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Report

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Historical Overview

The Stock

The natural oyster beds of the New Jersey portion of Delaware Bay (Figure 1) have been surveyed regularly since 1953; initially in response to historically low oyster abundance (Fegley et al. 2003). Since 1998, annual stock assessments have included the participation of Rutgers University- Haskin Shellfish Research Laboratory, the NJ Dept. of Environmental Protection-Bureau of Shellfisheries, and the oyster industry. From upbay to downbay on Delaware Bay oyster beds, oysters experience increasingly higher salinity, growth rates, predation mortality, disease mortality, and generally higher recruitment. The number of beds surveyed and their groupings have changed since 1953 but as of 2007, there are 23 surveyed beds grouped into six regions designated on the basis of relative magnitude of oyster mortality and current fishery usage (Figure 1). Prior to 2007, the three beds at the upbay limit of the oyster resource (Very Low Mortality region) were not included in the survey, thus most of the long-term time series and all retrospective analyses exclude them (see Figure 2). The acreage for each region is shown in Figure 3.

The long-term time series can be divided into several periods of high or low relative abundance corresponding to periods of low or high levels of disease intensity (Figure 4a). MSX disease, caused by the parasite, *Haplosporidium nelsoni* became a significant periodic source of mortality in 1957 (Ford and Haskin 1982) but has been of little consequence following a widespread epizootic in 1986 after which resistance to it spread through much of the stock (Ford and Bushek 2012). From 1969-1985, MSX and mortality were low while oyster abundances were high. Circa-1990, Dermo disease, caused by the parasite *Perkinsus marinus* became prevalent in the Delaware Bay and has effectively doubled natural mortality rates since then (Powell et al. 2008). Throughout the time series, fishing has usually taken a small fraction of the stock compared to disease (Figure 4b). Shell planting has been an important management tool to enhance habitat and spat recruitment throughout the time series when funding was obtainable (Figures 5a and b).

Dermo disease has exerted major control on the oyster population in the Delaware Bay since 1990. Figures 6 and 7 show abundance and mortality by region for the 'Dermo era' time series. Note that the acreage of a region is not always reflected in the total oyster abundance, particularly during periods of high disease mortality. For example, in the early 1990s, the largest region, the High Mortality region (HM), experienced high Dermo mortalities because of its more saline location downbay and its oyster abundance was lower than that of two smaller regions. The three upbay regions; Very Low Mortality (VLM), Low Mortality (LM), and Medium Mortality Transplant (MMT) are managed as intermediate transplant regions, meaning that oysters are moved (transplanted) to one or more of the three downbay direct-market regions: Medium Mortality Market (MMM), Shell Rock (SR), and High Mortality (HM). Shell Rock, which otherwise would qualify as a medium-mortality bed, is separated from the medium-mortality market region due to its consistent high productivity. Until 2011, all stock status data for the medium-mortality beds were compiled with Sea Breeze assigned to the market, rather than the transplant, group. Following the 14th Stock Assessment Workshop (SAW) that reported and analyzed the 2011 season, all time series for the medium-mortality region were reconstituted so that Sea Breeze is now included in the transplant, rather than the market category (Figure 1).

The Fishery

From the 19th century to 1996, the natural oyster beds of New Jersey were used as a source of young oysters (seed) that were transplanted to private leases each spring for a period (in earliest times, months; later weeks) called 'Bay Season' (Ford 1997). From about 1953, this fishery was nominally managed by the loosely applied reference point called the '40% rule' that closed beds when the percentage of oysters in a dredge haul went down to 40% (Ford, 1997). Other factors such as spat set and economics were also considered in making management decisions (Fegley et al 2003). There were years of Bay Season closures due to MSX and Dermo mortality in the 1950's, 60's, 80's, and early 90's (Figure 8).

In response to both the increased number of Bay Season closures in the 1980s and 1990s and poor survival of oysters planted on leases, a system called the Direct Market Fishery was adopted for the natural oyster beds in 1996. This allows the industry to market oysters directly off the natural beds and avoid the high mortality rates present on the more downbay leases. Initially, the direct market harvest was based on constant market-size oyster abundance estimations (HSRL 2001) and eventually, a submarket surplus production model developed by Powell et al. (2009). Transplanting from non-marketable beds to other beds within the surveyed resource (Intermediate Transplants) was included and an area management scheme that opened and closed beds or groups of beds developed (see HSRL reports 2001 to 2005). Transplanting and area management were designed to make use of the whole resource and avoid overfishing of any region while sustaining an economically viable harvest. Three of the six regions are designated for Intermediate Transplant where an allocation of oysters from the non-marketable upbay regions is moved to the more saline regions where they quickly attain market quality and enhance the quota in the receiving region.

At the 8th SAW in 2006, the Stock Assessment Review Committee (SARC) established target and threshold abundance reference points based on the 1989-2005 time series for each survey region. Concern over potentially unrealistic submarket surplus production rates in upbay regions led to the abandonment of the original submarket surplus reference point used earlier. The 2006 SARC advised adoption of a system based on the evaluation of fishery exploitation by abundance for the time period 1996-2005 (later extended to 2006). It suggested that quotas be determined on a regional basis using exploitation rates associated with the 40th to 60th percentiles for each region. In 2004, a port-sampling program began to obtain fishery-dependent information on the size and number of oysters marketed, permitting the determination of exploitation-based estimates on spawning stock biomass as well as abundance (Powell et al. 2005). The exploitation-based reference point system stabilized year-to-year variability in the quota that was a byproduct of the more volatile submarket surplus projection and this basic scheme is still in use.

The Survey

From 1953 until 1989, the annual oyster survey was conducted from a small boat and dredge and occurred throughout a number of months in the fall, winter, and spring. Over time, grids of 0.2-min latitude X 0.2-min longitude were created for the primary beds and approximately 10% of them were sampled based on a stratified random sampling design (Fegley et al. 2003). In 1989, sampling was switched to a large traditional oyster boat, the *F/V Howard W. Sockwell,* using a commercial dredge and sampling was completed in a few days. Annual sampling now occurs during four days between late-October and mid-November with samples returned to the lab for intensive processing. Through 2004, the stock survey assessed most beds yearly although a selection of minor beds was sampled every other year. Since then, all beds have been sampled each year with the exception of Egg Island and Ledge that continue to alternate due to their consistent low abundance.

Prior to 1990, oysters were not measured but were categorized as 'spat', 'yearling', and 'oyster' based on morphology. Survey protocol updates in 1990 included measurements of yearlings and oysters permitting the calculation of biomass as well as abundance. Spat were still classified based on morphology. Boxes were not measured until 1998. Also in 1998, oysters < 20 mm that had been designated 'oyster' based on morphology, were relegated to the spat category. Although counted as oyster in the assessment, the yearling category was continued until 2002. Finally, in 2003, the 20 mm 'spat cutoff' was started to define the difference between being counted as a spat recruit or an oyster that was included in total abundance estimates.

The measurement of survey swept areas and dredge calibration experiments to determine gear efficiency began in 1998 allowing survey results to be quantified per square meter (Powell et al. 2002, 2007). Results of the dredge efficiency experiments indicated that the oyster beds could be divided into two groups; upbay and downbay with Shell Rock in the downbay group (see Figure 1). The dredge captured oysters, boxes, and cultch more efficiently on the downbay beds than on those upbay (Table 1). Multipliers calculated from these experiments are applied to survey dredge hauls by bed group to correct for dredge efficiency and thus account for what the dredge leaves behind to give more accurate density estimates, eg. oysters m^{-2} on the bay bottom.

In 2005 by request from the 6th SARC, the survey time series from 1953 to 1997 was retrospectively quantitated (Powell et al, 2008). The estimates were obtained by using bed-specific cultch density determined empirically from 1998-2004. This quantification assumes that cultch density is relatively stable over time. Comparison of retrospective estimates for 1998-

2004, obtained using the `stable cultch' assumption with direct measurements for 1998-2004, suggests that yearly time-series estimates prior to 1997 may be biased by a factor of 2 or less. Cultch varies with input rate from natural mortality and the temporal dynamics of this variation are unknown for the 1953-1997 time frame. However, understanding of shell dynamics on Delaware Bay oyster beds shows that shell is the most stable component of the survey sample supporting the assumption that a two-fold error is unlikely to be exceeded. Accordingly, the quantitative time-series estimates are considered the best for 1953 to 1997.

Prior to 2005, each bed had three strata. For each bed, grids with 'commercial' abundances of oysters 75% or more of the time were called 'high' (or 'test'); grids with marginal or highly variable 'commercial' densities of oysters 25-75% of the time were called 'medium' (or 'high'); grids with abundances well below commercial densities were called 'low' (HSRL personnel; Fegley et al. 1994). There were non-gridded areas between beds. Information in the early 2000's from oystermen indicated that harvesting between gridded areas was not uncommon. Therefore, from 2005 to 2008, the grid overlay was increased to cover all areas from the central shipping channel to the New Jersey Delaware Bay shoreline with every grid being assigned to an existing bed. In 2007, an HSRL survey investigated the upbay extent of the New Jersey oyster resource based on bottom sediment mapping that was conducted by the State of Delaware Department of Natural Resources and Environmental Control and provided by B. Wilson (2007, personal communication). The HSRL survey resulted in the addition of three more beds termed the Very Low Mortality region (VLM) into the stock assessment for a total of 23 beds (Figure 1). Earlier data for these beds are not present in the survey database; therefore, reconstruction of their 1953-2006 time series is not possible.

All oyster beds (except Ledge and Egg Island which have very low oyster abundance; survey averages of < 0.5 oysters per m^2) were resurveyed during the 2005-2008 time period. This resulted in a change of strata definition and survey design from that used historically (HSRL 2006). The restratification kept the three strata system within beds and used within-bed densities to determine High, Medium, and Low strata. Details of bed stratification are given in Survey Design below. Since 2002, a fourth 'Enhanced' stratum exists to temporarily identify grids that have received shellplants or transplants. A rotating schedule now restratifies each bed once per decade. Analysis of many survey simulations suggested that a random stratified survey based on the High and Medium quality strata is sufficient to estimate total abundance (HSRL 2006).

Stock Assessment Design

Sampling Methodology

As discussed above, the natural oyster beds of the New Jersey portion of Delaware Bay (Figure 1) have been surveyed yearly since 1953 using a stratified random sampling method. The complete extent of the natural oyster resource is divided into 0.2-min latitude x 0.2-min longitude grids of approximately 25 acres that are each assigned to one of 23 beds. Each grid on a bed is assigned to a stratum relative to the other grids on that bed. A subset of grids from the High and Medium strata on each bed is randomly selected each year for the survey (Egg Island and Ledge are sampled in alternate years). Grids assigned to the Enhanced stratum are sampled each year.

The survey instrument is a standard 1.27-m commercial oyster dredge towed from either port or starboard. The on-bottom distance for each one-minute dredge tow is measured using GPS recording positions every 2 to 5 seconds. A one-minute tow covers about 100 m^2 and usually prevents the dredge from filling completely thus avoiding the 'bulldozer' effect. Total haul volume is recorded. Three tows are taken for each sampled grid and a $^1/_3$-bushel subsample is taken from each haul to create a composite 37-quart bushel[1].

Each bushel sample is processed in the laboratory to quantify the following: volume of live oysters, boxes, cultch (normal and blackened from burial), and debris; the number of spat[2], older oysters, and boxes per composite bushel; the size of live oysters, spat, and boxes from the composite bushel; condition index; and the intensity of Dermo and MSX infections.

Stratification and Bed Resurveys

The current stratification method is based on ordering grids within beds by oyster abundance. Grids with the lowest densities that cumulatively contain 2% of the stock are relegated to the Low quality stratum. Initial analyses of resurveys showed that this stratum could be deleted from the fall stock assessment survey to focus on the grids that support 98% of the stock on each bed. In the initial resurveys, the remaining grids were input into a Monte Carlo model in which they were subsampled repeatedly without replacement under a given set of rules. The mean abundance estimated from the subsample was compared to the mean abundance obtained from the average of all grids. Analysis of many simulations suggested that a random survey based on two further strata would suffice. These are defined by ordering the remaining grids by increasing abundance. Those that cumulatively account for the middle 48% of the stock are designated as the `Medium Quality' stratum and the rest that cumulatively account for the upper 50% of the stock make up the `High Quality' stratum. The temporary Enhanced stratum includes transplant- or shellplant-receiving grids. Transplant grids are sampled only in the year they receive transplant and then are reassigned to their original stratum. Shellplant grids are sampled for three years after which they return to their original stratum. The Monte Carlo model is also used to determine how many grids per High and Medium quality stratum must be sampled for a statistically adequate stock assessment survey after each resurvey. Only two beds remain

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[1] The New Jersey standard bushel is 37 quarts (~35 liters).

[2] Beginning in 2003, oyster spat are defined based on size only (< 20 mm, the average first-season size on the Delaware Bay natural oyster beds). Prior to 2003, oysters were classified as spat based on morphology.

unsurveyed: Ledge and Egg Island. To minimize survey bias from changes in grid quality over time, a 10-year rotating spring resurvey schedule began in 2009 (Table 2)

Gear Efficiency Corrections

Current Application

All quantitative and post-1997 time series estimates are corrected for dredge efficiency using the dredge efficiency measurements made from 1998 to 2003 (Powell et al. 2002, 2007). The experiments to establish catchability coefficients[1] were conducted with the *F/V Howard W. Sockwell* using a commercial dredge and divers on another boat. Parallel transects were sampled to compare numbers of oysters caught in measured tows versus those collected in quadrats by divers presumed to be 100% efficient. Analyses revealed a differential in dredge efficiency between the upper (above Shell Rock) and lower oyster beds. It was also found that on average, the dredge caught oysters with greater efficiency than boxes, and boxes with greater efficiency than cultch. Each survey sample has multipliers applied to the number of oysters, the number of boxes, and cultch volume to account for the efficiency of the dredge. Due to concerns about the effect that natural bay bottom changes over time might have on dredge efficiency, different catchability coefficients (multipliers) are applied to the time series of survey results (Table 1). The 1998-2000 survey results use average catch multipliers from dredge efficiency experiments of that timeframe. Surveys from 2001-2004 used multipliers that also included results from the 2003 dredge calibration project in the average. These multipliers are also applied to surveys prior to 1998. Surveys since 2004 have used the 2003 dredge calibration average by itself under the assumption that it is the most accurate moving forward.

2013 Gear Efficiency Study

In September 2013, dredge efficiency experiments were conducted comparing the commercial dredge on the *F/V Howard W. Sockwell* with patent tongs deployed by the *R/V Baylor*. Parallel transects were sampled to compare numbers of oysters caught in measured tows versus those collected by the tongs that were presumed to be 100% efficient. Previous dredge efficiency studies on the NJ oyster beds used the same protocols with the *F/V Howard W. Sockwell* and a commercial dredge but with divers as the 100% efficient collectors (see Powell et al. 2002, 2007). Other studies have shown that divers and patent tongs are equally efficient (Chai et al. 1992). As in previous dredge efficiency studies, this study showed that dredge efficiency estimates and their associated catchability coefficients are highly variable within a given sampling location, across sampling sites, and within a given bay region (Figure 9). Significant upbay-downbay differences found with previous dredge efficiency experiments were also evident here (nested ANOVA; P=0.00395). However, on the two most upbay sites: Hope Creek and Round Island, the efficiency of the dredge was comparable to that of the downbay group. These two sites have never been included in previous dredge efficiency experiments. No

[1] The catchability coefficient (q) as used here is defined as the inverse of dredge efficiency e: $q=1/e$.

significant difference was found among beds within a bay region (P=0.26752) or between 2003 and 2013 results (P= 0.09233). Further analyses will be done in 2014 and will be presented to the SARC in order to make decisions about how to apply this new dredge efficiency data. Considerations include amongst other things, how best to average the data over time and how to group the sites based on the data.

Analytical Approach

Dredge efficiency-corrected results from the survey are obtained for each sampled grid in number per m^2 as described above. Grids are then averaged within stratum for each bed. The average is multiplied by stratum area and strata are summed for each bed. Bed sums are added to get regional totals. The quantitative point estimates of abundance in this report sum the High quality, Medium-quality, and Enhanced strata only. Low-quality areas are excluded as described earlier, underestimating bed abundances by approximately 2% providing a conservation buffer on fishing exploitation.

Throughout this report, 'oyster' refers to individuals ≥ 20 mm (0.8") in longest dimension while 'spat' refers to those < 20 mm. The 20 mm cutoff was chosen as the average spat size through the estuarine gradient of beds in the Delaware Bay. The result of this is that in upbay regions, e.g. Low Mortality, the < 20 mm size class may include oysters that are older than their first season while in the High Mortality region (HM), oysters in their first season may be > 35 mm (1.4"). Prior to 2003, spat were categorized by shell morphology rather than size. Spat abundance is not included in the estimates of oyster abundance but is shown separately. Oysters ≥ 35 mm are considered to be adults. Calculations of spawning stock biomass (SSB) are based on the ≥ 35 mm size class and were derived using bed-specific and year-specific regressions between dry weight (g) and shell length (mm) to convert size to biomass. Market-size oysters are divided into individuals ≥ 76 mm (3") and individuals ≥ 63.5 mm (2.5"), but < 76 mm (3"). These two size categories are based on a knife-edge selection of oysters for market by the fishery that has been routinely observed since monitoring began in 2005 in which nearly all harvested oysters are ≥ 63.5 mm (2.5") and historical use of the 76-mm (3") boundary to define a market oyster.

Uncertainty around the survey point estimate is calculated by conducting 1,000 simulated surveys, each with a selection of samples from each bed and each corrected for dredge efficiency by a randomly chosen value from all efficiency estimates available (HSRL 2008). Confidence-level values are obtained by sorting the simulated surveys on the number of all oysters and also on oysters ≥ 2.5". Dredge efficiency is less certain for oysters < 2.5" so this approach includes uncertainty that cannot be evaluated. However, smaller oysters make up much of the population and sorting by the larger size class sometimes fails to order the surveys in hierarchical position by total abundance.

2013 Spring Resurvey

For the current assessment, the strata for Upper Arnolds and New Beds have been updated based on a Spring 2013 resurvey of all grids on these beds. Evaluation of oyster density on each grid was consistent with other resurveys in finding that a large number of low quality grids could be deleted from the Fall stock assessment survey to focus on the grids that support 98% of the stock on each bed (Figure 10).

Both New Beds and Upper Arnolds were last resurveyed in 2007. At that time, densities on the Medium and High strata of New Beds ranged from 0.2 to 13 oysters per m^2 (see Appendix A, data year 2006 for New Beds) and 8 grids cumulatively accounted for the upper 50% of oysters (High stratum). The middle 48% of the oysters were contained in 37 grids (Medium stratum) while the 67 remaining grids (Low stratum) cumulatively contain 0 to 2% of the oysters on New Beds. Six years later in Spring 2013, the range of densities for the High and Medium strata on New Beds was higher at 0.8 to 27 oysters per m^2 with approximately the same division of grid numbers per stratum. There were 9 grids in the High stratum and 38 grids in the Medium stratum after the resurvey. The increase in oyster abundance on New Beds may be the result of two years of relatively high spat sets on New Beds in 2011 and 2012 (see Appendix A).

Oyster density on Upper Arnolds ranged from 39 to 334 oysters per m^2 in 2007 (see Appendix A, data year 2007 for Upper Arnolds) on the Medium and High strata but was lower in 2013, ranging from 17 to 129 oysters per m^2. Upper Arnolds was used as a transplant donor bed in 2013 a month prior to the Resurvey. The transplant removed 15,500 bushels (approximately 6.3 million oysters) from Upper Arnolds. In 2007, there were 5 high quality and 13 medium quality grids out of 29 total on Upper Arnolds. In 2013, there were 6 high quality and 11 medium quality grids of the 29 on Upper Arnolds. Figure 11 shows the New Beds and Upper Arnolds grid strata before and after the 2013 resurvey.

2013 Fall Assessment Survey

The fall survey is constructed by randomly choosing a designated number of grids from each Medium and High quality stratum on each bed plus transplant and shellplant grids as described above. Sampling for the 2013 assessment survey was conducted October 29 and November 6, 21, and 22 using the oyster dredge boat *F/V Howard W. Sockwell* with Lemmy Robbins as captain. The sampling intensity is shown in Table 3 and the specific grids sampled are shown in Figure 12. Total sampling effort in 2013 was 165 grids: 5 more than in 2012. The Enhanced stratum consisted of 13 selectively sampled grids that included 3 grids that received intermediate transplants in 2013, 3 grids that received shellplants in 2013, 3 grids that received shellplants in 2012, and 4 grids that received shellplants in 2011. The intermediate transplant grids revert back to their original stratum after one year. The shellplant grids revert back after 3 years. These grids are then subject to the random choice within strata for following stock assessment surveys. Effects of the transplants or shellplants on oyster density in the grids get assessed in the next bed resurvey.

Status of the Stock in 2013

Whole Stock – excluding the VLM due to short time series

Whole stock oyster abundance in 2013 was at the 12th percentile of the long-term time series (1953-2013) and at the 22nd percentile of the Dermo era from 1989-2013 (Table 4). This continues a three-year decline in oyster abundance and at 1.17 billion oysters, is the lowest abundance since the extended period of low recruitment in the mid-2000s (Figure 5b). Box-count mortality was 20%, a slight decline from 2012 (Figure 4a). This level of mortality was at the 70th percentile for the full time series and at the median of the 1989 – 2013 time series (Table 4). Spat (< 20mm, 0.8") abundance in 2013 was at the 39th and 46th percentiles respectively for the long-term and Dermo era time series (Table 4). This abundance was a 45% decrease from 2012 spat numbers but not as low as most of the years since 2000 (Figure 5b). Spawning stock biomass (SSB) and market-sized (>63.5 mm, 2.5") abundance can only be calculated since 1990. SSB often tracks total abundance (Figure 13) and was low in 2013 at the 19th percentile (Table 4). The abundance of market-sized oysters was 411 million and fell at the 35th percentile (Table 4). This size group has been relatively stable since 2008 when the current fishery management scheme went into effect although the 2013 abundance is the lowest since then (Figure 14).

Stock by regions[1][2]

Upbay Regions (Very Low Mortality, Low Mortality)

The VLM and LM regions at the uppermost extent of the Delaware Bay, New Jersey oyster resource, are transplant regions of similar acreage (Figures 1 and 3). Since the mid-2000s, each of these regions has held more oysters than any of the other regions except the MMM which has more area (Figure 6). Average oyster density on non-enhanced (no shellplants or transplants) grids sampled on the VLM for the Fall 2013 survey (Figure 12) was 48 oysters m^{-2} and ranged from 1 to 145 m^{-2} (Appendix A). This average is not very different from 2011 (when oyster mortality was very high due to a late summer freshet, see Figure 7) or 2012 when oyster densities were 51 and 45 oysters m^{-2} respectively (Appendix A). Prior to the 2011 mortality event, the average density of oysters on sampled grids of the VLM was 83 m^{-2}, nearly double the 2013 density. Although the LM region also suffered some freshwater mortality in 2011 (Figure 7), oyster density in 2013 (54 m^{-2}) is similar to that prior to the event in 2010 (59 m^{-2}). Densities in 2013 ranged from 0.2 to 136 oysters m^{-2} on the LM (Appendix A). Abundance decreased by over 30% on the LM from 2012 to 2013 and is very low compared to either the 61 or the 24-year time series with abundance at the 7th and 14th percentiles respectively (Table 4). Comparison of Figure 15b and 15c indicates that the decrease is due to fewer oysters in the market (> 2.5") size class. Despite this, the 2013 percentile for market-size abundance is 0.65 for the 24-year time

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[1] Oyster per m^2 densities by grid in Appendix A.

[2] Region trend summary figures in Appendix B.

series (Table 4) reflecting the fact that a larger proportion of oysters have been market-size in recent years. For example, the proportion of oysters > 2.5" from 1990 to 2001 on the LM was 15% while the same proportion from 2002 to 2013 was 27% (see Figure 15). Due to the short time series, percentiles have not been calculated for the VLM but the abundance there has decreased by 12% since 2012 (Figure 6). Spat set on both the VLM and LM was higher in 2013 than it has been for some years (Figure 15a) and fell at the 47th percentile for the 61-year time series and at the 74th percentile for the 24-year time series (Table 4). The usually lower mortality rates in the VLM and LM regions may allow this relatively high set to survive and increase abundance in these regions (Figure 7). Box-count mortality rates on the LM fell at the 58th and the 50th percentiles for the 61 and 24-year times series respectively (Table 4).

The Central Regions (Medium Mortality Transplant, Medium Mortality Market)

The Medium Mortality Transplant region (MMT) is comprised of three beds, one of which (Sea Breeze) is separated from the other two by the Medium Mortality Market region (MMM) (Figure 1). This bed was originally assigned to the MMM as described previously in the overview although all retrospective numbers have been adjusted so that Sea Breeze data is included with the MMT. The acreage of the MMT is nearly identical to that of the LM while the acreage of the MMM is quite a bit larger (Figures 3 and 6). The average oyster density of the non-enhanced grids sampled on the MMT for the Fall 2013 survey was 26 oysters per m^2 and ranged from 2 to 82 oysters per m^2 (Appendix A). On the MMM, oyster densities averaged 41 per m^2 on non-enhanced grids and ranged from 12 to 81 per m^2. Since 1990, the MMM region has often had the highest oyster abundance of all six regions with the MMT tracking its trends but at lower abundance (Figure 6). Both regions experienced a decline in oyster abundance from 2011 to 2012 and that continued in 2013. The 2013 total abundance on the MMM was 383 million oysters, a 48% decrease since 2011 and at the 26th percentile for the 1990-2013 time series (Table 4). The situation on the MMT was even worse with a 55% decrease in abundance since 2011 (Figure 6) to 152 million oysters which is only the 10th percentile for abundance in the 24-year time series (Table 4). The sets of percentiles for both time series were very similar for each of these two regions. Box-count mortality rates were high for both regions in 2012 and in 2013: between 22% and 26% (Figure 7). Mortality in 2013 was at the 66th percentile for the MMM region and an extremely high 94th percentile for the MMT for the 24-year time series, again similar to the 61-year time series (Table 4). The trajectory of the MMT and MMM situation is clarified by examining Figure 15. A relatively good spat set in 2010 on both regions (Figure 15a) led to a moderate increase in numbers of small oysters in 2011(Figure 15b), some of which can be seen as larger oysters in 2012 (Figure 15c) but the combination of two years of high mortality in 2012 and 2013 (Figure 7) that correspond with high levels of Dermo disease (see Appendix B) appear to have led to the steep declines in market-sized oyster abundance seen in Figure 15c for 2013.

The Lower Regions (Shell Rock and High Mortality)

Shell Rock (SR) is the smallest region in acreage and the only one composed of a single bed (Figure 3). It has maintained a relatively consistent abundance over the 1990-2013 time series (Figure 6) but has also been the recipient of numerous transplants and shellplants over the years. Density of oysters on non-enhanced grids in the SR for the 2013 survey was 20 m^{-2} ranging from 7 to 47 oysters m^{-2} (Appendix A). The High Mortality (HM) region is the largest (> 6 times larger than SR; Figure 3) but from 2003 to 2011 had total oyster abundances similar to those on Shell Rock despite also receiving transplants and shellplants (Figure 6). Densities on non-enhanced grids in the HM ranged from 0 to 59 oysters m^{-2} and averaged only 11 m^{-2} (Appendix A). Abundance on the HM region has increased somewhat for the most recent two years and is at the median for the 24-year time series (Table 4). This can be attributed to a very good spat set in 2012 (Figure 15a) and two years of decreased mortality rates continuing a downward trend in mortality since 2007 (Figure 7). Mortality on the HM is at a very low 14th percentile for the 24-year time series (Table 4). In contrast, there was a sharp increase in mortality rate on SR in 2012 and that has remained high with a slight decrease in 2013 (Figure 7) where it stands at the 70th percentile for the 24-year time series (Table 4). The mortality increase on SR in 2012 was mirrored on the MMT and MMM; all these regions had a concurrent increase in Dermo weighted prevalence (see Appendix B).

Habitat and Recruitment

Background

Oysters are unusual in terms of stock assessment because they create their own habitat. Spat settlement requires hard surfaces and in their environment, oyster shell is generally the hard surface. Without spat recruitment (and survival) there are no oysters, without oysters, there is no habitat. Oyster shell is not a permanent resource for potential oyster spat (Mann and Powell 2007). Chemical, physical, and biological processes degrade the shell over time (Powell et al 2006). Burial of shell by sediment or smothering by epibionts make it inaccessible to recruits. Fewer oysters equate to less habitat as do smaller oysters whose shells 1) provide less surface area for spat set and 2) degrade faster. The circular nature of this relationship between oysters and the habitat they create makes evaluation and management just as important for shell as it is for oyster abundance (Powell and Klinck 2007; Powell et al 2012). Without a balance between habitat and oysters, the population will decrease over time.

Shell Half-lives

Powell et al. (2006) developed a model to estimate surficial oyster shell (cultch) half-lives for each bed. The model was developed during an extended period of low recruitment accompanied by a decline in both oyster abundance and in cultch that suggested loss of shell resource over time. The time series for which half-lives can be calculated begins with 1999, the year after the survey became quantitative. The analyses are subject to substantial yearly variations retrospectively due to limited sampling of some beds in years prior to 2005, because some conversions are poorly known (eg. the individual proportions of oysters, boxes, and shell when they are clumped together), and because the time series is still relatively short, being of the same order as many of the half-life estimates. This results in some half-life estimates being negative which is in fact undefined. Shell half-life estimates for each bed are updated yearly from the Fall assessment survey data.

Bed-specific half-life estimates for surficial cultch for 2013 are presented in Table 5 with estimates from previous years for comparison. Half-lives ranged generally between 3 and 12 years, with a 2013 median of 7.1-7.2 years although a few beds had much higher values and some beds had negative values which are undefined. Shell half-lives for the VLM, Upper Middle, New Beds, or Ledge could not be estimated in 2013. Continued experience with this database confirms the original conclusions of Powell et al. (2006) that half-lives routinely fall below 10 years.

Shell Budget

A shell budget was constructed using the half-life estimates following the model of Powell and Klinck (2007). Values for the beds with uncertain half-lives (Table 5) were borrowed from neighboring beds. Shell inputs are counted when oysters die and become boxes or when clamshell is planted. Shell is debited based on half-life values. New Jersey oyster beds have been losing on the order of 300,000 bushels of cultch annually since 1999 with loss rates much higher early in the time series (Figure 16). Since 1998 is the first year that full survey data are available, 1999 is the first year an estimate can be made. The shell budget was updated using the 1998-2013 time series based on 2013 half-life estimates with comparisons that use the 2012 and 2011 half-life estimates. The shell budget shows a general reduction in shell loss until 2005 followed by two years of increased shell loss until 2008 when the shell budget estimates bound the equilibrium point of 0 (Figure 16). From about 2000 to 2006, there was very little spat set or shellplanting (Figure 5a and b). Shell input resulted from oyster mortalities at rates of 15-20% per year (Figure 4a). In 2006-2008, there were large-scale shellplants (Figure 4a) and in 2007-2008 mortalities were over 20% (Figure 4a). Since 2008, shellplanting levels are much reduced although mortalities remain high and shell loss has generally increased (Figure 16).

Shellplanting

Shellplanting is recognized as an important management activity to maintain the oyster beds and has been practiced at various intensities throughout the survey time series with planted volumes usually dependent on funds (Figure 5a). Earlier programs planted large volumes of oyster or clamshell on NJ oyster beds, particularly in the 1960s and 70s. Efforts since 2003 have primarily used clamshell (quahog and surf clam), a by-product of local clam processing plants. There are two types of plantings: direct and replant. Both are dependent on careful timing and site selection. Direct planting places the bare shell directly on a chosen site while replanting first puts the shell downbay in a high recruitment but low survival area. Once it catches a set, the spatted shell is moved upbay by suction dredge to its final site. Shellplant sites are sampled for their first three years in the Fall survey. Planted shell continues to recruit spat in years following the initial plant.

In 2013, there were two direct shellplants and one replant that were sampled in the Fall Survey (Table 6). The replant was part of a mitigation program that began in 2011 on Middle bed, in the Medium Mortality Transplant region. This bed is further upbay than most planted areas and spat sets here are less reliable than those downbay. The 2013 Fall survey sampled the replanted Middle sites and results show spat densities of 20 and 26 spat m^{-2} on those grids (see Appendix A). The average density of spat found on non-planted grids on Middle in the survey was about half that at 11 spat m^{-2} (ranging from 1 to 41 spat m^{-2}). Average spat density on non-planted grids in Shell Rock was similar to that of Middle (10 spat m^{-2} ranging from 2 to 26 m^{-2}). Spat densities on the planted Shell Rock grids were approximately three times higher at 28 and 30 m^{-2} (see Appendix A).

Spat recruitment in 2013 to shellplants deployed in 2012 was also monitored in the 2013 Fall survey (Table 7). In most years, the recruitment to shell planted in the previous year is lower than the recruitment to shell planted within the current year. This was true in 2013. Ship John grids planted in 2012 had fewer spat per bushel of clamshell (Table 7) than any of the grids planted in 2013 on Middle (upbay of Ship John) or Shell Rock (downbay of Ship John) (Table 6, Figure 12). The spat per bushel of clam shell on the older Ship John plantings were 0 and 5 (Table 7) while the newer plantings on Middle and Shell Rock had 21 and about 80 spat per bushel, respectively (Table 6). Densities of spat in 2013 on the two Ship John grids planted in 2012 were lower (0.3 and 0.4 m^{-2}) than the average of densities for non-planted grids on Ship John (6 spat m^{-2}; Appendix A).

As has been noted before (eg. prior SAW reports, Ashton-Alcox et al. 2009), shellplants provide a noticeable increase in overall spat set, even when looked at from the perspective of a whole region as opposed to a grid or bed (Table 8). This has been true in every year (for which we have data) that shellplanting was done, regardless of shellplant volume or recruitment level. In many cases, the return in recruitment from a small percentage of a region's area planted is quite high. For example, in 2011, a small percentage (2.1%) of the Shell Rock region was planted with 50,000 bushels of clamshell and that one grid's worth of planting provided nearly 50% of all spat recruiting to Shell Rock (Table 8). On the other hand, twice as much shell on a similar proportion of total regional area on the Medium Mortality Market region in 2012 yielded only 1% of the total regional spat recruitment. In 2013, the Shell Rock direct planting of 100,000 bushels of shell on two grids was 4.5% of Shell Rock's area and was responsible for 16% of the total spat recruitment to Shell Rock (Table 8). The replanting of sparsely-spatted shell onto 1.7% of the Medium Mortality Transplant region in 2013 yielded merely 0.7% of the total spat that recruited to this region (Table 8).

Projections of potential numbers of market-sized oysters (>63.5 mm, 2.5”) that might result from the 2013 recruitment to each shellplanting are given in Tables 6 and 7. For these projections, years to market size were calculated using von-Bertalanffy parameters as described in Kraeuter et al. (2007) and previous reports for each region of shellplants. For all shellplanted grids where spat on plant were found in 2013, the estimate is three years to market-size oyster. The median of the regional ‘juvenile’ (first year post-spat) mortality rate from the 1990-2013 time series was used for year 1 and the median regional ‘adult’ mortality rate for the same time series was applied to the next two years to determine numbers of individuals remaining in the 3rd year. The number can be further translated into bushels of market-size oysters if desired by dividing by 264, the number of oysters in a bushel going to market. The number per bushel is determined by a dock-monitoring program run throughout the harvest season as part of the stock assessment process; it is described below.

Spat and Small Oyster Morphology

For the purposes of this stock assessment, oysters < 20 mm are defined as spat (recruits in their first season or ‘young of the year’). This assumes 20 mm to be the average size an oyster attains in its first season of growth across all regions. The estuarine salinity gradient over the Delaware Bay oyster beds corresponds to a gradient in growth that is faster downbay (higher salinity) and slower upbay (lower salinity). Application of the single 20 mm size cutoff to define a spat would thus define a 40 mm individual as a small oyster when it is actually a spat in its first year or it might erroneously define a 19 mm individual as a spat when it is an oyster in its second year. Abundance, biomass, and quota allocation estimates (for transplant regions) in the fall stock assessment are based on oysters >20 mm, some of which are probably ‘young of the year’. Shellplantings comprised of surf clam and ocean quahog shell deployed at known times on an oyster bed can be used to develop more precise estimates of spat and (first and second year) oysters for stock assessment purposes.

A preliminary analysis was done using oyster and spat length frequency observations from various shell plantings deployed from 2005 to 2012 (n = 19 plantings). Of the plants used for this analysis, there were: 5 on Ship John, 7 on Shell Rock, 4 on Bennies Sand, 2 on Nantuxent, and 1 on Hawk’s Nest (Figure 17). Non-spatted clamshell was planted in late June or early July throughout this time and monitored approximately monthly between March and November for two years after deployment. Oysters on the planted shell were measured and the mean length from each site at each time provides a measure of the growth for that cohort. This generates a population-based growth metric that incorporates loss of animals from the population. If it became difficult to distinguish cohorts at a single site due to subsequent spat sets catching up in growth, the time series was terminated. These data provide growth rates from 19 shell plants on 5 beds in 3 regions of the central part of the stock over 8 years. The growth rates can be used to estimate the number of days it took for each cohort to reach the 20mm spat cutoff threshold and the size of an average oyster in the cohort at one year post-settlement.

Two distinct groups of cohort observations were identified: early settling cohorts that reached 20mm in ≤ 225 day, and late settlers that reached 20mm in >225 days. The early settlers reached 20mm significantly before the late settlers in approximately 120 days (about 4 months) while the late settlers had to survive the cold temperatures of late fall, winter, and early spring when no growth occurs and reached 20mm in an average of 330 days or approximately, 11 months (Figure 18a). Both early and late settlers reach an average size > 20mm shell length at 1 year.

These two response variables (days to reach 20 mm and average length at 1 year) were analyzed using analysis of variance (ANOVA) to test whether year, salinity and settlement timing were significant drivers of the growth on shell plants for each of the early and late settlement groups. Year (df =7; F=46; p<0.0001) and settlement timing (df =1; F=22; p=0.0015) significantly influence the time it takes a cohort to reach the 20 mm cutoff; however, salinity has no significant effect. Year (df =7; F=9; p<0.003) and salinity (df =2; F=10; p=0.007) significantly influence the shell length of a cohort at 1 year old whereas settlement timing is no longer significant (Figure 18b).

Some of these spat cohorts were sampled (shell measurements) within two weeks of the Fall (2013) stock assessment survey when the 20mm spat definition is applied to samples. At that time, on average, 45% (±16%, 95% confidence interval) of the spat sampled on shell plants were 20mm or smaller and would be correctly categorized as spat in their first year. This means that on average, for the beds in the central area of the stock (where the shellplants were situated), potentially half of the spat are being misidentified based on the 20mm cutoff. From the data available, it appears that the fraction misidentified varies annually and with settlement timing. The central part of the stock that contains the shellplants from which these measurements are made includes both direct market and intermediate transplant regions. The quota estimates for the following year's intermediate transplants is based on the abundance of all oysters ≥20mm evaluated during the Fall survey. These findings indicate that some proportion of these purported oysters are actually spat (in their first year) possibly overestimating the animals available for transplant. Further study is warranted to determine bed (or region) -specific fractions of spat that may be misidentified using the 20mm cutoff.

Broodstock-Recruitment

Broodstock-recruitment relationships for the New Jersey Delaware Bay oyster survey time series suggest a positive relationship between broodstock abundance and recruitment of spat. Figure 19 shows the abundance of broodstock, excluding the VLM region, for the entire time series since 1953. Time periods of low, high, and medium abundance are separated into regimes and plotted as the abundance of broodstock from each Fall survey against the recruitment resulting from that broodstock in the following year. A 1:1 line or a Ricker curve adequately describes the relationship of broodstock and recruitment over the duration of the time series. The time series can be broken out into four distinct abundance regimes and the broodstock:recruit relationship plotted individually by regime (Figure 20). Within each time period, the broodstock:recruit relationship seems adequately described by a 1:1 line suggesting stability and undersaturation with respect to spat recruitment within the time period.

