), an energetic scientific advisor (Reginald Truitt), and a supportive governor (Albert Ritchie, 1923-35). Although the oyster surveys were sporadic in scope and remained descriptive in nature, they provided valuable information for management actions. After some initial experimental shell plantings, the practice became institutionalized through legislation in 1922, with dedicated funding provided by the state legislature in 1927 through a shell tax and work boat gasoline tax. By the mid-1930's almost one million bushels of shell per year were being planted on oyster bars.

These shell planting efforts were not always successful. Because the program was relatively new, the best locations for spatfall potential took time to work out. This was hampered by the absence of quantitative historical records from the survey work. Another hindrance was the insertion of politics into the process, resulting in planting sites being selected on hearsay which could neither be confirmed nor refuted because of the lack of records. Lastly, shell planting was done when watermen were available for labor, often months before the oyster spawning season. Consequently, the planted shells sat on the bottom getting fouled, leaving them in less than optimal condition for attachment of the baby oysters.

As these shortcomings became more apparent, in 1939 a new Conservation Commission began keeping records of the shell planting surveys, with the results recorded as spat per bushel of dredged material. This landmark action, which seems so basic to us now, precipitated a fundamental shift in oyster management in Maryland. It also marks the beginning of an unbroken record of annual oyster surveys extending 75 years to the present-day Fall Survey.

Photo by: C. Fleming

Senior Shellfish Biologist Roy Scott entering data into the shipboard computer.

Following up on the improved survey record keeping, an evaluation of shell planting practices by the recently created Board of Natural Resources led to a complete overhaul of the program in 1941. In an effort to optimize shell use, oyster bars were categorized as either: 1. seed production bars in high spat set[2] areas, 2. seed growout bars in areas of good growth but poor spat set, and 3. self-sustaining bars of moderate spat set. The plan was to plant shell for seed production, which would then be moved to growout areas or sold to private growers. Some shell was to be planted to improve the self-sustaining bars when required. In effect, this was the initiation of a large scale aquaculture operation which continues to the present day as the MDNR Oyster Repletion Program. Obviously essential to the success of seed production was to plant shell in high spat setting areas. Spat surveys and quantitative record keeping were paramount in determining these areas and evaluating the plantings.

Through the years the Fall Survey has been refined, expanded, and otherwise modified to reflect changing objectives, although its core purpose to evaluate the seed grounds remained, keeping it intimately linked to the Oyster Repletion Program. The survey variously has been conducted in the fall, winter, and spring before returning to the fall again over the past two decades.

In order to allow more meaningful comparisons of spatfall among years, a spat index was developed in 1974. Fifty-three “Key” bars distributed throughout the Bay and major tributaries and sampled annually were designated to represent the measure for spatset in Maryland. Although spat are counted on all of the Fall Survey bars, only the “Key” bars are used to derive the spat index, which is simply the arithmetic mean of the spat counts on them.

When the oyster parasite diseases MSX and Dermo first appeared in Maryland waters during the 1960's, the Survey was expanded to include the collection of oysters for disease analyses, presently conducted at the Sarbanes Cooperative Oxford Laboratory in Oxford, Maryland. Since 1990, sampling locations have been standardized into 43 “Disease” bars. Most of these are also “Key” spat index bars. With oyster disease ratcheting up in Maryland over the past 15 years, this component of the Fall Survey has been crucial to understanding the impact of the parasites on oyster populations. This is particularly important in light of the numerous oyster restoration efforts now taking place or being planned.

Present-Day Fall Survey

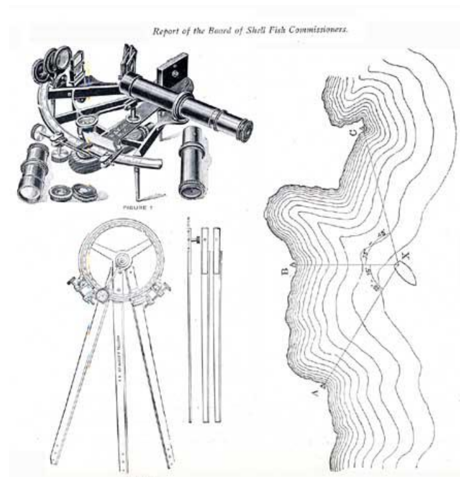
Oyster bars are sampled on the Fall Survey much the same way as in the days of Lt. Winslow, by dragging a dredge along the bottom. The standard oyster dredge consists of a metal rod frame with a chain mesh bag at the end of it. A three feet wide bar equipped with short teeth is attached to the lower leading edge of the frame for digging into the bottom and scooping up the oysters and shell. The main concession to modernity

[2]Spat set or spat fall are the terms used when the microscopic free-swimming oyster larvae settle out of the water column and cement themselves to some hard substrate such as shell to become spat.

is the use of a hydraulic winder to haul up the dredge, which when full weighs about three hundred pounds, from the bottom. In the old days four-man hand winders were used; backbreaking work that on the more unscrupulously captained dredge boats was often relegated to shanghaied crew members.

