Executive Summary of the
2005 Stock Assessment Workshop
(7^{th} SAW) for the
New Jersey Delaware Bay Oyster Beds

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February 7-9, 2005

Haskin Shellfish Research Laboratory – Rutgers, The State University of New Jersey

Status of the Stock

Oyster abundance dropped in 2004 to the lowest level since the onset of Dermo disease circa 1989 and to one of the lowest levels in the 1953 to 2004 record (Figure 1). Declines were most serious on Shell Rock and on the low-mortality beds (Arnolds/Upper Arnolds/Round Island). 2004 was the fifth consecutive year of low recruitment, an unprecedented period in the 1953-2004 time series (Figure 2). Recruitment rose above 50 spat per bushel only on Ship John, Bennies Sand, and Shell Rock. The number of spat per >20-mm oyster was 0.335; insufficient to sustain the present population. Inadequate recruitment has resulted in a population size frequency deficient in the smaller oyster size classes. Population dynamics modeling indicates that the market-size component of the population is in a period of negative surplus production as a consequence of the five years of low recruitment. That is, the abundance of $\geq 3''$ oysters is expected to decline in 2005 as natural mortality exceeds the growth of smaller individuals into the market size class (Table 1). Natural mortality, bay-wide, was 13% of the stock in 2004, a relatively typical non-epizootic mortality rate (Figure 3). Natural mortality was unusually high on the low-mortality beds. Continued decline in Dermo disease infection intensity lowered natural mortality rates downbay of this region. The 2004 harvest removed 1.4% of the stock and 2.8% of the stock $\geq 2.5''$, with most of the harvest coming from Ship John, Shell Rock, Cohansey, Bennies, and Bennies Sand (Figure 4). Overall, low recruitment since 1999 and the consequent ongoing reduction in abundance that is anticipated to continue in 2005 is the most serious issue facing sustainability of the stock.

Management Advice

2005 Management Goals

Managing the Delaware Bay oyster resource in this time of low stock abundance, continued disease pressure, and historically low recruitment is a challenge. While a simple approach might be to close the fishery and let nature take its course, the SARC has tried to find a balance between preserving the remaining fishery and infrastructure that supports the fishery, while conserving a broodstock of oysters that will have the potential to provide sufficient recruitment in the future so that the stock can rebuild. The approach that has been taken is to recommend closure of bay regions expected to decline in population through natural processes in 2005, emphasizing those areas thought to be significant sources of broodstock. For the remaining areas, the approach taken is to try to achieve a balance between recruitment-into-the-fishery and loss through natural death and harvest that will have an even or better chance of occurring in 2005.

Long-term time-series analysis indicates that the Cohansey/Ship John/Sea

Breeze/Middle area, along with Shell Rock, provides the core of the stock during periods of low abundance. In 2005, market-size abundance is expected to decline on these four beds without fishing. The likelihood that this part of the bay above Shell Rock provides the bulk of the broodstock during periods of low abundance is high. Consequently, the SARC recommends that harvesting not occur on these beds in 2005.

Recommended allocation levels are based on those areas of the bay expected to have positive surplus production in 2005; namely, the direct-market beds (Shell Rock and beds downbay) plus Nantuxent Point and Beadons. Assuming a fishing season of April 1-November 15, the SARC recommends a 2005 quota on these beds of 26,203 bushels (Table 2). Shortening the season to April 1-August 1 permits an increase in allocation by increasing the proportion of animals fished that would otherwise die from disease. The SARC recommends an allocation of 28,510 for this shortened season (Table 2). The SARC notes that the recommended allocation alternatives are both about 1% of the stock, a fishing rate that should be precautionary given the status of the stock and anticipated 2005 abundance decline due to unsupported natural mortality.

Given the importance of Shell Rock in maintaining both the industry and oyster population, the SARC recommends that the allocation for Shell Rock be independently managed from the remaining direct-market beds.

The SARC recommends a limited transplant of oysters from Middle to Shell Rock after closure of Shell Rock to enhance abundance. This transplant should be less than 5% of the Middle stock. As the transplant is specifically designed for abundance enhancement, the SARC notes (1) that the transplant should be closed for the reminder of 2005 and (2) that the increased abundance be subjected to the 'constant-abundance' reference-point rule in future assessments.

The SARC recommends that oysters be transplanted from the Maurice River to the river mouth tonging beds for harvest. Market oysters should be targeted for transplant. The SARC recommends that a survey be conducted to estimate abundance in order to determine what fraction of the animals can be transplanted in 2005.

Long-term Abundance Goals

In order to increase abundance, two long-term management approaches should be undertaken. First, a multiyear recruitment enhancement program using shell planting to increase recruitment should be established. Given the low present-day abundance, it is essential that this shell-planting program be multiyear. Second, in years when surplus production is positive, some portion of the surplus production should be set aside to increase abundance. Establishing a specific rebuilding plan should be included as one of the Terms of Reference for the 8^{th} SAW.

Table 1. Surplus production estimate of the 2004 oyster stock on the New Jersey natural oyster beds in Delaware Bay, assuming a 75^{th} percentile natural mortality rate and no fishing. A negative number indicates a situation where abundance for that bay region is expected to decline through natural mortality during 2005.

Bay Region	Surplus Production (bushels)
Low-Mortality	264
Medium-Mortality Transplant (Upper)	-21,228
Medium-Mortality Transplant (Lower)	-99,351
Shell Rock	6,777
High-Mortality Market	160
High-Mortality Transplant	5,238
Total	-102,266

Table 2. Derivation of example allocations for 2005 based on the bay regions expected to have surplus production in 2005 under the expectation that natural mortality rate in 2005 will be at the 75^{th} percentile (Shell Rock) or 50^{th} percentile (remaining bed groups). The 2004 transplant number represents the number of bushels of animals already of market size transplanted downbay in 2004.

April 1-November 15 Fishing Season

Bay Region	Allocation (market-equivalent bushels)
Shell Rock	6,777
High-Mortality Market (surplus production)	6,302
High-Mortality Market (2004 transplant)	5,874
High-Mortality Transplant	7,250
Total	26,203

April 1-August 1 Fishing Season

Bay Region	Allocation (market-equivalent bushels)
Shell Rock	7,547
High-Mortality Market (surplus production)	7,029
High-Mortality Market (2004 transplant)	5,919
High-Mortality Transplant	8,015
Total	28,510

Figure 1. Time series of oyster abundance, cumulatively by bay region. High-mortality transplant: Beadons, Nantuxent Point; high-mortality market: Strawberry, Hog Shoal, Vexton, Hawk's Nest, New Beds, Egg Island, Ledge, Bennies, Bennies Sand; medium-mortality market: Shell Rock; medium-mortality transplant: Ship John, Cohansey, Sea Breeze, Middle, Upper Middle; low mortality: Arnolds, Upper Arnolds, Round Island.

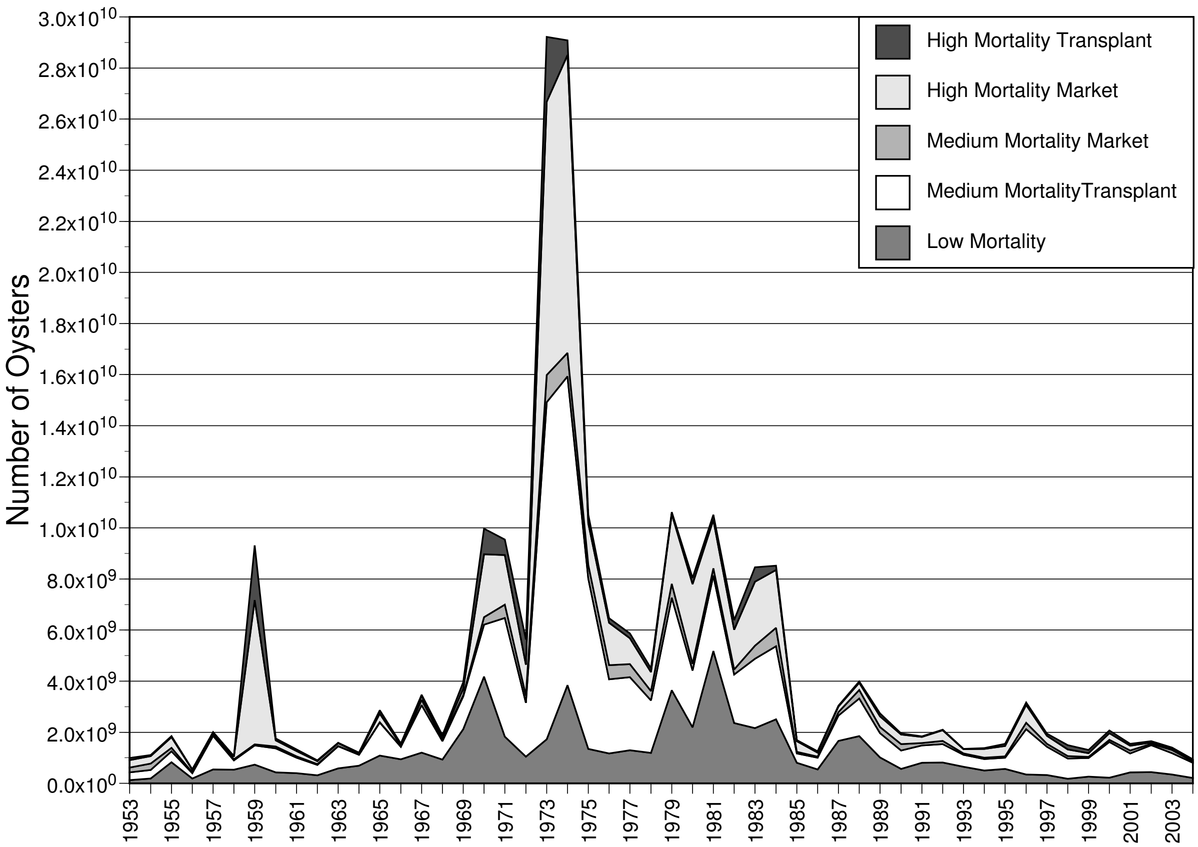


Figure 2. Number of spat recruiting per year for the 1953-2004 time series, cumulatively by bay region. Bay regions are defined in Figure 1.