Oyster Fishery

Direct Market Harvest

The 2013 direct market harvest occurred from April 8th to November 22nd and included a period of curtailed harvest hours during summer months to comply with the New Jersey's approved *Vibrio parahaemolyticus* management plan[1]. The number of single-dredge boats dropped from 17 to 14 as a result of continued license consolidation that allows one boat to harvest on more than one license. Total quota allocation is divided by the number of licenses in the direct market fishery. The number of dual-dredge boats remained at 21 for a total of 35 active boats. The total direct market harvest in 2013 was 84,276 bushels (Table 9).[2] This was an increase of 6,136 bushels from 2012 and marked the 7th consecutive year with a harvest at or above the 18-yr mean (Figure 21). Nine of the 14 beds opened to the direct market harvest, plus one transplant bed, were fished in 2013 (Table 9) but 90% of the harvest came from five beds: Shell Rock (29%), Ship John (23%), Cohansey (13%), Bennies Sand (13%) and Nantuxent (12%).

The catch per unit effort (CPUE) increased in 2013 possibly helped by license consolidation (Figure 22a.). There has been a general increase in CPUE since the 2001 low point of the direct market time series. Figure 22b shows CPUE on the beds where harvest occurred in 2013. CPUE was highest on Shell Rock and Ship John, representing 29% and 23% of the harvest respectively and lowest on New Beds and Strawberry, both representing <1% of the harvest (Table 9). Sea Breeze, not a direct market bed but harvested on in 2013, represented 6% of the direct market harvest with an intermediate CPUE (Table 9, Figure 22b).

The fraction of each bed covered by a dredge during the harvest season was estimated using the methods described by Banta et al. (2003) and exceeded bed area in five of the nine beds fished for the 2013 direct market (Table 9). The highest fraction (2.87) occurred on Nantuxent followed by Shell Rock (2.30) and Ship John (2.27). Powell et al., (2001) suggest that a cumulative annual swept area of less than four times the area of a bed is unlikely to have significant negative impacts on the oyster population. In general, these fractions have been decreasing over the years with fewer beds experiencing coverage fractions > 1 (see harvest tables in previous reports).

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[1] http://www.nj.gov/dep/bmw/Reports/2013vpplan.pdf

[2] Harvest data provided by the New Jersey Department of Environmental Protection.

Port Sampling

The port-sampling program counts and measures oyster at dockside from boats unloading direct market harvest. In 2013 the average number of oysters per 37-qt bushel harvested was 269 including small but non-targeted oysters (Figure 23). The average number of market-size oysters per marketed bushel in 2013 was 227, a number that has remained relatively constant since 2004 when port sampling began. Conversion of oysters to bushels for allocation projections used the value of 264 oysters bu^{-1} in 2013, the average of 10 years of port sampling (Figure 23). This value is the overall mean of all dockside oysters per bushel and those presumably targeted ($\geq$ 2.5") oysters per bushel. The rationale for using the mean is that the number of attached small oysters will vary widely between years depending on recruitment dynamics so that using the total number per bushel risks underestimation. On the other hand, the smaller number does not account for all of the oyster removals and this undervalues the fishing mortality rate. Figure 24 illustrates the 2013 size frequency of dockside oysters compared to those from the two years before. Compared to the previous two years, there was a higher proportion of oysters >3" harvested in 2013 than in 2011 or 2012. This may be a result of the higher spat sets and small oysters moving into the system around 2010-2011, particularly in the MMM region (Figures 15a, 15b) and is evident in the higher numbers per bushel of small oysters depicted in Figure 23 for 2010 and 2011.

Intermediate Transplant[1]

In 2013, the intermediate transplant program moved 20,500 bushels of culled material from the Low Mortality (LM) region to Shell Rock in late April. An additional 550 bushels were moved from Liston Range in the VLM due to a misunderstanding (Table 9). The Very Low Mortality (VLM) region has been closed to exploitation since 2011 when it experienced high oyster mortalities following an extreme late summer freshet. In late April/early May, 14,600 bushels of culled material was moved from the Medium Mortality Transplant (MMT) region to Bennies Sand in the High Mortality (HM) region.

A sample was taken by the NJDEP from each deckload of each transplanting boat throughout the transplant period and evaluated by HSRL personnel. Overall 12.3 million oysters were moved which was less than the target number (15.4 million) associated with exploitation decisions made by the Shellfish Council in March 2013 for each of these regions after the 2013 SAW (see Table 9, Appendix C, and HSRL 2013). The LM transplant moved 85% of the oysters (8,459,940) that would represent the chosen 60th percentile exploitation rate and the MMT transplant moved only 70% of the oysters (3,798,531) that would represent the chosen 60th percentile exploitation rate and in fact moved only 86% of the oysters that would represent the 50th percentile exploitation rate (Table 9 and Appendix C). It is unknown if logistical reasons or inadequate densities of oysters was the cause of the transplants failing to reach the desired goals.

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[1] Intermediate transplant memoranda in Appendix C.

Exploitation rates for the Transplant regions are based on all sizes of oysters because high proportions of oysters smaller than market size get moved during transplanting. Boats deckloading oysters for transplant use automatic cullers as the only sorting device because of the large volumes that must be moved. Small oysters (< 2.5") do not enter into the calculations for the quota increase in the receiver regions but a good proportion of them survive and add to abundance in that region. Ashton-Alcox, et al. (2013) found proportions of small oysters in the transplant to be as high as 60%. In the 2013 LM transplant, small oysters made up a similar proportion (56%) while in the MMT transplant, they made up a much smaller percentage (34%). This is likely a reflection of the placement of the beds used in these transplants and the sizes of the oysters on them. The LM region is upbay of the MMT region and oysters do not tend to grow as large as oysters further downbay (see Kraeuter et al. 2007). This is particularly true on beds upbay of Arnolds (see Figure 12). The LM transplant included oysters from all three beds in the region as well as 550 bushels erroneously moved from a bed in the VLM region (Appendix C). The MMT transplant included 6,200 bushels from Sea Breeze bed, adjacent to Shell Rock and Cohansey, beds in Direct Market regions where oysters tend to grow larger than they do upbay. Sea Breeze was previously classified as a Direct Market bed in the Medium Mortality Market region (see earlier text, Historical Overview) but very few harvesters had used it so it was moved into the MMT in 2011 to limit Intermediate Transplant from Middle bed to alternate years and thus spread transplant exploitation pressure more evenly (HSRL 2012, see 2011 Management goals).

Oysters ≥2.5" contained in the transplant were converted to market bushel equivalents using the number of market oysters per bushel (266) calculated from the Port Sampling program of 2012 (HSRL 2013) and were added to the quota for the receiving regions. The transplants increased the quota by 23,454 bushels. This was 27% of the final Direct Market allocation (Table 10b) and the highest proportion of total allocation due to the intermediate transplant since 2010.

Exploitation Rates

The basis for the range of exploitation rates used for the fishery is the exploitation record from the early part of the direct market era (see Historical Overview). These abundance-based rates were from a period of conservative fishery management during a time of persistent high disease pressure and were deemed likely to provide conservative management goals. The 2006 SARC suggested exploitation-based reference points based on the median (50^{th} percentile) exploitation rate defined in terms of the fraction of abundance removed per region for the years 1996 to 2005, the latest data year at that time. Since then, SARCs have retained the precedent that the 40^{th}, 50^{th}, and 60^{th} percentiles of abundance-based exploitation in that time series normally be used.

The basic approach was revised in 2007 using estimates of size-dependent exploitation rates because direct market fishing and intermediate transplants remove size classes differently. Two sets of exploitation percentiles were calculated: one using the assumption that all size classes were removed proportionately in transplants and one using a knife-edge assumption that size classes ≥ 2.5" were removed proportionately for direct market regions.

Fishing activity during this decade-long time series was concentrated on the more downbay regions of the stock leading to limited data for regions upbay of Shell Rock. Data were so limited for the Transplant regions that it was decided that they should share the same set of exploitation rates. An adjustment was made to the original set of Transplant region exploitation percentiles by the 2009 SARC in order to smooth a temporally biased change in exploitation rates at the 50^{th} percentile that separated as high and low. The 50^{th} and 60^{th} percentile values (.0127 and .0233 respectively) from the original data were averaged. The average (.0188) is used as the 50^{th} percentile and .0127 is used as the 40^{th} (Figure 25).

The 1996-2006 exploitation data for the Medium Mortality Market region (MMM) that lies between the transplant regions and Shell Rock has a relatively narrow range from the 10^{th} (0.01% of oysters ≥ 2.5" were harvested) to the 90^{th} percentile (3.6% of oysters ≥ 2.5" were harvested). The 1996-2006 range of exploitation for Shell Rock, just downbay of the MMM, was much larger (4.4 - 23.6 %) from the 10^{th} to the 90^{th} percentiles (Figure 25). This led to an experimental fishery at the 100^{th} percentile rate of 4% exploitation on the MMM that began in 2009. Note that the 100^{th} percentile exploitation rate of 4.0% on the MMM is still below the 10^{th} percentile exploitation rate of 4.4% on Shell Rock (Figure 25).

The range of exploitation rates is highest on Shell Rock, approximately 19 percentage points, yet the rates at the 40^{th} and 50^{th} percentiles, considered as those normally to be used for exploitation, are almost identical at 8.7 and 8.8%, respectively (Figure 25). The 60^{th} percentile rate of 11.4% is the upper bound of the usual percentile rates considered. Consequently, when market-size oyster abundance is low on Shell Rock and other parameters are not promising, the only logical choice for conservative exploitation is to choose the rate associated with the 25^{th} percentile, 5.3%.

Unlike the situation on Shell Rock, the largest increase between exploitation percentiles for the High Mortality region occurs between the 40^{th} (1.2% exploitation) and the 50^{th} (6.5% exploitation). The change on either side of those two percentiles is very small leading to limited management choices in rates of exploitation (Figure 25). This pattern is not unlike that described above for the Transplant regions.

The percentiles associated with the chosen exploitation rates following the advice of the 2013 SARC are shown in Table 10. The 60^{th} percentile rate of 2.33% exploitation was chosen for both the LM and MMT region transplants in 2013; higher than that chosen in 2012 for these regions (Table 10a). The achieved rates of exploitation as described in the Intermediate Transplant text were lower than those chosen. In the case of the MMT region, it was much lower as discussed earlier. This is in contrast to 2012 when the exploitation rate associated with the 50th percentile (1.88%) was chosen but the transplant resulted in exploitation greater than the 60th percentile rate of 2.33%.

Examination of Table 10b shows that in the six years listed, the total allocation has never been harvested. 'Under-harvest' in these years has ranged from 722 bushels left in the allocation in 2008 when over 90,000 bushels were allocated, to nearly 7,000 bushels left in 2010 when the allocation was the lowest of the six years at just over 81,000 bushels. That is a range of 0.8 – 8.5% of allocated bushels left unharvested. The average number of allocated bushels left unharvested is 3,089 out of an average harvest allocation of 86,728 bushels or 3.6%. Reasons for this likely vary from the meteorological to the logistical to the economical.

Fishing Mortality

During the Bay Season years (see Historical Overview) from 1953 until the start of the Direct Market era in 1996, the oyster fishery commonly took well over 200 million oysters off the natural oyster beds of Delaware Bay, NJ (Figure 8). Since the inception of the Direct Market fishery, the number of oysters landed from the natural oyster beds in Delaware Bay, NJ has been an order of magnitude less than that; around 20 million oysters. This difference results from a change in population size (Figure 2), and a change in management strategy that sought to control exploitation rates while also shifting the harvest from all sizes of oysters to market-sized oysters.

Total harvest in 2013 was 84,276 bushels (Tables 9, and 10b) or approximately 22.7 million oysters, using the value of 269 harvested oysters per bushel (Figure 23). This number represents a fishing mortality of 1.6% of all oysters, excluding those from the VLM region in 2013, a proportion in line with exploitation rates since 2004 when the current management procedures were being established (Figure 26a). The fraction of market-sized oysters fished in 2013 was 3.3%, excluding the VLM, again similar to other values since about 2004 (Figure 26b).

Regional fishing mortality is shown in Figure 27 as both the percentage of all oysters and the percentage of ≥2.5" oysters. For historical reasons explained in the previous section, exploitation rates are generally higher in the downbay regions and are based on the larger oysters for the direct market. The intermediate transplant exploitation used in the upbay regions targets all sizes of oysters. Transplanting from the uppermost region, VLM, began in 2009 and was about 1.2% of all oysters for three years but this region remains closed after the late 2011 extreme freshet (Munroe et al. 2013). As mentioned earlier, a small portion (2%) of the LM transplant came from the VLM in 2013 (Table 9). This was only 0.07% of the oysters in the VLM region (Figure 27). Transplants conducted on the Low and Medium Mortality Transplant regions (LM, MMT) in 2013 were at the 2.3% exploitation rate, the 60th percentile for all sizes of oysters (Table 10), which the fishery achieved. The exploitation rates for ≥2.5" oysters only were somewhat higher: 2.4% for LM and 3% for MMT (Figure 27).

The percentage of market-sized oysters fished in 2013 on each of the three Direct Market regions (MMM, SR, HM) decreased for the second year in a row (Figure 27). The largest decrease was on Shell Rock where fishing mortality on market-size oysters was 13% in 2011, 12% in 2012, and 6.8% in 2013. The reason for this is likely the receipt of 21,050 bushels of oysters transplanted from the LM to Shell Rock in 2013 (Table 10). The last time Shell Rock received a similar amount of transplant material was in 2006 when it received 17,900 bushels (HSRL internal records) and the resulting fishing mortality rate on market-size oysters was 4.5%, the lowest rate since 1997 when the direct market program began. In both years, 2006 and 2013, fishing mortality on all oysters in Shell Rock was negative due to the influx of small oysters with the transplants (Figure 27). Although the HM also receives transplanted oysters in most years, the effects on fishing mortality are usually harder to see because it is a much larger region. The exception to this is 2002 – 2004 when there were high rates of disease mortality, a dearth of small oysters after a series of set failures, and many transplanted oysters were put on this region (HSRL internal records) resulting in two years of substantially negative fishing mortality.

Stock Performance Targets

Overview

Long-term patterns since assessments began in 1953 indicate that the Delaware Bay oyster stock is largely controlled by disease pressure. The overall abundance and biomass of the stock is generally driven by the intensity of disease and the mortality it causes. The record provides evidence of decadal or longer shifts in disease regimes driven by MSX from the 1950s to the 1980s and by Dermo disease since 1990 (Figure 4a). At least three periods are indicated in the record. The first was low abundance on the oyster beds in the 1950s that continued as MSX caused significant mortality. In the 1960s, MSX and mortality rates declined on the beds while shellplanting increased (Figure 5a) beginning a new period marked by high abundance that lasted into the 1980s. Circa 1985, an extended drought facilitated the spread of MSX upbay causing extensive mortality that began a third period characterized by high mortality and low abundance. Although the MSX epizootic had dissipated by 1990 and the population became resistant (Ford and Bushek 2012), abundance did not recover as Dermo disease became established and effectively doubled natural mortality (Powell et al. 2008). This state of low abundance and high mortality has persisted. Dermo disease and mortality are highly influenced by salinity along the upbay-downbay gradient that creates regions of varying oyster mortality identified in Figure 1 (Bushek et al. 2012). The continuing influence of Dermo disease on Delaware Bay oyster population dynamics has led the SARC to conclude that management goals should be set relative to population assessments made during the 'Dermo era' that began in 1990.

Whole-stock

Although the oyster resource is managed by region, the population is a single stock (Hoffman et al. 2009) and thus whole-stock reference points are important criteria upon which to judge stock status. From 2006 to 2010, the SARC considered three whole-stock abundance targets. The first two are the sums of the regional total and market-size oyster abundance targets: 2.311 billion and 334 million (see Table 11 and following Regional section for derivation) with the thresholds at half those values (1.156 billion and 167 million). The third was derived more theoretically from an analysis of biological relationships and formulation of a surplus production model (Powell et al. 2009) and is described in previous stock assessment reports. Several SARCs have debated the validity or relevance of using the surplus production model to identify whole stock reference points and have thus far agreed to use the medians of the sums of regional total and market abundance from the period 1989-2005 as whole stock reference points. Note that the Very Low Mortality region (VLM) has been excluded from all stock-wide reference point estimates and comparisons because time series data are insufficient to include them at this time.

The 2013 total abundance was estimated to be 1.209 billion oysters (excluding the VLM) of which 411 million were market-sized. The 1.2 billion estimate falls significantly below the whole-stock reference point of 2.3 billion (Figure 28) as it has at least since 2009 (HSRL 2010). This estimate falls around the 15th percentile of the 2013 survey uncertainty envelope where the lower 90% confidence limit is 1.184 billion and the threshold abundance reference point for the whole stock is 1.156 billion. In contrast to total abundance, market abundance across the entire stock sits significantly above the stock performance target as it has since 2010 (Figure 29). The whole stock market-sized abundance estimate of 411 million falls just over the 50th percentile with the 90% confidence limits being 349 and 469 million.

Regional

In 2006, the SARC set specific targets and thresholds for total abundance, market-sized abundance, and spawning stock biomass based on the 1989-2005 and 1990-2005 time periods respectively under the assumption that this time period likely represents the entire scope of oyster population dynamics in the present climate and disease regime. For each region, the median abundance and SSB values from these time periods were set as targets with values half these levels set as threshold levels (Table 11). Due to the absence of a time series for this period, the Very Low Mortality region (VLM) targets and thresholds were established by applying Low Mortality region (LM) conditions adjusted for region area (HSRL 2012).

In 2013, total oyster abundance was at the threshold in the two most upbay regions, VLM and LM but was slightly below the threshold in the two Medium Mortality regions (Figure 30). In contrast, total abundance estimates on Shell Rock and the HM fall significantly above the thresholds. Market-size oyster abundance in 2013 was above threshold in all regions, near target in the VLM and MMT and above target in the other four regions, considerably so for LM and Shell Rock (Figure 31).

Figure 32 illustrates the relationship of 2013 total abundance and biomass by region with respect to their targets and thresholds (see Table 11) and in relationship to the previous four years (2009-2012). Figure 33 shows the same information with market-size abundance in place of biomass. As noted earlier, total abundance hovers around threshold values in the four regions upbay but approaches the target value in Shell Rock and the HM region (Figures 32 and 33). Similarly, biomass in the uppermost three regions (VLM, LM, MMT) is also at threshold level although it approaches the target in the MMM region and exceeds it at Shell Rock (Figure 32). Biomass is near the middle of target and threshold values in the HM (Figure 32). The abundance-SSB trend has been generally downward on the three uppermost regions, is intermediate in the MMM, and has increased on SR and HM (Figure 32). The latter is probably due to a combination of recent spat sets, transplants, and shellplants.

Unlike total abundance or spawning stock abundance, market-size abundance in all regions is near or above the target values (Figure 33). This has been true in all years shown on the figure with the exception of the freshwater event that killed many market-sized oysters on VLM in 2011. However, market-size abundance has decreased on three of the six regions in 2013. Both total abundance and market-size abundance have decreased on the LM and MMT and market-size abundance has fallen on the MMM (Figure 33). Market-size abundance has risen on Shell Rock, possibly helped by the addition of over 21,000 bushels of transplanted oysters (Table 10) and survival of the relatively large 2010 set (Figure 15a). Although the HM does not show as large an increase in the market-size oyster category, total abundance did increase from 2012 to 2013 (Figure 33). This region did receive transplant in 2013 but the bulk of the increased abundance is most likely due to growth of the large 2012 spat set (Figure 15a).

Sustainability

The concept of a sustainable stock under federal guidelines articulated by the Magnuson-Stevens Fishery Conservation and Management Act is expressed in the concepts of `overfishing' and an `overfished' stock. For full discussion of its application to the New Jersey Delaware Bay oyster stock, refer to the initial definition from the 2011 SAW with updates in the following years (HSRL 2011, 2012, 2013). Because the Delaware Bay oyster population is strongly influenced by disease, the 2010 SAW considered a number of metrics to judge sustainability that provide analogies to federal criteria. The most important of these is the trend in market-size abundance (Figure 14). Market-size abundance is the least volatile of the stock metrics (abundance, SSB, market abundance) and so may be most likely to provide unambiguous evidence of over-exploitation were it to occur. The 1990-2013 time series shows that the abundance of market-size oysters has remained relatively stable for over two decades, fluctuating around a median of 4.62×10^8 (Figure 14). This stability comes from two sources. First, a balance exists between the death of larger oysters primarily caused by disease and the recruitment potential of the population. Second, the fishing mortality rate has been constrained such that removals by the fishery have not exceeded the replacement capacity of the population. As a consequence, the population has been able to recover from epizootic events during periods of reduced mortality from disease. This can be considered indicative of a stock that is not in an overfished state. Fishing mortality has remained below 5% over much of the 1953-2013 times series (Figure 4b) and below 2% from 1997-2013 (Figure 26a) whereas natural mortality rates have been much higher at least since 1990 (Figure 4a), an indication that overfishing is not occurring.

Summary of Stock Status

Table 12 is a 'stoplight' table summarizing the 2013 status of the oyster stock by region relative to the previous five years or the 1989-2013 time period. Different parameters of the regional stocks are designated as improving (green), degrading (orange), or neutral. Metrics include percentile ranks (40^{th} - 60^{th} percentiles are considered neutral), comparison to 5-yr median, comparison to biological reference points, comparison to mortality rates, or comparison to Dermo levels known to cause mortalities.

Several regional patterns are apparent in Table 12. First, while abundance and biomass have decreased in the VLM and LM regions, good recruitment combined with low Dermo levels and mortality rates are positive indicators of future improvement. In contrast, declines in abundance and biomass in both the MMT and MMM regions were not accompanied by positive changes in future indicators. Market-size abundance is lower on both regions compared to the previous five years although on the MMT, it is still above the median of the 1990-2013 time series at the 57^{th} percentile. Total and market abundance on SR increased in 2013 after receiving transplants but total abundance remained low (34^{th} percentile) in comparison to the time series while market abundance was above the median at the 61^{st} percentile. Dermo and mortality rates remain high on SR and recruitment has decreased indicating improvement in the coming year is unlikely without intermediate transplant and/or shell plants. The HM region is in the best relative condition with nearly all indicators positive or neutral.

Across regions, total abundance and spawning stock biomass are the most consistently negative indicators but market abundance remains near or above target levels in all. Recruitment and mortality patterns were unusual in that they were positive upbay (VLM, LM), negative in the central regions (MMT, MMM, SR), and relatively positive in the HM region downbay. Dermo levels remain high downbay of the Low Mortality Region.

Management Advice

- The fact that not one region fell near its total abundance target indicates that actions to enhance recruitment and minimize shell loss continue to be important. To increase abundance, a shellplanting program to enhance recruitment must continue with the aim of planting 250,000 bushels or more of shell annually. Sources of funding to expand shellplant efforts should be sought wherever possible.

- The 2013 high Dermo and natural mortality levels combined with low recruitment on the SR and MMM regions (Table 12) augur future low abundance without transplant and shellplant activity. The SARC recommends directing 2014 shellplants to Ship John in the MMM and to Shell Rock.

- A replant program to move spatted shell upbay should be implemented to return cultch and increase recruitment to the transplant regions. The SARC expressed particular concern about the MMT due to its low recruitment and increased mortality. The SARC notes that the Athos shellplanting on Middle bed is a useful model but low set on the initial downbay planting was not as good as expected.

- The SARC notes that the VLM has behaved as an ephemeral resource. Therefore, exploitation should be limited to periods of high abundance so the shell resource is not unduly depleted.

- The ten-year resurvey program should be continued in order to reallocate grids to strata as required to take into account changes in oyster distribution on beds as a consequence of natural population dynamics and enhancement programs.

- Because Dermo is the primary factor controlling mortality in the oyster population, the seasonal monthly monitoring program should continue. The collection of ancillary data on mortality, size-frequency, and growth rates should be continued as part of this program.

Science Advice

- Based on preliminary results from the 2013 dredge calibration study, the SARC concluded that averaging all current and previous dredge efficiency estimates is likely the best method to apply to existing data. A more thorough analysis of the 2013 study should be completed and options for using this new information should be presented for evaluation. Mid-year contact with the SARC may be required to make decisions prior to the next stock assessment. The evaluation should include examination of previous and new dredge calibration regressions using tow-based data to determine if more accurate estimates can be obtained from data collected *in situ* as the fall survey occurs.

- Analyses of spat growth rates should continue to evaluate the 20-mm cutoff for defining spat. Additional data are needed from upbay areas and should be collected when possible. These data should be used to re-evaluate spat recruitment events across the time series.

- Re-evaluation of the stock-performance reference points should be undertaken consistent with the apparent change in population dynamics observed between the decades of the 1990s and 2000s. The SARC recommends an analysis be developed to examine whether or not the time period of 1989 to 2005 should continue to be used as a baseline for establishing stock performance targets and thresholds.

- Updated growth rate information for all oyster sizes is needed to determine whether growth rates may be increasing with increases in water temperatures due to climate change. Use of the ten-acre Gandy's Beach Oyster Restoration and Enhancement Area being used by Project PORTS (Promoting Oyster Restoration Through Schools) program may provide information on growth rates up through market sizes that may prove valuable as the growth data on larger size classes within the fishery are difficult to obtain.

- The SARC recommends further examination of the management strategy that uses percentiles of exploitation from the 1996-2006 time series with a view toward understanding how the different regions respond to different exploitation rates. Refinement of methods to review prior recommendations for intermediate transplant and direct market harvest in comparison to management decisions and population response should continue. Previous suggestions for new strategies including using the median exploitation rate +/- 25%, a box plot with the hinges set at a desired level, or 40% and 60% of the range bounded by the 0 and 100th percentiles represent reasonable alternatives for consideration.

- Experimental efforts should be explored to consider mechanisms to facilitate rapid recovery of the VLM to maintain its integrity and so that it can be used more routinely as a resource for the intermediate transplant program. The experimental plant of spatted shell to Hope Creek is worth repeating with a better capture of spat from down bay.

- A long-range plan for reef management taking into account sea level rise, salinity shifts and other factors related to climate change, should be developed.

- Further evaluation of the rate of box disarticulation throughout the regions, particularly in the LM and VLM, is needed.

- The relationship between condition and other population and disease variables should be investigated and contrasted among different management areas.

- A more fundamental understanding and explanation of the shell budget should be developed. Some more basic metrics such as cultch volumes through time should be examined.

- Data on fecundity and spawning potential are needed for the VLM.

Harvest Recommendations

Based on the observations in this report, the SARC makes the following recommendations for 2014 harvest and intermediate transplant:

- Oyster quota allocation should continue to be set using abundance-based exploitation rates as decided in 2006 using the exploitation rate percentiles for the time series of 1996-2006.

- All transplants should use mechanical cullers and all attempts should be made to limit the transplantation of cultch.

- The VLM region should remain closed to allow continued recovery from the 2011 mortality event. The SARC recommends that this strategy continue until recovery is evident before significant reliance is placed on this region by the intermediate transplant program.

- The LM region may be used for transplanting up to the 60th percentile of exploitation with the transplant targeted to Ship John in the MMM. The SARC cautions, however, against using the same donor bed in consecutive years. Upper Arnolds was the primary bed used in 2013 (Table 13).

- The MMT region may be exploited up to the 60th percentile and that transplant should go to Shell Rock (Table 13). The MMT region, however, has more negative indicators than any other (Table 12). Therefore, lower exploitation rates should be considered. Regardless of the level chosen, exploitation must be split between Upper Middle, Middle, and Sea Breeze such that no more than 50% of the allocation is taken from Middle. Efforts should be made to ensure that Sea Breeze is not used as both a transplant and harvest bed.

- The MMM region indicated some signs of degradation following multiple years of stability and high productivity. The SARC recommends reducing harvest pressure to the 60th or possibly the 75th percentile following a successful intermediate transplant to the region (Table 14).

- The SR region improved in 2013 but disease remains high and recruitment low; caution is required to avoid damaging this valuable region. An exploitation rate no higher than the 50th percentile is recommended unless a successful intermediate transplant is directed to this bed after which exploitation may be increased to the 60th percentile (Table 14). Given that SR contains only 6% of the stock (Table 12) but provided 29% of the Direct Market harvest (Table 9), continued efforts to improve this region are advised.

- The HM region had the most consistently positive indicators. With relatively strong recruitment and a relatively abundant sub-market size class, the exploitation rate may be increased to the 60th or even the 75th percentile to help maintain a stable harvest (Table 14).

- No increases in quota should occur before transplants are completed and efforts should be made to complete a significant portion of the intermediate transplant program before harvesting is allowed on the region.

References

Ashton-Alcox, K.A., E.N. Powell, D. Bushek. 2009 Shell-Planting program in Delaware Bay, *Report to the U.S. Army Corps of Engineers*. 34pp.

Ashton-Alcox, K.A., E.N. Powell, J.A. Hearon, C.S. Tomlin, R.M. Babb. 2013. Transplant Monitoring for the New Jersey Delaware Bay Oyster Fishery. *J. Shellfish Res.,* 32: 2, 459-469.

Banta, S.E., E.N. Powell, and K.A. Ashton-Alcox. 2003. Evaluation of dredging effort by the Delaware Bay oyster fishery in New Jersey waters. *N. Am. J. Fish. Manag.* 23:732-741.

Bushek, D., S.E. Ford and I. Burt. 2012. Long-term patterns of an estuarine pathogen along a salinity gradient. *J. Mar. Res*. 70:225-251.

Chai, A., M. Homer, C. Tsai, and P. Goulletquer. 1992. Evaluation of oyster sampling efficiency of patent tongs and an oyster dredge. *N. Am. J. Fish. Manag.* 12: 825-832.

Fegley, S. R., S. E. Ford, J. N. Kraeuter & D. R. Jones. 1994. *Relative effects of harvest pressure and disease mortality on the population dynamics of the Eastern oyster (Crassostrea virginica) in Delaware Bay*. NOAA, Final Rpt # NA26FL0588. Bivalve, NJ: Haskin Shellfish Research Laboratory, Rutgers University. 36pp text, 28 tables, 58 figures.

Fegley, S.R., S.E. Ford, J.N. Kraeuter, and H.H. Haskin, 2003. The persistence of New Jersey's oyster seedbeds in the presence of oyster disease and harvest: the role of management. *J. Shellfish Res.* 22:451-464.

Ford, S.E. 1997. History and present status of molluscan shellfisheries from Barnegat Bay to Delaware Bay. In: *The History, Present Condition, and Future of the Molluscan Fisheries of North and Central America and Europe, Vol. 1,North America* (MacKenzie, C.L., Jr., V.G. Burrell Jr., A. Rosenfield and W.L. Hobart, Eds.) pp. 119-140. U.S. Dept. of Commerce, NOAA Tech. Report NMFS, Seattle, WA.

Ford, S.E. and H.H. Haskin. 1982. History and epizootiology of *Haplosporidium nelsoni* (MSX), an oyster pathogen in Delaware Bay, 1957-1980. *J. Invertebr. Pathol.* 40:118-141.

Ford, S.E. and D. Bushek. 2012. Development of resistance to an introduced marine pathogen by a native host. *J. Mar. Res*. 70:205-223.

Hofmann, E., D. Bushek, S. Ford, X. Guo, D. Haidvogel, D. Hedgecock, J. Klinck, C. Milbury, D. Narvaez, E. Powell, Y. Wang, Z. Wang, J. Wilkin and L. Zhang. 2009. Understanding how disease and environment combine to structure resistance in estuarine bivalve populations. Oceanography. 22:212-231.

HSRL. 2001. *Report of the 2001 Stock Assessment Workshop (3rd SAW) for the New Jersey Delaware Bay Oyster Beds*. Haskin Shellfish Research Lab., Port Norris, NJ. 53 pp.

HSRL. 2006. *Report of the 2006 Stock Assessment Workshop (8th SAW) for the New Jersey Delaware Bay Oyster Beds*. Haskin Shellfish Research Lab., Port Norris, NJ. 95 pp.

HSRL. 2008. *Report of the 2008 Stock Assessment Workshop (10th SAW) for the New Jersey Delaware Bay Oyster Beds*. Haskin Shellfish Research Lab., Port Norris, NJ. 131 pp.

HSRL. 2010. *Report of the 2010 Stock Assessment Workshop (12th SAW) for the New Jersey Delaware Bay Oyster Beds*. Haskin Shellfish Research Lab., Port Norris, NJ. 145 pp.

HSRL. 2011. *Report of the 2011 Stock Assessment Workshop (13th SAW) for the New Jersey Delaware Bay Oyster Beds*. Haskin Shellfish Research Lab., Port Norris, NJ. 179 pp.

HSRL. 2012. *Report of the 2012 Stock Assessment Workshop (14th SAW) for the New Jersey Delaware Bay Oyster Beds*. Haskin Shellfish Research Lab., Port Norris, NJ. 190 pp.

HSRL. 2013. *Stock Assessment Workshop New Jersey Delaware Bay Oyster Beds (15th SAW) Report*. Haskin Shellfish Research Lab., Port Norris, NJ. 133 pp.

Kraeuter, J.N., S. Ford, & M. Cummings. 2007. Oyster growth analysis: a comparison of methods. *J. Shellfish Res*. 26:479-491.

Mann, R. and E.N. Powell. 2007. Why oyster restoration goals in the Chesapeake Bay are not and probably cannot be achieved. *J. Shellfish Res*. 26:4, 905-917.

Munroe, D., A. Tabatabai, I. Burt, D. Bushek, E.N. Powell, and J. Wilkin. 2013. Oyster Mortality and Disease in Delaware Bay: Impact and Recovery Following Hurricane Irene and Tropical Storm Lee. *Estuar. Coast. Shelf Sci.* 135:209-219.

Powell, E.N., K.A. Ashton-Alcox, S.E. Banta and A.J. Bonner. 2001. Impact of repeated dredging on a Delaware Bay oyster reef. *J. Shellfish Res*. 20:961-975.

Powell, E.N., K.A. Ashton-Alcox, J.A. Dobarro, M. Cummings, and S.E. Banta. 2002. The inherent efficiency of oyster dredges in survey mode. *J. Shellfish Res*. 21:691-695.

Powell, E.N., J.J. Gendek, K.A. Ashton-Alcox. 2005. Fisherman choice and incidental catch: Size frequency of oyster landings in the New Jersey oyster fishery. *J. Shellfish Res.* 24:469-476.

Powell, E.N., J.N. Kraeuter and K.A. Ashton-Alcox. 2006. How long does oyster shell last on an oyster reef? *Estuar. Coast. Shelf Sci.* 69:531-542.

Powell, E.N., K.A. Ashton-Alcox, J.N. Kraeuter. 2007. Re-evaluation of eastern oyster dredge efficiency in survey mode: application in stock assessment. *N. Am. J. Fish. Manage.* 27:492-511.

Powell, E.N. and J.M. Klinck. 2007. Is oyster shell a sustainable estuarine resource? *J. Shellfish Res.* 26:181-194.

Powell, E.N., K.A. Ashton-Alcox, J.N. Kraeuter, S.E. Ford and D. Bushek. 2008. Long-term trends in oyster population dynamics in Delaware Bay: regime shifts and response to disease. *J. Shellfish Res.* 27:729-755.

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

Powell, E.N., J.M. Klinck, K.A. Ashton-Alcox, E.E. Hofmann, & J. Morson. 2012. The rise and fall of *Crassostrea virginica* oyster reefs: The role of disease and fishing in their demise and a vignette on their management. *J. Mar. Res.*, 70, 505-558.

Table 1. Dredge efficiency multipliers (catchability coefficients) used to convert oyster, box, and cultch estimates to 'on bottom' numbers. Time series indicates how sets of multipliers are applied to the data. Sets of multipliers are averaged results from one or more dredge calibration experiments conducted at various times (see text). Upbay, all beds above Shell Rock; Downbay, Shell Rock and beds below. The oyster and box multipliers include all size classes of oysters (or boxes) >20mm recognizing that the smaller sizes are often attached to larger sizes and that oysters and boxes are often attached to each other.

Time Series	Bed Group	Oysters	Boxes	Cultch
Base	Upbay	8.22	11.12	17.11
	Downbay	2.96	5.67	8.97
1998-2000	Upbay	9.40	11.47	21.49
	Downbay	2.83	6.50	9.55
2001-2004	Upbay	8.22	11.12	17.11
	Downbay	2.96	5.67	8.97
2005-2013	Upbay	7.30	10.87	13.71
	Downbay	3.11	4.64	8.14

Table 2. Ten year resurvey schedule for NJ Delaware Bay oyster beds and number of grids on each bed. All beds were resurveyed prior to 2009 when the current schedule was implemented. One grid is 0.2" latitude x 0.2" longitude (approximately 25 acres, 101,175 m^2 or 10.1 hectares).

Year	Bed	# Grids	# Grids/Year	Resurvey Year
1	Cohansey	83		
	Bennies Sand	49	132	2009
2	Ship John	68		
	Nantuxent Point	68	136	2010
3	Beadons	38		
	Middle	51		
	Vexton	47	136	2011
4	Sea Breeze	48		
	Shell Rock	93	141	2012
5	Upper Arnolds	29		
	New Beds	112	141	2013
6	Bennies	171	171	Scheduled 2014
7	Arnolds	99		
	Strawberry	29	128	
8	Upper Middle	84		
	Hog Shoal	23		
	Liston Range	32	139	
9	Hawk's Nest	28		
	Hope Creek	97	125	
10	Fishing Creek	67		
	Round Island	73	140	

Table 3. Sampling scheme for the 2013 Fall survey of the Delaware Bay oyster beds in New Jersey. The numbers given are the number of sampled grids devoted to that bed stratum. The strata designations are described in the text. The Enhanced stratum includes those grids that received transplant or shellplant in the survey year or shell plant within the previous two years. Egg Island and Ledge are sampled in alternate years.

Region	Bed	High Quality	Medium Quality	Low Quality	Enhanced
Very Low Mortality	Hope Creek	4	4	0	1
	Fishing Creek	2	3	0	0
	Liston Range	2	4	0	0
Low Mortality	Round Island	2	3	0	0
	Upper Arnolds	3	4	0	0
	Arnolds	3	3	0	0
Medium Mort. Trans.	Upper Middle	1	3	0	0
	Middle	2	5	0	2
	Sea Breeze	3	4	0	0
Medium Mort. Mkt.	Cohansey	5	5	0	0
	Ship John	6	5	0	2
Shell Rock	Shell Rock	4	6	0	5
High Mortality	Bennies Sand	3	6	0	2
	Bennies	3	9	0	1
	Nantuxent Pt.	3	3	0	0
	Hog Shoal	3	3	0	0
	Strawberry	1	3	0	0
	Hawk's Nest	2	3	0	0
	New Beds	4	5	0	0
	Beadons	2	3	0	0
	Vexton	2	2	0	0
	Egg Island	1	5	0	0
	Ledge	0	0	0	0
Total		61	91	0	13

Grand Total: 165

Table 4. Percentile positions in the indicated time series for the given bay regions and stock variables. A lower percentile equates to a lower value of the variable relative to the entire time series. Table is divided into the 61-year time series (1953–2013) and the 24-year time series (1989–2013). Very Low Mortality region is not included in the percentile evaluations of the time series. Recruitment values do not include the enhancements from shell planting.