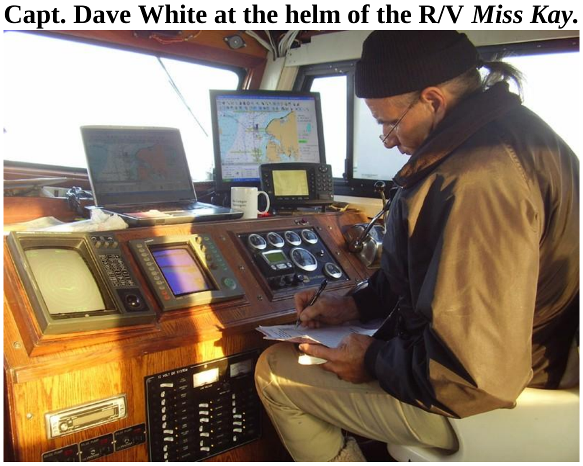
E. Ramsey manning the dredge. (Photo: C. Judy)

In contrast to the sampling gear, the navigation equipment is state of the art, which translates to accurate positioning and efficient operation. A differential geographic positioning system (dgps) unit is hooked up to a laptop computer displaying a detailed nautical chart with the boat's position superimposed on it. All of the station locations are entered into the computer, so it is an easy matter to steer toward the next bar and take a sample. Before the advent of electronic navigation, positions were fixed using a horizontally-held sextant, a very time consuming process.



Method of fixing boat's position using a sextant and three-arm protractor.

Capt. Dave White at the helm of the R/V *Miss Kay*.



A color fishfinder shows a profile of the bottom and the location of shell deposits, allowing the dredge to be dropped precisely onto the oyster bed. As is often the case, however, old habits die hard. Despite the electronic wizardry, the traditionalist of the crew still uses a hollow metal sounding pole to probe the bottom. When the pole resonates with the impact on oyster shell, he loudly proclaims in his Eastern Shore drawl, "Thar they arrr!!" So enthusiastically does he call out, in fact, that one day he startled a romantic couple, who apparently oblivious to the "Miss Kay" and her crew, were strolling hand-in-hand along the shoreline near St. Mary's College. Thinking that he was referring to them, the flustered couple took flight back to campus, much as a brace of quail being flushed out by a bird dog.


Photo by: C. Fleming
John Hess examining oysters while Robert Bussell records the findings.

After the dredge is hauled back and its contents dumped on a table, a half-bushel sample is taken and transferred to the culling table. Here the oysters are separated from the shell and other material. During this process a rapid-fire patois ensues as the cullers call out their findings to the recorder: “Market, small box recent, market gaper, SPAT”. Spat are usually called out the loudest, perhaps because they represent hope for the future, in contrast to the empty rattle of the boxes (dead oysters with the shells still attached but no meat inside). After sorting, the size range and estimated average for each size/age category (spat - under one year old, smalls - older than one year but less than 3 inches, markets - 3 inches or greater) are recorded and a few oysters are opened to examine their condition. In addition, at each station fouling and other associated organisms are noted and temperature and salinity readings are taken. All of this information is duly recorded on standardized sheets that haven’t changed in years.

During the course of a six-week odyssey around the Maryland portion of the Chesapeake, including the Potomac River and other major tributaries, nearly 300 bars are examined and close to 400 samples are taken. In addition to natural oyster bars, shell plantings for seed production and seed plantings are checked, as well as special management areas such as sanctuaries, power dredge zones, and experimental sites.

A tired crew ***(L – R: M.Tarnowski, L.Baylis, R.Bussell)***

Primarily due to improvements in navigation, the survey has been reduced to about 18 sampling days in October and November, not including travel days and bad weather days. Although the survey has been conducted in all manner of inclement weather, small-craft advisories usually mean a day in port. Even a 48 ft. boat gets to pitching and rolling pretty good in 20 knot winds, and hundreds of pounds of a fully loaded dredge swinging around in rough seas is more hazardous than a hard hat can deal with. During the 2002 survey there seemed to be more than the usual share of rough days - physically demanding trips requiring constant attention to balance, shifting obstacles, and the dredge, trying not to trip when transferring the 50 pound sample to the culling table. Those were the nights one slept the best.

So How Are The Oysters Doing?