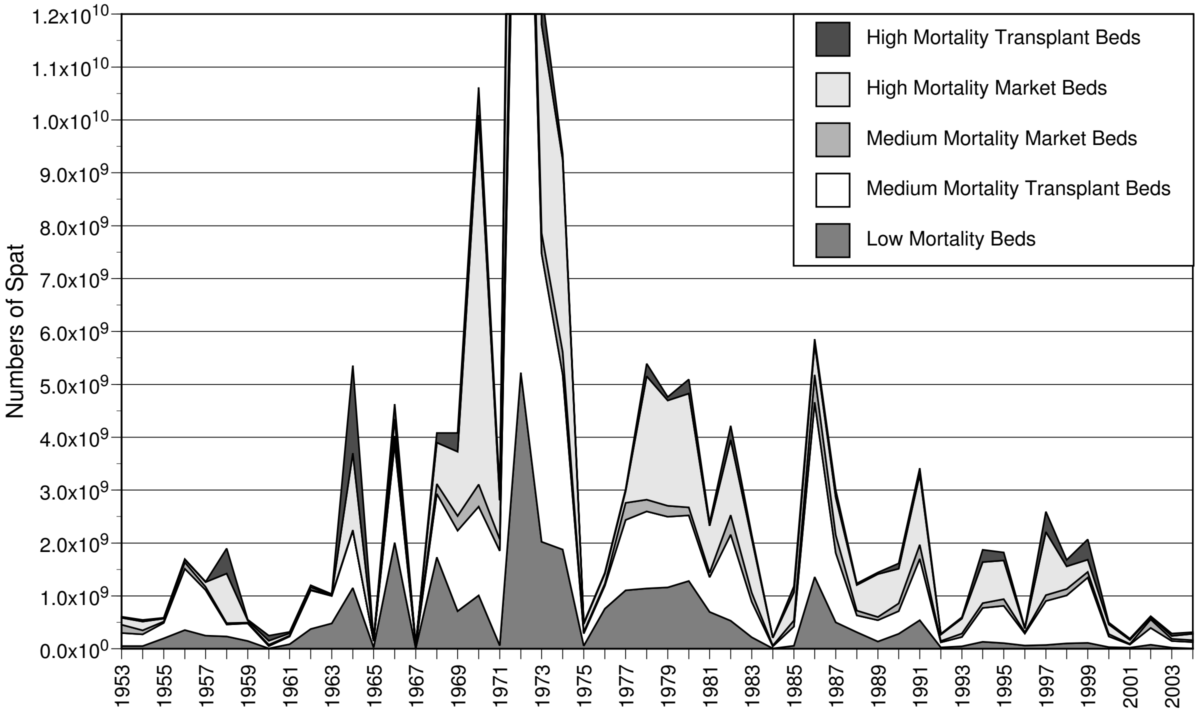


Figure 3. The fraction of bay-wide mortality contributed by each bay section. The cumulated total is the total mortality for the entire bay as a fraction of the abundance for that year. Individual bay-region values are the proportion of total bay mortality represented by mortality in that bay region. Bed groups defined in Figure 1.

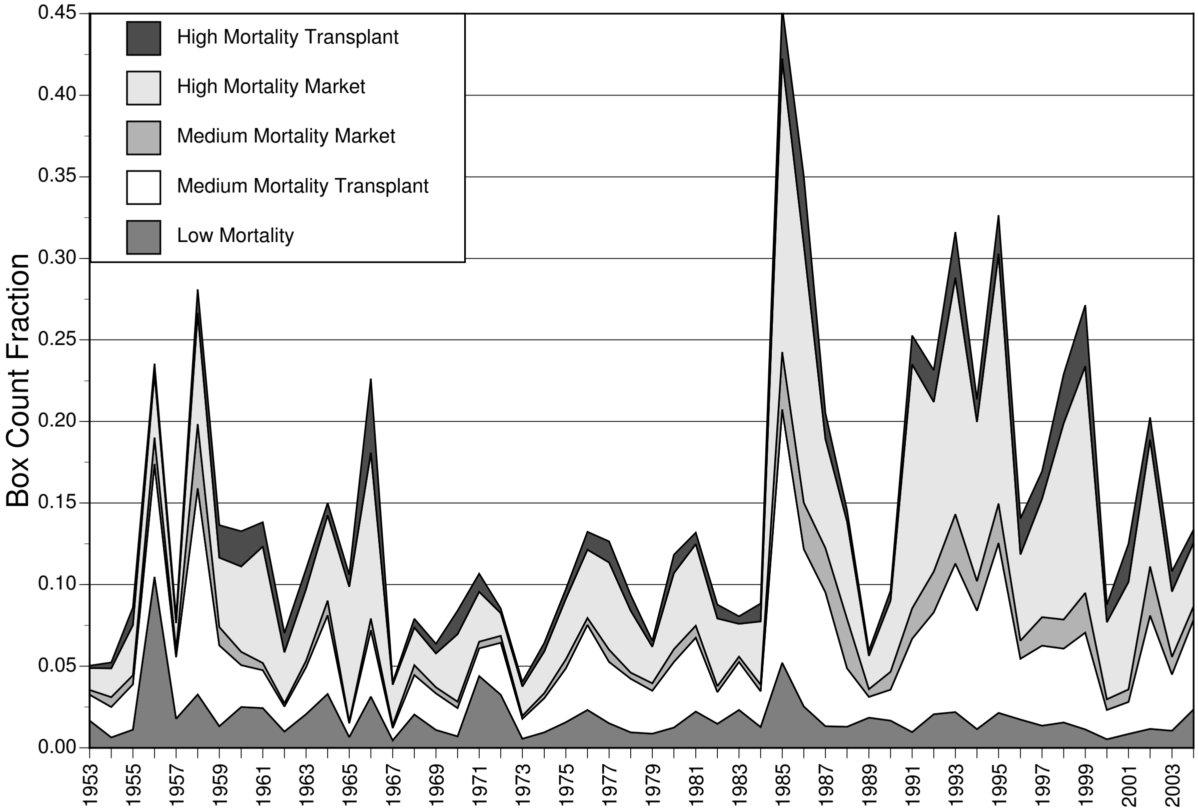
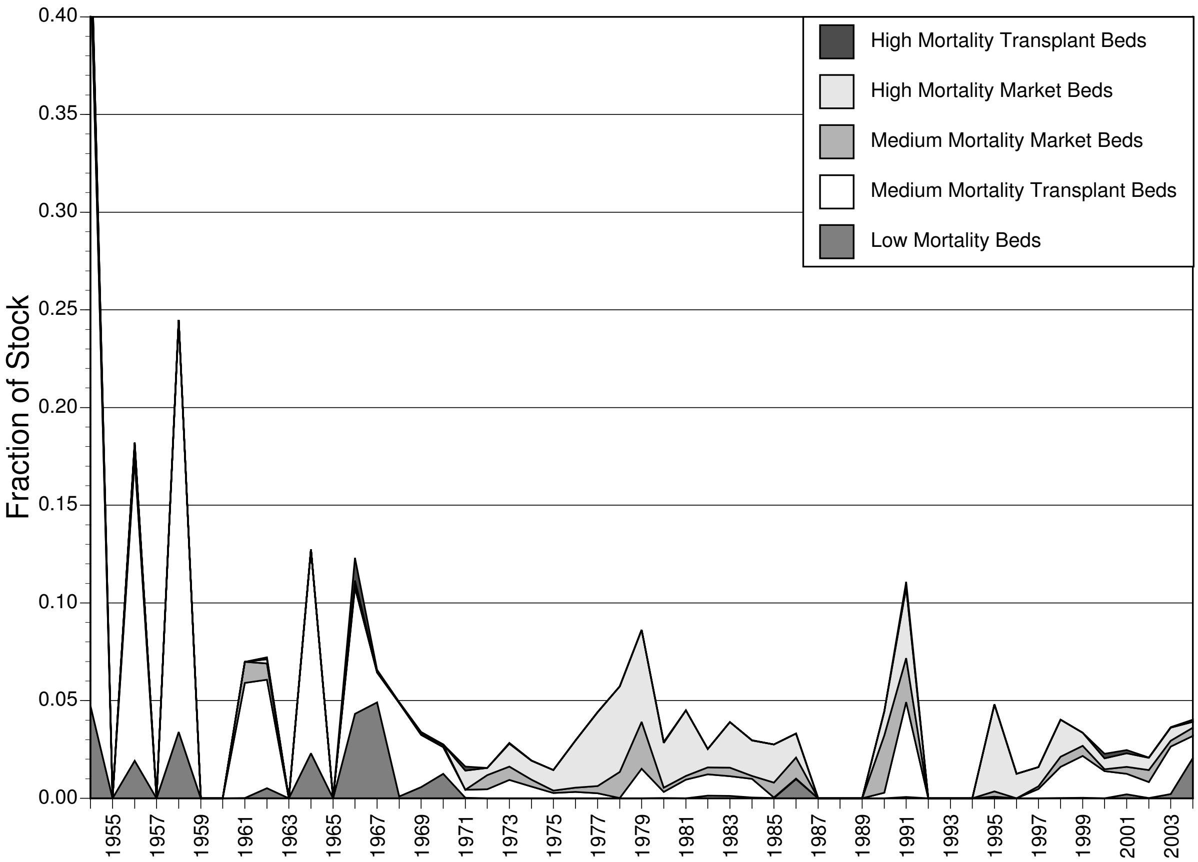


Figure 4. Oyster removals by bay region during the 1953-2004 time period. After 1996, the total reflects both the direct-market removals and those transplanted by the intermediate transplant program. Bed groups defined in Figure 1.



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Introduction

The natural oyster beds of the New Jersey portion of Delaware Bay (Figure 1) have been surveyed yearly, in the fall and/or winter, since 1953. Since 1989, this period has been concentrated into about one week in the latter part of October to early November, and has been conducted using a stratified random sampling method. Each bed is divided into a series of 25-acre grids. These grids fall into one of three strata. The strata consist of test (highest quality), bed proper (high quality), and bed margins (low quality). The test areas are areas of the bed with a high abundance of oysters 75% or more of the time. The bed proper includes areas where oysters are abundant 25-75% of the time, and the bed margin includes areas that have an abundance of oysters less than 25% of the time. The survey consists of about 100 samples covering the primary and most of the minor beds. Each sample represents a composite of 3 one-third bushels from three one-minute tows within each grid. The current survey instrument is a standard 1.27-m commercial oyster dredge on a typical large Delaware Bay dredge boat, the *F/V Howard W. Sockwell.*

Sample analysis includes measurement of the total volume of material obtained in each measured dredge haul; the volume of live oysters, boxes, and cultch; the number of spat, older oysters, and boxes per composite bushel; the size of live oysters >20 mm from the composite bushel, condition index, and the intensity of Dermo and MSX infections. The data are normalized to a 37-quart bushel, the New Jersey Standard Bushel. Until 1999, the principal data used in management was based on the proportion of live oysters, excluding spat, in the composite bushel, although spat set also entered the decision-making process. Samples continue to be collected and analyzed in the same way; however two modifications have since been undertaken: dredge tow lengths are measured and recorded every 5 seconds by GPS navigation during the survey and separate dredge calibration studies have been made to determine dredge efficiency. These new data are integrated into the regular sampling results to estimate the total numbers of oysters per square meter and the numbers of oysters in different size classes present on each bed. This improvement was added to the survey, at the recommendation of the Oyster Industry Science Steering Committee, because of concerns about management of the direct-market program that was initiated in 1996. Prior to that time, the beds had been used principally as a source of seed for transplanting to leased grounds and the semi-quantitative survey worked well. A third major alteration, again as a recommendation of the Oyster Industry Science Steering Committee, took place in 2002. Sampling was reconfigured on a number of beds to better reflect their current utilization, and to provide more accurate estimates of oyster abundance on frequently used beds. The old and new sampling regimens are provided (Table 1). In 2004, at the behest of the 6^{th} SAW, the entire survey time series from 1953 to the present-day was retrospectively quantitated. Quantitative 52-year time-series data are provided herein for the first time.