1953 – 2013	Oyster Abundance	Spat Abundance	Box-Count Mortality
Baywide	0.123	0.385	0.697
Low Mortality	0.074	0.467	0.582
Medium Mortality Transplant	0.090	0.287	0.926
Medium Mortality Market	0.254	0.402	0.779
Shell Rock	0.352	0.320	0.746
High Mortality	0.385	0.566	0.467

1989 – 2013	Oyster Abundance	Market >2.5" Abundance[1]	Spat Abundance	Spawning Stock Biomass[1]	Box-Count Mortality
Baywide	0.220	0.348	0.460	0.188	0.500
Low Mortality	0.140	0.652	0.740	0.229	0.500
Medium Mortality Transplant	0.100	0.565	0.380	0.146	0.940
Medium Mortality Market	0.260	0.391	0.460	0.229	0.660
Shell Rock	0.340	0.609	0.340	0.521	0.700
High Mortality	0.500	0.522	0.620	0.312	0.140

[1]SSB and market abundance values used the 1990 – 2013 time series.

Table 5. Average half-lives in years for surficial oyster shell on Delaware Bay oyster beds for 1999–2013 time series. Beds arranged in upbay to downbay order. --, unable to determine.

Location	99-08	99-09	99-10	99-11	99-12	99-13
Hope Creek	--	--	--	--	--	--
Fishing Creek	--	--	--	--	--	--
Liston Range	--	--	--	--	--	--
Round Island	21.95	47.45	17.94	--	--	--
Upper Arnolds	5.49	7.43	4.81	7.67	8.27	6.59
Arnolds	3.70	6.12	5.31	7.09	5.69	6.57
Upper Middle	--	--	--	--	--	--
Middle	7.02	4.09	4.18	6.29	4.72	5.54
Sea Breeze	21.29	37.39	6.64	33.17	6.63	17.27
Cohansey	4.88	3.79	5.85	5.56	5.84	7.14
Ship John	2.09	3.20	3.08	3.49	2.83	3.65
Shell Rock	4.49	4.44	2.95	4.62	2.95	4.86
Bennies Sand	3.84	5.08	4.65	10.61	5.35	8.47
Bennies	3.34	7.95	5.97	11.12	8.76	8.62
Nantuxent Pt.	2.75	2.56	3.10	3.58	3.58	5.05
Hog Shoal	2.78	3.39	3.12	4.71	5.42	5.83
Strawberry	4.29	5.82	15.56	19.65	9.06	11.91
Hawk's Nest	4.44	11.87	4.55	4.61	5.73	10.85
New Beds	65.71	20.70	9.67	36.22	109.78	--
Beadons	5.28	6.28	4.63	9.55	13.18	7.28
Vexton	6.00	3.34	3.83	18.80	7.25	22.74
Egg Island	--	5.40	5.60	78.65	84.18	102.88
Ledge	6.91	7.71	5.34	5.84	--	--

Table 6. Summary of shell planting activities for 2013. Direct plants occurred on Shell Rock. Spatted shell was moved from downbay plantings by suction dredge and replanted on Middle. Spat per bushel estimates are from the clamshell volumes in Fall 2013 survey dredge samples. Projections of market-size abundance used regional natural mortality at the juvenile rate in year 1 and at the adult rate in following years. The mortality rates used were the 50th percentiles of the 1989-2013 time series for the Medium Mortality Transplant (Middle) and Shell Rock regions. Calculation of years to market size used von Bertalanffy parameters (see Kraeuter et al., 2007) for the Medium Mortality region (Middle) and Shell Rock. Bushel conversion used 264 oysters per bushel from port sampling data.

	Plant Type	**Clamshell Planted (bu)**	**Clamshell Spat bu^{-1}**	**Clamshell Total Spat**	**Median Juvenile Mortality Rate**	**Juvenile Years**	**Median Adult Mortality Rate**	**Adult Years**	**Potential Mkt-Size Abund.(bu)**
Middle 27/28	replant	23,050	21	476,204	0.187	1	0.164	2	985
Shell Rock 29	direct	50,000	83	4,127,936	0.488	1	0.194	2	4,899
Shell Rock 30	direct	50,000	78	3,897,536	0.488	1	0.194	2	4,626

Table 7. Summary of 2013 spat recruitment on 2012 shell plants. Spat per bushel estimates are from the clamshell volumes in Fall 2013 survey dredge samples. Projections of market-size abundance used regional natural mortality at the juvenile rate in year 1 and at the adult rate in following years. The mortality rates used were the 50th percentiles of the 1989–2013 time series for the Low Mortality region (Hope Creek) and the Medium Mortality Market region (Ship John). Calculation of years to market size used von Bertalanffy parameters (see Kraeuter et al., 2007) for the Low Mortality region and the Medium Mortality region. Bushel conversion used 264 oysters per bushel from port sampling data.

	Plant Type	Clamshell Planted (bu)	Clamshell Spat bu^{-1}	Clamshell Total Spat	Median Juvenile Mortality Rate	Juvenile Years	Median Adult Mortality Rate	Adult Years	Potential Mkt-Size Abund.(bu)
Hope Creek 59	replant	12,000	0	0	0.255	1	0.085	4	0
Ship John 36	direct	50,000	5	257,614	0.251	1	0.202	2	436
Ship John 53	direct	50,000	0	0	0.251	1	0.202	2	0

Table 8. Contribution of shell planting by region, 2003 – 2013. Plant volumes include both directly planted shell and spatted shell moved into regions. Area planted is the percentage of the region's area that received plant. Spat on plant is the percentage of total recruitment due to the spat on planted shell. Details of 2013 and 2012 shellplantings are given in Tables 6 and 7; details from previous years can be found in earlier reports. --, no shellplanting.

	High Mortality Region			**Shell Rock Region**		
Year	Plant Vol (bu)	Area Planted	Spat on Plant	Plant Vol (bu)	Area Planted	Spat on Plant
2003	16,130	0.3%	17%	--	--	--
2004	--	--	--	--	--	--
2005	12,250	0.3%	12%	89,337	5.6%	54%
2006	142,207	1.5%	58%	125,354	5.6%	50%
2007	43,360	0.3%	1%	--	--	--
2008	172,487	2.1%	47%	--	--	--
2009	86,072	0.6%	17%	58,233	2.1%	31%
2010	49,645	0.3%	26%	40,199	2.1%	29%
2011	50,000	0.3%	4%	50,000	2.1%	49%
2012	--	--	--	--	--	--
2013	--	--	--	100,000	4.5%	16%

	Medium Mort. Market Region			**Medium Mort. Transplant Region**		
Year	Plant Vol (bu)	Area Planted	Spat on Plant	Plant Vol (bu)	Area Planted	Spat on Plant
2003	--	--	--	--	--	--
2004	--	--	--	--	--	--
2005	--	--	--	--	--	--
2006	--	--	--	--	--	--
2007	188,523	5.3%	5%	43,000	1.5%	11%
2008	21,898	1.1%	13%	--	--	--
2009	--	--	--	--	--	--
2010	--	--	--	--	--	--
2011	--	--	--	18,000	1.6%	0.6%
2012	100,000	2.2%	1%	--	--	--
2013	--	--	--	23,050	1.7%	0.7%

	Low Mortality Region			**Very Low Mortality Region**		
Year	Plant Vol (bu)	Area Planted	Spat on Plant	Plant Vol (bu)	Area Planted	Spat on Plant
2012	--	--	--	12,000	2.0%	1.8%
2013	--	--	--	--	--	--

Table 9. Harvest and transplant data for 2013. Bed areas include medium and high quality grids only. Fraction covered is the estimated fraction of bed area swept by industry dredges during the harvest season. Fractions above 1 indicate a total swept area greater than the bed area. Note: harvest bushels contain primarily oysters ≥2.5" whereas transplant bushels may contain a large fraction of smaller oysters.

Region	Bed	Bed Area (acres)	Fraction Covered	Harvest Bushels	Harvest Fraction	Transplant Bushels	Transplant Fraction
VLM	Hope Creek	734				0	0
	Fishing Creek	315				0	0
	Liston Range	289				550	0.02
LM	Round Island	472				2,250	0.06
	Upper Arnolds	446				15,550	0.44
	Arnolds	630				2,700	0.08
MMT	Upper Middle	236				3,200	0.09
	Middle	814				5,200	0.15
	Sea Breeze	525		5,454	0.06	6,200	0.17
MMM	Cohansey	1234	1.05	10,583	0.13		
	Ship John	1208	2.27	19,279	0.23		
SR	Shell Rock	1130	2.30	24,280	0.29		
HM	Bennies Sand	788	1.85	10,841	0.13		
	Bennies	2077	0.06	870	0.01		
	Nantuxent Pt.	631	2.87	10,218	0.12		
	Hog Shoal	447	0.83	2,385	0.03		
	Strawberry	447	0.07	140	0		
	Hawk's Nest	500	0	0	0		
	New Beds	1236	0.06	226	0		
	Beadons	210	0	0	0		
	Vexton	316	0	0	0		
	Egg Island	1000	0	0	0		
	Ledge	474	0	0	0		
	Total or Mean	16,158	1.28	84,276	1.00	35,650	1.00

Table 10. Shellfish Council allocation decisions based on SARC recommendations and the ultimate outcomes after Intermediate Transplant (a) and Direct Market harvest (b) from 2008 to 2013. Quota and transplant decisions are based on SARC recommendations of several abundance-based exploitation rate projections for each region. Some options for the Direct Market regions come with SARC advice to transplant from upbay regions prior to fishing. Additional quota from transplants is determined post-transplant from the proportion of marketable oysters in the transplants converted to bushels using the latest average number of oysters per bushel from the port-sampling program. (b) also shows the proportion of the final quota that derives from the transplant.

a.

Transplant Year	Transplant Donor Region	Council Exploit. Percentile	Bushels Moved	Actual Exploit. Percentile	Predicted Quota Increase (bu)	Actual Quota Increase (bu)	Receiver Region
2008	LM	50th	9,450	>50th	5,492	8,161	MMM
	MMT	50th	8,200	>60th	2,677	6,337	HM
2009	VLM	40th	9,100	>40th	5,609	7,699	MMM
	LM	50th	10,400	>50th	7,427	9,713	HM
	MMT	60th	14,100	<60th	7,326	7,865	HM
2010	VLM	40th	6,550	40th	5,992	4,839	SR
			1,400			1,232	HM
	LM	60th	1,200	<60th	12,864	839	SR
			17,050			14,814	HM
	MMM	50th	12,550	<50th	5,566	5,502	HM
2011	VLM	40th	7,950	40th	4,716	6,540	MMM
	LM	40th	10,150	>40th	4,450	6,098	HM
	MMT	50th	17,750	>50th	5,940	10,549	HM
2012	LM	40th	7,650	<40th	3,509	3,558	HM
	MMT	50th	21,825	>60th	5,869	11,574	HM
2013	LM	60th	21,050	<60th	12,883	13,949	SR
	MMT	60th	14,600	<50th	9,307	9,505	HM

b.

Harvest Year	Direct Market Region	Council Direct Market Percentile	Direct Market Quota (bu)	Transplant Quota Increase (bu)	Total Quota	Actual Total Harvest (bu)	Over/ Under Quota	Transplant Fraction of Quota
2008	Med. Mort. Mkt.	50th	16,710	8,161	24,871	25,370	499	0.33
	Shell Rock	60th	29,889	0	29,889	29,736	-153	0.00
	High Mortality	60th	29,507	6,337	35,844	34,776	-1,068	0.18
	TOTAL		**76,106**	**14,498**	**90,604**	**89,882**	**-722**	**0.16**
2009	Med. Mort. Mkt.	100th	24,634	7,699	32,333	24,558	-7,775	0.24
	Shell Rock	60th	21,858	0	21,858	22,918	1,060	0.00
	High Mortality	50th	13,316	17,578	30,894	33,214	2,320	0.57
	TOTAL		**59,808**	**25,277**	**85,085**	**80,690**	**-4,395**	**0.30**
2010	Med. Mort. Mkt.	100th	29,410	0	29,410	23,491	-5,919	0.00
	Shell Rock	40th	10,814	5,678	16,492	17,493	1,001	0.34
	High Mortality	60th	13,793	21,548	35,341	33,391	-1,950	0.61
	TOTAL		**54,017**	**27,226**	**81,243**	**74,375**	**-6,868**	**0.34**
2011	Med. Mort. Mkt.	100th	31,551	6,540	38,091	38,286	195	0.17
	Shell Rock	60th	24,775	0	24,775	24,112	-663	0.00
	High Mortality	60th	16,995	16,647	33,642	32,072	-1,570	0.49
	TOTAL		**73,321**	**23,187**	**96,508**	**94,470**	**-2,038**	**0.24**
2012	Med. Mort. Mkt.	100th	30,219	0	30,219	29,213	-1,006	0
	Shell Rock	60th	22,071	0	22,071	22,628	557	0
	High Mortality	60th	14,006	15,132	29,138	26,299	-2,839	0.52
	TOTAL		**66,296**	**15,132**	**81,428**	**78,140**	**-3,288**	**0.19**
2013	Med. Mort. Mkt.	100th	34,576	0	34,576	35,316	740	0.00
	Shell Rock	40th	9,875	13,949	23,824	24,280	456	0.59
	High Mortality	60th	17,592	9,505	27,097	24,680	-2,417	0.35
	TOTAL		**62,043**	**23,454**	**85,497**	**84,276**	**-1,221**	**0.27**

Table 11. Region-specific stock performance biomass and abundance targets and thresholds. The target is taken as the median of abundance or biomass for 1989-2005 (1990-2005 for biomass) with the exception of the Very Low Mortality beds. The threshold is taken as half of these values. SSB, spawning stock biomass. Reference point estimates for the Very Low Mortality beds are obtained by assuming the equivalent condition on a per-area basis to the Low Mortality beds and using the Low Mortality bed numbers so-corrected as the base values.

	Very Low Mortality	**Low Mortality**	**Medium Mortality Transplant**	**Medium Mortality Market**	**Shell Rock**	**High Mortality**
Abundance						
Target (50th Percentile)	451,681,800	531,733,632	342,824,960	850,364,224	113,350,896	473,125,088
Threshold (1/2 Target)	225,840,900	265,866,816	171,412,480	425,182,112	56,675,448	236,562,544
SSB						
Target (50th Percentile)	149,078,151	175,499,360	178,104,672	337,117,920	62,450,392	267,982,768
Threshold (1/2 Target)	74,539,075	87,749,680	89,052,336	168,558,960	31,225,196	133,991,384
Mkt (≥ 2.5″) Abundance						
Target (50th Percentile)	36,856,056	43,388,077	46,366,382	167,407,462	25,622,244	51,205,771
Threshold (1/2 Target)	18,428,028	21,694,039	23,183,191	83,703,731	12,811,122	25,602,886

Table 12. Summary status of the stock for 2013. Green indicates variables judged to be improved relative to the 1989 (or 1990) – 2013 time period or improving relative to 2012 or the 2008-2012 median. Orange indicates variables judged to be degraded or degrading for the same comparisons. A neutral color is used for near-average conditions falling within the 40th to 60th percentiles of the 1989 (or 1990) – 2013 time period and also for trend changes less than + 15%.

	Transplant Very Low Mortality	Transplant Low Mortality	Transplant Medium Mortality	Market Medium Mortality	Market Shell Rock	Market High Mortality
Fraction of Stock	0.15	0.19	0.11	0.27	0.06	0.22
Total Abundance						
2013 Percentile	Not Incl.	0.14	0.10	0.26	0.34	0.50
2008-2012 Median	Decrease	Decrease	Decrease	Decrease	Decrease	Increase
2012-2013 Trend	Decrease	Decrease	Decrease	Decrease	Increase	Increase
Target-Thresh.	Below	Between	Below	Between	Between	Between
Spawning Stock Biomass						
2013 Percentile	Not Incl.	0.23	0.15	0.23	0.52	0.31
2008-2012 Median	Decrease	Decrease	Decrease	Decrease	Decrease	Increase
2012-2013 Trend	Decrease	Decrease	Decrease	Decrease	Increase	Increase
Target-Thresh.	Between	Between	Between	Between	Above	Between
Market Abundance						
2013 Percentile	Not Incl.	0.65	0.57	0.39	0.61	0.52
2008-2012 Median	Decrease	Decrease	Decrease	Decrease	Decrease	Increase
2012-2013 Trend	Decrease	Decrease	Decrease	Decrease	Increase	Increase
Target-Thresh.	Between	Above	Above	Between	Above	Above
Recruitment						
2013 Percentile	Not Incl.	0.74	0.38	0.46	0.34	0.62
2008-2012 Median	Increase	Increase	Decrease	Increase	Decrease	Increase
2012-2013 Trend	Increase	Increase	Decrease	Decrease	Decrease	Decrease
Mortality						
Rate	0.08	0.11	0.25	0.23	0.24	0.16
2013 Percentile	Not Incl.	0.50	0.94	0.66	0.70	0.14
2008-2012 Median	Decrease	Decrease	Increase	Increase	Increase	Decrease
2012-2013 Trend	Decrease	Decrease	Increase	Decrease	Decrease	Decrease
Dermo						
Weighted Prevalence	0.05	0.37	1.96	1.74	2.23	2.21
2013 Percentile	Not Incl.	0.68	0.87	0.40	0.73	0.27
2008-2012 Median	Decrease	Decrease	Decrease	Decrease	Increase	Increase
2012-2013 Trend	Increase	Decrease	Decrease	Increase	Decrease	Increase

Table 13. Transplant region projections for intermediate transplanting in 2014. Cullers are used for these transplants. Exploitation rate and numbers to be removed are based on all oyster size classes. The estimated number of bushels to be moved is derived from the mean of the number of oysters per bushel for these regions from the 2013 intermediate transplant program or other as noted.[1] The proportion of oysters available for market is estimated based on the fraction of oysters ≥2.5" converted to bushels using the average 264 oysters/bu derived from the 2004-2013 port-sampling program. Percentiles for the VLM and LM use the exploitation reference points for the MMT (see text for details). Footnotes identify alternatives available under specified conditions. Arrows indicate SARC-recommended options in each region.

Region	Percentile	Exploit. Rate	Number of Oys Removed	Deckload Oys / bu	Transpl. Bushels	Mkt.Equiv. Bushels
Very Low Mortality[2]	25th	.0103	2,277,674	328	6,944	1,363
	40th	.0127	2,808,394	328	8,562	1,681
	50th	.0188	4,157,307	328	12,675	2,488
	60th	.0233	5,152,407	328	15,709	3,084
Low Mortality[3]	→25th	.0103	2,830,895	404	7,007	3,742
	→40th	.0127	3,490,521	404	8,640	4,614
	→50th	.0188	5,167,070	404	12,790	6,831
	→60th	.0233	6,403,869	404	15,851	8,466
Medium Mortality Transplant[4]	→25th	.0103	1,554,916	262	5,935	2,662
	→40th	.0127	1,917,226	262	7,318	3,283
	→50th	.0188	2,838,098	262	10,832	4,859
	→60th	.0233	3,517,430	262	13,425	6,022

[1] Oysters/Bu taken from 2013 intermediate transplant samples; actual numbers for 2014 may not be similar. Because of this, Transplant Bushels for 2014 intermediate transplant will differ, perhaps by a lot. VLM projection based on 550 bushels transplanted from Liston Range in April, 2013.

[2] The SARC recommended closure of the VLM region for 2014 to allow its continued recovery from the 2011 mortality event.

[3] The SARC recommends that transplant from the LM region alternate beds each year and that the 2014 transplant goes to Ship John in the MMM region.

[4] The SARC recommends that no more than 50% of the transplant from the MMT region come from Middle in any year and that the 2014 transplant goes to SR.

Table 14. Allocation projections for direct marketing on the High Mortality, Shell Rock, and Medium Mortality Market regions in 2014. Exploitation rates and numbers to be removed are based on the abundance of ≥2.5 oysters in each region. Projections use the average oysters per marketed bushel (264) derived from the 2004-2013 port-sampling program. Arrows indicate SARC-recommended options. Shaded percentiles require that intermediate transplant must occur.

Region	Percentile	Exploitation Rate	Number of Oysters Removed	Direct-Market Bushels
Medium Mortality Market (Ship John & Cohansey)	→25th	.0154	2,275,146	8,618
	→40th	.0178	2,629,714	9,961
	→50th	.0214	3,161,567	11,976
	→60th	.0267	3,944,572	14,942
	→75th	.0328	4,845,766	18,355
	100th	.0398	5,879,924	22,272
Shell Rock	→25th	.0531	1,936,036	7,334
	→40th	.0870	3,172,036	12,015
	→50th	.0880	3,208,496	12,153
	→60th	.1140	4,156,462	15,744
	75th	.1586	5,782,586	21,904
High Mortality	→25th	.0095	592,763	2,245
	→40th	.0122	761,232	2,884
	→50th	.0652	4,068,226	15,410
	→60th	.0782	4,879,374	18,483
	→75th	.0827	5,160,157	19,546

Figure 1. The natural oyster beds of Delaware Bay, NJ and their regional designations. The 23 oyster beds are grouped into six regions based on the estuarine gradient of salinity that influences growth, disease, and mortality rates. Dark green, Very Low Mortality; yellow, Low Mortality; light green, Medium Mortality Transplant; light blue, Medium Mortality Market; orange, Shell Rock; dark blue, High Mortality. Bed footprints include grids from the High and Medium quality strata. Strata designation described in main document. Each grid is 0.2" latitude x 0.2" longitude; approximately 25 acres (101,175 m^2 or 10.1 hectares).

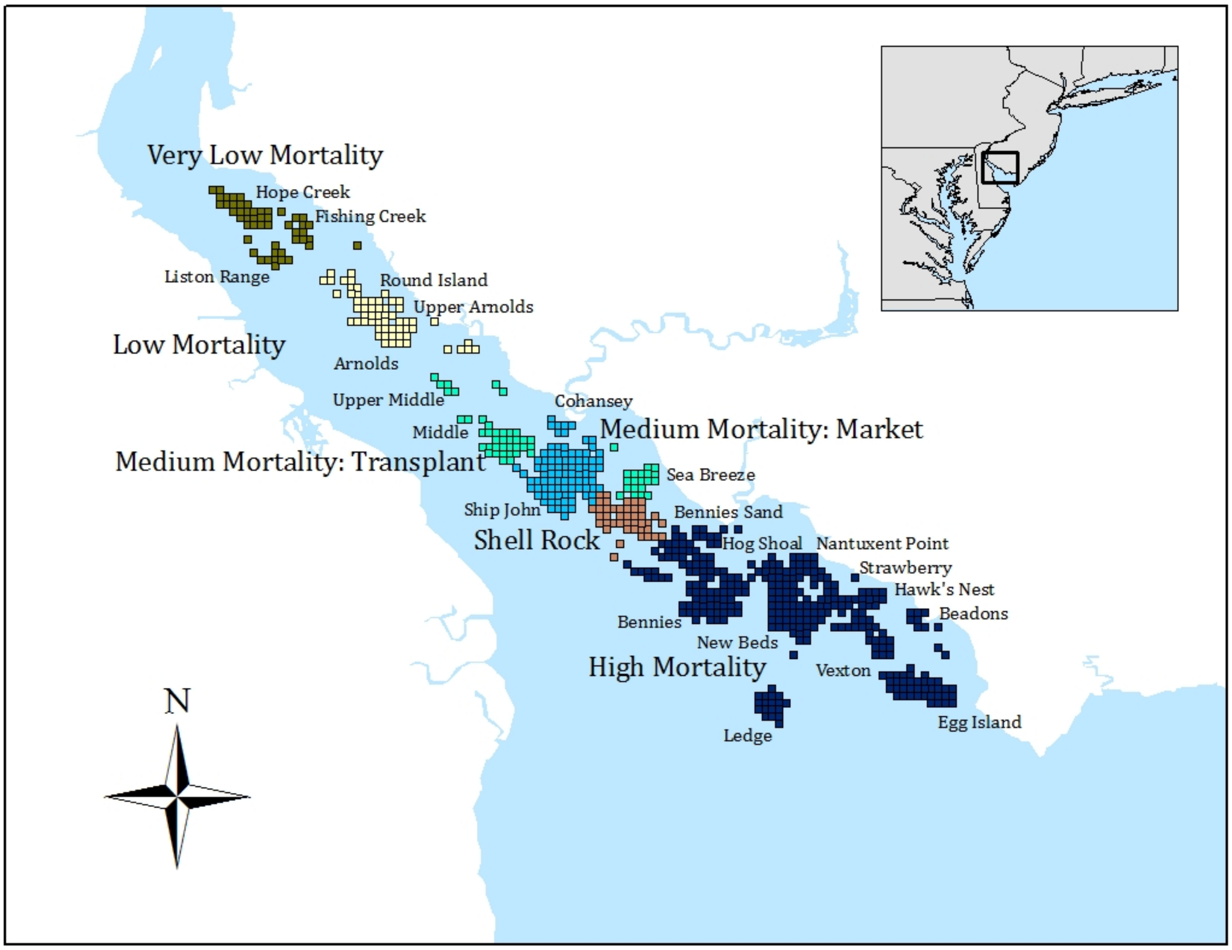


Figure 2. Abundance of oysters on the oyster beds of Delaware Bay, NJ for the entire time series of stock surveys (1953–2013). Until 2007, the three most upbay beds that comprise the Very Low Mortality Region (see Figure 1) were not included in the annual surveys and therefore they are not included in most of the whole stock analyses.

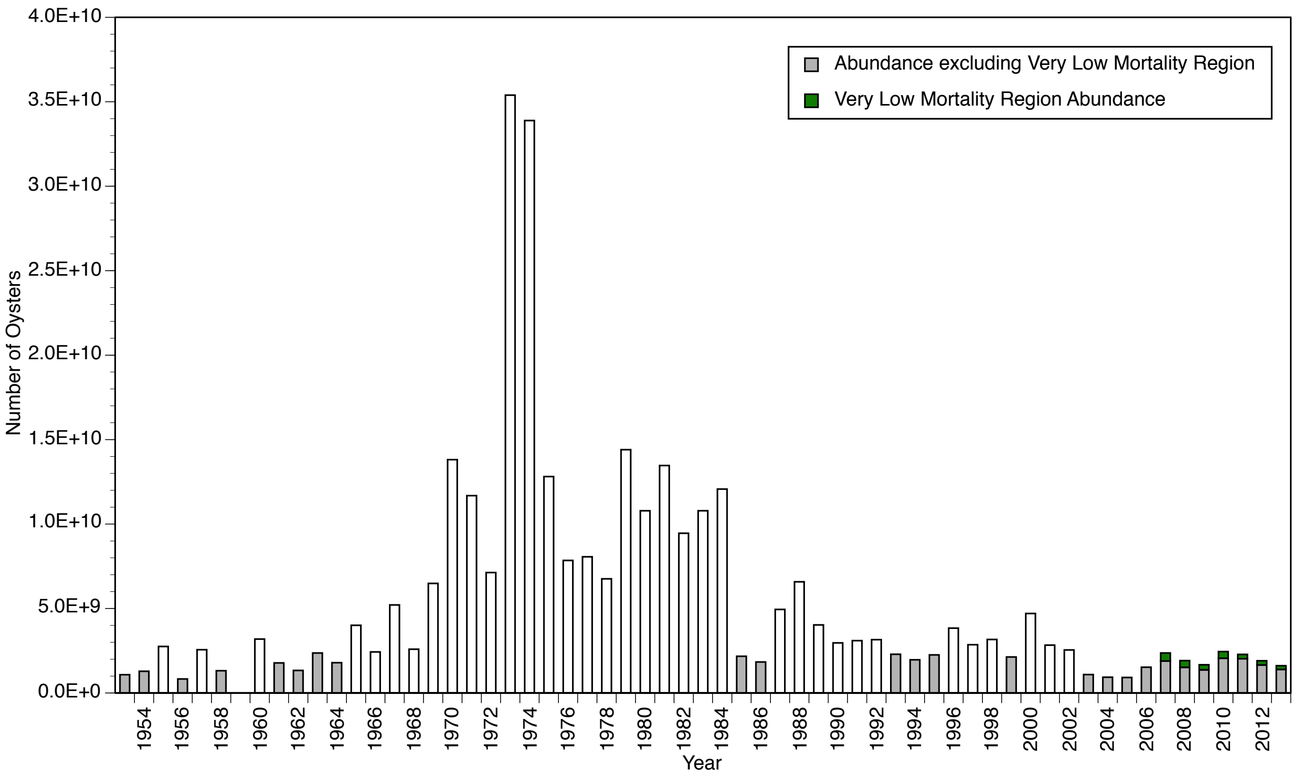


Figure 3. Acreage of the six bed regions. From upbay to downbay: Very Low Mortality (VLM), Low Mortality (LM), Medium Mortality Transplant (MMT), Medium Mortality Market (MMM), Shell Rock (SR), High Mortality (HM). Total Acreage: 16,184 acres.

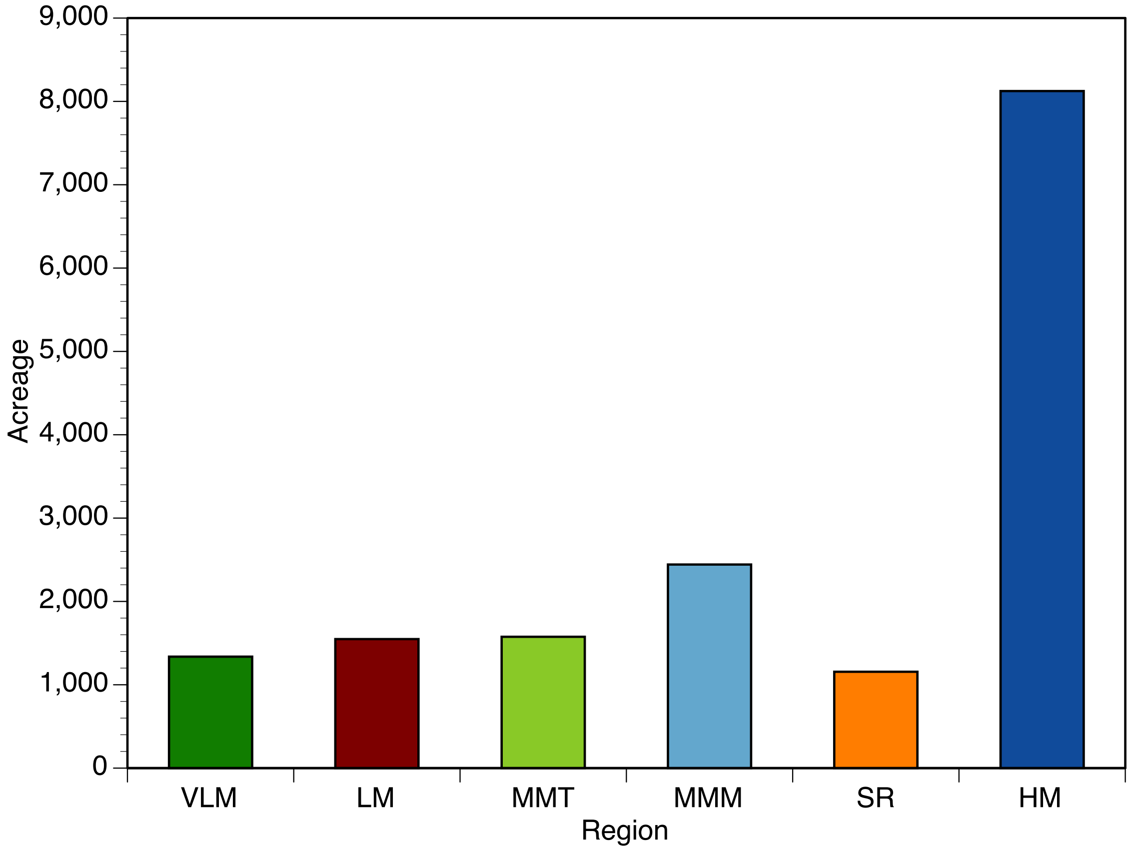
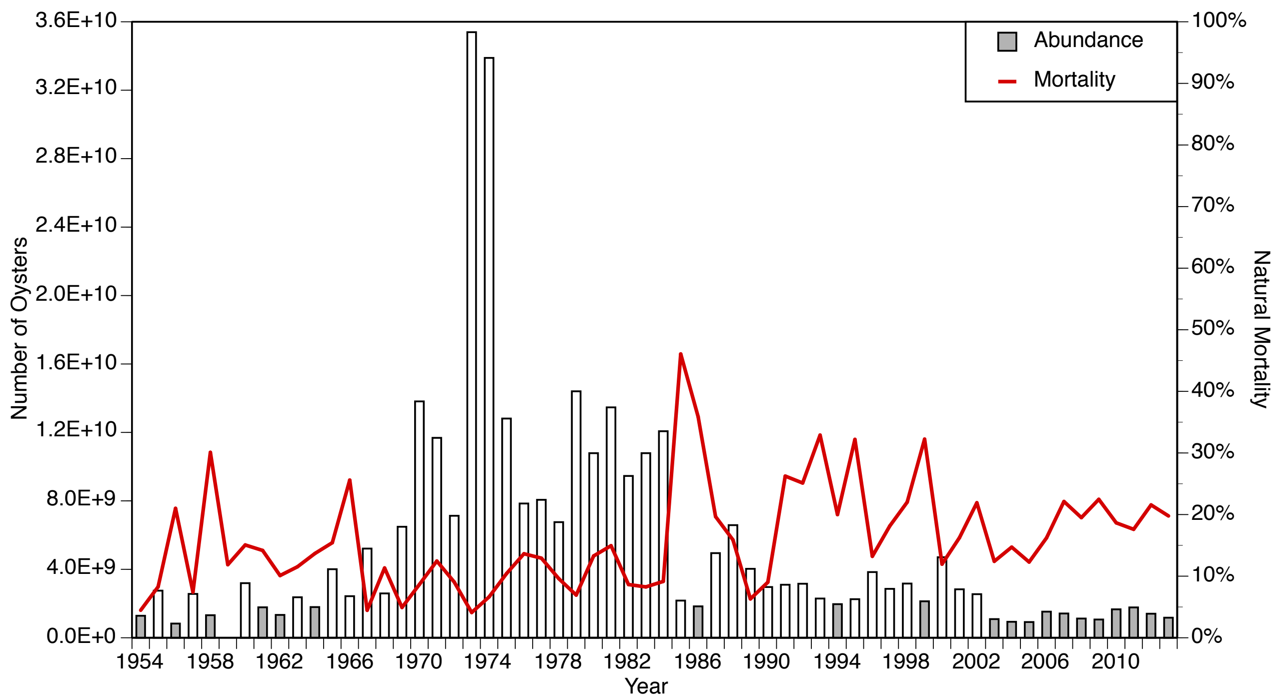


Figure 4. Box-count mortality rates (**a**) and fishing exploitation rates (**b**) compared to total abundance of oysters on the oyster beds of Delaware Bay, NJ, excluding the Very Low Mortality region, for the entire time series of stock surveys (1954–2013).

a.



b.

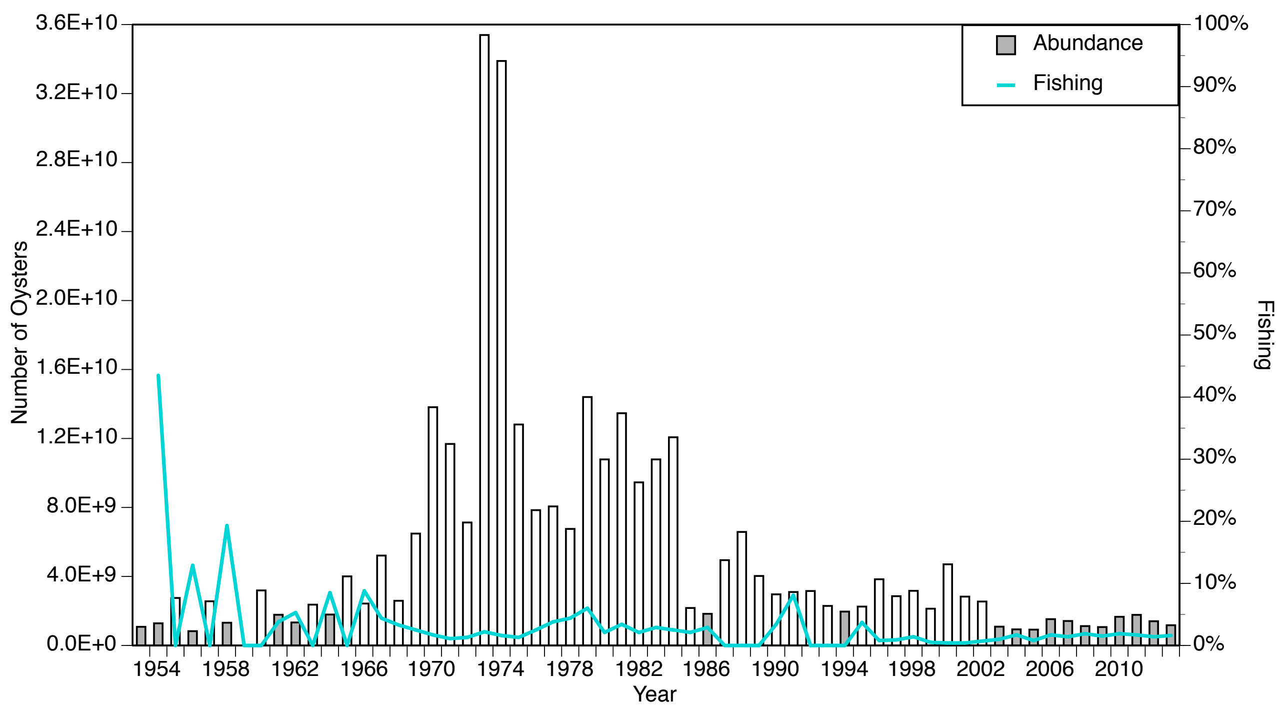
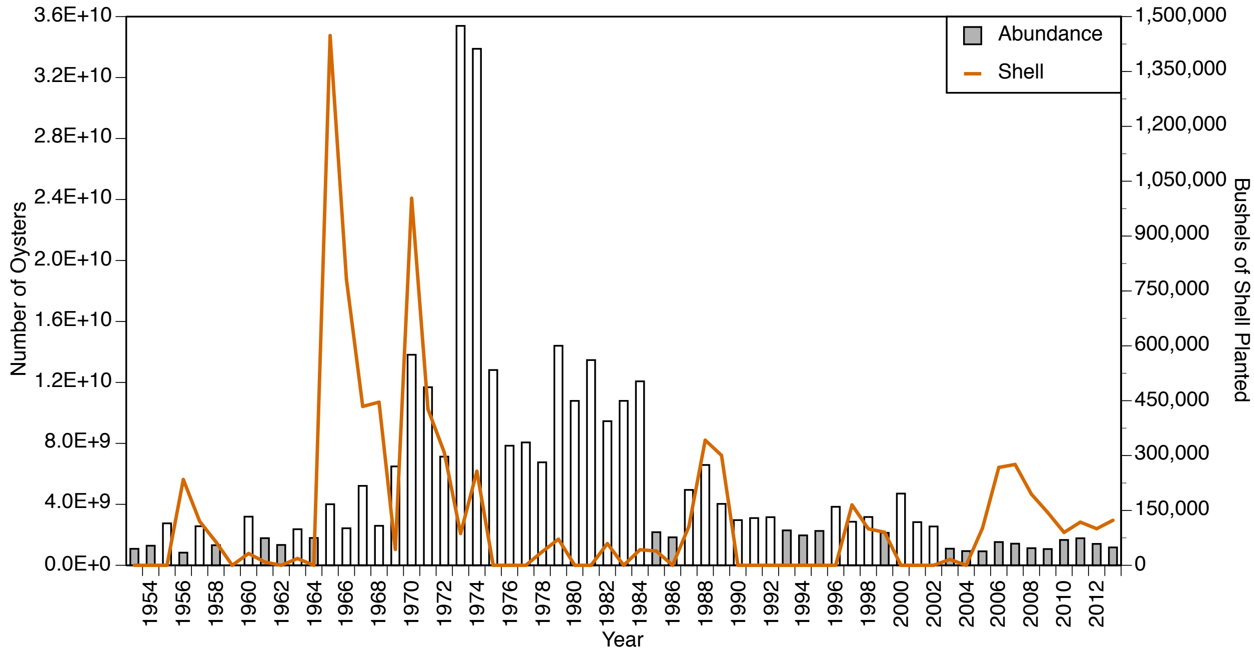


Figure 5. Bushels of shell planted for spat recruitment (**a**) and number of spat from the stock assessment time series (**b**) compared to total abundance of oysters on the oyster beds of Delaware Bay, NJ, excluding the Very Low Mortality region, for the entire time series of stock surveys (1953–2013).

a.



b.