There has been one overriding environmental factor affecting the findings of the 2002 Fall Survey: RAINFALL, or lack thereof. The Chesapeake watershed has been in the grip of a drought for four years. Consequently, Susquehanna River flows, the primary source of fresh water into the Maryland portion of the Chesapeake, have been well below the 50 year average. As a result, bay salinities have climbed. For example, in September the salinity at the Bay Bridge averaged 17 parts per thousand (ppt), which is normally found much further down bay. (Coincidentally, the skies finally opened up during the Fall Survey, requiring more than normal use of the foul weather hoods).

Elevated salinities can be both a blessing and a curse for oysters. On the one hand, reproductive effort is often benefitted, particularly in marginal salinity areas. This past year, although the spat index was slightly below average, the spatfall was considered respectable or even greatly improved in several areas. Good spat counts, in the hundreds of spat per bushel, were found in Tangier Sound and the St. Mary's River. One seed production area had counts as high as 1500-1800 spat per bushel. Perhaps even more remarkable was the presence of spat in the Head of the Bay above the Bay Bridge, a region which does not usually receive a set because the normal salinity regime is too low. Although many of the counts could be tallied on the fingers of one hand (despite the fact that one of the recorders is missing the tips of a couple of digits), just about every bar examined had spat on it. The Kent Island shore below the Bay Bridge also received a higher than normal spatfall.

Photo by: C. Judy

Oyster spat on shells planted by MDNR.

Unfortunately, other usually productive regions such as Eastern Bay and the Choptank River and its tributaries had disappointing sets, while the Little Choptank River, which was once a source of seed for planting elsewhere, was almost devoid of spat.

Another benefit to higher salinities is improved growth. Ordinarily, oysters in the low salinity reaches of the tributaries exhibit stunted growth. A good example is the oyster population on Beacon, a bar in the Potomac River above the Rt. 301 bridge. This is the upriver-most bar sampled, with few oysters inhabiting the river further upstream. Because of the depressed salinity regime, oysters there can be six or seven years old and still be sublegals (less than 3 inches in size). In contrast, the rule of thumb for oyster growth in other parts of the Bay is 1 inch per year or three years to attain market size. As a result of higher salinities, this year the market oysters on Beacons averaged an astounding 4 inches, displaying fresh growth along the bill or leading growing edge of the shell.

For areas where the salinity is normally conducive for spatfall and growth, the picture during a drought is possibly more complex. The lack of runoff from rainfall reduces nutrient input into the bay, which might mean suboptimal phytoplankton (single cell plants) concentrations for oysters to feed on. As the theory goes, with less food available during a drought oyster growth and reproduction may be actually impaired. However, this drought induced effect has yet to be confirmed.

A more ominous and well documented down side to the present environmental conditions is that the two oyster parasites which cause MSX and Dermo diseases thrive in higher salinities. That same Beacon Bar was always considered to have a “naive” population of oysters, that is, oysters that had never been exposed to disease, due to the low salinity and isolated location of the bar. Having a source of naive oysters was of great value for experimental purposes. This fall, 43% of the oysters sampled from this bar were infected with the Dermo parasite. The significance of these findings is that there is no refuge from Dermo for oysters in the Potomac River, even on bars in areas normally not conducive to disease and remote from infective sources.

Photo by: M. Homer

Carol McCollough of the Sarbanes Cooperative Oxford Laboratory processing oyster samples for disease analysis.

This is just the tip of the iceberg. Every one of the 42 Disease Bars (DB) examined had oyster populations infected with Dermo (the 43rd DB, Cook Point in the Choptank River, had its oyster population so decimated that not enough could be caught for a laboratory sample). The average infection rate or prevalence on these bars was 94%, that is, almost all of the oysters examined tested positive for the disease. The Disease Bar findings, along with the Beacon Bar results, indicate that Dermo is found on nearly every oyster bar (if not all) in the state of Maryland and most of the oysters are infected with the disease, a truly disheartening situation.

The news about MSX is equally grim. This parasite, which requires higher salinities than Dermo and therefore is normally confined to the lower bay, has been found as far upbay as Hackett Point, a bar off the mouth of the Severn River near Annapolis. Nearly 90% of the Disease Bars tested positive for MSX, the highest on record. The portion of the sampled oyster population infected with MSX was 28%.

What all this disease translates into is record high mortality levels, averaging 58% on the Disease Bars. In contrast, before Dermo became established in the mid-1980's, mortality averages ranged between 5% and 10%. The big boost this year from the 35%

mortality average of the previous three years was probably due to the spread of MSX, which can be a particularly rapid proliferating and lethal disease once the oyster is infected.

Some areas fared worse than others, especially the higher salinity tributaries. The St. Mary's River on the western shore had observed mortalities averaging 80%. Even more devastated was the Little Choptank River, a leading producer of oysters in Maryland during the late 1990's, which had an average observed mortality of 93%. The difference between the two tributaries was the good spatfall in the St. Mary's, whereas the Little Choptank has almost nothing to replace the oysters that have died, a truly worst case scenario.