Status of Stock and Fishery

Historical Overview

From 1953 to 2004, the bay-wide mean number of >20-mm oysters per bushel was about 264. The highest numbers of oysters were on the upper beds and the lowest, on the lower beds (Table 2). During the past 1.5 decades since Dermo became prevalent in the bay (1989 to 2004), the bay-wide overall mean of 139 oysters/bu., about half the long term average, has varied little, and the changes, with the exception of the extremes (1989, 1992, and 1994 and 2004), have not been statistically significant (Figure 2). Throughout this report, present-day conditions will be compared to these two periods of time, the 1953-2004 period encompassing the entire survey time series and the 1989-2004 portion encompassing the period of time during which Dermo has been a primary source of mortality in the bay.

The 1953-2004 bay-wide mean spat/bu. was about 177, with the greatest set of 1700+ spat/bu. occurring in 1972 (Table 2). Since 1988, the bay-wide overall average has been 87 spat/bu., slightly less than half the long-term mean.

The long-term (1953-2004) average box-count mortality is approximately 15% (Table 2). The appearance of Dermo in the bay has increased the average mortality for the last decade and a half to 19%, and in some years the mortality has exceeded 30%.

The maximum seed removed from the beds by the industry since the onset of Dermo occurred in 1991 when nearly 300,000 bushels were transplanted to leased grounds. This is typical of the MSX period from the 1970's to the mid 1980's, when 300,000 to 450,000 bu. per year were transplanted to the lower bay leased grounds (Figure 3). Since the direct landing of market-size oysters from the beds was instituted in 1996, the greatest landing occurred in 1998 (136,000 bu.). The average yearly landing since 1996 has been slightly more than 76,500 bu.

Oyster Abundance

Sampling in 2004 was conducted from October 25 to October 27, 2004 using donated time on the oyster dredge boat *F/V Howard W. Sockwell* with Sam Elias as Captain. Samples were collected from the standard random stratified grid system on each of the major seedbeds and a subset of the minor beds (Figure 4). An additional stratum "transplant" was added to assure that oysters transplanted to the direct-market beds were explicitly accounted for in the estimation of abundance.

The data that follow are presented in three ways. (1) Data are presented in terms of numbers per 37-qt bushel. This is the datum used historically since the inception of the formal stock survey in 1953. Bay-region averages are obtained by the averaging of survey samples per bed, summed over the beds in any bay-region group. (2) Since 1998, swept areas have been directly measured, permitting estimation of oyster density. Bay-region point-estimates are obtained by averaging the per-m^2 samples per stratum, expanding these averages for each bed according to the stratum area for that bed, and then summing over the beds in any bay-region group. Throughout this report, these quantitative point estimates of abundance sum the high quality (bed proper), test, and transplant strata only. Low quality (bed margin) areas are included separately as part of the time-series analysis, but restricted sampling in this stratum limits the accuracy of single-year abundance estimates. (3) In 2004, the 1953-2004 survey time series was retrospectively quantitated. Data from this retrospective analysis will be termed 'time-series estimates' throughout this report. These 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, so that the amount of cultch taken by the dredge is proportional to swept area[‡]. Comparison of retrospective analysis to direct measurements for 1998-2004 suggests that the time-series estimates for 2004 may be biased high. All quantitative and time-series estimates were corrected for dredge efficiency using the average of dredge efficiency measurements made in 2000 and 2003. The size-class-specific dredge efficiencies were applied whenever size-class data were analyzed; for total oysters, the dredge efficiency averaged over all size classes was used (Figure 5[⊘]). The differential in dredge efficiency between the upper and lower beds was retained in all cases[†]. In 2003, a program was begun to develop tow-based dredge efficiency estimates, so that the efficiency of each survey tow could be estimated. Figure 5 provides preliminary estimates of dredge efficiency obtained during the survey and compares them to the 2000/2003 average used in this assessment. This analysis suggests that the quantitative estimates of abundance based on the 2000/2003 average dredge efficiencies may be biased low.

Throughout this report, oyster refers to all animals >20 mm. Animals $\leq$20 mm are referred to as spat. Adult oysters are animals $\geq$35 mm. Calculations

‡ A full description of the method used for retrospective quantification of the 1953-2004 survey is available as an HSRL report: Powell, E.N., K.A. Ashton-Alcox, J.N. Kraeuter, J.M. Klinck, S.E. Ford; Long-term Trends in Stock Status on the Delaware Bay Oyster Beds of New Jersey: Inertia in Abundance, Compensatory Recruitment, Depensatory Mortality, and Reference Point-Based Management

⊘ Figure 5 depicts catchability coefficients, Q,calculated in this case as the reciprocal of dredge efficiency. These are the values used to correct survey samples, N_s to quantitative estimates of oyster abundance, N: $N = QN_s$.

† Details of the dredge efficiency program are available as an HSRL report: Powell, E.N., J.N. Kraeuter, K.A. Ashton-Alcox; Re-evaluation of Oyster Dredge Efficiency in Survey Mode: Application in Stock Assessment

of spawning stock biomass (SSB) are based on this size class and bed- and year-specific regressions between AFDW and shell volume estimated from measurements of length, height, and width. Market-size animals are animals ≥75 mm. Submarket size classes are variously defined depending on growth rates and analytical goals as indicated.

Because oysters are being sampled along a salinity gradient that reflects spat set, predation, disease and growth, combining the data into bay-wide averages results in high variances. Since 1989, the natural oyster beds have experienced a two-fold fluctuation in the number of oysters per bushel, but, with the exception of the two highest and lowest values, no statistical differences (Figure 6). The bay-wide average number of 95 oysters/bu. in 2004 was statistically the same as for most of the 1989-2004 period, but 64% lower than the long-term average of 264 oysters/bu.

Quantitative estimates using the time-series analysis indicate that oyster abundance summed across all bay regions declined in 2004 to 1,361,571,840 from the 2003 estimate of 1,815,295,488. About 70% of the oysters, 944,441,280, were found on the bed proper and test strata. The 2004 point estimate obtained directly from the quantitated survey for the bed proper and test strata was lower, 753,955,620. In 2004, abundance fell to the 5^{th} percentile of the 1953-2004 time series and was the lowest value observed post-1988 (Figure 7).

Beds in the Upper and Upper Central segments of the bay (see Table 2 for bed groupings) continue to support relatively high oyster abundance (Table 3). Most of these beds (except Upper Middle, Sea Breeze) have > 150 oysters/bu. In 2004, oyster abundance on beds in the Central and Lower segments of the bay remained about the same as the prior year (Figure 7, Table 3). In 2004, of these beds, only Bennies Sand had >33 oysters/bu.

Quantitative estimates confirm that most oysters were on the medium-mortality transplant beds (Ship John, Cohansey, Sea Breeze, Middle, Upper Middle) (Figure 8). Abundance on these beds ranked at the 26^{th} percentile of the 52-yr time series and the 22^{nd} percentile post-1988. In comparison, abundances on the low- and high-mortality beds ranked at the 9^{th} and 11^{th} percentiles, respectively, for the 52-year time series and at the 9^{th} and 16^{th} percentiles post-1988. Abundance in 2004 on the high-mortality direct-market beds rose from 2003, by a factor of 1.18, principally as a result of the 2004 intermediate transplant program. Abundance declined substantially on Shell Rock (by 53%), on the medium-mortality transplant beds (by 29%), and on the low-mortality beds (by 40%).

Spawning stock biomass (SSB) declined in 2004, continuing a trend begun in 2003 (Figure 9). SSB increased on the high-mortality direct-market beds, by a factor of 1.38. SSB declined by 50% on Shell Rock, by 11% on the medium-mortality transplant beds, and by 16% on the low-mortality beds.

Round Island and Arnolds appear to be deteriorating with fewer grids supporting high oyster abundance (Table 3, Figure 7). Unlike the remainder of the natural oyster beds, these beds have not received a significant recruitment event since 1990; as a consequence, abundance has declined more or less continuously for the last 14 years.

New Beds, Bennies and Bennies Sand received transplanted oysters from the Upper and Upper Central Regions last year. In total, 90,183 bushels of oysters were transplanted in 2004. Those from Middle supported the 2004 harvest. Fishing on the remainder was not allowed in 2004. Some of these recruits will enter the fishery in 2005; however many were too small to reach market size in 2005, but should begin to become available in 2006.

Oyster Size Frequency

The percentage of >2.5″ oysters exceeded 50% on all beds in the Central and Lower areas and on Shell Rock, Cohansey and Ship John in the Upper Central area. The general trend for a proportional increase in large oysters is continuing. Since 1988, the percentage of oysters >2.5″ has been in the 15% to 20% range on all of these beds. The recent increase in this percentage is primarily due to low recruitment rather than unusually high mortality. That is, the number of smaller oysters has declined as these animals have grown to >2.5″ in size or have died, and these small oysters have not been replaced by recruitment.

In 2003, all inshore beds had low oyster abundance, high Dermo prevalence, and a high percentage of oysters > 2.5″ (Tables 3 and 4). These conditions remained in 2004, except that Dermo disease declined. Numbers of submarket oysters (2.5″-3″) remained about the same in the Upper Central and Market Bed areas in the past year, but there is a slight indication the numbers may be dropping (Figure 10). This reflects the continued lack of recruitment to replenish the supply as these oysters grow into the ≥3″ category. The percentage of oysters ≥3″ continues to increase in the Upper Central and Market areas of the bay (Figure 11), whereas the 2.5″-to-3″ size category has remained static in both areas. This reflects the poor spat set of the last five years.

The Upper Central region supplied the majority of market oysters this past year. The numbers of ≥3″ oysters on the beds supplying the bulk of the 2004 fishery, Shell Rock, Cohansey, and Ship John, increased from last year (Table 4).

Focusing on the direct-market beds, in 2003 the percentage of total oysters in the >2.5″ size class was 50% or greater on all beds below Shell Rock and has remained above 50% on these beds in 2004. In comparison, the percentage of oysters >2.5″ on Cohansey and Ship John rose above 50% and the percentage on Middle was nearly 50% (Table 3). Thus, the trend towards an increasing proportion of large oysters upbay continues. As noted previously, this trend is principally due to the poor spat sets of the last 5 years that have resulted in the failure to replace the smaller-sized oysters that have died or grown into the larger size classes.

Surplus Production

Surplus production is defined in this treatment as the number of animals available for harvest under the expectation of no net change in market-size abundance over the year, given a specified natural mortality rate and growth rate. If fishing mortality rate is set to zero, it is equivalent to a comparison between the number of animals expected to recruit to market size in a year less the number of market-size animals expected to die naturally. In the absence of fishing, a positive surplus production indicates that the market-size population is expected to expand in abundance. If negative, the market-size population is expected to contract even in the absence of fishing. The model used for the calculation assumes an uneven distribution of mortality rate during the year as observed; however this assumption is only noteworthy if market-size animals are removed from the population by means other than natural mortality. A detailed description is found in Klinck et al. (2001)*.