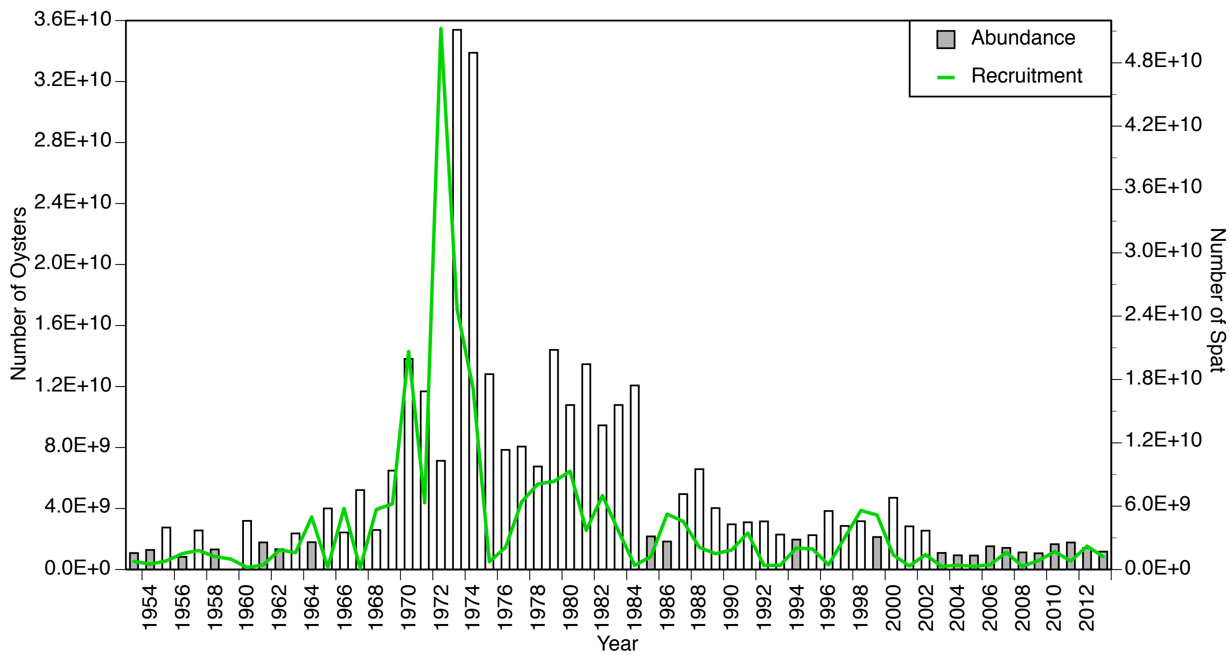


Figure 6. Oyster abundance by region for the 1990–2013 survey time series (lines). Relative acreage of each region shown in pie chart. Acreage includes only the high and medium quality strata footprint for each bed from the 2013 survey. Regions are color-coded as in Figure 1. From upbay to downbay: Very Low Mortality (VLM); Low Mortality (LM); Medium Mortality Transplant (MMT); Medium Mortality Market (MMM); Shell Rock (SR); High Mortality (HM).

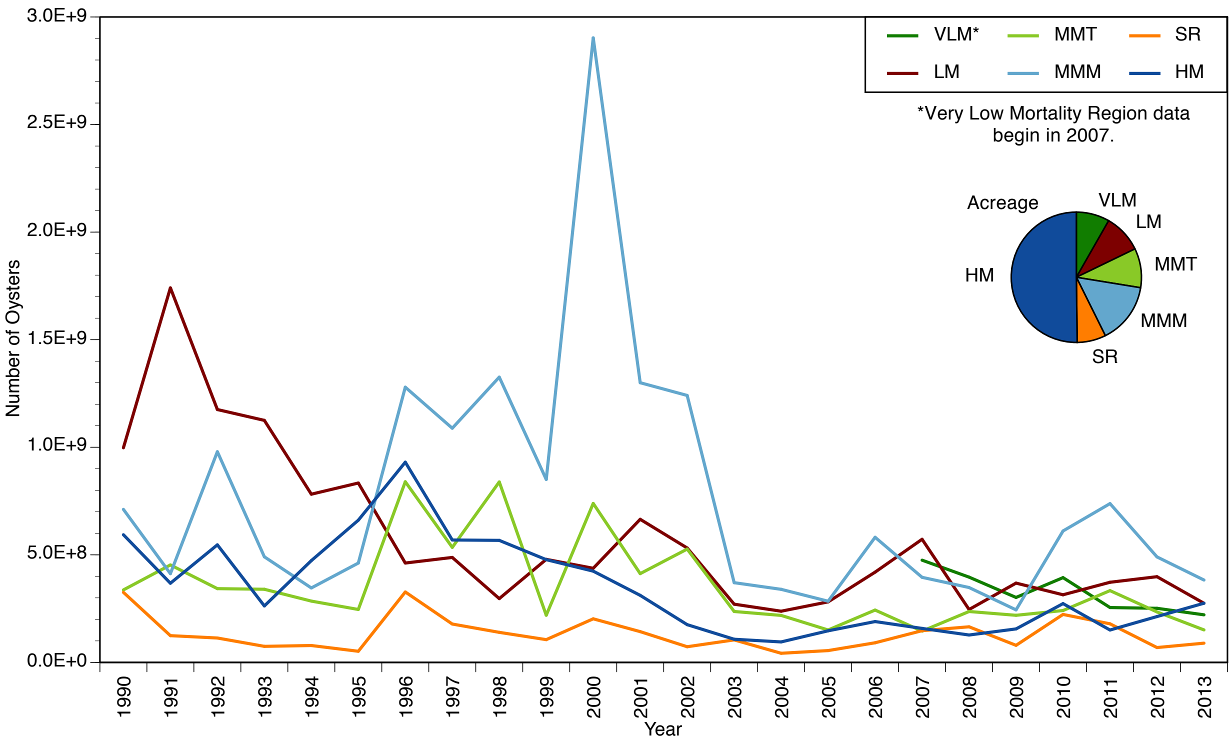


Figure 7. Box-count mortality rate by region for the 1990–2013 time series.

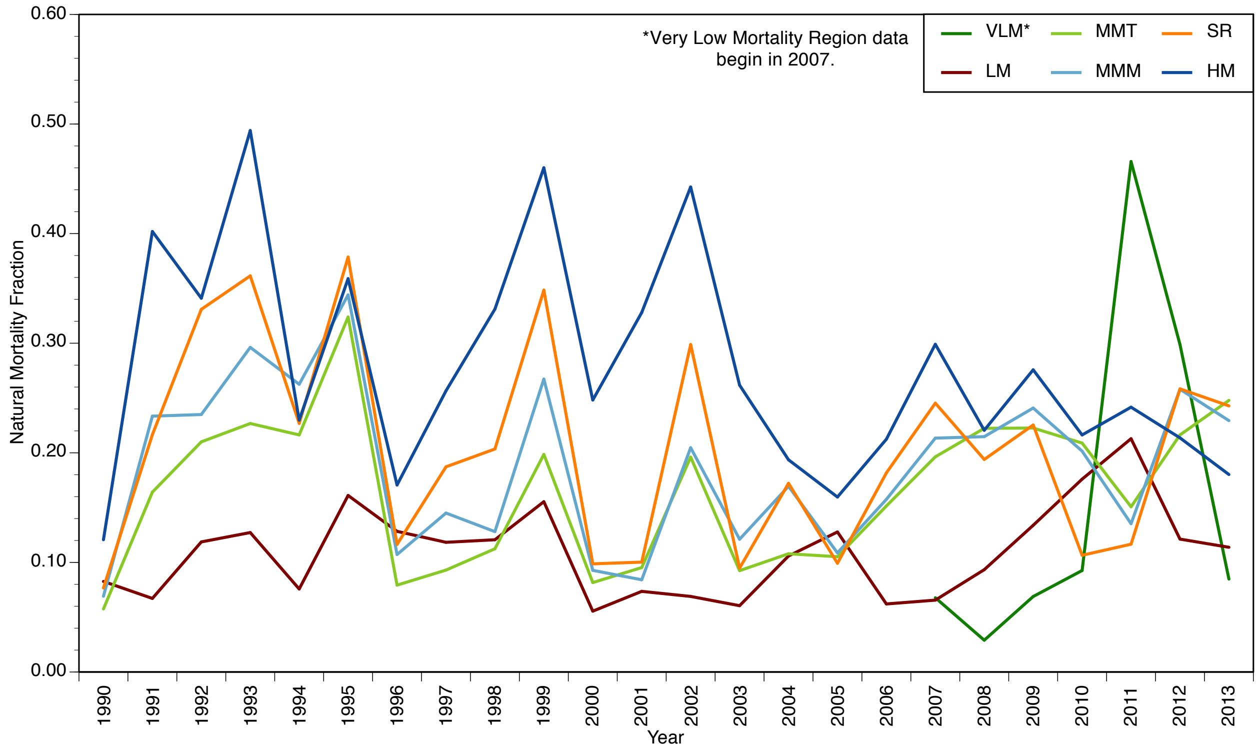


Figure 8. Number of oysters harvested from the natural oyster beds of Delaware Bay, NJ from 1953–2013. Prior to 1996, the bay-season fishery removed oysters from the natural beds and transplanted them downbay to leased grounds. The direct-market fishery began in 1996. In 1997, an intermediate transplant program began. Zeros represent years of fishery closure.

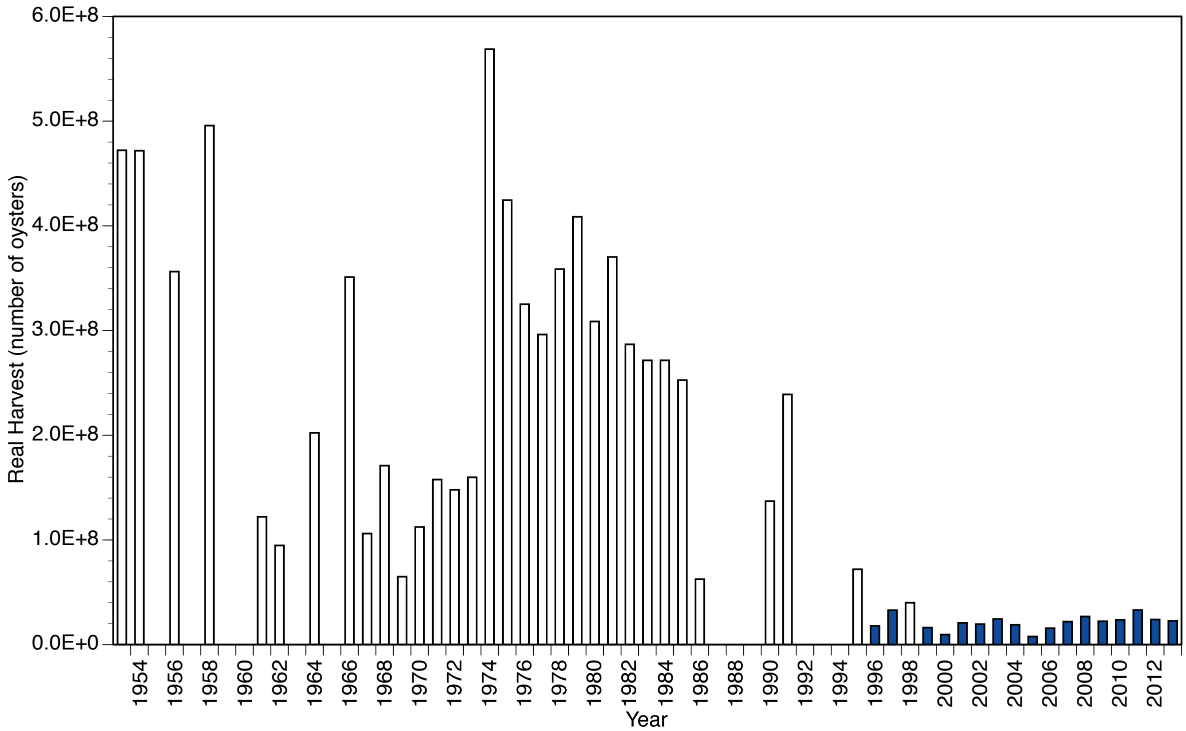


Figure 9. Mean catchability coefficient (q=1/efficiency) and standard error of the mean estimated from dredge efficiency experiments conducted in 2003 and 2013. Shaded boxes on the y-axis group beds into "Up-Bay" and "Down-Bay" sections. *Inset*: Mean catchability coefficient and standard error of the mean for data grouped by bay section.

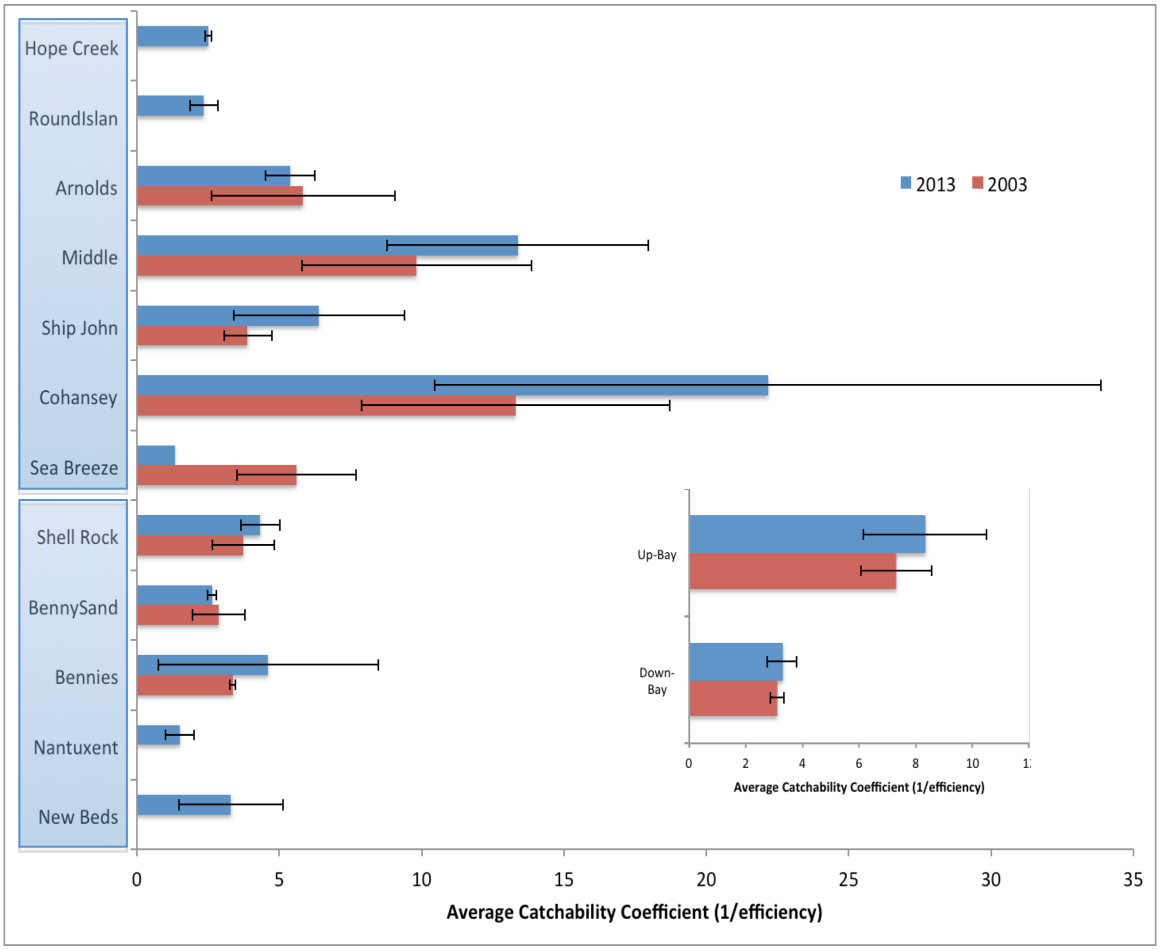
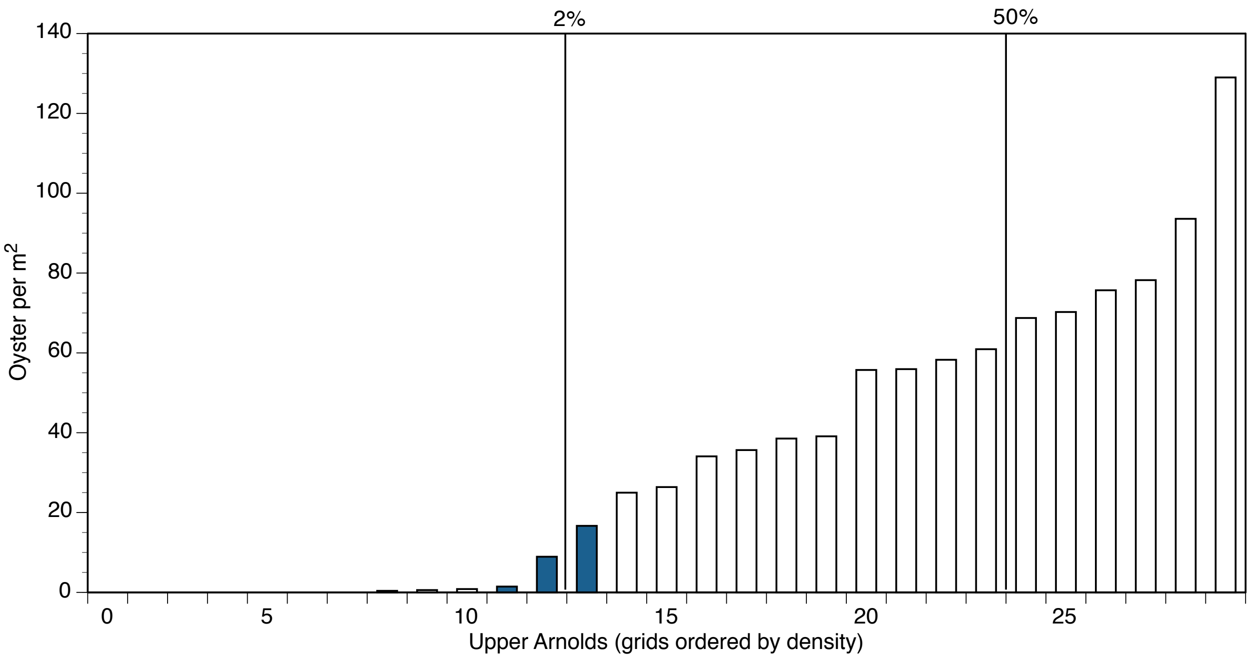


Figure 10. Relationship of cumulative oyster abundance versus density for grids ordered by increasing abundance on Upper Arnolds and New Beds for the 2013 resurvey. The 2013 resurvey program covered all navigable grids associated with these beds. The vertical lines mark the boundaries between the Low (2%), Medium (2-50%), and High (50%) quality strata based on cumulative abundance.



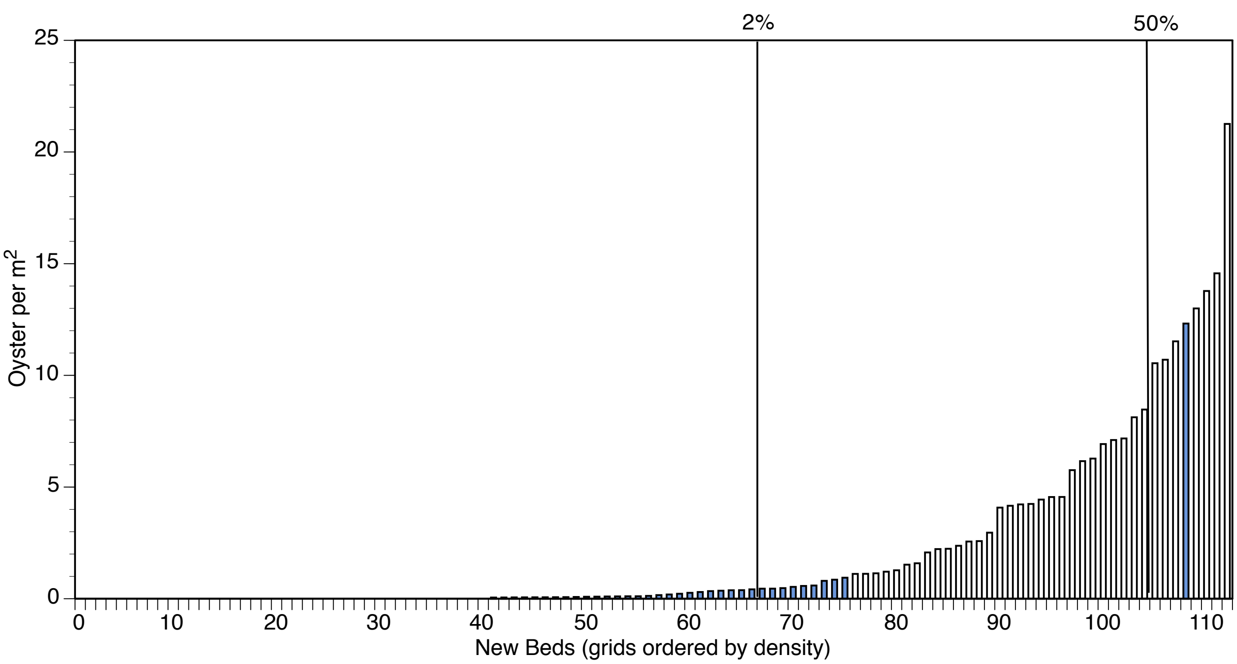


Figure 11. Distribution of grids on New Beds and Upper Arnolds in 2012 before and in 2013 after the spring 2013 resurvey shaded according to oyster density. The 2013 resurvey program covered all navigable grids associated with these beds. High-quality grids are shaded darkly, medium-quality grids are shaded an intermediate color, and low-quality grids are shaded a light color. New Beds has 112 grids and Upper Arnolds has 29 grids.

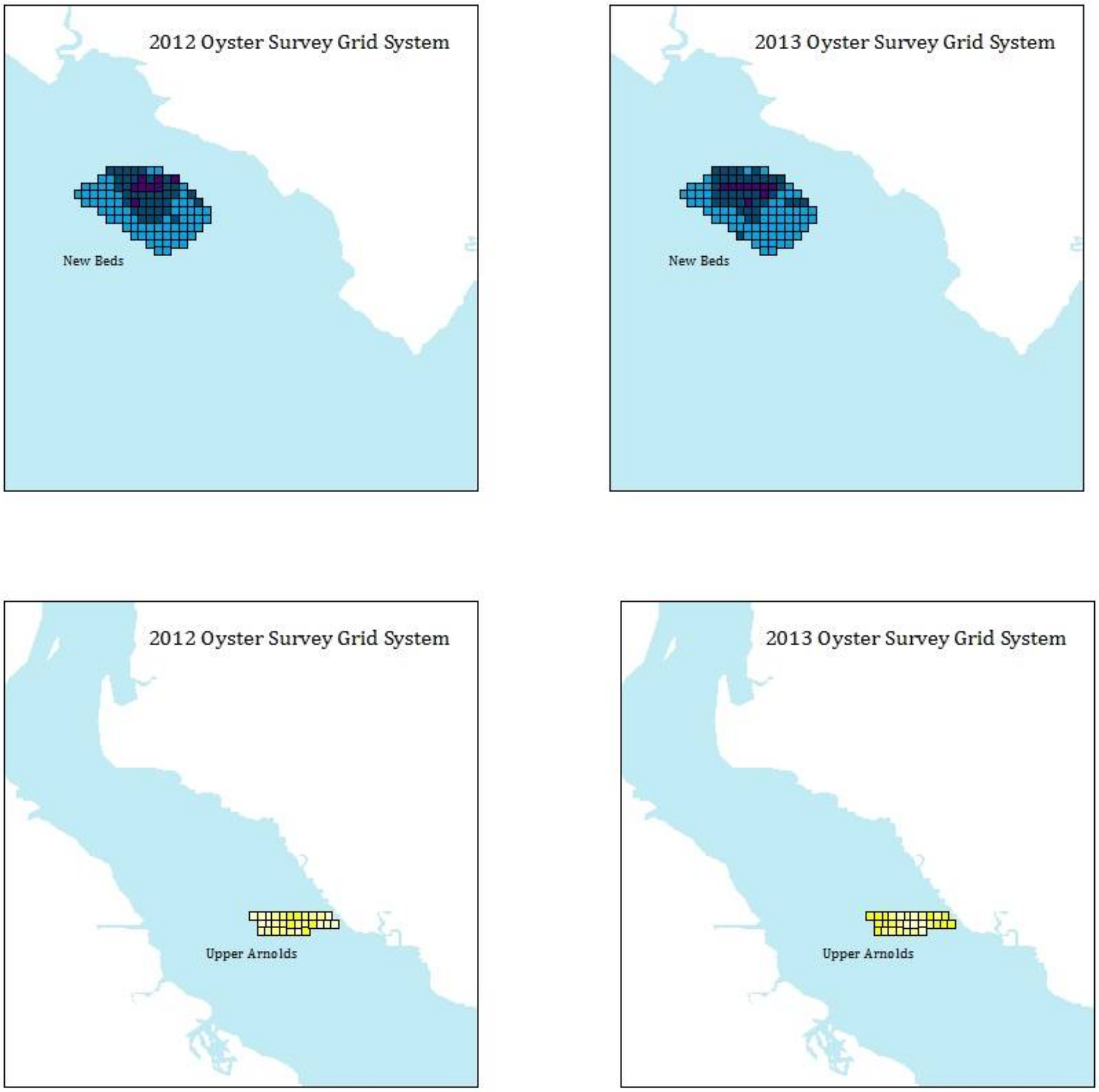


Figure 12. The natural oyster beds of Delaware Bay, NJ and their regional designations. Olive green, Very Low Mortality; yellow, Low Mortality; light green, Medium Mortality Transplant; light blue, Medium Mortality Market; orange, Shell Rock; dark blue, High Mortality. Beds included in each region are listed in Table 3. Bed footprints include grids from the High (dark shade) and Medium (light shade) quality strata. Strata designation is described in the text. Grids are 0.2” latitude x 0.2” longitude; approx. 25 acres (101,175 m^2 or 10.1 hectares). Bed footprints are based on resurveys beginning in 2005. Ledge and Egg Island do not have many oysters and have not been resurveyed. Sites for the 2013 stock assessment survey are indicated by white stars.

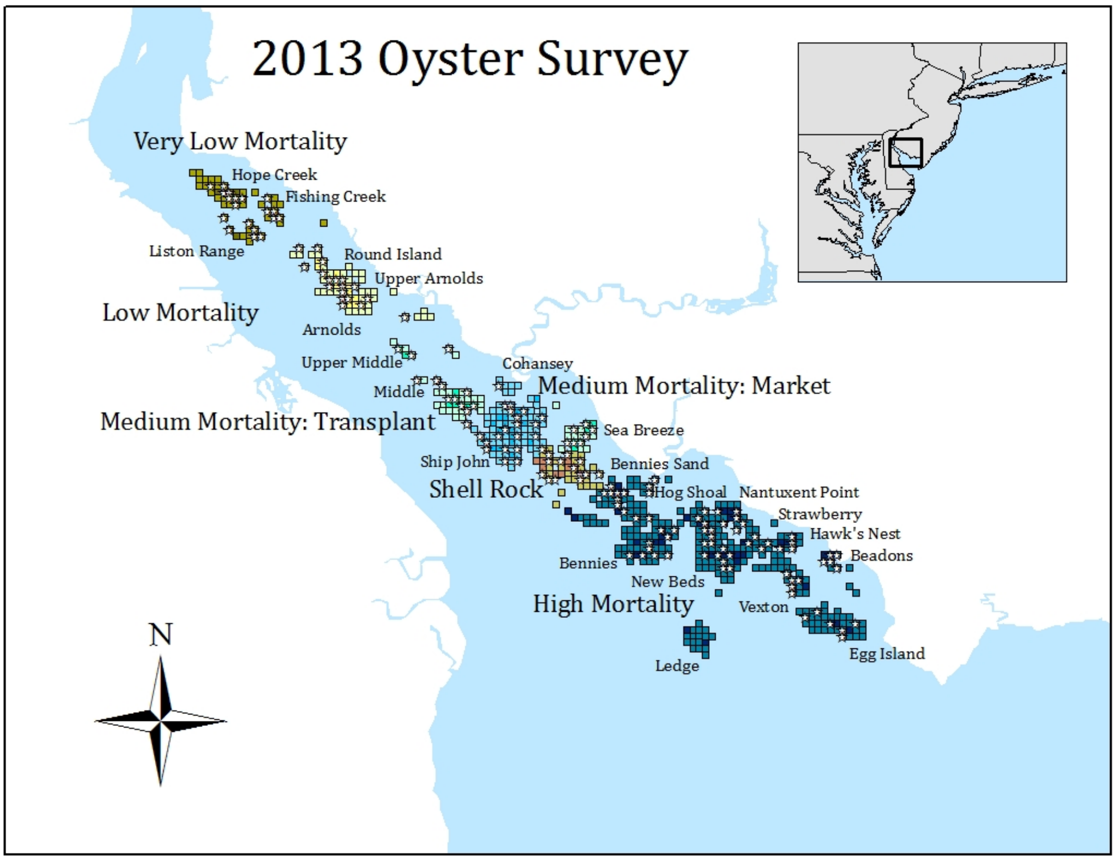


Figure 13. Total abundance of oysters >20mm on the oyster beds of Delaware Bay, NJ for the 1990–2013 time series (bars). Purple line overlay is the spawning stock biomass (SSB) which is based on oysters >35mm (right y-axis). VLM is not included in either set of data.

Figure 14. Number of market-size oysters (> 2.5 inches) for the 1990–2013 time series. Green line is the median value for the time series, 4.62 x 10^8 market-size oysters. Data from the Very Low Mortality region is not included.

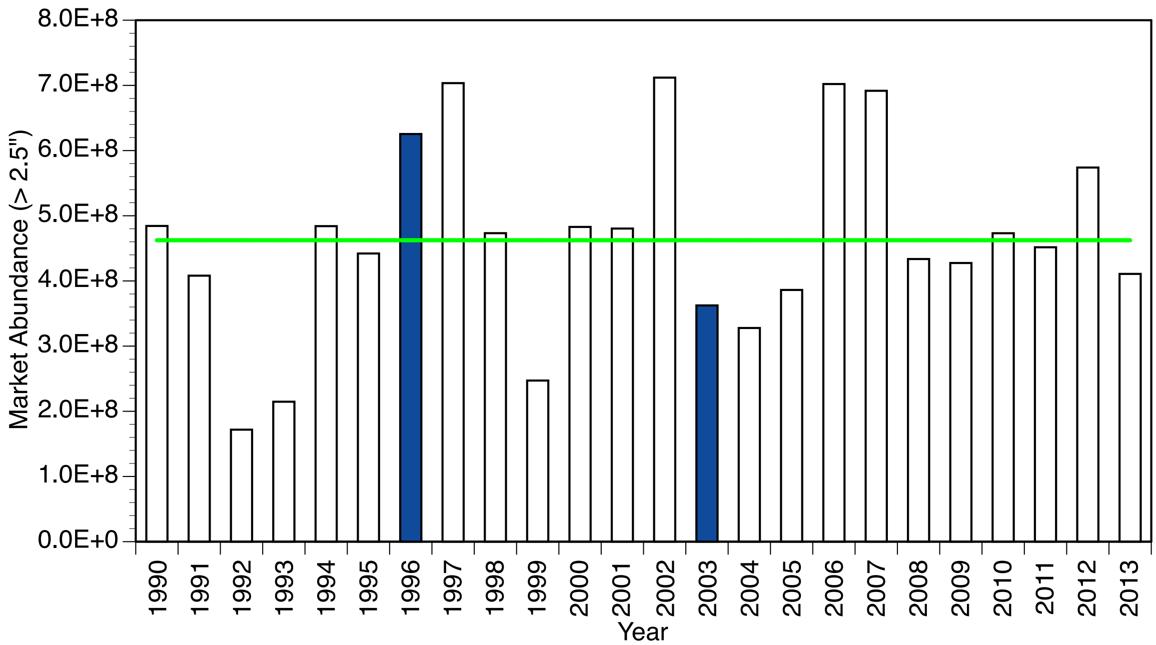


Figure 15. Oyster abundance by region and size for the 1990–2013 survey time series. (**a**) abundance of spat (< 20 mm, 0.8”); (**b**) abundance of small oysters (20–63.5 mm, 0.8”–2.5”); (**c**) abundance of market-size oysters (> 63.5 mm, ≥ 2.5”).

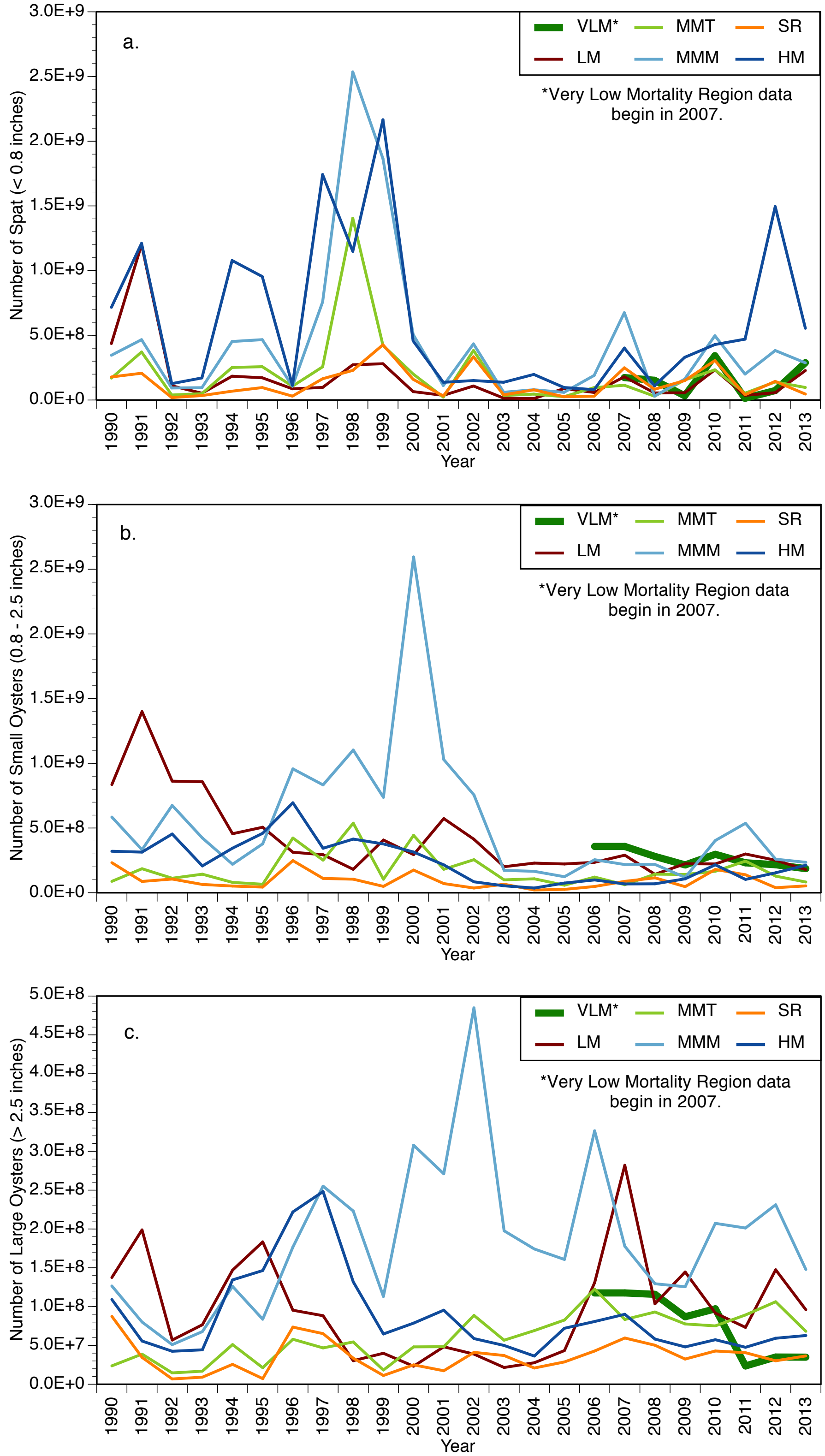


Figure 16. Estimated number of bushels of shell lost from the New Jersey oyster beds for the time period 1999–2013. Shell budgets are calculated using updated half-lives estimated in this assessment and using half-lives estimated in 2011 and 2012 for comparison.

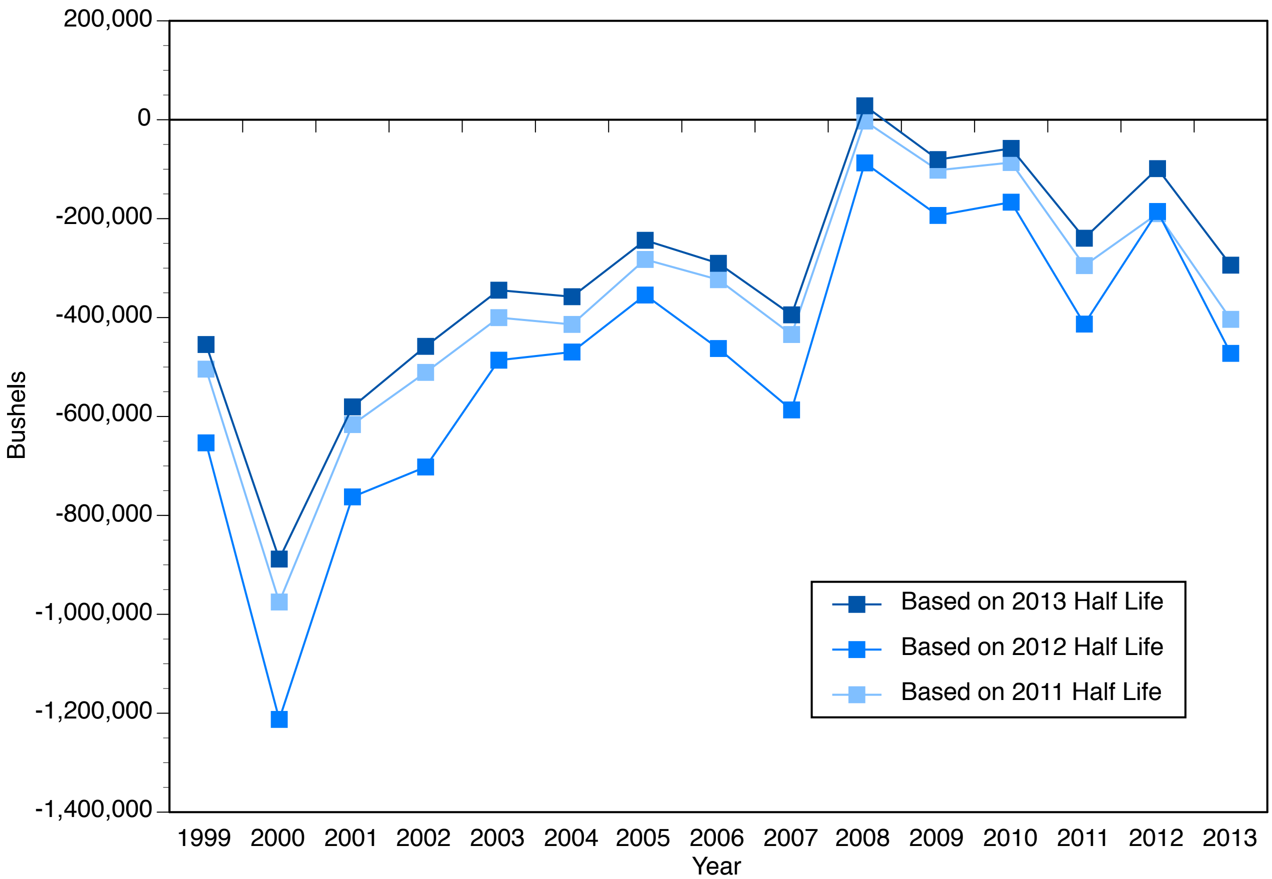


Figure 17. Site map of shellplants from 2005 – 2012 used for the spat growth rate analysis on NJ Delaware Bay oyster beds. Shellplants included: 5 on Ship John, 7 on Shell Rock, 4 on Bennies Sand, 2 on Nantuxent, and 1 on Hawk's Nest. See Figure 12 for complete bed footprints and geographic relationship to other oyster beds.