Elevated salinities can also bring an increase in other pests and predators. For instance, during the spring of 2002 spat counts were taken at some experimental locations in Tangier Sound. Surprisingly, at one site 76% of the spat had recently died. A closer inspection of the still attached upper valves (shells) of the dead spat revealed that most of them had a small hole bored through them. They obviously had fallen victim to oyster drills, small snails that are notorious oyster predators. Sure enough, a few individuals of two drill species turned up in every sample, and egg cases abounded. The drills were thriving in the higher salinities of Tangier Sound with the ample supply of food provided by the previous year's spat set.

With the increase in rainfall and snowfall that the region has experienced this fall and winter, there is hope that the drought is broken and salinities will decline. What is needed for a real impact is a buildup of the snowpack in central New York and Pennsylvania, so that come the spring thaw the freshwater rush will drive down salinities. It must be remembered, however, that too much freshwater (called a freshet) can also kill oysters, with the Head of the Bay and upper bars of the Potomac (including Beacon) particularly at risk. Let's hope that's not next year's story.

A cold, wet day on the Chester River (*L – R: M. Tarnowski, E. Campbell, L. Fegley, A. Willey*)

Selected Readings

A Chronology of Factors Affecting Oyster Harvests

http://mddnr.chesapeakebay.net/mdcomfish/oyster/OYSFACT.cfm?which=oyster

More historical facts about the oyster industry in Maryland during 20th century

Maryland's Oysters: Research and Management. Victor Kennedy and Linda Breisch.

1981. Maryland Sea Grant. A highly informative though somewhat dated and often opinionated summary of oyster biology and management along with an annotated bibliography.

The Oyster Wars of Chesapeake Bay. John Wennertsen. 1981. Tidewater Publishers. A colorful history of oystering in the old days.

Most of the historical information for this article was gleaned from old government reports, supplemented by the above publications. Many of these reports can be found in university libraries and the Maryland State Archives. They include:

- Ingersoll, E. 1881. The History and Present Condition of the Fishing Industries. The Oyster-Industry. U.S. Census Bureau, 10th Census. Dept. of Interior. Washington, D.C.

-Report of the Oyster Commission of the State of Maryland. 1884.

-Stevenson, C.H. 1894. The oyster industry in Maryland. Bull. U.S. Fish Commission for 1892. pp.205-297.

-Grave, C. 1912. Fourth report of the Shell Fish Commission. Summary of the biological findings of the Yates Survey.

-Maryland Conservation Commission, Conservation Department, Board of Natural Resource. 1916-1969. Annual reports of MDNR's predecessor organizations.

-Meritt, D. 1977. Oyster Spat Set on Natural Cultch in the Maryland Portion of the Chesapeake Bay (1939-1975). Univ. Md. CEES Spec.Rept. No.7.

-Krantz, G.E. 1996. Oyster Recruitment in the Chesapeake Bay, 1939 to 1993. MDNR Fish. Srv. Spec. Publ. Oxford, Md.

The Houseboat "Oyster"- Headquarters of state and federal field parties.
From the 1912 Yates Survey report.

APPENDIX 4

FACES and PLACES

A photo collection of field biologists and crews who have participated on the Maryland Fall Oyster Survey over the past two decades.

The forerunners: from the 1912 Yates Survey report.

Fall Survey crew at Deal Island, 2012 (*L - R*: *D. Webster, Dr. M. Homer, M. Tarnowski, C. McCollough, Capt. D. White, T. Wilson, R. Bussell*)

(Return)

A Photo Collection of Fall Oyster Survey Biologists and Crew Along with Some Scenes from Around the Bay

This collection represents only a portion of the numerous individuals who have participated on the Survey aboard the R/V *Miss Kay* over the past two decades. Many were not included for lack of photographs or space, but their contributions to the field effort were and remain deeply appreciated.

1. Mickey Astarb
2. Lisa Baylis
3. Robert Bussell
4. Eric Campbell
5. Dr. Jim Wesson
6. John Collier, Capt.
7. Ellen Cosby
8. Alyssa Cranska
9. Stanley “Lee” Daniels, Capt.
10. Carla Fleming
11. John Hess
12. Dr. Mark Homer
13. Chris Judy
14. Dr. George Krantz
15. Carol McCollough
16. Maude Livings Morris
17. Gene Ramsey
18. Charles Rice
19. Steve Schneider
20. Roy Scott
21. Mitch Tarnowski
22. Lisa Warner
23. Eric Weissberger
24. Dave White, Capt.
25. Leon Williams
26. Tom Wilson, 1st Mate
27. Erik Zlokovitz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Miss Kay
Annapolis, MD
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