An unbalanced size-frequency distribution is now present on many of the New Jersey oyster beds brought on by five years of low recruitment. This size-frequency distribution is not sustainable under normal natural mortality rates. Too few small animals are present on these beds to replace, through growth, those larger animals that are expected to die in 2005. Calculation of surplus production over a wide range of mortality rates indicates that abundance can be expected to decline on these beds in 2005 without fishing. As an example, assuming a 75^{th} percentile of natural mortality rate, market-size abundance is expected to decline in 2005 bay-wide by 102,266 bushels, with most of this decline focused on the medium-mortality beds (Table 5). Assuming a mortality rate equivalent to that observed in 2004 produces a positive estimate of surplus production in 2005 of 32,803 bushels (Table 5). That is, market-size abundance would expand by that value in 2005 in the absence of fishing, if natural mortality approximated the 2004 value. The positive surplus production estimate for the high-mortality market beds is, in part, due to the transplant of smaller oysters downbay from the low-mortality beds in 2004.

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* Klinck, J.M., E.N. Powell, J.N. Kraeuter, S.E. Ford and K.A. Ashton-Alcox. 2001. A fisheries model for managing the oyster fishery during times of disease. *J. Shellfish Res.* 20:977-989

Oyster Condition

On a bay-wide basis, condition index increased slightly this year (Figure 12, Table 3), and the increase appeared to be similar in all areas of the bay. The gradient in condition from greater condition in the more saline areas to poorer condition in the less saline areas remained.

Spat Set

Spat set in 2004 was an improvement over 2003, but was still poor (Table 3, Figure 13). 2004 continues a sequence of poor setting for an unprecedented fifth consecutive year (a similar, but not as severe trend occurred from 1959 to 1963) (Figure 14). The bay-wide 2004 spat counts (mean = 27/bu.) were far below the long term mean of 177 spat/bu., and well below the 87 spat/bu. post-1988 long-term mean.

No bed achieved a spat set of 100/bu. and spat set was 50/bu. or higher on only three beds – Ship John, Bennies Sand, and Shell Rock. These three beds also provided 68% of the 2004 landings and are the only beds in which industry dredging effort exceeded bed area by more than 2.5 times (Table 6). Spat set on the low-mortality beds (Arnolds, Upper Arnolds, and Round Island) was 3 to 5/bu., continuing an unprecedented record of set failure that commenced in 1991 on these beds. Typically, some of the inshore beds of the Central Region (Nantuxent, Hog Shoal, Strawberry, Hawk's Nest, Beadons and Vexton) receive a good set, but this did not materialize in 2004.

Quantitative estimates of spat set confirm that the 2004 set was low bay-wide, making the fifth year in a row of poor settlement (Figure 14). Total recruitment was highest on the medium-mortality beds (Ship John, Cohansey, Sea Breeze, Middle, Upper Middle), in part because the number of spat per area was highest there and in part due to the areal contribution of this bay region to total bed area. The 2004 spat settlement ranked at the 14^{th} percentile for the 1953-2004 time series and at the 22^{nd} percentile post-1988. The number of spat recruiting per oyster improved somewhat over 2004; however, it continued to be very low, 0.335 spat per >20-mm oyster. The ratio has been below 0.5 since 1999 (Figure 15).

A spat monitoring program was initiated in 2004 and showed the anticipated trend of greater spat availability downbay (Figure 16); however the total number of spat caught on the collectors was low and the majority of the spatfall occurred later in the year than usual, indicating that the origin of the 2004 recruitment failure stems from lack of availability of larvae or low larval survivorship rather than substrate availability or immediate post-set survival.

Mortality and Disease

Dermo is diagnosed using the standard RFTM tissue assay with rectal and mantle tissues. The percent of oysters in the sample with detectable infections is termed the prevalence. Infection intensity is scored along the Mackin scale from zero (= pathogen not detected) to five (= heavily infected) and then averaged among all oysters in the sample to calculate a weighted prevalence*.

In general, mortality and Dermo disease increase downbay as salinity increases. A regression between Fall Dermo disease and mortality explains approximately 42% of the variation in mortality among beds since 1990 (Figure 17). The y-intercept for this regression is just above 10%, supporting time-series analysis that background (non-disease-epizootic) box-count mortality is about 10% (Figure 18).

In 2004, the prevalence and intensity of Dermo were generally well below long-term means on all beds (Table 7, Figures 19 and 20). In fact, 2004 values approached the lowest values recorded since 1990. Detectable infections were 40% or below on all beds from Round Island downbay to Bennies, with the exception of Shell Rock (60%). On Shell Rock and all beds downbay, Dermo prevalence dropped appreciably (Table 3), and no bed had higher than an 85% infection level (Figure 20). Weighted prevalence, which includes infection intensity, was considerably lower this year, particularly in the Central and Lower beds where disease intensity is normally highest. No weighted prevalence index exceeded 1.95 (Hog Shoal) this year and, although weighted prevalence increased in a downbay direction, the typically sharp distinctions between bay regions were greatly reduced.

In 2003 and 2004, summer water temperatures were cooler than normal and watershed runoff was reportedly higher than normal. The increased flow of freshwater probably decreased disease transmission while cooler temperatures likely reduced proliferation rates within infected oysters.

MSX, *Haplosporidium nelsoni*, disease prevalence continued to be insignificant in 2004.

Since the onset of the Dermo epizootic in 1990, average mortality on the seed beds, as assessed by box counts during the fall survey, has fallen into 3 major groups: Upper (low mortality), Upper Central (medium mortality) and Central/Lower (high mortality), with the lowest values on the Upper beds. Over the past year, however, mortality was elevated on Round Island, but then remained in the 10% to 15% range on all beds downbay through Bennies Sand (Figure 21). Below Bennies Sand mortality was in the 21% to 39% range with the exception of Hawk's Nest (13%)

* A full analysis of the 2004 disease monitoring program is available as an HSRL report: Bushek, D. 2005; Delaware Bay Oyster Seedbed Mortality and Disease Report for 2004.

and Ledge (17 %) (Table 3, Figure 21). In 2004, mortality was generally slightly lower on the beds below Bennies Sand than last year, and about the same or slightly higher above Bennies Sand.

Quantitative areal estimates of box-count mortality were 13% bay-wide in 2004 (Figure 22). This is a slight rise from 2003, but well below epizootic mortality levels. Nevertheless, 2004 box-count mortality was at the 61^{st} percentile of the 52-yr time series, but only at the 34^{th} percentile post-1988. Quantitative estimates confirmed that box-count mortality dropped for the second consecutive year on the high-mortality market beds, coming in at half the rate observed in 2002. Box-count mortality was 23.1% on the direct-market beds, a value at the 64^{th} percentile of the 52-year time series, but only the 22^{nd} percentile of the post-1988 time series. Mortality declined upbay. Box-count mortality on the medium-mortality beds was 10.3%, a value slightly higher than observed in 2003. The 2004 level of mortality was at the 55^{th} percentile for the 52-year time series and the 41^{st} percentile for the post-1988 time series. Quantitative estimates of box-count mortality confirmed a significant increase in mortality on the low-mortality beds from the previous 5 years. The 2004 level of mortality is at the 76^{th} percentile for the 52-year time series and at the 78^{th} percentile for the post-1988 time series. An explanation for this sharp increase in mortality is not available; Dermo disease was not responsible.

Quantitative estimates of abundance, recruitment, and box-count mortality expressed numerically permit an estimate of unrecorded mortality for the first time. The equation

$$\begin{aligned} &Beginning\,Year\ Abundance + Recruitment \\ &\qquad - Box\text{-}Count\ Mortality - Fishing\ Mortality \\ &\qquad = End\text{-}of\text{-}Year\ Abundance \end{aligned}$$

should be in balance. Typically, the left-hand side overestimates end-of-year abundance because a certain fraction of mortality is unaccounted for by box counts. Much of this unrecorded mortality is likely juvenile mortality.

In 2004, the amount of unrecorded mortality increased downbay (Table 8), presumably indicating the increased survivorship of juveniles at lower salinity. As well, the trend may in part accrue from a shorter half-life of boxes at higher salinity. Most of the bay regions had unrecorded mortalities near the 50^{th} percentile, indicating average conditions in 2004. The lower percentile ranking for the high-mortality transplant beds (Beadons and Nantuxent Point) in part accrues from the fact that only one of these beds was sampled in 2004, so the 2004 abundance on Nantuxent Point is an estimate. The low percentile rank for the medium-mortality market beds (Shell Rock) suggests an unusually high amount of unrecorded mortality in 2004. The likely explanation is unreported harvesting, as other sources of mortality are unlikely to be this much in error.

Population Dynamics Trends

Brood-stock recruitment, abundance-mortality, and mortality-recruitment relationships are provided for the first time this year, as part of the retrospective quantification of the 52-year survey time series.

The broodstock-recruitment diagram (Figure 23) suggests that present-day abundance may limit reproductive potential. However, oyster larvae tend to set preferentially on live oysters, so that one cannot exclude the possibility that broodstock abundance modulates settlement success. Nevertheless, neither possibility offers a likely explanation for five consecutive years of very low recruitment, as other years with abundances in the 2000-2004 range have provided a much higher number of spat per >20-mm oyster (Figure 15, also compare Figures 7 and 13). The 52-year average recruitment rate expressed as the number of spat per >20-mm oyster per year is 0.977. Since 1988, the same long-term average has been somewhat lower: 0.735. The long-term likelihood of a one-year population replacement event, 1 spat per >20-mm oyster, is 17 of 52 and a recruitment rate half that high occurred in 27 of 52 years. Since 1988, the same two probabilities, 6 of 16 and 8 of 16, are not significantly different, so that the expectation of a respectable recruitment event remains approximately 50%. Such an event has not occurred since 1999, however. Coincidentally, 1999 was the last year that spatfall exceeded 1 spat per >20-mm oyster. Thus, spatfall since 1999 has been well below the level anticipated from broodstock abundance.

Epizootics (bay-wide mortality events greater than 20% of the stock) have occurred in about half of the years since 1989 (Figure 18). Non-epizootic years tend to average around 10% mortality. The bay-wide average for 2004 was 13%, a non-epizootic mortality rate (Figures 18 and 22). Geographic contraction of the stock continued in 2004, so that the stock is increasingly concentrated in the central part of the bay where mortality rates tend to be moderate. This should tend to reduce total mortality rate and therefore decrease the chance of epizootics. In 2004, 63.6% of the stock was on the medium-mortality transplant beds (Ship John/Cohansey/Sea Breeze/Middle/Upper Middle), 21.7% on the low-mortality beds (Arnolds/Upper Arnolds/Round Island), 5.7% on Shell Rock, 6.7% on the high-mortality market beds, and 2.4% on the high-mortality transplant beds (Nantuxent Point/Beadons). A relationship between box-count mortality and recruitment continues to be poor (Figure 24). Little evidence exists that disease routinely limits population reproductive potential beyond its effect on stock abundance; however, the four largest recruitment events since 1953 all occurred in years with below-average mortality rates.

The important areas for the oyster industry are the beds in the Upper Central and Central region. Examination of the trends on these individual beds indicates that these two regions have substantially different processes controlling oyster abundance (Figure 25). The average numbers of oysters on the Upper Central beds for the 1989 to 2004 period was statistically greater than for the Central beds (Figure 25). The spat set was not statistically different over the same period (Figure 25); thus some factor or factors affected post-set survival differentially. Unrecorded mortality was higher on these downbay beds, commensurate with this trend. This phenomenon is a continuation of the historical trend of differentiation between the bed groups and re-enforces the belief that the factors that most affect post-set survival are predation and disease.