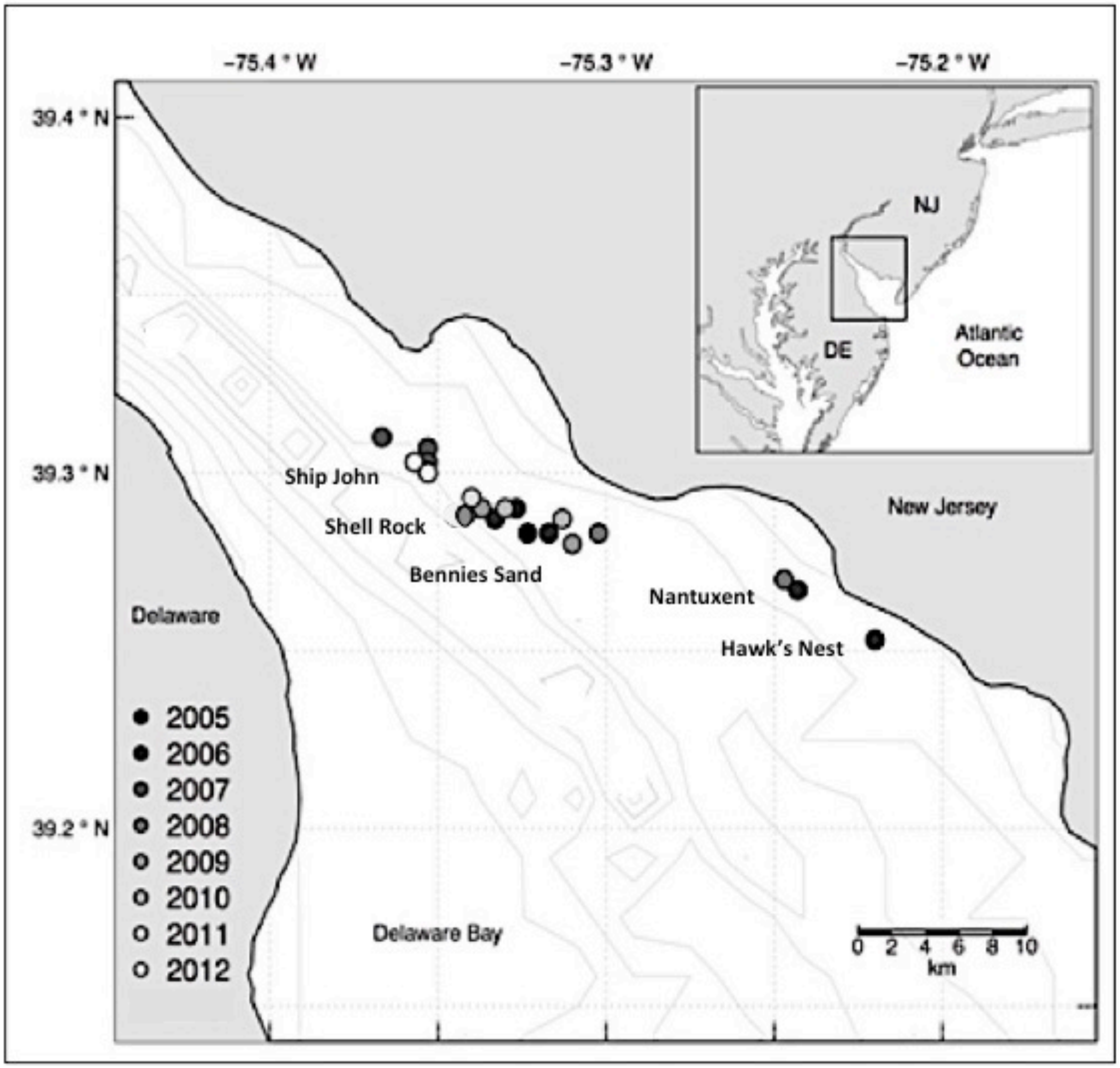


Figure 18. Summary growth statistics for spat setting on shell planted from 2005-2012. Shell lengths of spat set on clamshell were observed monthly between March and November. Early and Late set groups were delineated from spat reaching 20mm in +/-_225 days. a) The average number of days (+/- 95% confidence interval) for spat to reach 20mm in each group. b) The average shell length at one year (+/-95% confidence interval) for each group.

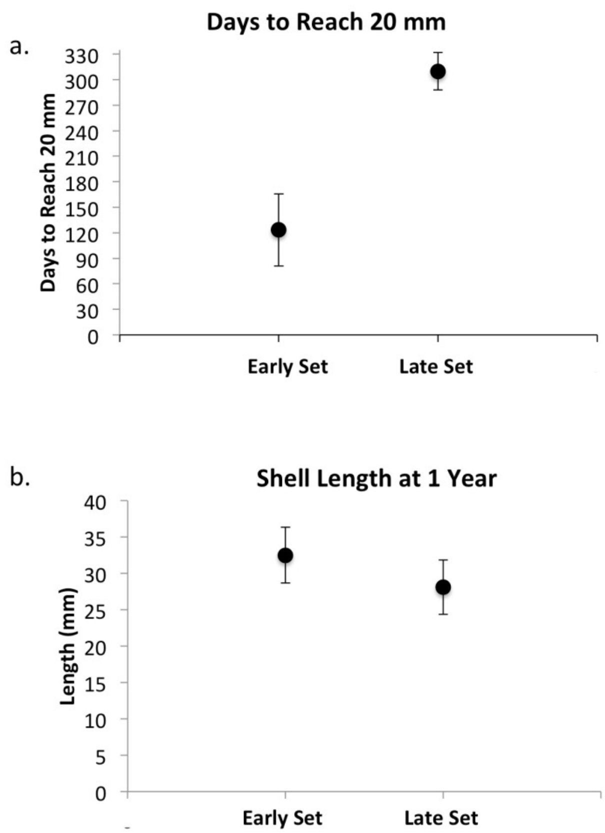


Figure 19. Broodstock-recruitment relationships for the 1953-2013 time period for the natural oyster beds of Delaware Bay excluding the Very Low Mortality region. Broodstock-recruitment relationships in larger graph are color-coded according to abundance periods as indicated along the x-axis of the abundance time series in the inset at top. Recruitment is lagged to pair with previous year's Fall survey broodstock. The black line is 1:1; Ricker curve fit is shown as a bold line.

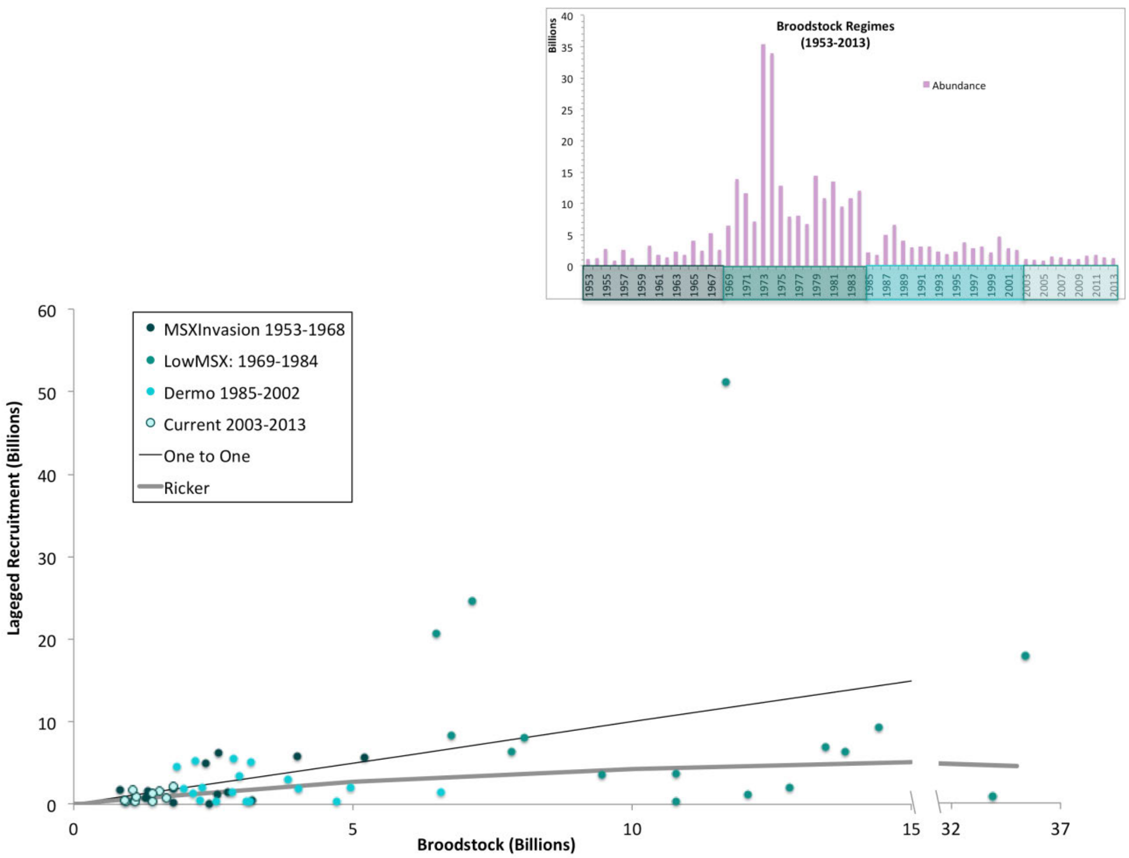


Figure 20. Broodstock regimes and broodstock-recruitment relationships for the 1953-2013 time period for the natural oyster beds of Delaware Bay excluding the Very Low Mortality region. Relationships are grouped separately in the bottom panels according to abundance periods as indicated by the colors along the x-axis of the abundance time series above. Recruitment is lagged to pair with previous year's Fall survey broodstock. Black lines are 1:1. Outliers 1959, 1973 and 1974 are not included in the lower panels.

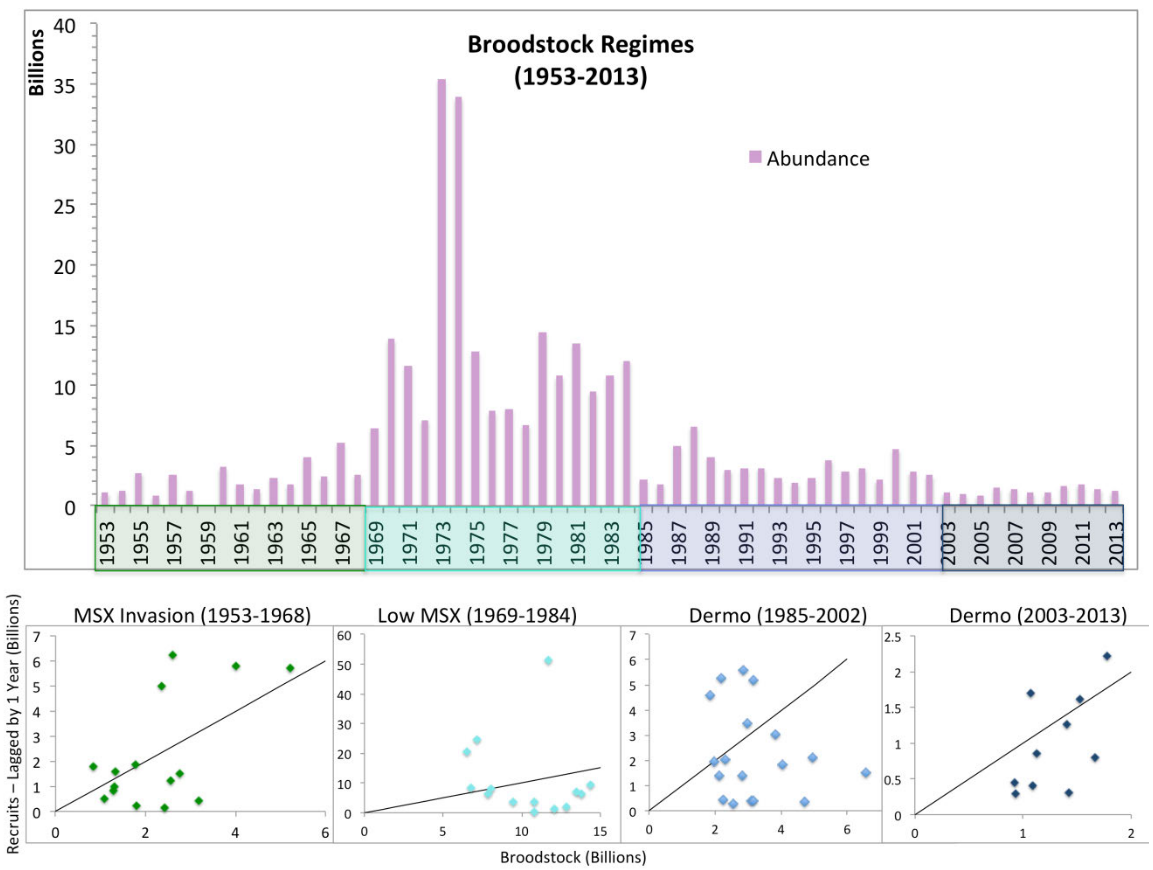


Figure 21. Number of bushels harvested from the natural oyster beds of Delaware Bay since the inception of the direct-market program in 1996. Orange line, time-series average harvest = 75,409 bushels.

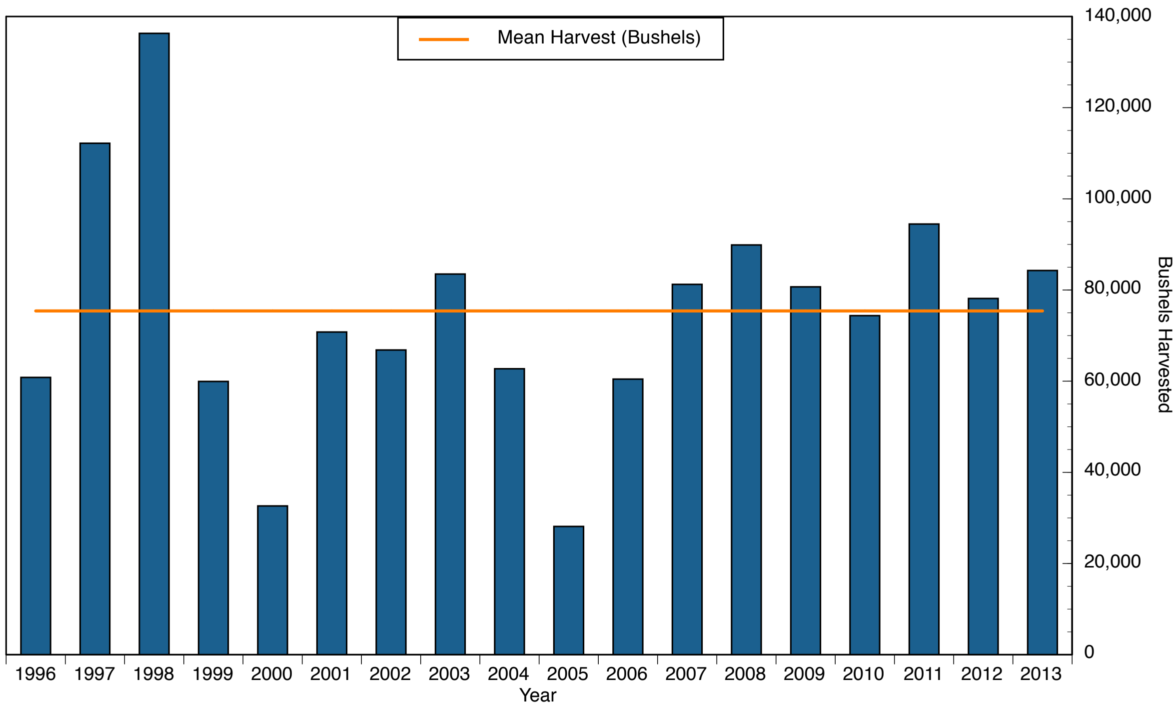
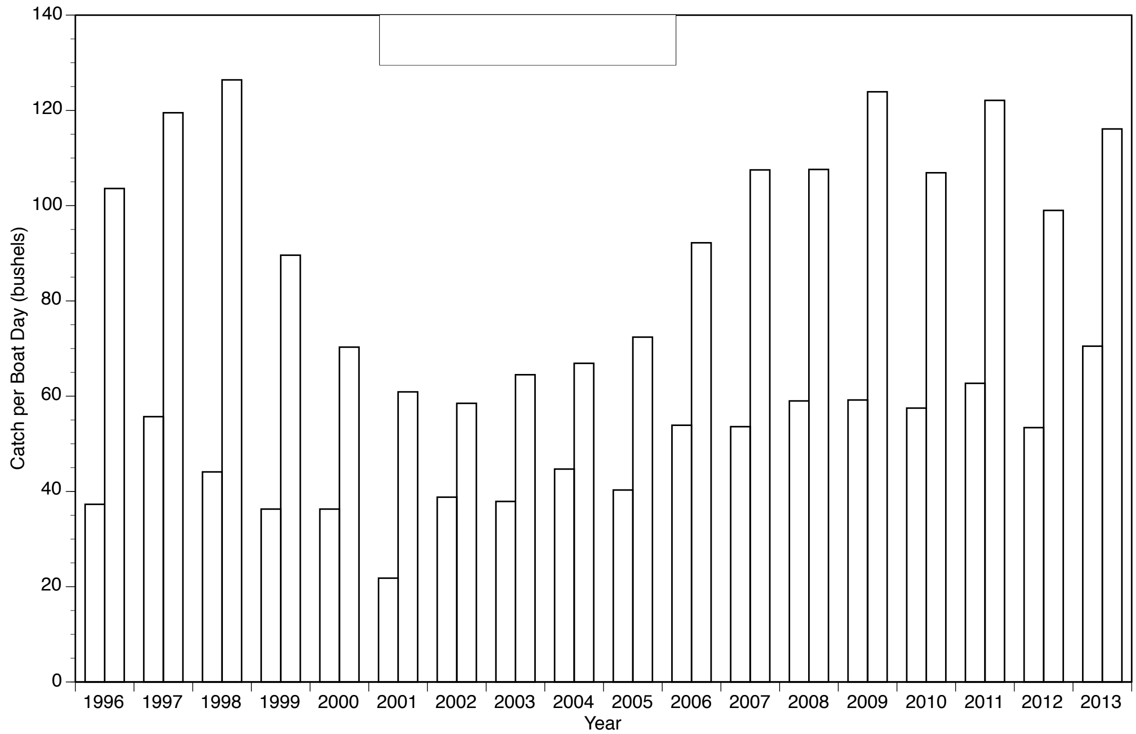


Figure 22. Catch per unit effort (CPUE) in days by one- and two-dredge boats. License consolidation in recent years has allowed one boat to fish multiple licenses. Total quota is divided by the number of licenses. (a). CPUE each year since direct marketing began on all harvested beds. (b) CPUE in boat-days on the beds fished in 2013.

a.



b.

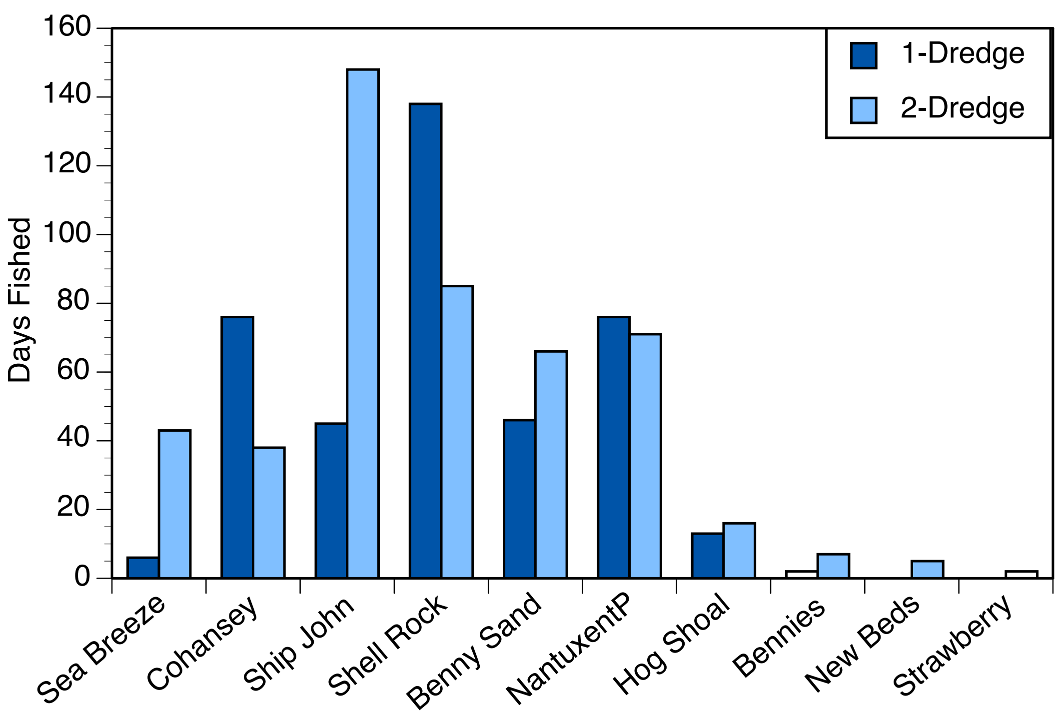


Figure 23. Landed oysters per bushel in three groups: market-size (>2.5”), smaller attached oysters, and smaller unattached oysters. The long-term mean number per bushel of all harvested oysters (264) is shown as an orange line.

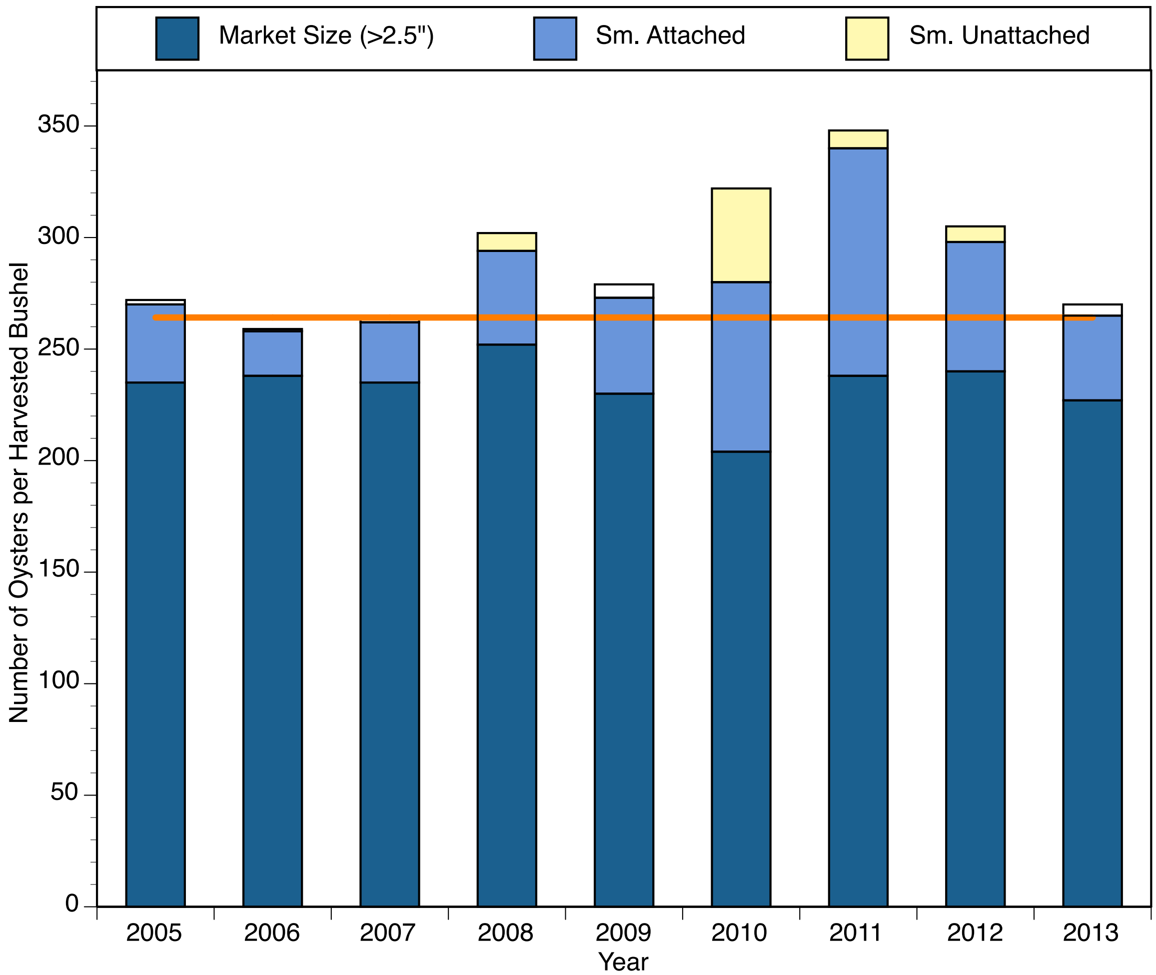


Figure 24. Size frequency of oysters landed in 2013 compared to the size frequencies of the previous two years. Size class labels are the lower bounds of the size class.

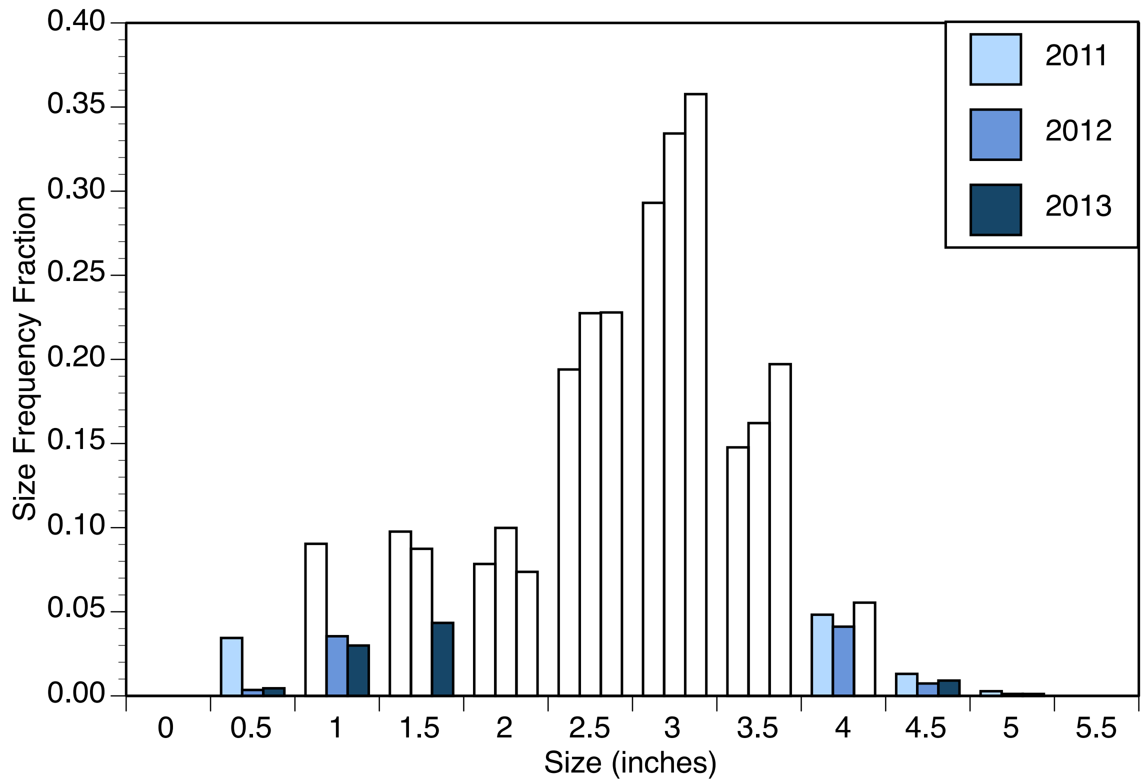


Figure 25. Exploitation rates and their percentiles used for Delaware Bay, New Jersey oyster fishery allocation decisions since 2007. SARC recommendations ca. 2006 resulted in use of the 1996-2006 decade of Direct Market exploitation as the basis for the current system of within-region, abundance-based exploitation. Limited data for the upbay regions resulted in use of one set of data for the Transplant regions. Low range of exploitation rates in the Medium Mortality Market region led to an experimental fishery at the rate associated with the 100th percentile. Limited timeframe for reference results in abrupt step changes in some cases.

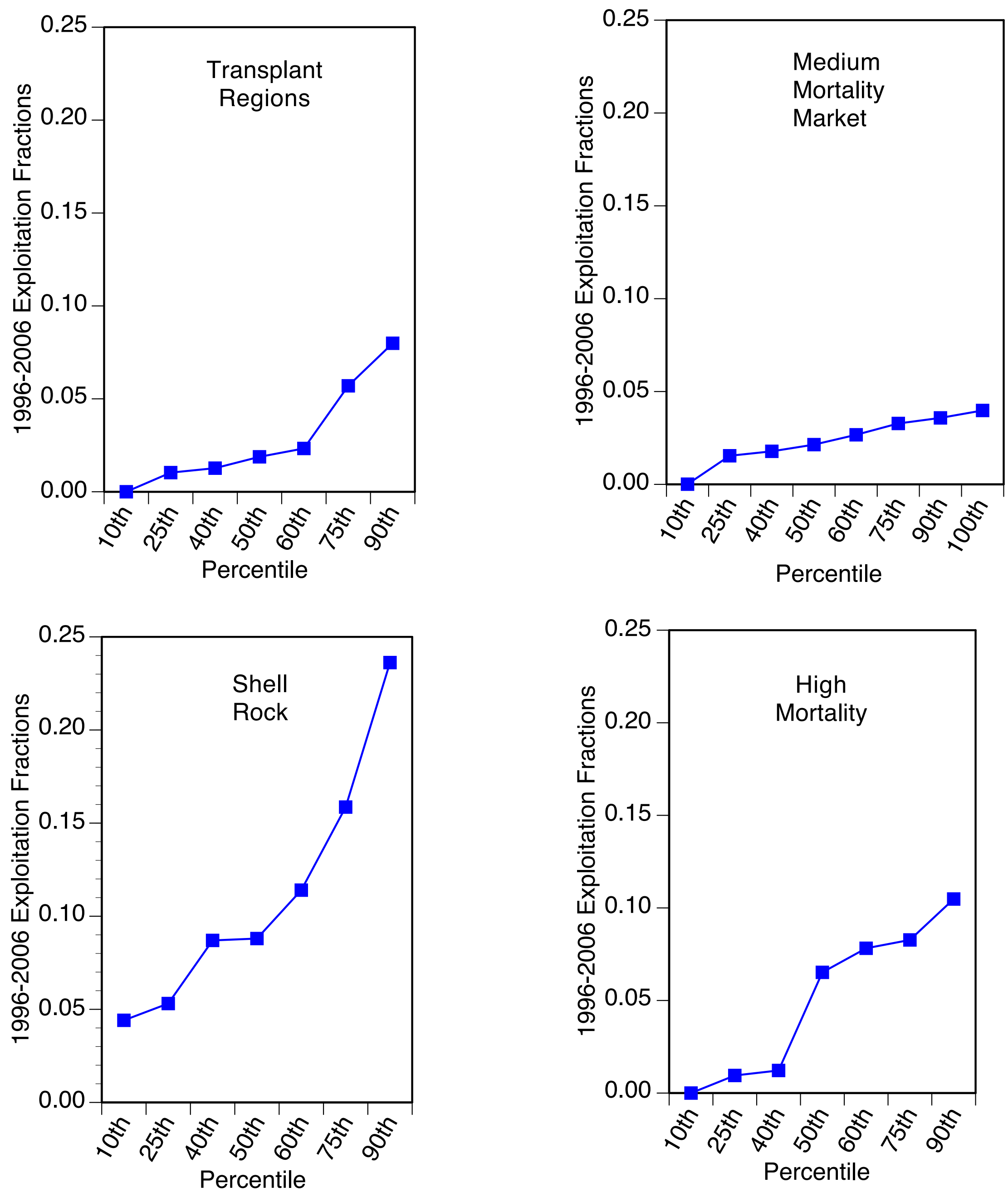
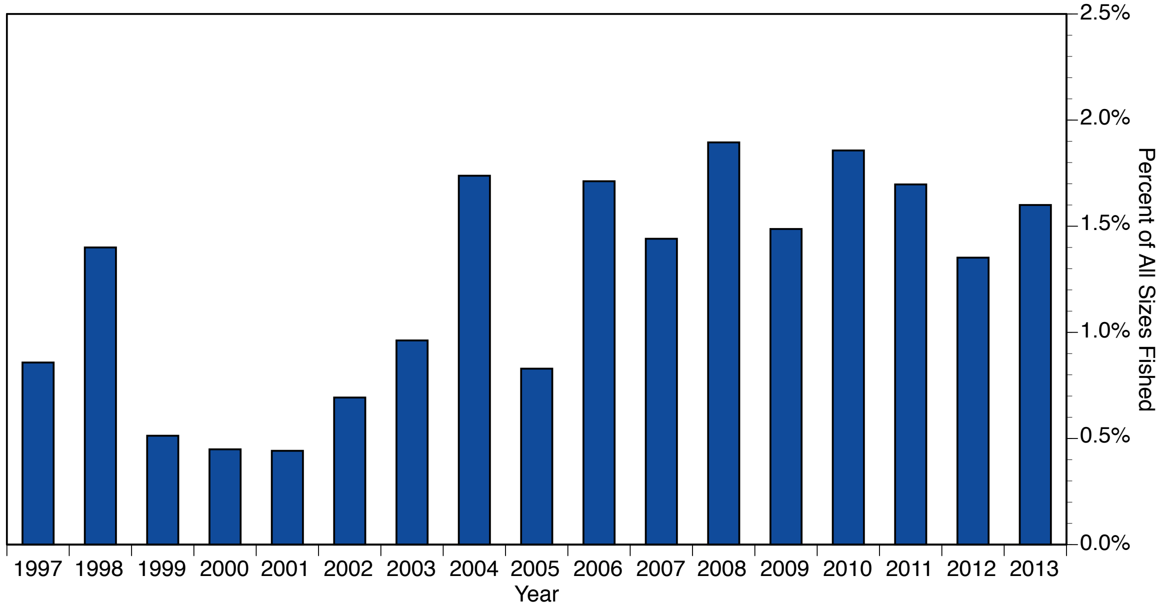


Figure 26. Fishing mortality for the 1997–2013 time period, excluding the VLM as a percentage of: a) total oyster abundance and b) market-size oyster abundance (>2.5”).

a.



b.

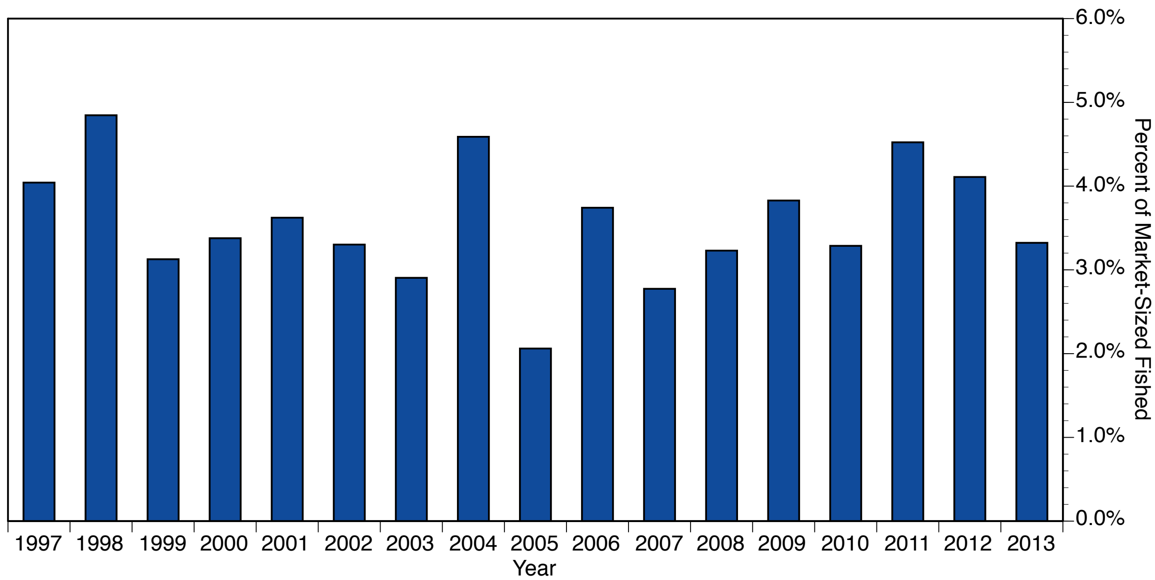


Figure 27. Fishing mortality percentages by region during the Direct Market time series (1997-2013). Percentages reflect transplant removals from the Very Low Mortality, Low Mortality, and Medium Mortality Transplant regions and transplant additions plus direct market harvest from the Medium Mortality Market, Shell Rock, and High Mortality regions. If more oysters are transplanted to a region than are harvested, negative percentages will result. Dark bars depict the percentage fished of all oysters and light bars, the percentage fished of ≥2.5” oysters. There was no exploitation of the Very Low Mortality region prior to 2009; otherwise, no bars indicate no oysters removed from the region in that year.

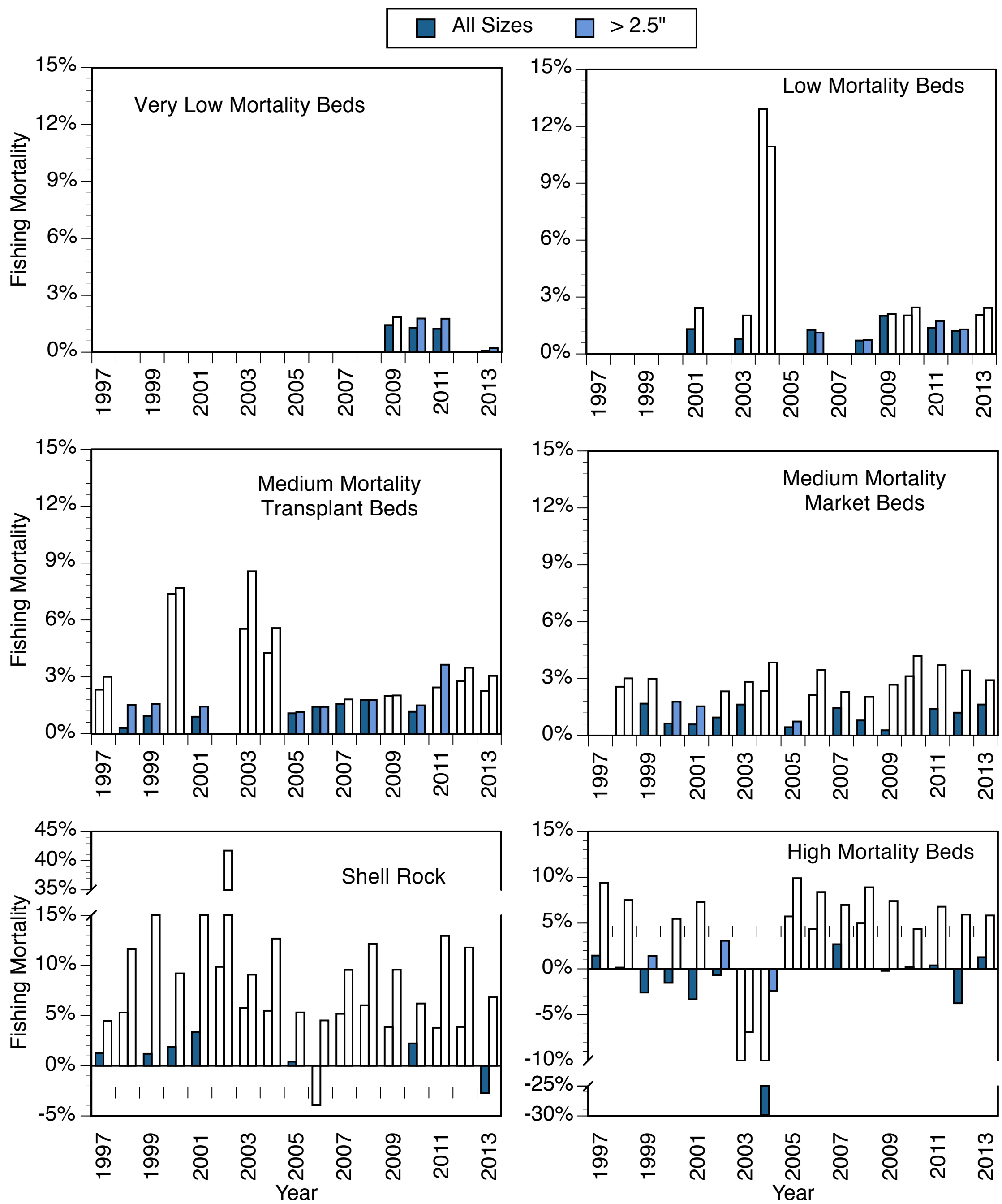


Figure 28. 2013 total abundance whole-stock estimate within confidence percentiles for the 2013 survey taking into account between-sample variation and uncertainty in dredge efficiency. Whole stock reference points are included for comparison. All values exclude the Very Low Mortality region. Note that the percentiles (P) above the 50th are shown as 1 – *P* so that, for example, the 60th percentile is indicated as the 40th percentile but on the right-hand side of the curve.

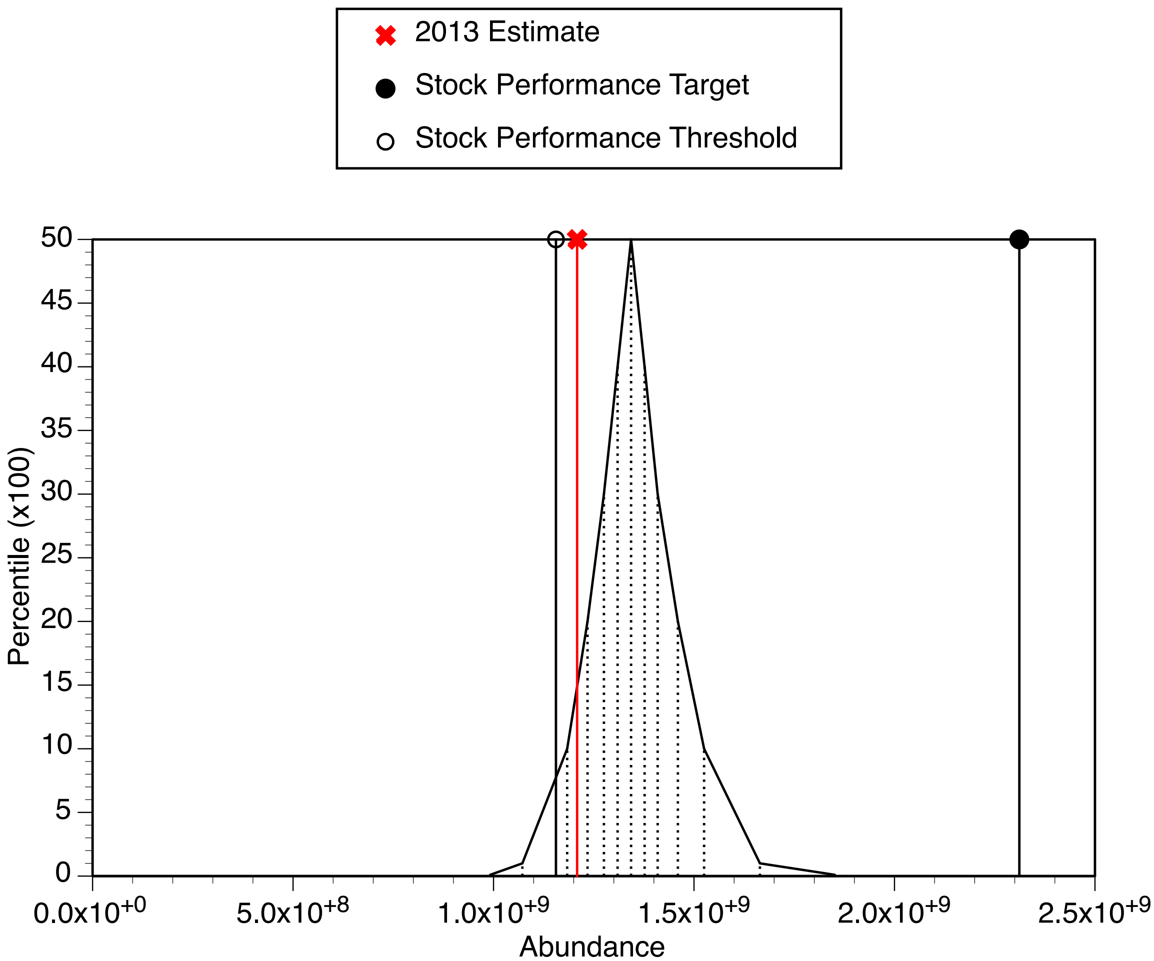


Figure 29. 2013 market-size oyster whole-stock abundance estimate within confidence percentiles for the 2013 survey taking into account between-sample variation and uncertainty in dredge efficiency. Whole stock reference points are included for comparison. All values exclude the Very Low Mortality region. Note that the percentiles (P) above the 50^{th} are shown as $1 - P$ so that, for example, the 60^{th} percentile is indicated as the 40^{th} percentile but on the right-hand side of the curve.

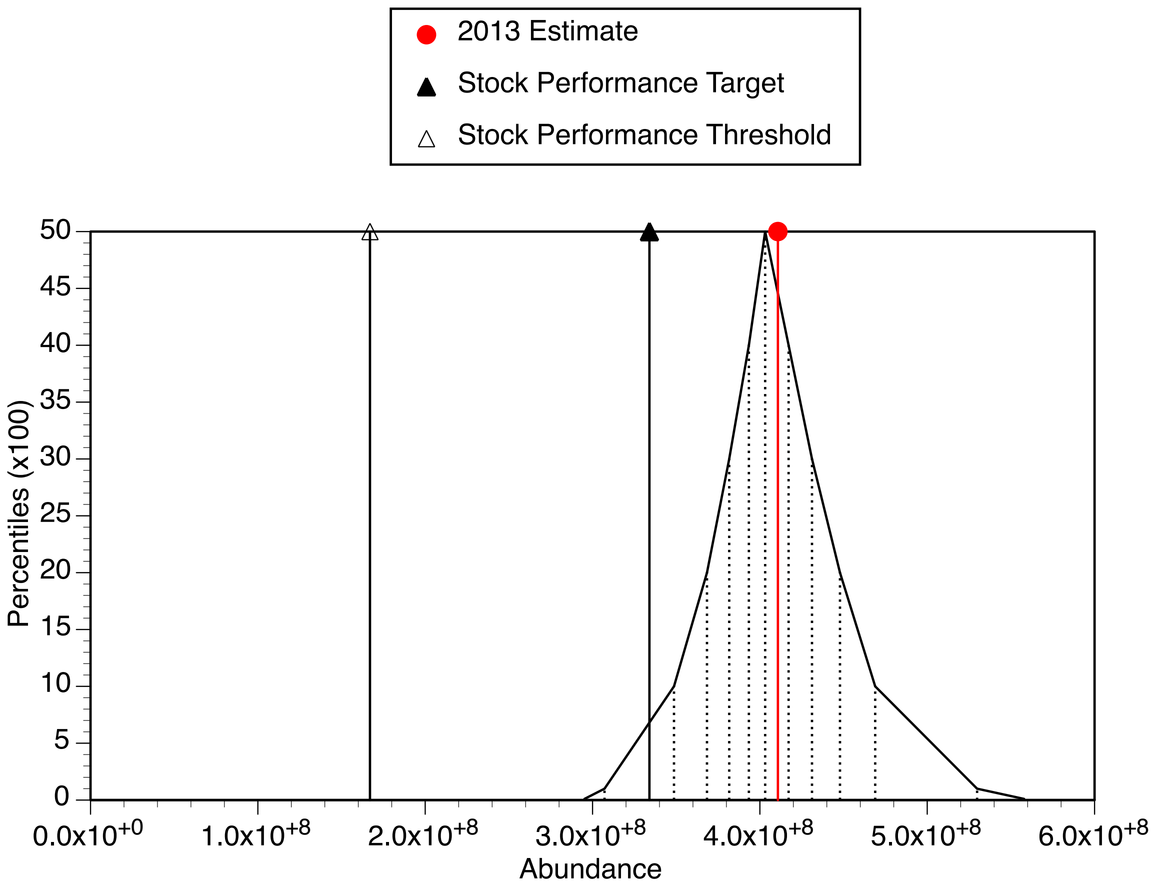


Figure 30. 2013 total oyster regional abundance estimates within confidence percentiles taking into account between-sample variation and uncertainty in dredge efficiency. Reference points are included for comparison. Note that the percentiles (P) above the 50th are shown as 1 – P so that, for example, the 60th percentile is indicated as the 40th percentile but on the right-hand side of the curve.

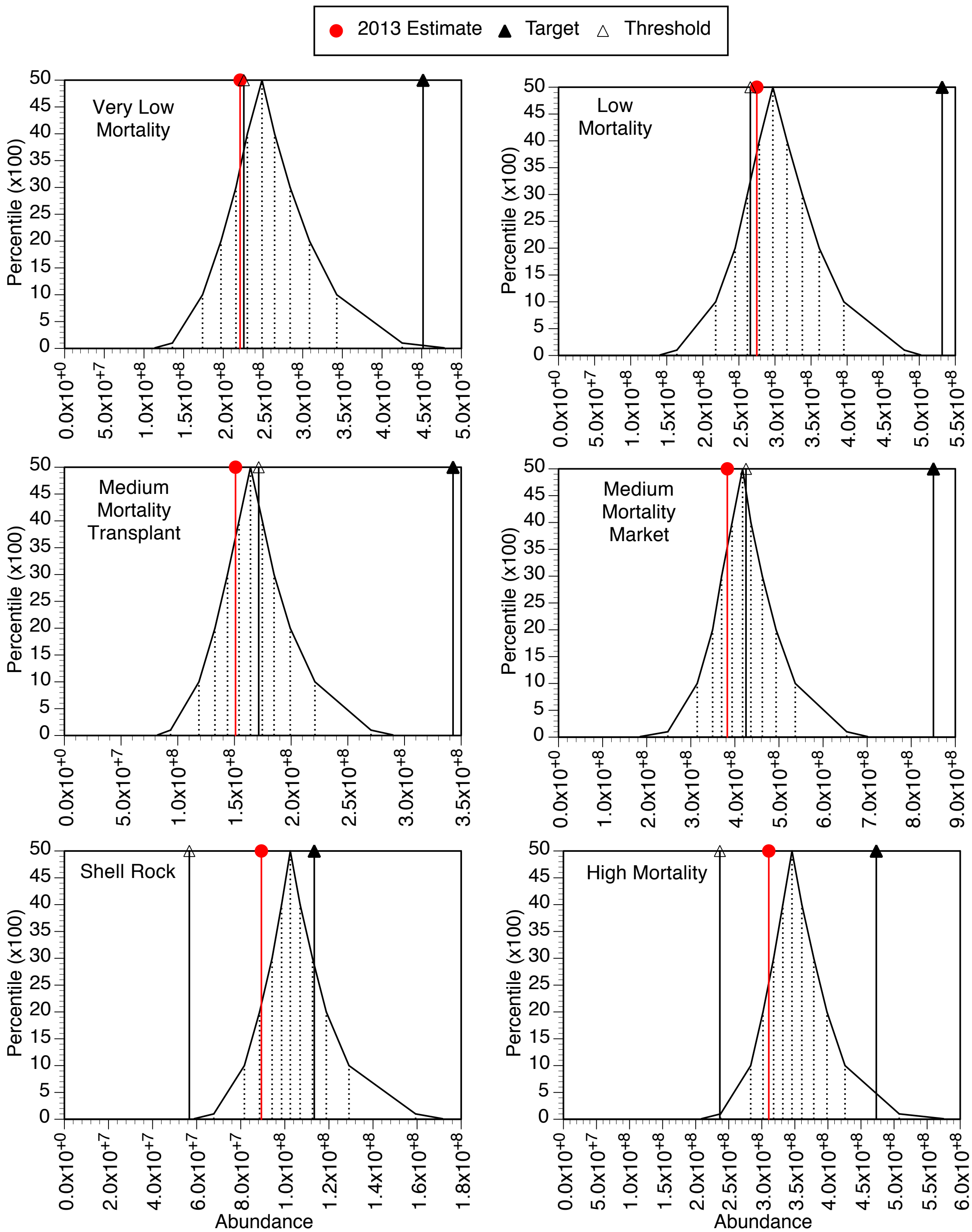


Figure 31. 2013 market-size oyster abundance estimates by region within confidence percentiles taking into account between-sample variation and uncertainty in dredge efficiency. Reference points are included for comparison. Note that the percentiles (P) above the 50th are shown as $1 - P$ so that, for example, the 60th percentile is indicated as the 40th percentile but on the right-hand side of the curve.

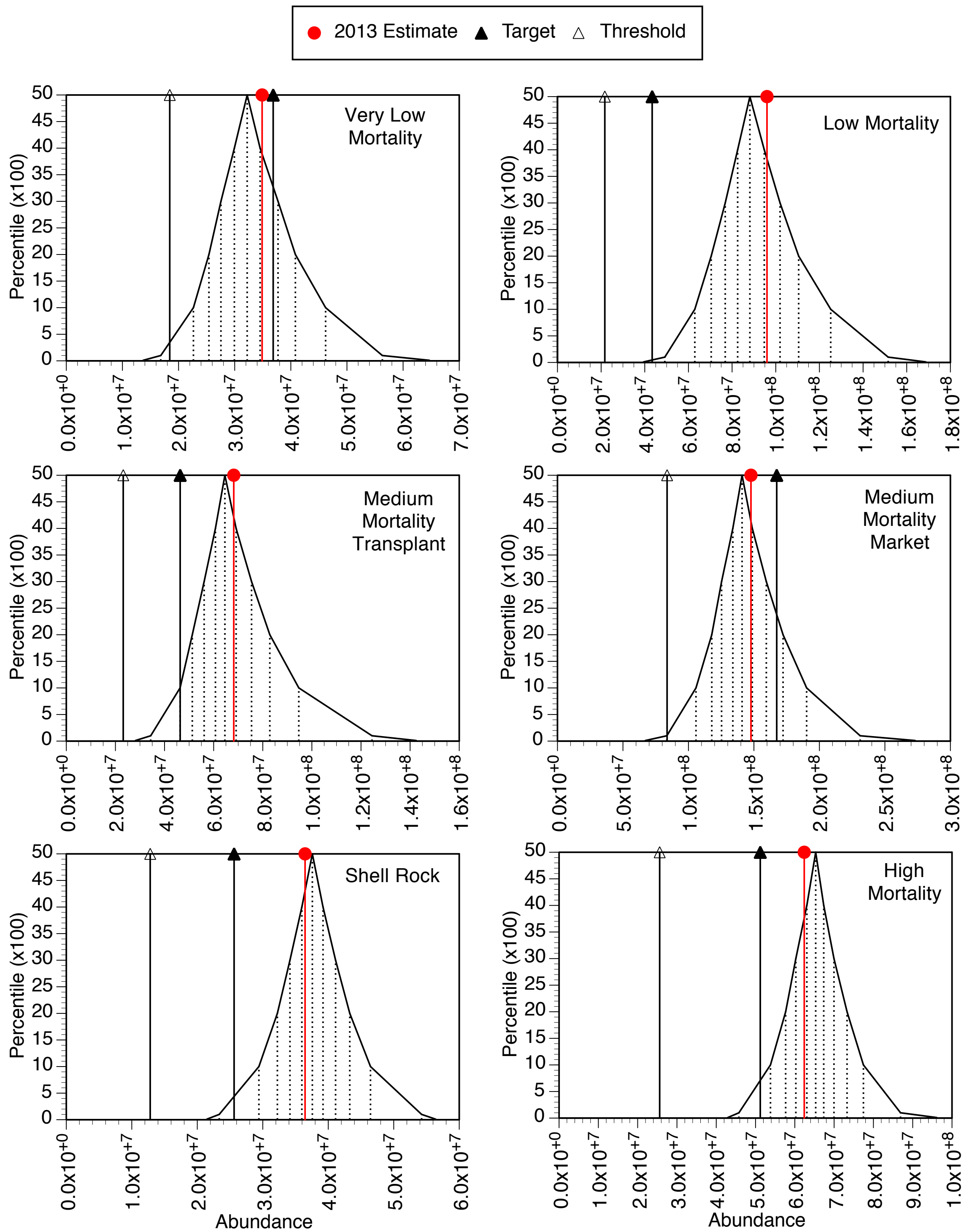


Figure 32. Position of the oyster stock 2009–2013 with respect to targets and thresholds of regional abundance and biomass. The target is taken as the median of abundance or biomass from the 1989–2005 (1990–2005) time period. The threshold is taken as half these values.

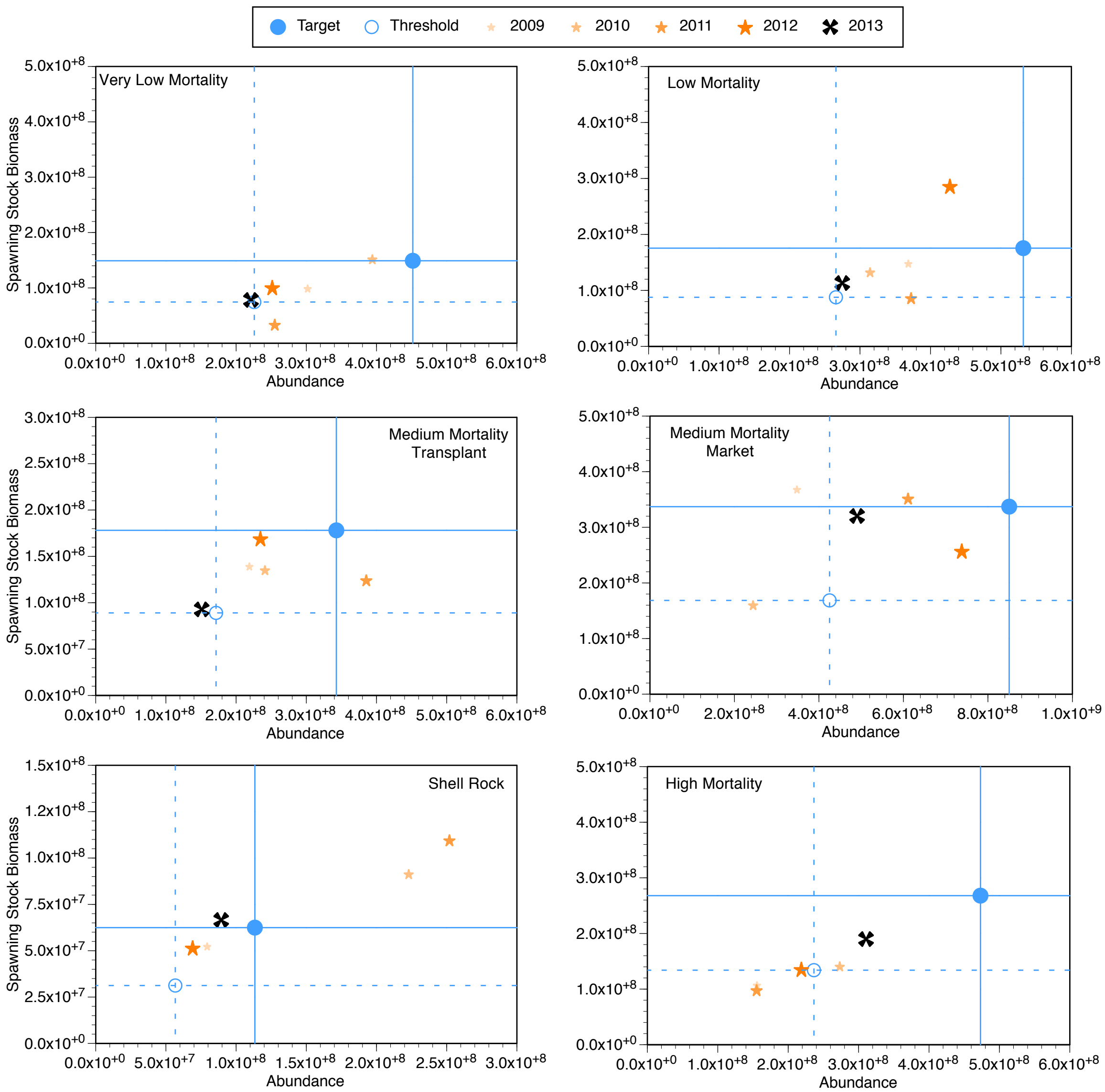
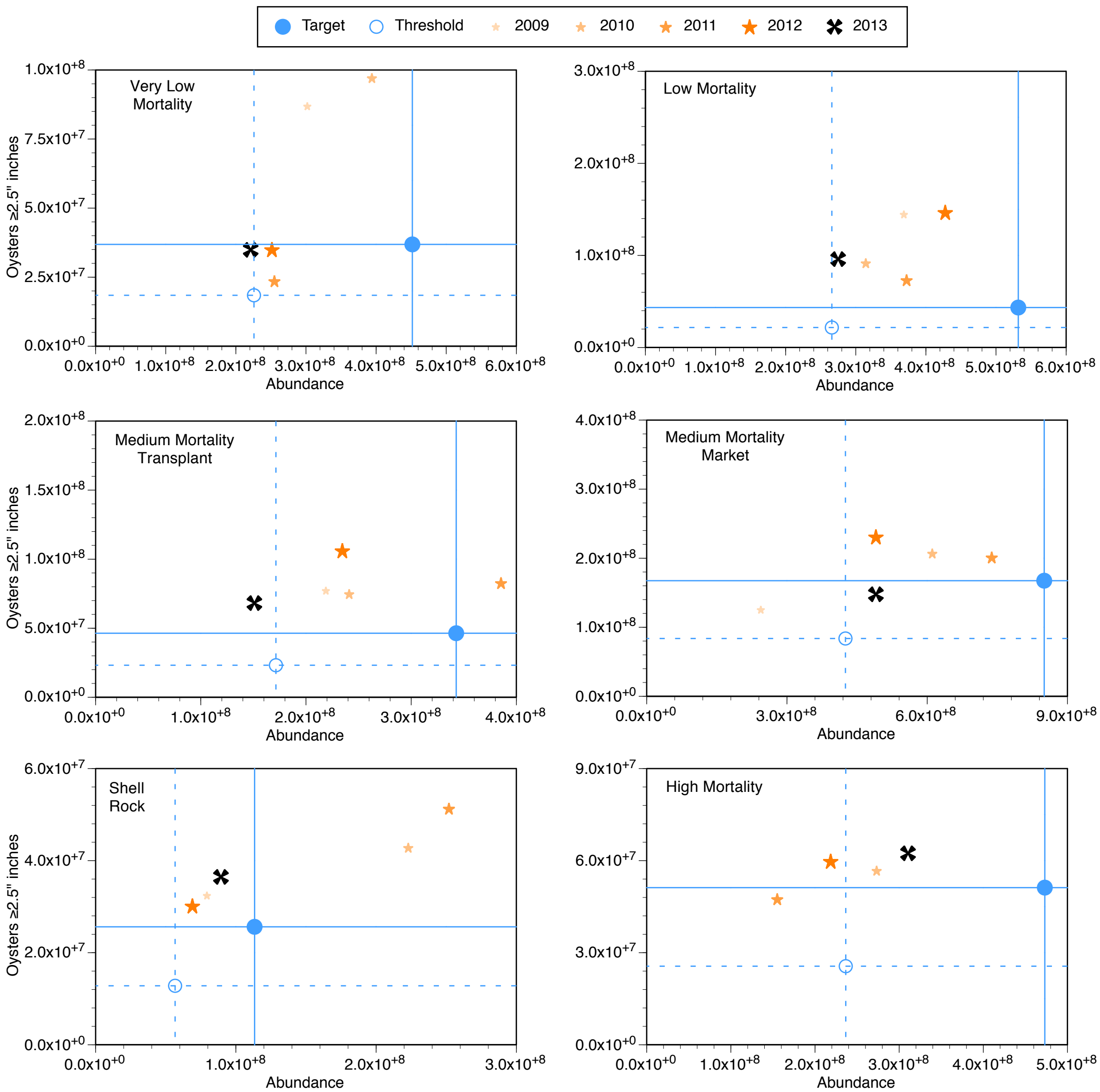


Figure 33. Position of the oyster stock in 2009–2013 with respect to targets and thresholds of regional abundance and market-size abundance (≥2.5”). The target is taken as the median of abundance or market abundance from the 1989–2005 (1990–2005) time period. The threshold is taken as half these values.



Appendix A. Density data by sampled grid from Fall surveys (stock assessment) and Spring resurveys (bed stratification) for 2011-2013. Data year indicates the year with which survey sample data is associated, eg. Spring resurvey data are biologically closer to the previous Fall survey data. In cases where a grid is sampled in both Spring and Fall, the Fall survey data is used. Grids that were sampled in the Fall survey are in **bold**. Quality identifies the stratum to which a grid is assigned: 1= High; 2= Medium; 3= Low; 4= Enhanced. Enhanced grids are those that have received transplants in the current year or shellplants in the current or preceding two years. Each bed gets fully surveyed (all grids sampled) once a decade so grid quality designations may change over time (see report text). The Fall survey does not sample grids designated as Low quality (see report text). The data are arranged by year from upbay to downbay and highest to lowest oyster per m^2 within each bed.

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2011	Nov-11	VLM	Hope Creek	**86**	2	79.329	3.669	13.140
2011	Nov-11	VLM	Hope Creek	**63**	1	74.649	2.774	14.159
2011	Nov-11	VLM	Hope Creek	**64**	1	74.214	4.252	11.313
2011	Nov-11	VLM	Hope Creek	**61**	1	74.035	3.524	8.524
2011	Nov-11	VLM	Hope Creek	**76**	1	71.339	2.693	9.896
2011	Nov-11	VLM	Hope Creek	**84**	2	55.171	2.852	3.855
2011	Nov-11	VLM	Hope Creek	**55**	2	50.199	3.709	8.256
2011	Nov-11	VLM	Hope Creek	**46**	2	0.193	0	0.043
2011	Nov-11	VLM	Liston Range	**24**	1	133.080	15.513	11.861
2011	Nov-11	VLM	Liston Range	**17**	2	44.264	3.056	2.092
2011	Nov-11	VLM	Liston Range	**23**	2	18.554	1.187	1.849
2011	Nov-11	VLM	Liston Range	**25**	2	10.655	1.391	0.668
2011	Nov-11	VLM	Liston Range	**21**	1	8.155	0.480	0.588
2011	Nov-11	VLM	Liston Range	**22**	2	5.917	0.185	1.417
2011	Nov-11	VLM	Fishing Creek	**25**	1	108.279	3.347	11.480
2011	Nov-11	VLM	Fishing Creek	**4**	2	93.301	2.292	11.087
2011	Nov-11	VLM	Fishing Creek	**5**	2	33.564	1.626	7.780
2011	Nov-11	VLM	Fishing Creek	**16**	1	19.069	0.970	5.907
2011	Nov-11	VLM	Fishing Creek	**8**	2	7.088	0	1.479
2011	Nov-11	LM	Round Island	**26**	1	176.458	12.402	11.587
2011	Nov-11	LM	Round Island	**25**	2	91.746	8.030	7.986
2011	Nov-11	LM	Round Island	**12**	1	84.908	7.469	11.885
2011	Nov-11	LM	Round Island	**5**	2	32.335	2.216	2.859
2011	Nov-11	LM	Round Island	**4**	2	0.188	0	0.342
2011	Nov-11	LM	Upper Arnolds	**8**	2	89.482	7.929	12.056
2011	Nov-11	LM	Upper Arnolds	**18**	1	81.248	8.002	8.531
2011	Nov-11	LM	Upper Arnolds	**5**	1	79.395	5.459	4.657
2011	Nov-11	LM	Upper Arnolds	**13**	2	32.666	5.599	11.357
2011	Nov-11	LM	Upper Arnolds	**21**	2	13.556	1.744	0.995
2011	Nov-11	LM	Arnolds	**7**	1	159.254	16.182	7.756
2011	Nov-11	LM	Arnolds	**16**	1	140.622	13.129	6.821
2011	Nov-11	LM	Arnolds	**17**	1	123.645	8.963	4.877
2011	Nov-11	LM	Arnolds	**19**	2	46.482	5.316	13.309
2011	Nov-11	LM	Arnolds	**72**	2	25.012	5.229	12.178
2011	Nov-11	LM	Arnolds	**26**	2	8.337	1.266	1.183
2011	Nov-11	MMT	Upper Middle	**48**	1	110.174	8.294	15.230
2011	Nov-11	MMT	Upper Middle	**36**	2	10.906	0.913	3.338
2011	Nov-11	MMT	Upper Middle	**56**	2	2.175	0	1.455
2011	Nov-11	MMT	Upper Middle	**49**	2	1.428	0.224	2.660
2011	Oct-11	MMT	Middle	**28**	1	154.080	53.344	9.220
2011	Oct-11	MMT	Middle	**35**	1	70.432	16.733	2.200
2011	Oct-11	MMT	Middle	**21**	2	64.541	6.747	14.126
2011	Oct-11	MMT	Middle	**38**	1	41.771	6.816	10.944
2011	Oct-11	MMT	Middle	**41**	2	26.019	6.373	4.938
2011	Oct-11	MMT	Middle	**51**	2	18.485	3.759	5.238
2011	Oct-11	MMT	Middle	**1**	2	16.566	2.807	9.043
2011	Nov-11	MMT	Middle	**26**	4	13.250	1.186	3.442
2011	Oct-11	MMT	Sea Breeze	**18**	1	169.619	60.415	20.315
2011	Jun-12	MMT	Sea Breeze	30	2	145.397	12.191	10.617
2011	Jun-12	MMT	Sea Breeze	14	2	139.575	5.713	8.444
2011	Oct-11	MMT	Sea Breeze	**15**	2	133.638	28.530	5.207
2011	May-12	MMT	Sea Breeze	36	2	125.190	10.742	3.651
2011	Jun-12	MMT	Sea Breeze	31	2	120.096	5.715	10.120
2011	Jun-12	MMT	Sea Breeze	19	1	118.331	13.933	25.978
2011	Jun-12	MMT	Sea Breeze	17	2	117.015	6.507	8.108

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2011	Jun-12	MMT	Sea Breeze	20	2	114.719	5.105	4.549
2011	Jun-12	MMT	Sea Breeze	22	1	114.454	4.480	6.513
2011	Jun-12	MMT	Sea Breeze	23	3	72.585	6.235	4.809
2011	Oct-11	MMT	Sea Breeze	**13**	2	59.732	14.269	12.577
2011	Oct-11	MMT	Sea Breeze	**24**	1	47.544	5.604	6.407
2011	Jun-12	MMT	Sea Breeze	25	2	39.887	2.920	4.413
2011	May-12	MMT	Sea Breeze	37	2	32.934	2.312	4.830
2011	Jun-12	MMT	Sea Breeze	39	3	17.449	0	3.157
2011	Oct-11	MMT	Sea Breeze	**16**	1	16.896	4.117	8.894
2011	May-12	MMT	Sea Breeze	38	2	13.366	3.310	3.382
2011	May-12	MMT	Sea Breeze	46	3	12.781	1.737	1.131
2011	Jun-12	MMT	Sea Breeze	26	2	8.742	0.990	7.569
2011	Jun-12	MMT	Sea Breeze	29	2	8.045	0.226	3.188
2011	May-12	MMT	Sea Breeze	48	3	5.161	0	5.460
2011	Jun-12	MMT	Sea Breeze	33	3	4.226	0.661	6.500
2011	Jun-12	MMT	Sea Breeze	34	3	4.202	0	6.903
2011	Jun-12	MMT	Sea Breeze	32	3	3.460	0	1.123
2011	Jun-12	MMT	Sea Breeze	12	3	2.696	0.241	2.691
2011	May-12	MMT	Sea Breeze	47	3	2.111	0	2.422
2011	Jun-12	MMT	Sea Breeze	1	3	1.649	0	2.549
2011	May-12	MMT	Sea Breeze	35	2	1.210	0.186	0.760
2011	Jun-12	MMT	Sea Breeze	27	3	1.154	0.210	1.015
2011	Jun-12	MMT	Sea Breeze	3	3	0.907	0	0.930
2011	Jun-12	MMT	Sea Breeze	2	2	0.679	0.064	0.523
2011	Jun-12	MMT	Sea Breeze	28	3	0.672	0.180	1.271
2011	Jun-12	MMT	Sea Breeze	45	3	0.647	0.128	1.322
2011	Jun-12	MMT	Sea Breeze	11	3	0.431	0	4.760
2011	Jun-12	MMT	Sea Breeze	43	2	0.339	0	1.365
2011	Jun-12	MMT	Sea Breeze	21	3	0.268	0.045	0.957
2011	Jun-12	MMT	Sea Breeze	6	3	0.250	0.134	0.703
2011	Jun-12	MMT	Sea Breeze	8	3	0.225	0	1.733
2011	Jun-12	MMT	Sea Breeze	9	3	0.187	0	1.621
2011	Jun-12	MMT	Sea Breeze	5	3	0.168	0	0.473
2011	Jun-12	MMT	Sea Breeze	42	3	0.162	0	1.068
2011	Jun-12	MMT	Sea Breeze	44	3	0.107	0	0.354
2011	Jun-12	MMT	Sea Breeze	10	1	0.075	0	2.131
2011	Jun-12	MMT	Sea Breeze	4	3	0	0	0.046
2011	Jun-12	MMT	Sea Breeze	7	3	0	0.093	0.329
2011	Jun-12	MMT	Sea Breeze	40	3	0	0	0.096
2011	May-12	MMT	Sea Breeze	41	3	0	0	0
2011	Oct-11	MMM	Ship John	**25**	1	192.446	77.909	9.862
2011	Oct-11	MMM	Ship John	**18**	2	181.692	48.234	12.677
2011	Oct-11	MMM	Ship John	**31**	1	147.975	61.533	6.073
2011	Oct-11	MMM	Ship John	**33**	1	132.608	59.434	6.584
2011	Oct-11	MMM	Ship John	**15**	1	113.926	17.575	9.631
2011	Oct-11	MMM	Ship John	**42**	1	110.921	51.300	3.668
2011	Oct-11	MMM	Ship John	**16**	1	88.536	26.017	6.494
2011	Oct-11	MMM	Ship John	**8**	2	68.736	13.428	9.425
2011	Oct-11	MMM	Ship John	**30**	2	54.911	4.351	3.019
2011	Oct-11	MMM	Ship John	**57**	2	11.956	51.044	16.093
2011	Oct-11	MMM	Ship John	**52**	2	7.665	8.253	12.435
2011	Oct-11	MMM	Cohansey	**54**	1	146.294	19.646	5.494
2011	Oct-11	MMM	Cohansey	**50**	1	144.916	18.249	6.931
2011	Oct-11	MMM	Cohansey	**46**	2	110.118	7.850	8.353
2011	Oct-11	MMM	Cohansey	**36**	1	101.892	14.872	7.066

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2011	Oct-11	MMM	Cohansey	**44**	1	79.182	7.168	3.096
2011	Oct-11	MMM	Cohansey	**43**	1	54.653	4.214	4.390
2011	Oct-11	MMM	Cohansey	**66**	2	46.404	4.355	9.822
2011	Oct-11	MMM	Cohansey	**3**	2	38.506	12.034	7.645
2011	Oct-11	MMM	Cohansey	**65**	4	33.733	2.068	2.313
2011	Oct-11	MMM	Cohansey	**33**	2	27.524	2.957	7.240
2011	Oct-11	MMM	Cohansey	**8**	2	22.161	4.697	9.192
2011	May-12	SR	Shell Rock	24	1	111.636	14.641	3.445
2011	Oct-11	SR	Shell Rock	**15**	2	110.931	24.029	7.265
2011	Oct-11	SR	Shell Rock	**23**	4	106.490	44.320	9.706
2011	May-12	SR	Shell Rock	20	1	99.509	14.193	3.427
2011	Oct-11	SR	Shell Rock	**14**	1	92.056	43.696	5.122
2011	Oct-11	SR	Shell Rock	**19**	1	84.175	34.667	5.817
2011	Oct-11	SR	Shell Rock	**21**	4	81.486	10.875	2.640
2011	May-12	SR	Shell Rock	13	2	75.668	7.595	2.150
2011	May-12	SR	Shell Rock	5	2	70.792	5.384	2.029
2011	May-12	SR	Shell Rock	2	2	68.733	3.589	1.787
2011	Oct-11	SR	Shell Rock	**9**	1	67.893	7.188	3.320
2011	May-12	SR	Shell Rock	4	2	59.868	3.355	1.401
2011	May-12	SR	Shell Rock	62	2	52.689	3.999	4.886
2011	May-12	SR	Shell Rock	12	1	48.533	2.815	0.809
2011	May-12	SR	Shell Rock	22	2	45.646	3.175	0.822
2011	May-12	SR	Shell Rock	58	2	44.730	2.930	3.951
2011	Oct-11	SR	Shell Rock	**11**	4	44.558	10.545	2.209
2011	May-12	SR	Shell Rock	17	2	43.603	8.999	1.723
2011	Oct-11	SR	Shell Rock	**32**	1	41.714	27.775	6.611
2011	May-12	SR	Shell Rock	89	2	39.867	3.770	0.846
2011	May-12	SR	Shell Rock	10	1	33.172	1.292	0.750
2011	Oct-11	SR	Shell Rock	**1**	2	29.702	5.092	3.006
2011	May-12	SR	Shell Rock	43	1	28.010	14.484	2.933
2011	May-12	SR	Shell Rock	55	3	27.753	2.149	5.854
2011	May-12	SR	Shell Rock	59	3	25.353	1.664	2.646
2011	May-12	SR	Shell Rock	6	2	24.140	2.627	2.089
2011	May-12	SR	Shell Rock	3	2	23.058	1.188	0.929
2011	May-12	SR	Shell Rock	25	2	20.048	2.655	0.262
2011	May-12	SR	Shell Rock	85	2	19.687	7.270	1.728
2011	Oct-11	SR	Shell Rock	**27**	2	15.041	8.748	4.868
2011	May-12	SR	Shell Rock	90	2	13.979	1.363	1.032
2011	May-12	SR	Shell Rock	56	2	11.733	1.684	3.102
2011	May-12	SR	Shell Rock	7	2	9.550	0.841	1.436
2011	May-12	SR	Shell Rock	46	2	8.761	14.226	3.609
2011	May-12	SR	Shell Rock	34	2	7.826	1.679	0.401
2011	May-12	SR	Shell Rock	33	2	7.465	0.667	0.316
2011	May-12	SR	Shell Rock	68	2	6.974	2.929	0.998
2011	May-12	SR	Shell Rock	35	1	6.284	1.104	0.232
2011	May-12	SR	Shell Rock	29	2	6.046	7.632	2.313
2011	May-12	SR	Shell Rock	91	3	5.359	0.204	0.395
2011	May-12	SR	Shell Rock	45	2	4.813	1.109	1.406
2011	May-12	SR	Shell Rock	44	2	4.528	2.593	0.854
2011	May-12	SR	Shell Rock	63	3	3.397	0	3.374
2011	Oct-11	SR	Shell Rock	**42**	2	3.221	3.887	5.012
2011	May-12	SR	Shell Rock	31	2	2.729	1.062	0.482
2011	May-12	SR	Shell Rock	40	3	2.624	3.098	1.844
2011	May-12	SR	Shell Rock	38	1	2.251	4.132	0.961
2011	May-12	SR	Shell Rock	75	2	2.237	4.183	1.701