Harvest and Transplant

The 2004 harvest limit was set at 68,000 bu. Persistent low recruitment has minimized surplus production on the direct-market beds. As a consequence, the 6^{th} SAW recommended that direct marketing extend to certain medium-mortality beds otherwise reserved for transplant, namely Cohansey and Ship John. Area-management to assure some harvest on these 'transplant' beds was successful in 2004.

Figure 26 shows the time-series of oyster harvest in Delaware Bay. Since 1996, an intermediate transplant program has moved oysters among beds. In this figure, the total stock manipulation, including transplant and direct-market, is identified as the apparent harvest; those oysters taken to market are identified as the real harvest. Harvest has been relatively stable during direct-marketing times and below all bay-season years.

Beds were harvested almost continually from April 1 to November 15, 2004. The 33 weeks (less 1.5 weeks for a transplant program) of fishing this year is the same as last year (Figure 27). Harvest was from 11 beds and totaled 62,720 bushels. Three beds accounted for slightly over 75% of harvest: Ship John (30.3%), Shell Rock (29.7%), and Cohansey (15.6%) (Table 6). When Bennies (6.6%) and Bennies Sand (8.9%) harvests are added, these 5 beds comprise over 90% of the total. Sixty boats participated in the fishery and worked for a total of 1,094 boat days. The catch per boat-day for dual dredge boats increased slightly for the second year in a row (Figure 28). The catch per boat-day for single dredge boats also increased this year to a level that was only exceeded in 1997 (Figure 28). This stabilization or increase in catch per boat may reflect the high percentage of marketable or nearly marketable oysters on most of the market beds.

Total dredging impact was estimated[⊗]. Four beds were covered by dredging more than once during 2004: Bennies Sand, Shell Rock, Ship John, and Cohansey (Table 6).

Transplantation from upbay and high-mortality transplant beds (Nantuxent Point/Beadons) to replace those being harvested was recommended by the 6^{th} SAW. In 2004, oysters were transplanted from Nantuxent Point, Beadons, Arnolds, Upper Arnolds, Round Island, and Middle. Receiver beds included Bennies, Bennies Sand, and New Beds (Table 9) The net of all fishing and transplant activities was that most oysters taken to market ultimately were debited from the low-mortality and medium-mortality-transplant beds (Figure 29). 2004 was the first year since 1986 that significant oysters were utilized from the low-mortality beds.

Apparent fishing mortality was 4.0% of the stock; that is, 4% of the stock was manipulated whether through transplant or harvest. True fishing mortality was 1.4% of the stock; that is, the direct-market harvest in 2004 removed about 1.4% of the stock (Figure 30). This equates to 2.8% of the stock $\geq 2.5''$. Fishing mortality in 2004 was at the 16^{th} percentile of the 52-yr time series excluding closure years, and at the 50^{th} percentile of open years post-1988.

Management Advice

Long-term Abundance Goals

From approximately 1970 through 1984, stock abundance averaged near 10×10^9 oysters. Present-day abundance is about 20% of that level. Examination of the relationship between abundance and recruitment (Figure 23) and the relationship between abundance and natural mortality (Figure 18) suggests that an abundance value of about 4×10^9 would significantly increase the chance of large recruitment events and possibly reduce the sensitivity of the population to epizootics. These estimates are, as yet, tentative, however. Substantial uncertainty exists, for example, as to whether the high abundances of the mid-1970s would be achievable under present-day biological and environmental conditions. Nevertheless, bay abundances only slightly below 4×10^9 were measured in 1990 and 1996. Thus, 4×10^9 can be set as an abundance goal. Further evaluation of this goal should be undertaken at the 8^{th} SAW.

In order to increase abundance, two long-term management approaches should be undertaken. First, a multiyear recruitment enhancement program using shell

[⊗] The method for estimation is described in: 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.

planting to increase recruitment should be established. Given the low present-day abundance, it is essential that this shell-planting program be multiyear. Second, in years when surplus production is positive, some portion of the surplus production should be set aside to increase abundance. Establishing a specific rebuilding plan should be included as one of the Terms of Reference for the 8^{th} SAW.

2005 Management Goals

Managing the Delaware Bay oyster resource in this time of low stock abundance, continued disease pressure, and historically low recruitment is a challenge. While a simple approach might be to close the fishery and let nature take its course, the SARC has tried to find a balance between preserving the remaining fishery and infrastructure that supports the fishery, while conserving a broodstock of oysters that will have the potential to provide sufficient recruitment in the future so that the stock can rebuild. The approach that has been taken is to recommend closure of bay regions expected to decline in population through natural processes in 2005, emphasizing those areas thought to be significant sources of broodstock. For the remaining areas, the approach taken is to try to achieve a balance between recruitment-into-the-fishery and loss through natural death and harvest using assumptions that will provide an even or better chance of success in 2005.

The following beds have been designated direct-market beds in all years since the direct-market fishery began in 1996: Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Ledge, and Egg Island. For 2005, the SARC recommends that Beadons and Nantuxent Point also be designated as direct-market beds.

The simulations were run under the proviso that the number of market-size oysters at the end of the year would equal the number at the beginning of the year. In essence, this allocates to the fishery a number of oysters equivalent to the number expected to grow into market size during the year. This is the 'constant market-size abundance' reference point. Direct-market calculations were made using the assumption that natural mortality was lower on Shell Rock than on the other direct-market beds. Growth rate was also decremented on Shell Rock. Submarket-size oysters were defined using the smallest individual that could attain 75 mm during the year: 73.2 mm (low growth), 68.1 (medium growth), 65.0 (high growth). Natural mortality rates were taken from box counts because unrecorded mortality is assumed to be mostly juvenile. The 2^{nd} SAW recommended a precautionary approach of managing at the 75^{th} percentile of the box-count mortality rate. This lessons the chance of overharvesting. The SARC recommends that this percentile continue to be used for Shell Rock, but that the remainder of the direct-market beds be managed at the 50^{th} percentile in 2004. This approach permits increased removals of market-size animals as a method of reducing transmission of Dermo disease on these beds, particularly during times when a shell-planting program is being carried out, as is anticipated in 2005, and conforms to the expectation from long-term Dermo mortality trends that disease mortality should be relatively low in 2005. Calculations were conducted for a continuous season scenario, April 1-November 15, and for a shorter continuous season running from April 1 to August 1.

Allocation estimates used an updated value of 282 to convert market-size and submarket-size abundance to market-bushel equivalents and 302 to convert total oysters to market-bushel equivalents. These values are lower than the value of 317 used in 2004. The updated values were obtained by direct measurement of selected bushels landed throughout the 2004 season[⊕] .

Long-term time-series analysis indicates that the Cohansey/Ship John/Sea Breeze/Middle area provides the core of the stock during periods of low abundance. This happened in the 1950s and 1960s and has happened again in the decades of the 1990s and 2000s (Figure 8). In 2005, these beds are anticipated to undergo negative surplus production; that is, market-size abundance is expected to decline without fishing (Table 5). The likelihood that this part of the bay provides the bulk of the broodstock during periods of low abundance is high. Consequently, the SARC recommends that no harvesting occur on these beds while negative surplus production exists.

As a consequence, recommended allocation levels are based on those areas of the bay expected to have positive surplus production in 2005 under an assumed 75^{th} percentile (for Shell Rock) or 50^{th} percentile (for the high-mortality beds) level of natural mortality in 2005. Assuming a fishing season of April 1-November 15, the SARC recommends a 2005 quota on these beds as:

Bay Region	Allocation (market-equivalent bushels)
Shell Rock	6,777
High-Mortality Market (surplus production)	6,302
High-Mortality Market (2004 transplant)	5,874
High-Mortality Transplant	7,250
Total	26,203

The 2004-transplant value for the high-mortality market beds represents those oysters transplanted downbay in 2004 that were already of submarket and market size at that time, but unharvested in 2004. The constant-abundance reference point

⊕ Details of this analysis are available as an HSRL report: Powell, E.N., J.J. Gendek, K.A. Ashton-Alcox; Fisher Choice and Accidental Catch: Size-frequency of Oyster Landings in the New Jersey Oyster Fishery.

assumes constant abundance of market-size animals. Inclusion of these animals in calculating surplus production would constitute a rebuilding plan[⊖].

A shorter fishing season will allow more harvest because some oysters that would die in August and September due to disease can be harvested in earlier months. Assuming a fishing season of April 1-August 1, the 2005 quota would be:

Bay Region	Allocation (market-equivalent bushels)
Shell Rock	7,547
High-Mortality Market (surplus production)	7,029
High-Mortality Market (2004 transplant)	5,919
High-Mortality Transplant	8,015
Total	28,510

Given the sensitivity of Shell Rock, the SARC recommends that the allocation for Shell Rock be independently managed from the remaining direct-market beds.

The SARC notes that the recommended allocation is about 1% of the stock exclusive of the low-quality strata, 0.7% of the total stock, 5.1% of market-size abundance exclusive of the low-quality strata, and 3.9% of the total market-size stock exclusive of the low-quality strata. Thus, the fishing rate should be precautionary given the status of the stock and anticipated 2005 abundance decline due to unsupported natural mortality.

The SARC recommends that consideration be given to clearing any area of oysters destined to receive a 2005 shell plant or 2005 replant from shell planted off Cape Shore to obtain seed. This may reduce the infection rate of Dermo. These oysters can be transplanted to other beds of the same or lower mortality level or harvested under the yearly allocation.

[⊖] The value for the high-mortality transplant beds is somewhat uncertain because Nantuxent Point was not sampled in 2005. Therefore, three alternative approaches were taken to estimate this value. (1) The time-series estimates obtained by borrowing (see ‡) produce a value of 3,930 bushels. This value is obtained by borrowing information from beds with fewer submarket-size animals, as Nantuxent Point is, and has been for many years, an abundance high for this size class. Therefore, this estimate can be considered a lower bound. (2) Assuming that the independent trends in abundance for submarkets and markets on Beadons and Nantuxent Point was similar in 2003/2004 and, thusly, extrapolating 2004 values for the two size classes independently for Nantuxent Point from 2003 measurements and using Beadons trends yields 7,238 bushels. (3) This value is near that obtained in the usual way that assumes the relationship between submarket and market-size abundance has not changed between 2003 and 2004, that yields the given value of 7,250 bushels.

The SARC recommends that an experimental manipulation on Arnolds bed be conducted to determine if 'working' these beds can be used as a mechanism to increase recruitment. The SARC recommends that the experimental design be conducted without removal of oysters from the bed unless required by the experimental design.

The SARC recommends a limited transplant of oysters from Middle to Shell Rock after closure of Shell Rock to enhance abundance. This transplant should be less than 5% of the stock. As the transplant is specifically designed for abundance enhancement, the SARC notes (1) that the transplant should be closed for the reminder of 2005 and (2) that the increased abundance be subjected to the 'constant-abundance' reference-point rule in future assessments.

The SARC recommends that oysters be transplanted from the Maurice River to the river mouth tonging beds for harvest. Market oysters should be targeted for transplant. A survey should be conducted to estimate abundance in order to determine what fraction of the animals can be transplanted in 2005.