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2011	May-12	SR	Shell Rock	79	2	2.149	9.335	5.558
2011	May-12	SR	Shell Rock	16	3	1.971	0.275	0.108
2011	May-12	SR	Shell Rock	18	3	1.606	0.200	1.108
2011	May-12	SR	Shell Rock	30	2	1.527	1.749	0.815
2011	May-12	SR	Shell Rock	71	3	1.102	1.209	1.175
2011	May-12	SR	Shell Rock	50	3	0.720	0.233	0.410
2011	May-12	SR	Shell Rock	67	3	0.635	0.606	0.875
2011	May-12	SR	Shell Rock	36	3	0.534	0.055	0.179
2011	May-12	SR	Shell Rock	60	3	0.476	0.130	0.250
2011	May-12	SR	Shell Rock	65	2	0.458	0.141	1.388
2011	May-12	SR	Shell Rock	37	3	0.435	0.117	0.174
2011	May-12	SR	Shell Rock	57	3	0.419	0.027	0.231
2011	May-12	SR	Shell Rock	49	3	0.376	0.186	0.665
2011	May-12	SR	Shell Rock	61	3	0.319	0.083	0.154
2011	May-12	SR	Shell Rock	28	3	0.269	0.076	0.122
2011	May-12	SR	Shell Rock	41	2	0.266	0.603	0.522
2011	May-12	SR	Shell Rock	88	3	0.211	0.039	0.303
2011	May-12	SR	Shell Rock	51	3	0.165	0.086	2.710
2011	May-12	SR	Shell Rock	52	2	0.149	0.390	6.725
2011	May-12	SR	Shell Rock	93	3	0.145	0.058	0.200
2011	May-12	SR	Shell Rock	64	3	0.140	0.147	0.924
2011	May-12	SR	Shell Rock	39	3	0.127	0.111	0.525
2011	May-12	SR	Shell Rock	81	3	0.118	0.143	2.017
2011	May-12	SR	Shell Rock	26	3	0.113	0.023	0.121
2011	May-12	SR	Shell Rock	53	3	0.111	0.110	0.991
2011	May-12	SR	Shell Rock	54	3	0.097	0	1.113
2011	May-12	SR	Shell Rock	8	3	0.086	0.224	0.528
2011	May-12	SR	Shell Rock	48	3	0.068	0	0.270
2011	May-12	SR	Shell Rock	86	3	0.068	0.035	0.387
2011	May-12	SR	Shell Rock	69	3	0.043	0.085	0.251
2011	May-12	SR	Shell Rock	72	3	0.023	0	0.355
2011	May-12	SR	Shell Rock	47	3	0.013	0.033	0.103
2011	May-12	SR	Shell Rock	76	3	0.013	0	0.063
2011	May-12	SR	Shell Rock	73	3	0.012	0.045	0.114
2011	May-12	SR	Shell Rock	66	3	0	0	3.383
2011	May-12	SR	Shell Rock	70	3	0	0	0.230
2011	May-12	SR	Shell Rock	74	3	0	0	0
2011	May-12	SR	Shell Rock	77	3	0	0	0.278
2011	May-12	SR	Shell Rock	78	3	0	0	1.587
2011	May-12	SR	Shell Rock	80	3	0	0	0.157
2011	May-12	SR	Shell Rock	82	3	0	0	0.492
2011	May-12	SR	Shell Rock	83	3	0	0.200	1.444
2011	May-12	SR	Shell Rock	84	3	0	0	1.249
2011	May-12	SR	Shell Rock	87	3	0	0.062	1.425
2011	May-12	SR	Shell Rock	92	3	0	0	0
2011	Oct-11	HM	Benny Sand	**4**	4	103.464	55.304	1.959
2011	Oct-11	HM	Benny Sand	**8**	1	50.597	74.081	9.669
2011	Oct-11	HM	Benny Sand	**15**	4	24.327	38.586	5.669
2011	Oct-11	HM	Benny Sand	**9**	1	17.355	21.481	1.646
2011	Oct-11	HM	Benny Sand	**7**	1	13.517	31.010	4.461
2011	Oct-11	HM	Benny Sand	**14**	2	12.399	26.034	8.735
2011	Oct-11	HM	Benny Sand	**1**	2	10.477	10.820	4.569
2011	Oct-11	HM	Benny Sand	**11**	4	6.263	39.837	7.678
2011	Oct-11	HM	Benny Sand	**13**	2	4.316	51.299	13.995
2011	Oct-11	HM	Benny Sand	**27**	2	3.318	3.074	3.568

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2011	Oct-11	HM	Benny Sand	**22**	2	2.907	8.189	4.068
2011	Oct-11	HM	Benny Sand	**26**	2	1.878	4.533	2.735
2011	Oct-11	HM	Bennies	**71**	4	18.036	63.974	10.591
2011	Oct-11	HM	Bennies	**70**	4	8.841	39.556	7.033
2011	Oct-11	HM	Bennies	**86**	1	5.722	50.374	5.898
2011	Oct-11	HM	Bennies	**123**	1	2.799	7.339	6.536
2011	Oct-11	HM	Bennies	**102**	4	1.827	14.123	5.742
2011	Oct-11	HM	Bennies	**148**	2	1.505	5.730	8.010
2011	Oct-11	HM	Bennies	**7**	2	0.821	2.091	0.916
2011	Oct-11	HM	Bennies	**107**	2	0.731	4.591	10.216
2011	Oct-11	HM	Bennies	**84**	2	0.642	5.169	10.090
2011	Oct-11	HM	Bennies	**133**	2	0.128	0.668	4.272
2011	Oct-11	HM	Bennies	**114**	2	0.125	1.308	9.349
2011	Oct-11	HM	Bennies	**97**	1	0.121	4.122	11.202
2011	Oct-11	HM	Bennies	**64**	2	0	0.332	5.022
2011	Oct-11	HM	Bennies	**96**	2	0	1.572	12.262
2011	Oct-11	HM	Bennies	**127**	2	0	0.137	0.686
2011	Oct-11	HM	NantuxentP	**24**	4	80.689	77.841	9.562
2011	Oct-11	HM	NantuxentP	**18**	1	44.482	26.589	9.293
2011	Oct-11	HM	NantuxentP	**16**	1	40.012	9.772	1.408
2011	Oct-11	HM	NantuxentP	**15**	1	23.151	65.238	5.304
2011	Oct-11	HM	NantuxentP	**26**	2	3.780	1.682	0.499
2011	Oct-11	HM	NantuxentP	**13**	2	1.843	5.704	3.026
2011	Oct-11	HM	NantuxentP	**29**	2	0.540	2.364	3.429
2011	Oct-11	HM	Hog Shoal	**1**	1	21.796	45.861	10.847
2011	Oct-11	HM	Hog Shoal	**13**	1	18.847	29.647	7.191
2011	Oct-11	HM	Hog Shoal	**12**	2	16.964	22.944	2.694
2011	Oct-11	HM	Hog Shoal	**2**	2	5.117	5.639	3.455
2011	Oct-11	HM	Hog Shoal	**4**	1	2.866	7.534	4.458
2011	Oct-11	HM	Hog Shoal	**20**	2	1.350	17.353	6.715
2011	Oct-11	HM	New Beds	**26**	1	8.887	61.856	10.710
2011	Oct-11	HM	New Beds	**17**	1	6.839	59.220	10.196
2011	Oct-11	HM	New Beds	**41**	2	5.306	21.864	4.820
2011	Oct-11	HM	New Beds	**53**	2	3.494	36.041	10.741
2011	Oct-11	HM	New Beds	**39**	2	2.659	25.398	6.217
2011	Oct-11	HM	New Beds	**28**	2	1.998	7.591	4.229
2011	Oct-11	HM	New Beds	**68**	2	1.018	0.899	1.297
2011	Oct-11	HM	New Beds	**55**	2	0.923	3.960	4.765
2011	Oct-11	HM	New Beds	**43**	2	0.676	2.780	5.764
2011	Oct-11	HM	Strawberry	**9**	2	3.321	19.068	10.872
2011	Oct-11	HM	Strawberry	**29**	1	1.217	13.064	12.456
2011	Oct-11	HM	Strawberry	**24**	2	0.924	0.316	0.156
2011	Oct-11	HM	Strawberry	**20**	2	0.260	0.733	1.058
2011	Oct-11	HM	Hawk's Nest	**25**	2	25.916	12.477	2.064
2011	Oct-11	HM	Hawk's Nest	**2**	1	13.938	33.484	2.951
2011	Oct-11	HM	Hawk's Nest	**1**	1	10.322	14.133	2.220
2011	Oct-11	HM	Hawk's Nest	**9**	2	3.261	3.101	3.028
2011	Oct-11	HM	Hawk's Nest	**19**	2	0.139	2.358	4.577
2011	Oct-11	HM	Beadons	**3**	1	26.855	119.763	10.094
2011	Oct-11	HM	Beadons	**4**	1	16.255	79.724	4.640
2011	Oct-11	HM	Beadons	**9**	2	2.232	7.945	0.271
2011	Oct-11	HM	Beadons	**5**	2	1.444	6.174	1.279
2011	Oct-11	HM	Beadons	**15**	2	0.432	1.681	0.173
2011	Oct-11	HM	Vexton	**4**	1	12.688	43.540	5.723
2011	Oct-11	HM	Vexton	**9**	1	11.496	92.935	16.673

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2011	Oct-11	HM	Vexton	**5**	2	3.497	38.677	14.991
2011	Oct-11	HM	Vexton	**33**	2	0	0.081	0.268
2011	Oct-11	HM	Egg Island	**44**	2	1.653	10.506	11.562
2011	Oct-11	HM	Egg Island	**62**	1	0.360	0.628	10.707
2011	Oct-11	HM	Egg Island	**101**	2	0.315	0.275	4.909
2011	Oct-11	HM	Egg Island	**82**	2	0.155	1.213	14.836
2011	Oct-11	HM	Egg Island	**59**	2	0	0.801	6.186
2011	Oct-11	HM	Egg Island	**85**	2	0	0.096	1.882
2012	Oct-12	VLM	Hope Creek	**43**	2	99.683	45.364	15.495
2012	Oct-12	VLM	Hope Creek	**64**	1	91.066	24.466	14.565
2012	Oct-12	VLM	Hope Creek	**54**	2	75.528	19.257	19.034
2012	Oct-12	VLM	Hope Creek	**75**	1	71.899	16.377	10.101
2012	Oct-12	VLM	Hope Creek	**61**	1	68.872	16.601	9.040
2012	Oct-12	VLM	Hope Creek	**59**	4	57.387	19.860	4.998
2012	Oct-12	VLM	Hope Creek	**63**	1	57.046	20.322	9.753
2012	Oct-12	VLM	Hope Creek	**65**	2	49.072	16.248	7.572
2012	Oct-12	VLM	Hope Creek	**86**	2	34.702	6.139	7.467
2012	Oct-12	VLM	Liston Range	**18**	2	100.675	16.916	5.798
2012	Oct-12	VLM	Liston Range	**24**	1	98.488	22.680	5.701
2012	Oct-12	VLM	Liston Range	**2**	2	4.296	1.560	0.812
2012	Oct-12	VLM	Liston Range	**22**	2	3.704	1.761	0.291
2012	Oct-12	VLM	Liston Range	**23**	2	2.135	0.577	0.462
2012	Oct-12	VLM	Liston Range	**21**	1	0.056	0	0.146
2012	Oct-12	VLM	Fishing Creek	**25**	1	74.525	9.465	7.542
2012	Oct-12	VLM	Fishing Creek	**16**	1	14.093	1.829	3.821
2012	Oct-12	VLM	Fishing Creek	**36**	2	13.960	2.053	3.811
2012	Oct-12	VLM	Fishing Creek	**8**	2	2.461	0.340	0.534
2012	Oct-12	VLM	Fishing Creek	**43**	2	1.832	0.186	1.963
2012	Oct-12	LM	Round Island	**11**	1	112.578	17.428	19.932
2012	Oct-12	LM	Round Island	**2**	2	94.376	19.514	6.263
2012	Oct-12	LM	Round Island	**12**	1	90.171	5.128	12.109
2012	Oct-12	LM	Round Island	**27**	2	20.331	2.771	1.767
2012	Oct-12	LM	Round Island	**68**	2	2.502	0.063	0.281
2012	May-13	LM	Upper Arnolds	11	2	202.528	18.118	8.710
2012	Oct-12	LM	Upper Arnolds	**10**	1	158.164	30.671	13.273
2012	Oct-12	LM	Upper Arnolds	**16**	2	156.994	26.745	13.166
2012	May-13	LM	Upper Arnolds	3	2	146.995	25.144	20.970
2012	May-13	LM	Upper Arnolds	5	1	107.663	4.989	6.287
2012	Oct-12	LM	Upper Arnolds	**18**	1	105.235	7.748	9.525
2012	May-13	LM	Upper Arnolds	6	2	91.513	6.761	4.324
2012	May-13	LM	Upper Arnolds	22	2	87.865	10.508	22.356
2012	May-13	LM	Upper Arnolds	4	1	87.660	8.149	6.739
2012	May-13	LM	Upper Arnolds	17	3	61.445	6.656	5.172
2012	May-13	LM	Upper Arnolds	9	2	60.585	13.078	18.448
2012	May-13	LM	Upper Arnolds	25	1	53.300	4.689	5.148
2012	Oct-12	LM	Upper Arnolds	**2**	2	50.432	18.796	28.994
2012	Oct-12	LM	Upper Arnolds	**12**	2	44.730	7.550	3.870
2012	May-13	LM	Upper Arnolds	15	2	41.365	1.786	7.112
2012	May-13	LM	Upper Arnolds	14	2	39.289	3.012	9.437
2012	May-13	LM	Upper Arnolds	13	2	26.181	1.196	4.958
2012	May-13	LM	Upper Arnolds	8	2	14.052	4.197	2.605
2012	May-13	LM	Upper Arnolds	7	3	2.272	0.039	0.249
2012	May-13	LM	Upper Arnolds	21	2	1.305	0.085	0.070
2012	May-13	LM	Upper Arnolds	29	3	0.908	0.379	0.492
2012	May-13	LM	Upper Arnolds	23	3	0.611	0	0.070

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2012	May-13	LM	Upper Arnolds	19	3	0.134	0	0.073
2012	May-13	LM	Upper Arnolds	20	3	0.089	0.084	0.301
2012	May-13	LM	Upper Arnolds	26	3	0.047	0	0.010
2012	May-13	LM	Upper Arnolds	1	3	0	0	0.071
2012	May-13	LM	Upper Arnolds	24	3	0	0	0.098
2012	May-13	LM	Upper Arnolds	27	3	0	0	0
2012	May-13	LM	Upper Arnolds	28	3	0	0	0.001
2012	Oct-12	LM	Arnolds	**7**	1	149.686	22.770	6.909
2012	Oct-12	LM	Arnolds	**16**	1	112.908	19.631	4.304
2012	Oct-12	LM	Arnolds	**17**	1	100.883	11.959	6.095
2012	Oct-12	LM	Arnolds	**27**	2	80.153	12.410	9.372
2012	Oct-12	LM	Arnolds	**3**	2	5.843	0.370	2.539
2012	Oct-12	LM	Arnolds	**2**	2	2.959	0.778	2.390
2012	Oct-12	MMT	Upper Middle	**63**	2	79.150	26.471	9.527
2012	Oct-12	MMT	Upper Middle	**1**	2	77.474	4.039	12.743
2012	Oct-12	MMT	Upper Middle	**58**	1	73.834	3.427	14.265
2012	Oct-12	MMT	Upper Middle	**71**	2	45.329	4.691	9.494
2012	Nov-12	MMT	Middle	**35**	1	93.098	78.263	6.860
2012	Nov-12	MMT	Middle	**34**	1	91.671	108.246	6.069
2012	Nov-12	MMT	Middle	**28**	1	71.909	70.513	5.037
2012	Nov-12	MMT	Middle	**43**	2	24.931	12.881	6.785
2012	Nov-12	MMT	Middle	**26**	4	21.110	32.150	2.856
2012	Oct-12	MMT	Middle	**32**	2	13.275	3.996	5.587
2012	Nov-12	MMT	Middle	**17**	2	5.752	2.131	1.065
2012	Nov-12	MMT	Middle	**51**	2	5.527	2.011	2.345
2012	Nov-12	MMT	Sea Breeze	**14**	1	67.620	40.121	6.249
2012	Nov-12	MMT	Sea Breeze	**37**	2	53.202	42.821	2.452
2012	Nov-12	MMT	Sea Breeze	**20**	2	39.652	16.583	3.844
2012	Nov-12	MMT	Sea Breeze	**29**	2	34.586	33.634	2.908
2012	Nov-12	MMT	Sea Breeze	**15**	1	32.418	19.018	1.751
2012	Nov-12	MMT	Sea Breeze	**31**	1	16.663	11.719	1.481
2012	Nov-12	MMT	Sea Breeze	**46**	2	1.193	1.286	0.438
2012	Nov-12	MMM	Ship John	**14**	2	99.371	58.772	7.046
2012	Nov-12	MMM	Ship John	**39**	1	84.451	83.631	6.060
2012	Nov-12	MMM	Ship John	**23**	1	70.200	66.360	6.584
2012	Nov-12	MMM	Ship John	**38**	2	64.315	48.279	6.671
2012	Nov-12	MMM	Ship John	**21**	1	61.746	60.799	3.674
2012	Nov-12	MMM	Ship John	**25**	1	59.319	66.641	2.100
2012	Nov-12	MMM	Ship John	**24**	2	46.859	58.121	6.362
2012	Nov-12	MMM	Ship John	**9**	1	41.209	48.953	3.354
2012	Nov-12	MMM	Ship John	**29**	1	29.366	35.946	2.314
2012	Nov-12	MMM	Ship John	**53**	4	26.968	28.682	2.074
2012	Nov-12	MMM	Ship John	**35**	2	19.251	13.786	6.239
2012	Nov-12	MMM	Ship John	**49**	2	19.015	12.433	3.054
2012	Nov-12	MMM	Ship John	**36**	4	16.237	20.611	5.029
2012	Nov-12	MMM	Cohansey	**25**	1	94.234	28.033	8.701
2012	Nov-12	MMM	Cohansey	**8**	2	76.202	25.541	6.677
2012	Nov-12	MMM	Cohansey	**56**	2	64.430	53.676	4.341
2012	Nov-12	MMM	Cohansey	**44**	1	61.195	44.969	1.701
2012	Nov-12	MMM	Cohansey	**54**	1	55.232	91.918	7.106
2012	Nov-12	MMM	Cohansey	**20**	1	47.214	47.288	4.974
2012	Nov-12	MMM	Cohansey	**4**	2	40.400	29.048	14.212
2012	Nov-12	MMM	Cohansey	**35**	2	36.148	19.043	9.997
2012	Nov-12	MMM	Cohansey	**57**	1	13.825	7.846	3.661
2012	Nov-12	MMM	Cohansey	**32**	2	13.747	19.497	8.326

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2012	Nov-12	SR	Shell Rock	**20**	1	55.233	148.813	2.925
2012	Nov-12	SR	Shell Rock	**11**	4	29.282	37.178	1.599
2012	Nov-12	SR	Shell Rock	**90**	2	19.050	23.576	1.118
2012	Nov-12	SR	Shell Rock	**23**	4	18.190	30.294	0.686
2012	Nov-12	SR	Shell Rock	**44**	2	15.705	51.608	1.692
2012	Nov-12	SR	Shell Rock	**1**	1	13.720	19.071	1.532
2012	Nov-12	SR	Shell Rock	**46**	2	13.579	29.963	2.561
2012	Nov-12	SR	Shell Rock	**35**	2	12.222	20.097	0.467
2012	Nov-12	SR	Shell Rock	**45**	2	7.901	12.320	1.017
2012	Nov-12	SR	Shell Rock	**62**	1	6.866	13.834	0.657
2012	Nov-12	SR	Shell Rock	**9**	1	6.549	14.686	0.870
2012	Nov-12	SR	Shell Rock	**7**	2	6.533	12.261	0.449
2012	Nov-12	HM	Benny Sand	**7**	1	29.872	57.598	4.535
2012	Nov-12	HM	Benny Sand	**6**	2	28.316	68.223	6.568
2012	Nov-12	HM	Benny Sand	**4**	4	16.608	36.319	0.707
2012	Nov-12	HM	Benny Sand	**11**	4	16.524	23.082	2.834
2012	Nov-12	HM	Benny Sand	**12**	4	16.515	65.032	2.039
2012	Nov-12	HM	Benny Sand	**13**	2	13.844	52.196	3.818
2012	Nov-12	HM	Benny Sand	**8**	1	11.991	29.264	1.300
2012	Nov-12	HM	Benny Sand	**15**	2	11.902	34.104	0.889
2012	Nov-12	HM	Benny Sand	**5**	2	11.816	29.770	5.881
2012	Nov-12	HM	Benny Sand	**20**	2	6.896	17.884	4.504
2012	Nov-12	HM	Benny Sand	**9**	1	4.035	13.208	0.236
2012	Nov-12	HM	Benny Sand	**1**	2	1.809	2.331	0.442
2012	Nov-12	HM	Bennies	**70**	1	57.063	302.304	6.052
2012	Nov-12	HM	Bennies	**101**	1	27.757	152.079	4.660
2012	Oct-12	HM	Bennies	**148**	2	7.094	7.680	9.097
2012	Nov-12	HM	Bennies	**43**	1	6.196	83.761	2.598
2012	Oct-12	HM	Bennies	**152**	2	5.393	0.187	10.158
2012	Oct-12	HM	Bennies	**114**	2	3.457	13.198	8.427
2012	Nov-12	HM	Bennies	**102**	4	1.790	10.356	0.453
2012	Oct-12	HM	Bennies	**81**	2	1.776	0.496	7.393
2012	Oct-12	HM	Bennies	**34**	2	1.081	5.660	14.155
2012	Oct-12	HM	Bennies	**18**	2	0.353	1.308	1.390
2012	Nov-12	HM	Bennies	**38**	2	0.218	0.847	0.278
2012	Oct-12	HM	Bennies	**151**	2	0.149	0.078	1.705
2012	Oct-12	HM	Bennies	**119**	2	0.084	0	6.163
2012	Nov-12	HM	NantuxentP	**20**	4	32.016	131.208	5.871
2012	Nov-12	HM	NantuxentP	**24**	1	23.615	41.281	1.841
2012	Nov-12	HM	NantuxentP	**8**	2	17.321	14.132	6.893
2012	Nov-12	HM	NantuxentP	**18**	1	15.864	19.028	5.213
2012	Nov-12	HM	NantuxentP	**13**	2	15.325	71.747	9.625
2012	Nov-12	HM	NantuxentP	**25**	1	13.973	26.899	1.006
2012	Nov-12	HM	NantuxentP	**30**	2	1.725	4.262	2.845
2012	Nov-12	HM	Hog Shoal	**13**	1	26.299	169.352	5.134
2012	Oct-12	HM	Hog Shoal	**7**	2	18.492	74.178	13.423
2012	Nov-12	HM	Hog Shoal	**1**	1	10.372	84.067	4.149
2012	Oct-12	HM	Hog Shoal	**19**	2	7.783	49.866	12.815
2012	Oct-12	HM	Hog Shoal	**12**	2	5.198	43.470	1.420
2012	Nov-12	HM	Hog Shoal	**4**	1	4.338	17.401	2.802
2012	May-13	HM	New Beds	27	1	27.083	351.108	25.095
2012	May-13	HM	New Beds	23	2	25.633	87.547	13.497
2012	May-13	HM	New Beds	24	1	24.092	51.480	11.339
2012	May-13	HM	New Beds	26	1	22.901	105.519	14.815
2012	Nov-12	HM	New Beds	**25**	1	19.981	161.687	10.390

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2012	May-13	HM	New Beds	41	2	19.513	76.482	13.553
2012	May-13	HM	New Beds	53	2	15.709	8.037	15.175
2012	May-13	HM	New Beds	3	2	15.090	104.822	17.249
2012	Oct-12	HM	New Beds	**2**	2	13.576	94.659	18.221
2012	May-13	HM	New Beds	35	3	13.307	79.358	20.855
2012	Oct-12	HM	New Beds	**22**	2	13.124	210.540	12.759
2012	May-13	HM	New Beds	39	2	12.865	44.334	9.468
2012	May-13	HM	New Beds	38	2	11.446	32.587	11.995
2012	May-13	HM	New Beds	13	1	10.663	23.511	6.384
2012	Nov-12	HM	New Beds	**28**	2	8.785	129.866	7.867
2012	May-13	HM	New Beds	37	2	8.466	34.171	12.255
2012	May-13	HM	New Beds	59	3	8.450	16.022	13.629
2012	May-13	HM	New Beds	42	2	8.224	7.242	8.997
2012	May-13	HM	New Beds	15	1	7.864	55.993	14.874
2012	May-13	HM	New Beds	10	2	7.833	50.451	25.124
2012	May-13	HM	New Beds	36	3	7.713	23.956	21.086
2012	May-13	HM	New Beds	1	2	7.577	39.189	16.057
2012	Nov-12	HM	New Beds	**17**	1	6.787	79.210	9.242
2012	May-13	HM	New Beds	52	1	5.485	4.601	6.672
2012	May-13	HM	New Beds	54	2	4.775	0	13.978
2012	May-13	HM	New Beds	6	3	4.742	21.474	6.211
2012	May-13	HM	New Beds	40	2	4.405	2.984	11.200
2012	May-13	HM	New Beds	14	2	4.168	12.513	9.569
2012	May-13	HM	New Beds	11	2	4.128	7.481	19.425
2012	May-13	HM	New Beds	9	3	3.848	4.466	15.598
2012	May-13	HM	New Beds	21	3	2.949	7.445	10.570
2012	May-13	HM	New Beds	51	2	2.835	20.928	10.035
2012	May-13	HM	New Beds	66	2	2.369	2.685	19.684
2012	May-13	HM	New Beds	12	2	2.243	0	9.125
2012	May-13	HM	New Beds	29	2	2.112	3.160	17.036
2012	May-13	HM	New Beds	4	2	2.068	5.413	5.671
2012	May-13	HM	New Beds	65	2	2.067	1.803	28.252
2012	Oct-12	HM	New Beds	**16**	2	1.970	67.175	19.140
2012	May-13	HM	New Beds	98	3	1.742	4.905	0.385
2012	Oct-12	HM	New Beds	**55**	2	1.548	1.206	15.855
2012	May-13	HM	New Beds	67	2	1.100	0	8.119
2012	May-13	HM	New Beds	60	2	1.060	0	12.503
2012	May-13	HM	New Beds	58	3	0.988	0	23.264
2012	May-13	HM	New Beds	49	3	0.883	0.565	2.792
2012	May-13	HM	New Beds	79	2	0.838	0.274	9.714
2012	May-13	HM	New Beds	50	3	0.835	0.977	2.788
2012	May-13	HM	New Beds	80	2	0.780	0.292	6.731
2012	May-13	HM	New Beds	44	3	0.712	4.196	13.356
2012	May-13	HM	New Beds	43	2	0.703	0	11.163
2012	May-13	HM	New Beds	48	3	0.668	0.250	8.601
2012	May-13	HM	New Beds	105	3	0.633	0	11.205
2012	May-13	HM	New Beds	64	3	0.558	2.621	13.636
2012	Oct-12	HM	New Beds	**69**	2	0.500	0.873	18.690
2012	May-13	HM	New Beds	7	3	0.490	0	4.608
2012	May-13	HM	New Beds	74	3	0.413	0.541	12.102
2012	May-13	HM	New Beds	5	2	0.355	2.785	5.221
2012	May-13	HM	New Beds	93	3	0.301	0	5.088
2012	May-13	HM	New Beds	110	3	0.237	0.266	1.061
2012	May-13	HM	New Beds	95	3	0.206	0	5.505
2012	May-13	HM	New Beds	89	3	0.203	0.314	0.090

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2012	May-13	HM	New Beds	84	3	0.194	0	12.243
2012	May-13	HM	New Beds	92	3	0.187	0	2.474
2012	Oct-12	HM	New Beds	**83**	2	0.175	0	7.726
2012	May-13	HM	New Beds	88	3	0.172	0.134	0.294
2012	May-13	HM	New Beds	102	3	0.146	0.096	3.363
2012	May-13	HM	New Beds	96	3	0.132	0.173	4.175
2012	May-13	HM	New Beds	71	3	0.127	0	5.159
2012	May-13	HM	New Beds	57	3	0.120	0	8.287
2012	May-13	HM	New Beds	109	3	0.119	0.155	1.584
2012	May-13	HM	New Beds	82	3	0.115	0.301	10.708
2012	May-13	HM	New Beds	104	3	0.112	0	10.092
2012	May-13	HM	New Beds	46	3	0.104	0.035	1.462
2012	May-13	HM	New Beds	78	3	0.099	0	2.391
2012	May-13	HM	New Beds	70	3	0.094	0	6.549
2012	May-13	HM	New Beds	81	2	0.090	0.090	8.486
2012	May-13	HM	New Beds	77	3	0.057	0.087	0.657
2012	May-13	HM	New Beds	63	3	0.048	0.126	3.524
2012	May-13	HM	New Beds	31	3	0.038	0	0.100
2012	May-13	HM	New Beds	47	3	0.038	0.100	0.784
2012	May-13	HM	New Beds	20	3	0.019	0	0.149
2012	May-13	HM	New Beds	91	3	0.019	0	1.172
2012	May-13	HM	New Beds	101	3	0.019	0.051	0.203
2012	May-13	HM	New Beds	8	3	0.018	0.425	0.338
2012	May-13	HM	New Beds	34	3	0.018	0.191	0.523
2012	May-13	HM	New Beds	75	3	0.018	0	0.268
2012	May-13	HM	New Beds	99	3	0.018	0.018	0.074
2012	May-13	HM	New Beds	112	3	0.018	0	0.059
2012	May-13	HM	New Beds	18	3	0	0	0
2012	May-13	HM	New Beds	19	3	0	0	0.003
2012	May-13	HM	New Beds	30	3	0	0.479	6.007
2012	May-13	HM	New Beds	32	3	0	0	0.032
2012	May-13	HM	New Beds	33	3	0	0	0.024
2012	May-13	HM	New Beds	61	3	0	0	18.864
2012	May-13	HM	New Beds	62	3	0	0.311	4.477
2012	May-13	HM	New Beds	72	3	0	0	5.481
2012	May-13	HM	New Beds	73	3	0	0	18.440
2012	May-13	HM	New Beds	76	3	0	0.041	0.237
2012	May-13	HM	New Beds	85	3	0	0.194	5.451
2012	May-13	HM	New Beds	86	3	0	0	3.201
2012	May-13	HM	New Beds	87	3	0	0.217	5.606
2012	May-13	HM	New Beds	90	3	0	0	0.597
2012	May-13	HM	New Beds	94	3	0	0	7.386
2012	May-13	HM	New Beds	97	3	0	0.381	13.261
2012	May-13	HM	New Beds	100	3	0	0	0.055
2012	May-13	HM	New Beds	103	3	0	0	16.597
2012	May-13	HM	New Beds	106	3	0	0.058	0.089
2012	May-13	HM	New Beds	107	3	0	0	0.082
2012	May-13	HM	New Beds	108	3	0	0	0.024
2012	May-13	HM	New Beds	111	3	0	0	0.090
2012	May-13	HM	New Beds	45	2	0	0	2.516
2012	May-13	HM	New Beds	56	2	0	0.248	4.212
2012	May-13	HM	New Beds	68	2	0	0.642	8.725
2012	Oct-12	HM	Strawberry	**5**	1	1.525	4.431	3.455
2012	Oct-12	HM	Strawberry	**1**	2	1.334	1.027	3.765
2012	Oct-12	HM	Strawberry	**11**	2	0.505	0.132	2.799

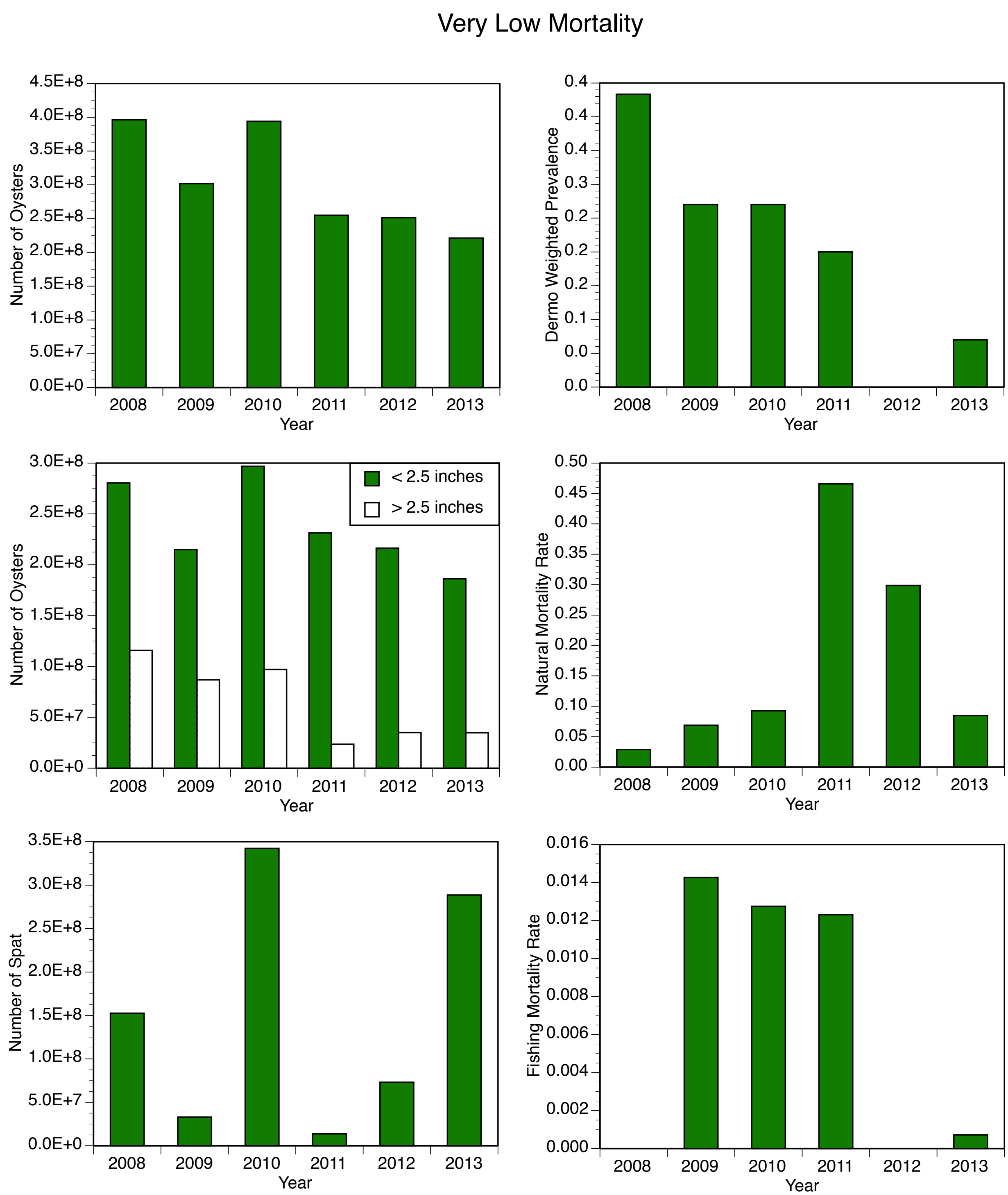
Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2012	Oct-12	HM	Strawberry	**16**	2	0.324	0.235	4.568
2012	Oct-12	HM	Hawk's Nest	**1**	1	15.275	111.783	3.124
2012	Oct-12	HM	Hawk's Nest	**27**	1	11.277	91.659	3.480
2012	Oct-12	HM	Hawk's Nest	**28**	2	7.760	55.951	1.782
2012	Oct-12	HM	Hawk's Nest	**9**	2	0.542	7.436	3.262
2012	Oct-12	HM	Hawk's Nest	**19**	2	0	0.786	6.177
2012	Oct-12	HM	Beadons	**4**	1	24.831	518.219	5.780
2012	Oct-12	HM	Beadons	**3**	1	12.340	188.717	8.810
2012	Oct-12	HM	Beadons	**16**	2	2.150	25.972	0.712
2012	Oct-12	HM	Beadons	**15**	2	2.132	20.114	1.120
2012	Oct-12	HM	Beadons	**18**	2	0.475	22.387	3.427
2012	Oct-12	HM	Vexton	**4**	1	11.449	256.798	5.996
2012	Oct-12	HM	Vexton	**9**	1	2.723	28.488	7.416
2012	Oct-12	HM	Vexton	**3**	2	0.787	29.106	3.857
2012	Oct-12	HM	Vexton	**2**	2	0.109	0.443	1.080
2012	Oct-12	HM	Ledge	**13**	2	0.585	2.042	16.062
2012	Oct-12	HM	Ledge	**14**	2	0.390	0.510	12.284
2012	Oct-12	HM	Ledge	**8**	2	0.330	3.456	22.859
2012	Oct-12	HM	Ledge	**6**	1	0.179	1.869	14.626
2012	Oct-12	HM	Ledge	**35**	2	0	0	0.199
2013	Nov-13	VLM	Hope Creek	**75**	1	81.547	128.786	10.386
2013	Nov-13	VLM	Hope Creek	**74**	2	75.718	146.781	12.935
2013	Nov-13	VLM	Hope Creek	**76**	1	75.707	81.497	8.026
2013	Nov-13	VLM	Hope Creek	**63**	1	64.592	96.614	6.846
2013	Nov-13	VLM	Hope Creek	**53**	2	53.812	98.932	11.572
2013	Nov-13	VLM	Hope Creek	**62**	1	49.312	88.791	5.253
2013	Nov-13	VLM	Hope Creek	**55**	2	25.335	26.278	1.709
2013	Nov-13	VLM	Hope Creek	**59**	4	19.158	19.112	2.564
2013	Nov-13	VLM	Hope Creek	**86**	2	17.424	12.661	1.744
2013	Nov-13	VLM	Liston Range	**24**	1	122.263	134.955	9.095
2013	Nov-13	VLM	Liston Range	**18**	2	54.347	50.048	3.540
2013	Nov-13	VLM	Liston Range	**12**	2	53.955	35.289	2.226
2013	Nov-13	VLM	Liston Range	**14**	1	45.843	40.760	2.318
2013	Nov-13	VLM	Liston Range	**2**	2	5.666	2.742	0.232
2013	Nov-13	VLM	Liston Range	**25**	2	1.173	0.529	0.244
2013	Nov-13	VLM	Fishing Creek	**25**	1	144.818	71.594	11.840
2013	Nov-13	VLM	Fishing Creek	**4**	2	17.687	20.910	3.299
2013	Nov-13	VLM	Fishing Creek	**26**	2	14.316	6.731	3.285
2013	Nov-13	VLM	Fishing Creek	**16**	1	14.228	5.487	5.060
2013	Nov-13	VLM	Fishing Creek	**17**	2	1.594	0.915	0.106
2013	Nov-13	LM	Round Island	**12**	1	44.947	27.607	5.758
2013	Nov-13	LM	Round Island	**24**	1	31.757	26.770	4.556
2013	Nov-13	LM	Round Island	**47**	2	25.080	10.040	3.311
2013	Nov-13	LM	Round Island	**15**	2	2.272	1.275	0.765
2013	Nov-13	LM	Round Island	**50**	2	0.209	0.019	0.043
2013	Nov-13	LM	Upper Arnolds	**17**	2	111.212	120.185	8.500
2013	Nov-13	LM	Upper Arnolds	**9**	2	91.892	84.317	11.351
2013	Nov-13	LM	Upper Arnolds	**3**	1	70.644	50.326	8.869
2013	Nov-13	LM	Upper Arnolds	**4**	2	55.126	73.253	3.794
2013	Nov-13	LM	Upper Arnolds	**11**	1	47.747	37.740	2.995
2013	Nov-13	LM	Upper Arnolds	**5**	1	35.691	49.689	2.137
2013	Nov-13	LM	Upper Arnolds	**25**	2	33.689	19.778	1.447
2013	Nov-13	LM	Arnolds	**7**	1	136.116	89.292	10.746
2013	Nov-13	LM	Arnolds	**18**	1	122.171	72.605	11.348
2013	Nov-13	LM	Arnolds	**6**	1	78.140	70.295	4.977

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2013	Nov-13	LM	Arnolds	**15**	2	53.812	51.464	3.420
2013	Nov-13	LM	Arnolds	**10**	2	23.500	11.959	3.129
2013	Nov-13	LM	Arnolds	**46**	2	4.908	3.643	3.180
2013	Nov-13	MMT	Upper Middle	**48**	1	82.053	75.547	14.432
2013	Nov-13	MMT	Upper Middle	**1**	2	29.174	28.049	12.036
2013	Nov-13	MMT	Upper Middle	**63**	2	24.581	10.718	3.890
2013	Nov-13	MMT	Upper Middle	**56**	2	4.200	5.363	8.333
2013	Nov-13	MMT	Middle	**36**	1	34.458	40.587	4.248
2013	Nov-13	MMT	Middle	**28**	4	31.608	26.452	3.817
2013	Nov-13	MMT	Middle	**22**	2	30.989	14.893	11.252
2013	Nov-13	MMT	Middle	**27**	4	29.760	20.230	3.035
2013	Nov-13	MMT	Middle	**43**	2	18.506	9.219	8.497
2013	Nov-13	MMT	Middle	**38**	1	10.107	5.082	2.783
2013	Nov-13	MMT	Middle	**26**	2	6.570	5.361	1.759
2013	Nov-13	MMT	Middle	**10**	2	5.109	2.322	13.520
2013	Nov-13	MMT	Middle	**1**	2	1.808	1.333	3.298
2013	Nov-13	MMT	Sea Breeze	**20**	2	63.217	21.499	17.462
2013	Nov-13	MMT	Sea Breeze	**25**	2	40.771	21.917	6.157
2013	Nov-13	MMT	Sea Breeze	**14**	1	39.206	45.054	11.558
2013	Nov-13	MMT	Sea Breeze	**31**	1	34.858	18.593	4.410
2013	Nov-13	MMT	Sea Breeze	**30**	1	15.671	5.591	1.832
2013	Nov-13	MMT	Sea Breeze	**29**	2	13.735	5.840	4.097
2013	Nov-13	MMT	Sea Breeze	**17**	2	12.801	3.295	4.594
2013	Nov-13	MMM	Ship John	**56**	2	80.569	91.468	22.337
2013	Nov-13	MMM	Ship John	**46**	2	77.048	44.291	13.538
2013	Nov-13	MMM	Ship John	**25**	1	70.498	52.585	8.492
2013	Nov-13	MMM	Ship John	**53**	4	69.984	9.481	5.321
2013	Nov-13	MMM	Ship John	**33**	1	52.675	56.343	5.132
2013	Nov-13	MMM	Ship John	**42**	1	47.069	44.481	5.409
2013	Nov-13	MMM	Ship John	**16**	1	40.977	54.149	7.322
2013	Nov-13	MMM	Ship John	**21**	1	37.306	34.914	7.426
2013	Nov-13	MMM	Ship John	**18**	2	29.363	13.291	3.191
2013	Nov-13	MMM	Ship John	**58**	1	27.756	36.987	13.626
2013	Nov-13	MMM	Ship John	**35**	2	20.967	8.101	5.667
2013	Nov-13	MMM	Ship John	**36**	4	12.988	3.480	4.795
2013	Nov-13	MMM	Ship John	**5**	2	12.229	6.200	4.722
2013	Nov-13	MMM	Cohansey	**59**	1	54.894	40.760	16.655
2013	Nov-13	MMM	Cohansey	**37**	1	53.998	37.810	13.051
2013	Nov-13	MMM	Cohansey	**25**	1	49.187	34.765	10.477
2013	Nov-13	MMM	Cohansey	**50**	1	42.612	38.451	8.154
2013	Nov-13	MMM	Cohansey	**24**	2	42.348	25.885	9.644
2013	Nov-13	MMM	Cohansey	**46**	2	34.469	21.218	7.779
2013	Nov-13	MMM	Cohansey	**3**	2	29.148	27.740	13.348
2013	Nov-13	MMM	Cohansey	**56**	2	27.521	12.849	3.471
2013	Nov-13	MMM	Cohansey	**35**	2	14.669	9.888	3.562
2013	Nov-13	MMM	Cohansey	**72**	1	14.038	4.571	7.056
2013	Nov-13	SR	Shell Rock	**24**	1	46.910	26.536	3.775
2013	Nov-13	SR	Shell Rock	**11**	4	40.425	7.905	3.309
2013	Nov-13	SR	Shell Rock	**34**	4	37.107	21.838	6.386
2013	Nov-13	SR	Shell Rock	**29**	4	31.916	27.553	7.627
2013	Nov-13	SR	Shell Rock	**2**	1	28.511	7.520	4.142
2013	Nov-13	SR	Shell Rock	**14**	1	23.440	20.268	4.554
2013	Nov-13	SR	Shell Rock	**30**	4	21.250	30.001	5.913
2013	Nov-13	SR	Shell Rock	**25**	2	18.134	11.374	1.724
2013	Nov-13	SR	Shell Rock	**27**	4	17.774	6.989	2.470

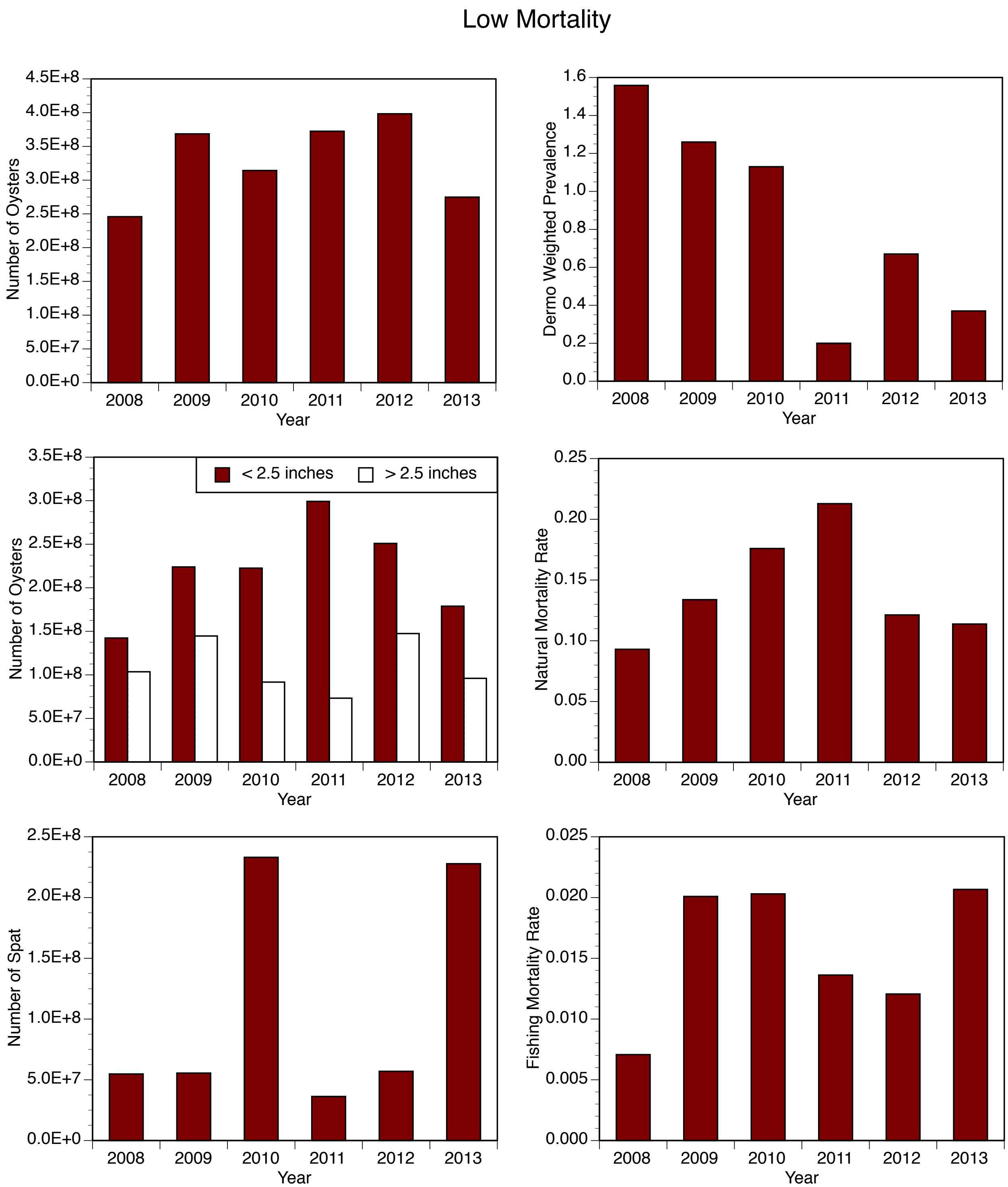
Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2013	Nov-13	SR	Shell Rock	**68**	2	17.471	10.391	5.641
2013	Nov-13	SR	Shell Rock	**4**	1	17.414	8.194	4.168
2013	Nov-13	SR	Shell Rock	**55**	2	14.123	3.107	5.254
2013	Nov-13	SR	Shell Rock	**59**	2	14.100	2.442	2.345
2013	Nov-13	SR	Shell Rock	**7**	2	8.762	5.061	1.902
2013	Nov-13	SR	Shell Rock	**89**	2	7.172	3.041	1.069
2013	Nov-13	HM	Benny Sand	**8**	1	51.209	62.095	7.112
2013	Nov-13	HM	Benny Sand	**11**	4	46.552	32.762	4.530
2013	Nov-13	HM	Benny Sand	**6**	2	23.754	23.265	4.979
2013	Nov-13	HM	Benny Sand	**14**	4	21.524	33.967	6.071
2013	Nov-13	HM	Benny Sand	**9**	1	20.894	48.573	3.707
2013	Nov-13	HM	Benny Sand	**22**	2	15.449	19.963	8.559
2013	Nov-13	HM	Benny Sand	**7**	1	10.268	8.167	2.021
2013	Nov-13	HM	Benny Sand	**44**	2	8.176	9.147	4.772
2013	Nov-13	HM	Benny Sand	**30**	2	7.688	1.624	5.288
2013	Nov-13	HM	Benny Sand	**3**	2	6.272	5.239	1.237
2013	Nov-13	HM	Benny Sand	**37**	2	1.208	0.703	2.391
2013	Nov-13	HM	Bennies	**87**	1	59.488	39.058	4.693
2013	Nov-13	HM	Bennies	**102**	4	27.591	14.223	1.743
2013	Nov-13	HM	Bennies	**70**	1	26.288	16.440	2.238
2013	Nov-13	HM	Bennies	**99**	2	24.774	16.804	8.697
2013	Nov-13	HM	Bennies	**123**	1	23.283	37.923	5.281
2013	Nov-13	HM	Bennies	**35**	2	18.220	62.301	12.502
2013	Nov-13	HM	Bennies	**72**	2	3.415	4.089	1.091
2013	Nov-13	HM	Bennies	**112**	2	3.066	4.489	3.400
2013	Nov-13	HM	Bennies	**37**	2	2.925	3.307	2.042
2013	Nov-13	HM	Bennies	**18**	2	1.732	3.878	3.576
2013	Nov-13	HM	Bennies	**125**	2	0.385	0.671	5.030
2013	Nov-13	HM	Bennies	**121**	2	0.271	0.181	8.606
2013	Nov-13	HM	Bennies	**127**	2	0.095	0.498	3.590
2013	Oct-13	HM	NantuxentP	**15**	1	30.260	39.988	6.405
2013	Oct-13	HM	NantuxentP	**25**	1	22.395	52.087	9.680
2013	Oct-13	HM	NantuxentP	**68**	2	22.237	25.811	9.718
2013	Oct-13	HM	NantuxentP	**18**	1	19.266	17.377	9.066
2013	Oct-13	HM	NantuxentP	**29**	2	11.356	25.879	8.689
2013	Oct-13	HM	NantuxentP	**13**	2	5.617	7.059	4.259
2013	Oct-13	HM	Hog Shoal	**1**	1	30.489	33.855	10.928
2013	Oct-13	HM	Hog Shoal	**6**	2	17.333	13.973	7.179
2013	Oct-13	HM	Hog Shoal	**4**	1	9.357	20.678	4.434
2013	Oct-13	HM	Hog Shoal	**5**	1	4.551	28.785	9.546
2013	Oct-13	HM	Hog Shoal	**9**	2	3.429	37.882	7.180
2013	Oct-13	HM	Hog Shoal	**16**	2	0.223	2.334	1.628
2013	Oct-13	HM	New Beds	**26**	1	45.888	46.252	14.225
2013	Oct-13	HM	New Beds	**22**	1	31.418	62.209	7.844
2013	Oct-13	HM	New Beds	**3**	2	28.576	74.757	12.649
2013	Oct-13	HM	New Beds	**2**	2	21.593	21.235	4.400
2013	Oct-13	HM	New Beds	**24**	1	13.625	44.824	10.904
2013	Oct-13	HM	New Beds	**13**	2	12.973	22.852	5.389
2013	Oct-13	HM	New Beds	**39**	2	7.248	29.141	11.681
2013	Oct-13	HM	New Beds	**53**	1	3.994	6.602	7.899
2013	Oct-13	HM	New Beds	**54**	2	3.220	19.119	9.369
2013	Oct-13	HM	Strawberry	**5**	1	2.471	11.019	8.675
2013	Oct-13	HM	Strawberry	**1**	2	0.442	0.400	3.566
2013	Oct-13	HM	Strawberry	**11**	2	0.143	1.499	4.438
2013	Oct-13	HM	Strawberry	**8**	2	0.043	0.056	0.510

Data Year	Coll. Date (m-yr)	Region	Bed	Grid	Stratum	Oyster/m2	Spat/m2	Cultch/m2
2013	Oct-13	HM	Hawk's Nest	**27**	1	16.639	43.936	6.734
2013	Oct-13	HM	Hawk's Nest	**3**	2	3.506	45.750	13.660
2013	Oct-13	HM	Hawk's Nest	**5**	1	1.004	2.796	4.140
2013	Oct-13	HM	Hawk's Nest	**7**	2	0.340	7.284	8.996
2013	Oct-13	HM	Hawk's Nest	**22**	2	0.146	2.365	4.297
2013	Oct-13	HM	Beadons	**4**	1	8.140	46.525	4.920
2013	Oct-13	HM	Beadons	**9**	2	3.238	11.145	1.544
2013	Oct-13	HM	Beadons	**8**	1	1.633	2.552	1.785
2013	Oct-13	HM	Beadons	**5**	2	0.198	0.443	0.450
2013	Oct-13	HM	Beadons	**16**	2	0.191	0	2.288
2013	Oct-13	HM	Vexton	**9**	1	4.292	79.465	11.405
2013	Oct-13	HM	Vexton	**4**	1	3.207	26.031	6.182
2013	Oct-13	HM	Vexton	**3**	2	1.954	45.608	11.422
2013	Oct-13	HM	Vexton	**17**	2	0.254	13.739	10.292
2013	Oct-13	HM	Egg Island	**28**	2	1.687	18.001	11.734
2013	Oct-13	HM	Egg Island	**41**	2	0	1.533	10.807
2013	Oct-13	HM	Egg Island	**66**	2	0	0.028	0.228
2013	Oct-13	HM	Egg Island	**82**	2	0	0	12.578
2013	Oct-13	HM	Egg Island	**98**	2	0	0	0.088
2013	Oct-13	HM	Egg Island	**62**	1	0	0.522	15.179

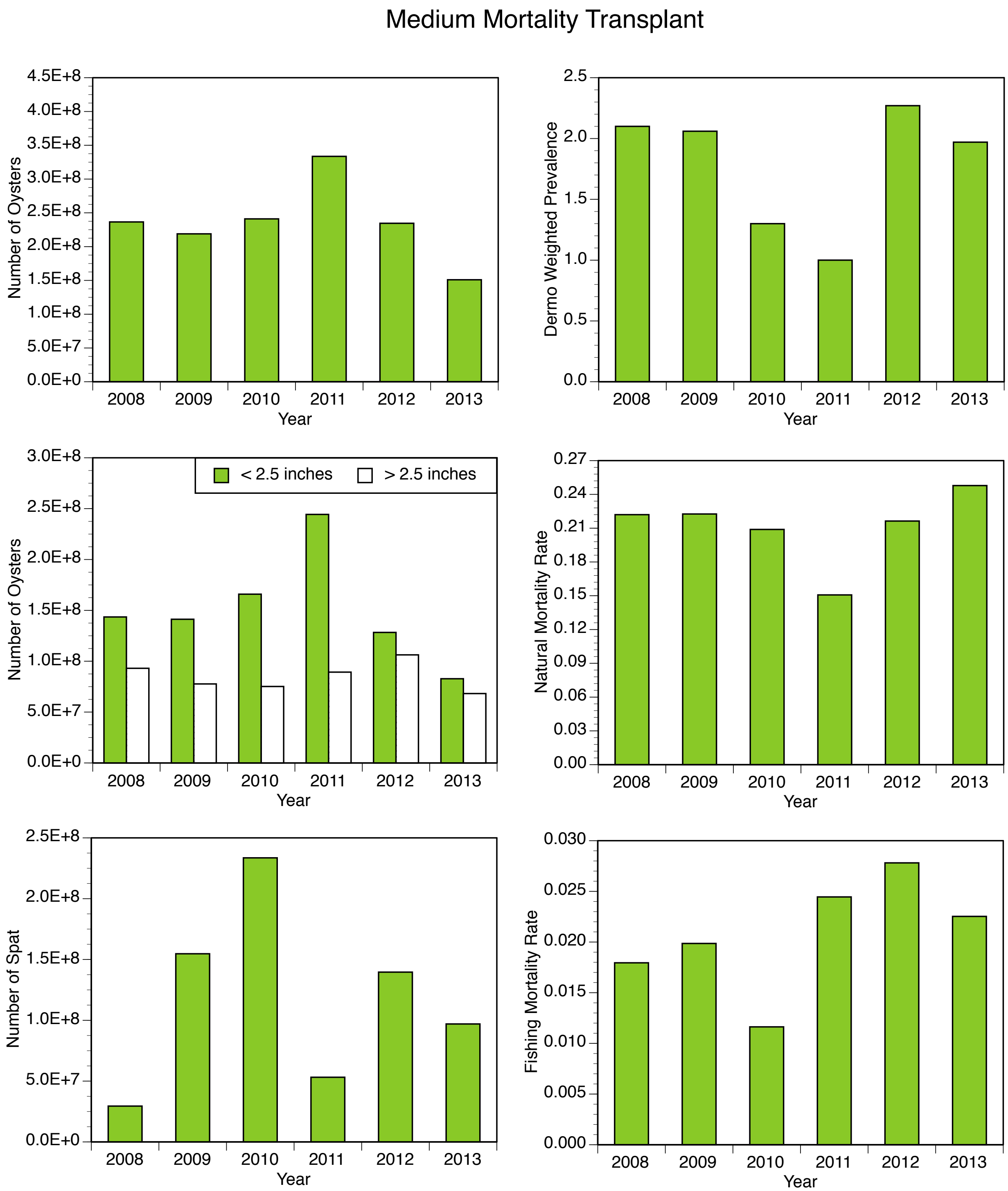
Appendix B.1. Region Trends. Six-year time series summary for the Very Low Mortality region. Left panels show total abundance (excluding spat), abundance by size class (excluding spat), and spat abundance (= oysters < 20 mm). Right panels show Dermo levels, natural mortality rate and fishing mortality rate.



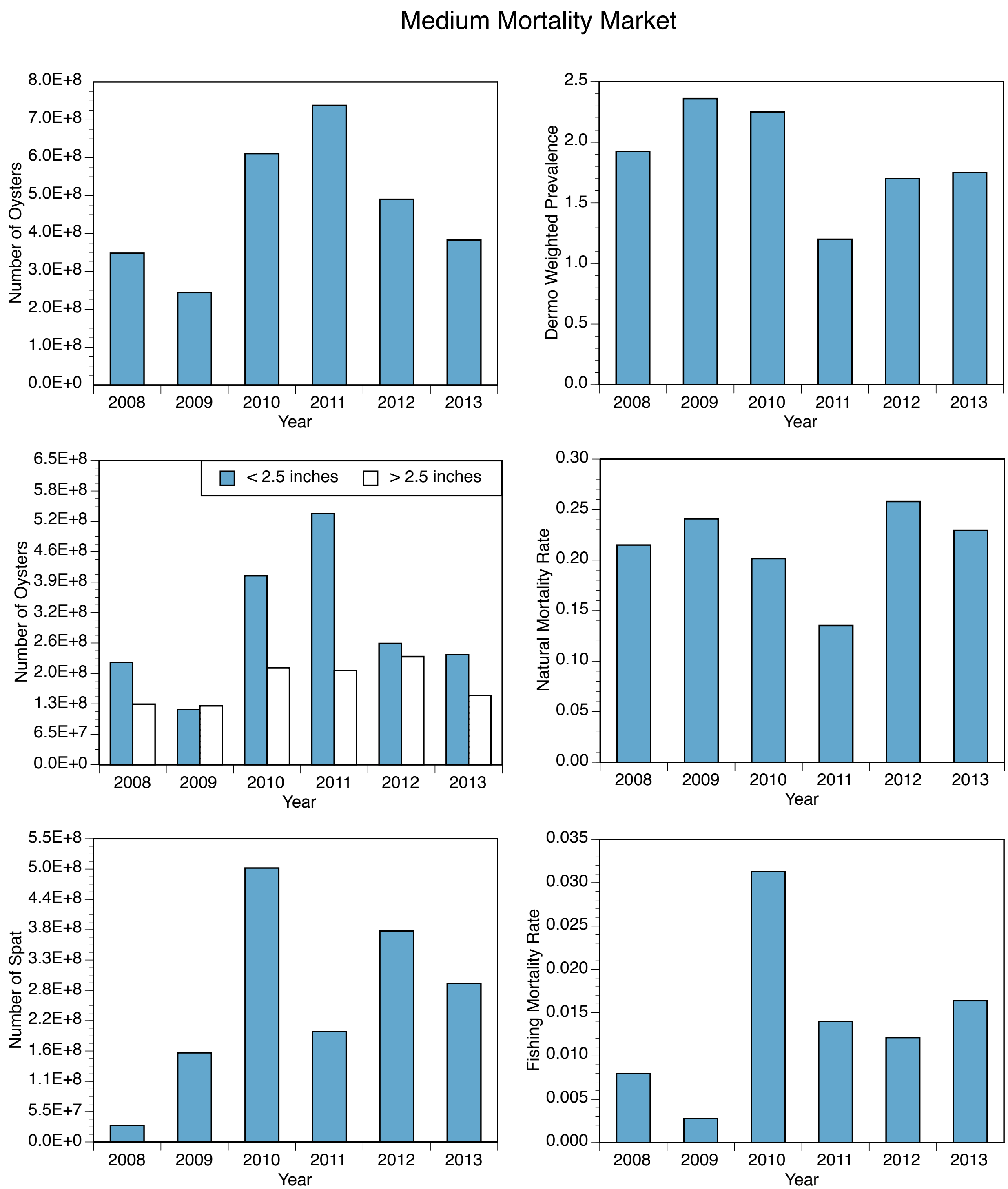
Appendix B.2. Region Trends. Six-year time series summary for the Low Mortality region. Left panels show total abundance (excluding spat), abundance by size class (excluding spat), and spat abundance (= oysters < 20 mm). Right panels show Dermo levels, natural mortality rate and fishing mortality rate.



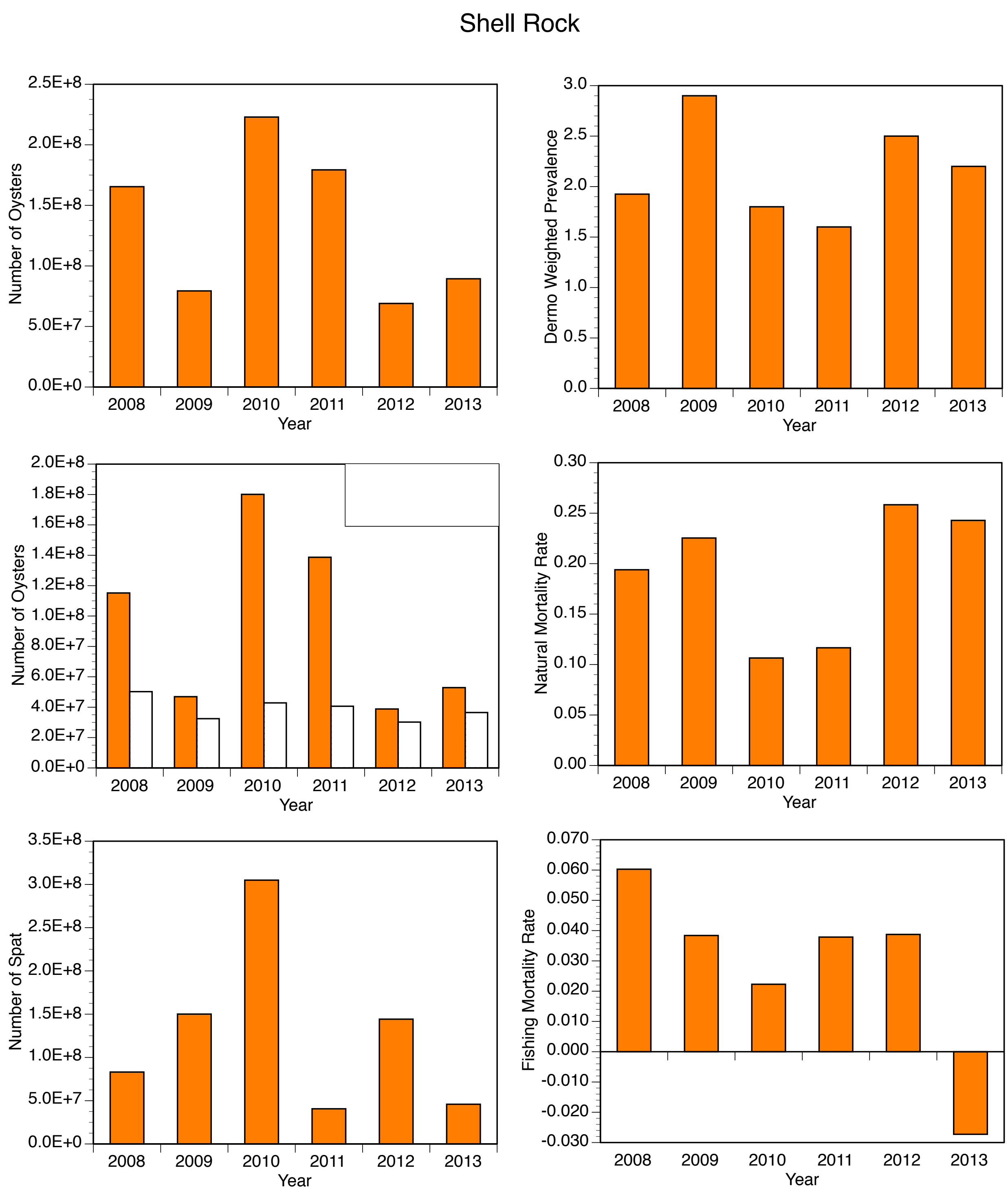
Appendix B.3. Region Trends. Six-year time series summary for the Medium Mortality Transplant region. Left panels show total abundance (excluding spat), abundance by size class (excluding spat), and spat abundance (= oysters < 20 mm). Right panels show Dermo levels, natural mortality rate and fishing mortality rate.



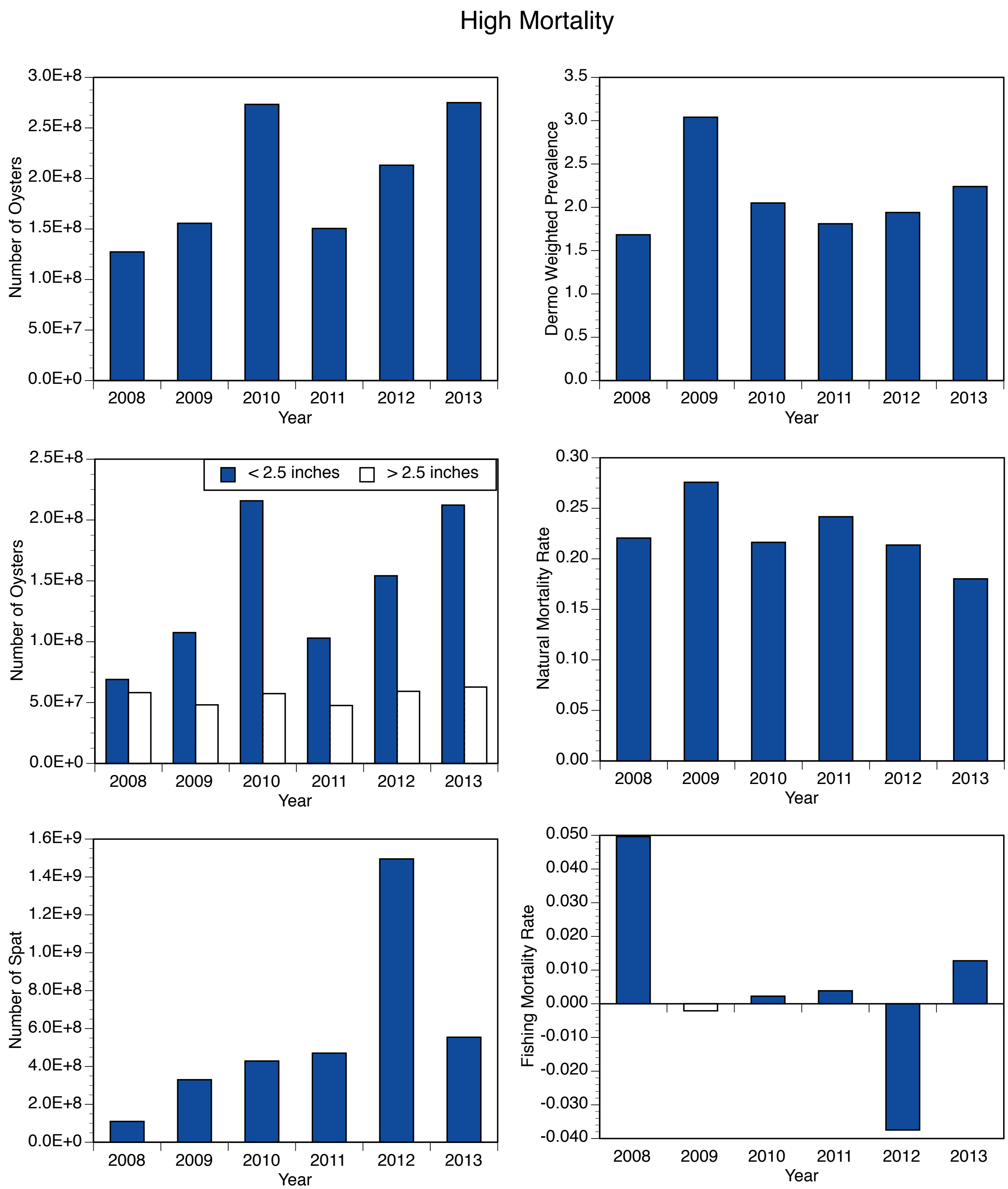
Appendix B.4. Region Trends. Six-year time series summary for the Medium Mortality Market region. Left panels show total abundance (excluding spat), abundance by size class (excluding spat), and spat abundance (= oysters < 20 mm). Right panels show Dermo levels, natural mortality rate and fishing mortality rate.



Appendix B.5. Region Trends. Six-year time series summary for the Shell Rock region. Left panels show total abundance (excluding spat), abundance by size class (excluding spat), and spat abundance (= oysters < 20 mm). Right panels show Dermo levels, natural mortality rate and fishing mortality rate.



Appendix B.6. Region Trends. Six-year time series summary for the High Mortality region. Left panels show total abundance (excluding spat), abundance by size class (excluding spat), and spat abundance (= oysters < 20 mm). Right panels show Dermo levels, natural mortality rate and fishing mortality rate.



Appendix C.1 2013 Intermediate Transplant memorandum for the Low Mortality region. The transplant was conducted from April 22 to April 29.

THE STATE UNIVERSITY OF NEW JERSEY

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HASKIN SHELLFISH RESEARCH LABORATORY

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May 7, 2013

MEMORANDUM

TO: Russell Babb, Jason Hearon, Craig Tomlin

FROM: Kathryn Alcox

Haskin Shellfish Research Laboratory

SUBJECT: Intermediate Transplant – Low Mortality Region

An intermediate transplant from beds in the Low Mortality region was conducted from April 22 to April 29, 2013. The goal for this transplant was to move 9,962,070 oysters which is the 60th percentile exploitation rate for the Low Mortality transplant beds listed in Table 23 of the 15th SAW document. Due to some oversights, there was one day of transplanting from Arnolds which the SARC had recommended against and one boat transplanted for half a day from Liston Range which is in the closed Very Low Mortality region. There were a total of 21,050 bushels of culled material removed from this region by five boats as follows:

2,700 bushels from Arnolds	to Shell Rock 34
8,600 bushels from Upper Arnolds	to Shell Rock 34
6,950 bushels from Upper Arnolds	to Shell Rock 27

2,250 bushels from Round Island	to Shell Rock 27
550 bushels from Liston Range	to Shell Rock 27

Deck samples were obtained from each boat each day with boatloads either measured or estimated by NJDEP. The number of oysters per bushel ranged from 323 to 503 with an average of 402. The percent cultch (not including boxes) in this transplant ranged from 16 to 49 % with an average of 28%.

The 60th percentile exploitation rate maximum of 9,962,070 oysters was not quite met with a total of 8,459,940 oysters moved in the 24 boat-days. This is a similar result to the 2010 transplant which also had a 60th percentile exploitation rate goal. The 2013 transplant included 4,706,156 small oysters that are not included in the quota increase calculations and 3,710,337 oysters that are included in those calculations. Using the conversion of 266 market-size oysters per bushel, this part of the transplant can increase the quota by up to 13,949 bushels. This projection is higher than the expected 12,883 bushels listed in Table 23 of the 15th SAW report for the 60th percentile exploitation rate for the Low Mortality transplant beds.

Tables can be found on the following page:

Tables for 2013 Intermediate Transplant—Low Mortality Region

OYSTERS PER BU	BOAT 1	BOAT 2	BOAT 3	BOAT 4	BOAT 5
4/22/13	383	400	--	449	--
4/23/13	424	323	402	--	--
4/24/13	326	444	390	390	329
4/25/13	467	468	--	503	340
4/26/13	422	328	422	--	--
4/29/13	325	436	434	432	--

PERCENT CULTCH	BOAT 1	BOAT 2	BOAT 3	BOAT 4	BOAT 5
4/22/13	33%	30%	--	23%	--
4/23/13	21%	28%	24%	--	--
4/24/13	28%	28%	33%	17%	34%
4/25/13	16%	37%	--	13%	31%
4/26/13	28%	49%	33%	--	--
4/29/13	37%	37%	21%	21%	--

PERCENT BOXES	BOAT 1	BOAT 2	BOAT 3	BOAT 4	BOAT 5
4/22/13	3%	2%	--	3%	--
4/23/13	2%	3%	4%	--	--
4/24/13	3%	4%	3%	3%	3%
4/25/13	2%	5%	--	2%	2%
4/26/13	4%	4%	5%	--	--
4/29/13	2%	5%	6%	1%	--

Appendix C.2 2013 Intermediate Transplant memorandum for the Medium Mortality Transplant region. The transplant was conducted from April 30 to May 3.

THE STATE UNIVERSITY OF NEW JERSEY

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May 7, 2013

MEMORANDUM

TO: Russell Babb, Jason Hearon, Craig Tomlin

FROM: Kathryn Alcox

Haskin Shellfish Research Laboratory

SUBJECT: Intermediate Transplant – Medium Mortality Region

An intermediate transplant from Upper Middle, and Sea Breeze beds in the Medium Mortality Transplant region was conducted from April 30 to May 3, 2013. The goal for this transplant was to move 5,465,140 oysters: the 60th percentile exploitation rate for the Medium Mortality Transplant beds listed in Table 23 of the 15th SAW document. The SARC advised that no more than half the amount could be taken from Middle bed. There were a total of 14,600 bushels of culled material removed from the Medium Mortality Transplant region by four boats as follows:

6,200 bushels from Sea Breeze	to Bennies Sand 14
5,200 bushels from Middle	to Bennies Sand 14
3,200 bushels from Upper Middle	to Bennies Sand 14

Deck samples were obtained from each boat each day with boatloads either measured or estimated by NJDEP. The number of oysters per bushel ranged from 143 to 365 with an average of 262. The percent cultch (not including boxes) in this transplant ranged from 8 to 41% with an average of 27%.

The 60th percentile exploitation rate maximum of 5,465,140 oysters was not met. Four boats moved a total of 3,798,531 oysters in 13 boat-days which is somewhat under the 50th percentile exploitation rate maximum for this region of 4,409,642 (15th SAW report Table 23). This included 1,295,766 small oysters that are not included in the quota increase calculations and 2,528,170 larger oysters that are included in those calculations. Using the conversion of 266 market-size oysters per bushel, this part of the transplant can increase the quota by up to 9,505 bushels.

Tables can be found on the following page:

Tables for 2013 Intermediate Transplant—Medium Mortality Region

OYSTERS PER BU	BOAT 1	BOAT 2	BOAT 3	BOAT 4
4/30/13	254	273	274	266
5/1/13	218	143	282	--
5/2/13	242	231	221	--
5/3/13	301	333	365	--

PERCENT CULTCH	BOAT 1	BOAT 2	BOAT 3	BOAT 4
4/30/13	34%	20%	33%	23%
5/1/13	35%	39%	27%	--
5/2/13	40%	19%	41%	--
5/3/13	8%	9%	21%	--

PERCENT BOXES	BOAT 1	BOAT 2	BOAT 3	BOAT 4
4/30/13	9%	12%	13%	12%
5/1/13	11%	19%	13%	--
5/2/13	3%	19%	5%	--
5/3/13	10%	18%	2%	--