Science and Management Issues

Management Issues

A shell-planting program aimed at enhancing abundance by enhancing recruitment should begin immediately with the aim of planting not less than 500,000 bushels annually.

The SARC encourages NJDEP to develop improved enforcement capabilities to limit overharvesting as this is the likely explanation for the 2004 abundance decline on Shell Rock. The SARC encourages NJDEP to involve industry members in developing enforcement strategies that can be self-maintained through peer pressure.

The SARC notes that increased funding is needed for HSRL to fulfill its expanding survey and assessment obligations and encourages the Delaware Bay Section of the Shell Fisheries Council to request a budget increase through the President of Rutgers University.

The SARC notes that increased funding is needed for NJDEP to fulfill its expanding resource management obligations and encourages the Delaware Bay Section of the Shell Fisheries Council to support a budget increase.

The SARC encourages NJDEP/HSRL to develop a proposal to ACCSP to establish an experimental program using position/time recording instruments onboard oyster boats to obtain information on vessel effort and location of harvest. These fishery-dependent data are important for improved management of the industry and will facilitate successful implementation of a shell-planting program.

The SARC recommends that the following issues be addressed at the 8^{th} SAW: (a) establishment of specific management parameters conducive to stock rebuilding in times of positive surplus production; (b) establishment of stock condition requirements leading to bay closure; and (c) re-evaluation of the 4×10^9 abundance goal.

Science Recommendations

The Dermo monitoring program should continue and intensify. Collection of ancillary data on mortality, size-frequency distribution, and growth rate should be continued. Shell plants should be added to the program to permit direct tracking of growth rates of cohorts. The 1989-2004 time series should be analyzed to provide improved probabilities for coming year mortality rates to be used in the 'constant abundance' estimation of surplus production.

A combined data collection and modeling effort should be formulated to better describe unrecorded mortality. This program should include a dock-side monitoring of the size composition of landings.

Further dredge calibration information is urgently needed to determine if tow-based dredge efficiencies are sufficiently accurate to be used in survey quantification and to determine if a temporal change in dredge efficiency is occurring or has occurred. This study should use experiments occurring simultaneously with the survey to directly test the tow-based regressions.

A spat settlement monitoring program should be continued and expanded.

A special survey of the low-quality (bed margin) grids is needed to determine the accuracy of present stock estimates and to evaluate the need/approach for improved yearly surveying.

The complexity of the 'reference-point' population dynamics model should be increased to include bay-region scale differences in population dynamics. Special attention should be given to the investigation of stock trajectories at low stock abundance.

Increased information on reproduction is needed. This should include (a) an estimate of population fecundity and (b) the development of a gonadal-somatic index monitoring program.

The historical spat monitoring database should be analyzed and incorporated into future assessments.

A growth monitoring program should be established either by direct observation of marked animals, intensive size-frequency sampling, or aging.

The time-series analysis should be expanded to track selected size classes by number and biomass. In particular, trends in spawning stock biomass need to be resolved at the size class level (e.g. biomass of market-size animals)

The susceptibility of animals on the low-mortality beds to MSX should be evaluated prior to any transplant program involving these beds.

Recruitment data suggests a relationship between fishing intensity and settlement success; however coincidence alone may be responsible. An experiment should be conducted to determine if a reduction in harvesting/transplanting on a bed like Ship John will deleteriously impact recruitment.

Table 1. Pre-2002 and 2002-to-2004 sampling schemes, Delaware Bay Seed Beds. The numbers given are the number of samples devoted to that bed in a survey. The upper group in each set identifies beds sampled each year. The lower two groups in each set identify beds sampled every other year.

	Pre-2002		**2002-2004**
Arnolds	6	Arnolds	6
Beadons	10	Beadons	10
Bennies	12	Bennies	12
Bennies Sand	4	Bennies Sand	4
Cohansey	5	Cohansey	7
Egg Island	10	Middle	9
Middle	9	New	9
New	9	Shell Rock	7
Round Island	6	Ship John	5
Shell Rock	7	Transplant	2
Ship John	5	Hawks Nest	4
		Strawberry	4
		Vexton	5
		Hog Shoal	4
Total	**83**		**88**
Hawks Nest	6	Ledge	5
Ledge	8	Upper Middle	2
Strawberry	6	Round Island	5
Upper Mid	2	Seabreeze	3
Total	**22**		**15**
Hog Shoal	6	Nantuxent	6
Nantuxent	6	Upper Arnolds	2
Upper Arn	2	Egg Island	8
Vexton	7		
OL	1		
Total	**22**		**16**

Table 2. Long-term numbers of oyster and spat per bushel (1953-2004), and percent mortality (total box count). Upper = Round Island, Arnolds, and Upper Arnolds. Upper Central = Upper Middle, Middle, Cohansey, Ship John, Sea Breeze, and Shell Rock. Central = Bennies Sand, Bennies, New Beds, Nantuxent Point, Hog Shoal, Strawberry, Hawk's Nest, Beadons, and Vexton. Lower = Ledge and Egg Island.

	Oyster	Spat	% Mort
Bay Average	264	177	15
Upper	581	293	12
Upper Central	315	190	13
Central	198	160	20
Lower	84	80	19

Table 3. Results of the 2004 random sampling program for the Delaware Bay natural oyster beds. Included for comparison are data for 2002 and 2003. All 2004 data were collected between October 25 and October 27 using the *F/V Howard W. Sockwell.* This information is based on a stratified random sampling of grids from the natural oyster beds (Figure 5). The strata (groups) from which the samples were selected are: Test area, bed proper, and bed margin. One sample was taken from one of the test area strata, and no more than two samples were taken from the marginal strata of the beds. The remainder of the samples were from the bed proper (Table 2). All data were adjusted to a 37-quart bushel.

The data format is the same as in the past years, with the exception of the deletion of the yearling category – data on yearlings are no longer collected – and the insertion of condition index (see below). Data are displayed from the farthest upbay beds to those downbay. The test area is a small area of grids that has been sampled consistently as representative of the better areas of the bed. The test area sample is indicated by an $*$. The column called 'Bushels/haul' to the left of the column headed 'Percent Oyster 2004' indicates the average number of bushels brought up by the 3 dredge hauls from each grid.

For each bed the percentage of oysters for each sample is presented, with rankings from highest to lowest. Percentage of oyster is based on volume of oyster in the sample divided by the total volume of shell, oyster and debris in the sample. Those samples that have over 40% oyster are underlined. Oysters per bushel and spat per bushel are based on actual counts adjusted to 37 quarts. Notable this year is the first sample in Bennies, the fourth sample in Bennies Sand, and the second sample in New Beds. These are italicized to designate "Transplant" samples. These samples are **NOT** included in the averages for the subsequent information.

Because of the emphasis on the direct marketing of oyster from the beds, we have continued the 'Size' columns. These columns indicate the number of oysters greater than 2.5″ and the percentage of oysters that are greater than 3″, based on the measurements of oysters (Table 4).

Condition index is a measure of the amount of dry meat weight in an oyster relative to the hinge-to-lip (greatest) dimension. Condition is generally greater in oysters farther downbay.

The 'Percentage Mortality' value is based on the number of boxes that were counted in the samples. Prevalence is the percentage of oysters with detectable infections by Dermo. Weighted Prevalence is the average infection intensity (scored from 0 to 5) of all sampled oysters.

Summary of the 2004 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2004.

Bed		Bushels/ Haul	Percent Oyster			Oysters/Bushel			Spat/ Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence			Size No./bu. >2.5 in.			Size %oysters >2.5 in.			Condition Index Dry Meat/Height		
			2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--			
Round Island		3.1	35.3	--	60.4																								
Round Island		1.8	27	--	57.1																								
Round Island	*	1.9	25.2	--	51.1	161	--	371	3	--	58	17	--	6	0.0	--	40	0.00	--	0.48	23	--	14	14	--	4	0.006	--	0.006
Round Island		0.3	7.69	--	50.7																								
Round Island		0.4	1.96	--	38.9																								
Round Island		1.2	0.71	--	27.0																								
Up. Arnolds			--	58.0	--																								
Up. Arnolds	*		--	27.7	--	--	311	--	--	12	--	--	9	--	--	20	--	--	0.15	--	--	32	--	--	10	--	--	0.005	--
Up. Arnolds			--	--	--																								
Arnolds		1.4	53.1	68.3	65.0																								
Arnolds	*	4.0	50.9	62.6	59.8																								
Arnolds		1.2	39.9	48.2	50.0	222	272	383	5	13	48	13	7	9	5	33	33	0.03	0.38	0.73	50	23	34	22.7	8	9	0.006	0.005	0.006
Arnolds		0.6	27.8	28.7	47.8																								
Arnolds		1.7	24.7	6.8	45.1																								
Arnolds		0.1	0	0.0	8.9																								
Up. Middle	*	0.0	0	--	15.6																								
Up. Middle		0.0	25	--	0.0	19	--	58	0	--	0	0	--	15	0	--	70	0.00	--	1.60	0	--	6	--	--	10	0.010	--	0.007
Middle	*	1.8	62.3	78.1	88.7																								
Middle		2.0	52.7	63.1	72.0																								
Middle		3.2	51.9	62.2	62.1																								
Middle		4.1	51.5	59.7	52.2																								
Middle		0.8	46.8	59.4	45.8	210	223	237	35	19	31	10	10	14	40	63	90	1.35	0.98	2.20	98	91	72	46.9	41	30	0.010	0.008	0.008
Middle		2.7	31.8	54.6	40.0																								
Middle		1.0	29	50.3	2.1																								
Middle		1.0	23.5	0.0	0.0																								
Middle		0.6	6.19	0.0	--																								
Cohansey	*	1.4	68.4	70.5	68.7																								
Cohansey		3.8	61.5	70.0	47.7																								
Cohansey		1.7	48.2	64.6	41.9																								
Cohansey		2.9	47.7	64.1	41.2	161	218	163	18	19	42	13	12	20	20	57	100	0.23	0.95	3.10	102	99	50	63.1	45	31	0.012	0.009	0.008
Cohansey		0.4	8.8	50.0	33.4																								
Cohansey		0.0	0	48.5	6.8																								
Cohansey		0.0		37.0	3.9																								
Cohansey		0.0		3.3	--																								
Ship John	*	2.7	62.9	68.2	81.8																								
Ship John		3.8	60.9	66.0	74.2																								
Ship John		2.6	53.5	61.5	63.2	245	226	225	58	24	57	11	13	22	--	90	100	--	1.18	2.80	129	105	100	52.6	47	44	0.012	0.009	0.011
Ship John		3.3	50.3	48.4	46.2																								
Ship John		0.1	11.8	28.4	14.6																								

Table 3, page 1.

Table 3, page 2.

Summary of the 2004 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2004.

Bed		Bushels/ Haul	Percent Oyster 2004	Percent Oyster 2003	Percent Oyster 2002	Oysters/Bushel 2004	Oysters/Bushel 2003	Oysters/Bushel 2002	Spat/ Bushel 2004	Spat/ Bushel 2003	Spat/ Bushel 2002	Percent Mortality 2004	Percent Mortality 2003	Percent Mortality 2002	Dermo Percent Prevalence 2004	Dermo Percent Prevalence 2003	Dermo Percent Prevalence 2002	Dermo Weighted Prevalence 2004	Dermo Weighted Prevalence 2003	Dermo Weighted Prevalence 2002	Size No./bu. >2.5 in. 2004	Size No./bu. >2.5 in. 2003	Size No./bu. >2.5 in. 2002	Size %oysters >2.5 in. 2004	Size %oysters >2.5 in. 2003	Size %oysters >2.5 in. 2002	Condition Index Dry Meat/Height 2004	Condition Index Dry Meat/Height 2003	Condition Index Dry Meat/Height 2002
		--	**--**	--	**--**	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--			
Seabreeze	*	2.4	**31.9**	--	29.0																								
Seabreeze		0.2	**12.6**	--	22.4	**108**	--	71	**20**	--	105	**15**	--	43	**30**	--	100	**0.48**	--	4.60	**31**	--	20	**28.8**	--	28	**0.012**	--	0.009
Seabreeze		0.2	**0.34**	--	2.6																								
Shell Rock		1.9	**57.9**	69.4	69.4																								
Shell Rock		0.5	**43.2**	67.7	40.0																								
Shell Rock	*	4.2	**37.9**	59.0	30.3																								
Shell Rock		2.2	**37.6**	55.9	27.4	**175**	186	141	**82**	54	212	**11**	12	20	**60**	80	100	**1.25**	1.25	3.27	**104**	68	70	**59.5**	36	50	**0.018**	0.013	0.015
Shell Rock		1.7	**35.7**	52.7	23.3																								
Shell Rock		3.5	**34**	46.6	19.8																								
Shell Rock		0.3	**27.2**	22.3	--																								
Bennies Sand		0.6	**33.2**	40.9	32.5																								
Bennies Sand		2.4	**31.8**	33.7	28.8																								
Bennies Sand		1.3	**29.1**	32.7	28.2	**142**	140	98	**71**	47	67	**14**	14	40	**40**	--	90	**0.73**	--	3.13	**77**	70	61	**53.9**	50	62	**0.019**	0.014	0.017
Bennies Sand		*2.8*	***28.6***	32.7	23.5																								
Bennies Sand		1.6	**28.3**																										
Bennies Sand	*	1.9	**25.8**																										
Bennies		*2.6*	***33.9***	26.9	65.6																								
Bennies		0.4	**21.5**	21.0	28.2																								
Bennies		0.8	**19.7**	17.2	18.4																								
Bennies		0.1	**18**	15.5	15.5																								
Bennies		0.2	**13.8**	15.0	15.4																								
Bennies		0.6	**11.9**	8.6	11.6																								
Bennies		2.6	**4.04**	8.1	4.0	**16**	19	16	**15**	4	4	**24**	29	39	**30**	85	90	**0.55**	1.80	2.76	**11**	13	13	**69.2**	68	81	**0.022**	0.017	0.022
Bennies		2.4	**3.64**	6.3	2.9																								
Bennies		0.3	**2.66**	3.4	1.5																								
Bennies		1.8	**1.74**	0.7	0.8																								
Bennies		0.6	**1.36**	0.6	0.6																								
Bennies	*	2.7	**0.12**	0.6	0.3																								
Bennies		0.7	**0**	--	0.0																								
Bennies		0.6	**0**	--	**--**																								
Nantuxent Pt		**--**	**--**	53.2	--																								
Nantuxent Pt		**--**	**--**	13.2	--																								
Nantuxent Pt		**--**	**--**	7.9	--	**--**	74	--	**--**	46	--	**--**	16	--	**--**	95	--	**--**	2.10	--	**--**	21	--	**--**	28	--	--	0.015	--
Nantuxent Pt		**--**	**--**	7.4	--																								
Nantuxent Pt		**--**	**--**	1.7	--																								
Nantuxent Pt		**--**	**--**	0.0	--																								
Hog Shoal	*	3.8	**20.7**	23.3	21.5																								
Hog Shoal		3.1	**18.5**	10.8	6.1																								
Hog Shoal		1.6	**5.16**	10.0	4.4	**33**	31	27	**23**	18	32	**39**	44	62	**85.0**	90	100	**1.95**	3.00	3.45	**22**	14	20	**66.4**	45	74	**0.020**	0.017	0.019
Hog Shoal		1.4	**4.41**	9.0	3.6																								
Hog Shoal		1.3	**3.02**	--	--																								

Summary of the 2004 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2004.

Bed		Bushels/ Haul	Percent Oyster			Oysters/Bushel			Spat/ Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence			Size No./bu. >2.5 in.			Size %oysters >2.5 in.			Condition Index Dry Meat/Height		
			2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002
		--	**--**	--	**--**	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--			
New Beds	*	1.2	**32.8**	24.1	17.5																								
New Beds		*4.2*	***21.5***	23.2	10.7																								
New Beds		2.6	**17.9**	10.1	8.9																								
New Beds		3.5	**6.9**	9.4	6.5																								
New Beds		2.0	**5.66**	4.5	5.5	**28**	20	12	**31**	16	5	**33**	35	59	**65**	95	93	**1.30**	1.38	2.64	**14**	11	10	**51.7**	56	83	**0.025**	0.020	0.026
New Beds		1.1	**5.44**	3.0	3.7																								
New Beds		0.1	**4.98**	2.4	2.7																								
New Beds		5.7	**3.17**	2.0	1.9																								
New Beds		0.5	**2.04**	1.4	0.0																								
New Beds		2.6	**0**	--	--																								
Strawberry		2.4	**23.5**	9.6	13.1																								
Strawberry		0.3	**8.55**	7.2	0.9																								
Strawberry	*	2.1	**3.68**	3.9	0.3	**32**	20	8	**37**	13	4	**21**	35	59	**70**	90	90	**1.85**	2.00	2.90	**20**	14	5	**63.4**	69	63	**0.017**	0.017	0.011
Strawberry		3.6	**2.72**	3.0	0.0																								
Strawberry		1.4	**1.88**	--	--																								
Hawks Nest	*	3.0	**14.7**	18.7	13.3																								
Hawks Nest		4.0	**7.05**	14.9	8.6																								
Hawks Nest		3.3	**4.25**	11.3	1.4	**19**	53	16	**13**	33	4	**26**	35	61	**50**	90	100	**1.20**	1.95	3.50	**14**	35	9	**72.5**	65	56	**0.019**	0.015	0.012
Hawks Nest		2.7	**2.4**	8.0	0.5																								
Hawks Nest		0.5	**2.05**	--	--																								
Beadons		3.3	**17.9**	19.7	23.1																								
Beadons		2.3	**8.62**	16.7	17.4																								
Beadons	*	1.7	**6.9**	6.0	6.0																								
Beadons		3.7	**6.02**	4.5	4.5																								
Beadons		2.3	**5.23**	2.9	3.3	**23**	19	18	**33**	14	53	**30**	42	62	**84**	100	100	**1.84**	3.20	4.25	**12**	11	10	**53.4**	58	56	**0.022**	0.018	0.012
Beadons		1.5	**3.97**	2.5	2.2																								
Beadons		0.3	**3.43**	2.2	1.5																								
Beadons		3.7	**3.29**	1.6	1.5																								
Beadons		1.3	**1.8**	0.0	0.8																								
Beadons		2.3	**1.13**	0.0	0.0																								

Summary of the 2004 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2004.

Bed	Bushels/ Haul	Percent Oyster			Oysters/Bushel			Spat/ Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence			Size No./bu. >2.5 in.			Size %oysters >2.5 in.			Condition Index Dry Meat/Height		
		2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002	2004	2003	2002
	--	**--**	--	**--**	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--	**--**	--	--			
Vexton	1.8	**10.6**	24.6	31.2																								
Vexton	0.3	**9.06**	11.0	16.7																								
Vexton	2.4	**6.39**	10.1	11.2	**13**	21	26	**4**	15	30	**30**	**44**	64	**65**	100	100	**1.60**	4.10	4.90	**11**	16	16	**83.9**	76	62	**0.025**	0.023	0.016
Vexton	2.3	**3.69**	7.1	11.0																								
Vexton	4.7	**1**	0.0	1.1																								
Vexton	1.6	**0**	--	--																								
Egg Island	--	--	5.9	--																								
Egg Island	--	--	4.9	--																								
Egg Island	--	--	3.1	--																								
Egg Island	--	--	0.7	--																								
Egg Island	--	--	0.5	--	--	4	--	--	0	--	--	29	--	**--**	100	--	**--**	2.30	--	--	3	--	--	84	--	--	0.009	--
Egg Island	--	--	0.5	--																								
Egg Island	--	--	0.3	--																								
Egg Island	--	--	0.0	--																								
Ledge	3.8	**1.96**	**--**	4.9																								
Ledge	0.6	**1.57**	**--**	1.3																								
Ledge	1.7	**1.09**	**--**	0.6																								
Ledge	3.1	**0.28**	**--**	0.0	**1.31**	**--**	1.1	**3**	**--**	0	**17**	**--**	59	**40**	**--**	100	**0.70**	--	2.40	**1**	--	1	**83.3**	--	100	--	--	--
Ledge	0.2	**0**	**--**	0.0																								
Ledge	0.0	**0**	**--**	--																								

Table 3. page 4.

Table 4. Oyster size frequency on the natural oyster beds in 2004. Frequencies are expressed as the number in each size class per bushel.

Table 4. Oyster Seed Beds Size Frequency 2004																	
	Round Is	**Arnold**	**Up Mid**	**Middle**	**Cohan**	**Ship Jn**	**Seabrz**	**Shell Rk**	**Ben Snd**	**Bennie**	**Hog Shl**	**New Beds**	**Straw**	**Hawks N**	**Beadon**	**Vexton**	**Ledge**
0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	2	4	0	4	2	1	1	3	2	0.3	0.5	3.0	0.2	0.3	1.1	0.2	0.0
30	5	7	0	8	3	3	2	2	2	0.3	0.2	1.9	0.2	0.0	0.4	0.0	0.0
35	10	12	0	10	7	12	4	3	2	0.2	0.7	1.3	0.7	0.0	0.6	0.0	0.0
40	15	19	0	16	6	13	9	7	9	0.2	1.0	0.7	1.2	0.6	2.0	0.2	0.2
45	28	27	0	14	9	20	18	10	11	0.3	2.4	1.3	1.2	0.0	2.0	0.2	0.0
50	31	33	0	17	10	22	21	11	11	0.7	1.9	1.4	2.4	1.4	1.6	0.2	0.0
55	28	37	0	19	7	22	13	18	14	1.2	1.7	2.4	3.3	0.8	1.2	0.5	0.0
60	19	31	0	23	15	23	9	16	14	1.8	2.6	1.5	2.4	2.2	1.8	0.7	0.0
65	12	23	0	24	17	28	10	19	15	1.3	3.1	1.9	4.8	1.1	1.7	0.7	0.0
70	6	14	0	26	17	27	5	22	15	1.0	2.9	1.8	1.9	3.3	1.8	0.9	0.0
75	**4**	**7**	**0**	**17**	**20**	**22**	**4**	**21**	**15**	**1.5**	**1.4**	**2.0**	**4.5**	**2.5**	**1.8**	**0.9**	**0.0**
80	**1**	**2**	**0**	**14**	**16**	**19**	**6**	**17**	**12**	**0.9**	**2.6**	**2.3**	**2.9**	**1.7**	**1.7**	**1.6**	**0.4**
85	**0**	**2**	**0**	**7**	**12**	**15**	**3**	**10**	**8**	**1.3**	**3.6**	**1.9**	**2.1**	**1.1**	**1.6**	**0.7**	**0.0**
90	**0**	**1**	**0**	**5**	**10**	**7**	**2**	**6**	**4**	**1.4**	**2.6**	**1.4**	**1.0**	**1.7**	**1.3**	**2.3**	**0.0**
95	**0**	**0**	**0**	**3**	**4**	**6**	**0**	**3**	**4**	**0.9**	**2.2**	**1.4**	**1.4**	**1.1**	**0.7**	**0.9**	**0.0**
100	**0**	**0**	**0**	**1**	**2**	**2**	**1**	**2**	**2**	**0.9**	**0.7**	**1.0**	**0.7**	**0.6**	**0.8**	**1.6**	**0.0**
105	**0**	**0**	**0**	**1**	**2**	**1**	**1**	**1**	**1**	**0.4**	**1.4**	**0.5**	**0.2**	**0.6**	**0.4**	**0.2**	**0.2**
110	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**1**	**1**	**0.7**	**0.0**	**0.5**	**0.5**	**0.3**	**0.1**	**0.5**	**0.0**
115	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**	**0.5**	**0.0**	**0.2**	**0.0**	**0.1**	**0.2**	**0.2**
120	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.2**	**0.5**	**0.0**	**0.0**	**0.0**	**0.1**	**0.2**	**0.2**
125	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
130	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**
135	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
140	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total/Bu.	161	222	1	210	161	245	108	175	142	16	33	28	32	19	23	13	1
No. Measured	726	984	1	1541	880	985	198	844	767	292	137	352	134	69	191	56	6
Greater than 3"	**5**	**13**	**0**	**49**	**68**	**74**	**16**	**63**	**47**	**9**	**16**	**11**	**14**	**9**	**9**	**9**	**1**
> 3" 2003	-	4	-	41	51	55	-	34	35	9	9	7	9	24	7	11	-
> 3" 2002	3	6	0	28	20	44	11	33	29	10	13	7	3	7	6	10	1
Greater than 2.5"	**23**	**50**	**0**	**98**	**102**	**129**	**31**	**104**	**77**	**11**	**22**	**14**	**20**	**14**	**12**	**11**	**1**
> 2.5" 2003	-	23	-	91	99	105	-	68	70	13	14	11	14	35	11	16	-
> 2.5" 2002	14	34	6	72	50	100	20	70	61	13	20	10	5	9	10	16	1

Table 5. Surplus production estimate of the 2004 oyster stock on the New Jersey natural oyster beds in Delaware Bay. High-mortality transplant: Beadons, Nantuxent Point; high-mortality market: Strawberry, Hog Shoal, Vexton, Hawk's Nest, New Beds, Egg Island, Ledge, Bennies, Bennies Sand; medium-mortality market: Shell Rock; medium-mortality transplant (lower): Ship John, Cohansey, Sea Breeze; medium-mortality transplant (upper): Middle, Upper Middle; low mortality: Arnolds, Upper Arnolds, Round Island.

75^{th} Percentile Mortality Rate Assumption

Bay Region	Surplus Production (bushels)
Low-Mortality	264
Medium-Mortality Transplant (Upper)	-21,228
Medium-Mortality Transplant (Lower)	-99,351
Shell Rock	6,777
High-Mortality Market	160
High-Mortality Transplant	5,238
Total	-102,266

33^{rd} Percentile Mortality Rate Assumption

Bay Region	Surplus Production (bushels)
Low-Mortality	1,209
Medium-Mortality Transplant (Upper)	1,620
Medium-Mortality Transplant (Lower)	-6,520
Shell Rock	17,320
High-Mortality Market	10,538
High-Mortality Transplant	8,636
Total	32,803

Table 6. Harvest statistics for 2004. Fraction covered indicates the fraction of bed area swept by the dredge during fishing. Fractions above 1 indicate a total swept area greater than the bed area.

Oyster Bed	Bed Area (m^2)	Fraction Covered	Bushels Harvested	Percent of Harvest
Round Island	0	0	0	0%
Upper Arnolds	0	0	0	0%
Arnolds	0	0	0	0%
Upper Middle	0	0	0	0%
Middle	0	0	0	0%
Cohansey	7,339,142	2.25	9,751	15.55%
Sea Breeze	841,421	0.75	931	1.48%
Ship John	13,679,016	4.64	18,978	30.26%
Shell Rock	15,105,540	4.37	18,655	29.74%
Bennies Sand	5,188,386	6.37	5,574	8.89%
Bennies	4,307,586	0.77	4,120	6.57%
Nantuxent Point	1,185,242	0.65	1,133	1.81%
New Beds	529,794	0.09	224	0.36%
Hawk's Nest	1,155,388	0.60	1,260	2.01%
Hog Shoal	429,149	0.47	435	0.69%
Beadons	37,039	0.02	26	0.04%
Strawberry	990,356	0.65	1,194	1.90%
Vexton	429,149	0.30	439	0.70%
Egg Island	0	0	0	0%
Ledge	0	0	0	0%
Total	51,217,208		62,720	100%

Table 7. Comparisons of 2004 mortalities, Dermo prevalence and Dermo weighted prevalence with 1989-2004 averages by bay region. Numbers are means (95% confidence interval). Bay regions are defined in Figure 12.

	Percent Mortality		Prevalence		Weighted Prevalence	
Region	2004	Long-term	2004	Long-term	2004	Long-term
Upper	15 (4)	11 (2)	1 (9)	31 (17)	0.02 (0.3)	0.4 (0.3)
Upper-Central	8 (8)	16 (3)	36 (14)	75 (10)	0.8 (0.4)	1.5 (0.5)
Central-Lower	26 (5)	36 (3)	56 (13)	92 (3)	1.3 (0.4)	2.6 (0.2)
All regions	18 (6)	26 (2)	42 (15)	81 (5)	1.0 (0.3)	2.0 (0.4)

Table 8. An estimate of the unrecorded mortality in 2004 as a fraction of the stock. Bed regions defined in Table 5

	2004 Unrecorded Mortality	52-year Percentile	Post-1988 Percentile
Low-mortality	-.1362	61	72
Medium-mortality Transplant	-.2435	61	66
Medium-mortality Market	-.4628	38	28
High-mortality Market	-.4663	57	59
High-mortality Transplant	-.5997	36	41

Note that higher unrecorded mortality is indicated by more negative numbers; hence a lower percentile rank indicates a higher mortality rate.

Table 9. The 2004 transplant program. Fraction deployed indicates the fraction of the total transplant taken from the originating bed deployed on the receiving bed.

Originating Bed	Bushels Transplanted	Oysters per Bushel	Receiving Bed	Fraction Deployed
Nantuxent Point	6,200	184	Bennies	1.00
Beadons	1,200	39	Bennies	1.00
Arnolds	31,018	431	Bennies Sand	1.00
Upper Arnolds	3,771	536	Bennies Sand	1.00
Round Island	30,392	424	Bennies	.12
		483	New Beds	.88
Middle	17,602	363	New Beds	1.00

Figure 1. Delaware Bay natural oyster beds showing the grid system used in the random sampling program.

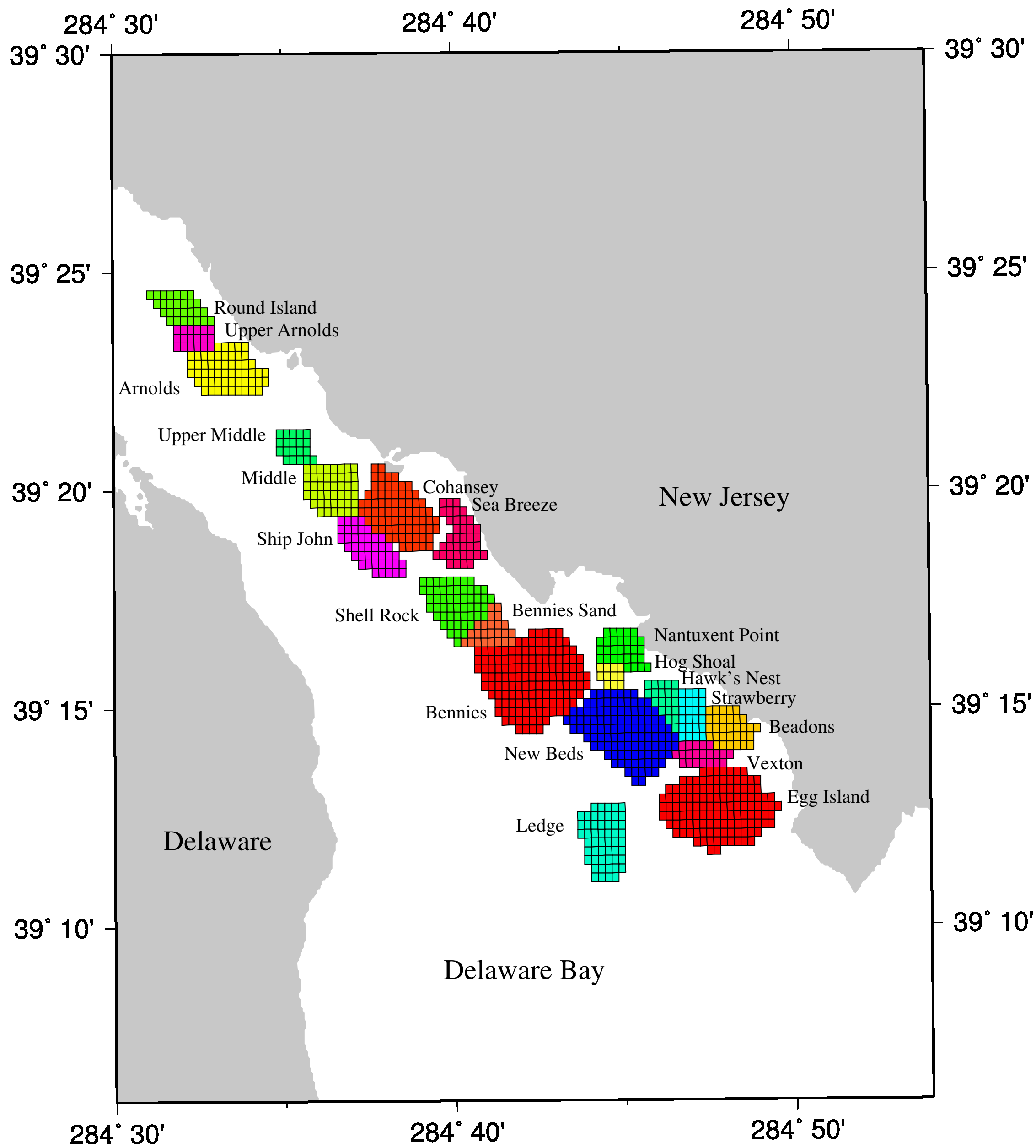

Figure 2. Annual bay-wide average number of oysters per 37-quart bushel. Error bars are the 95% confidence intervals.

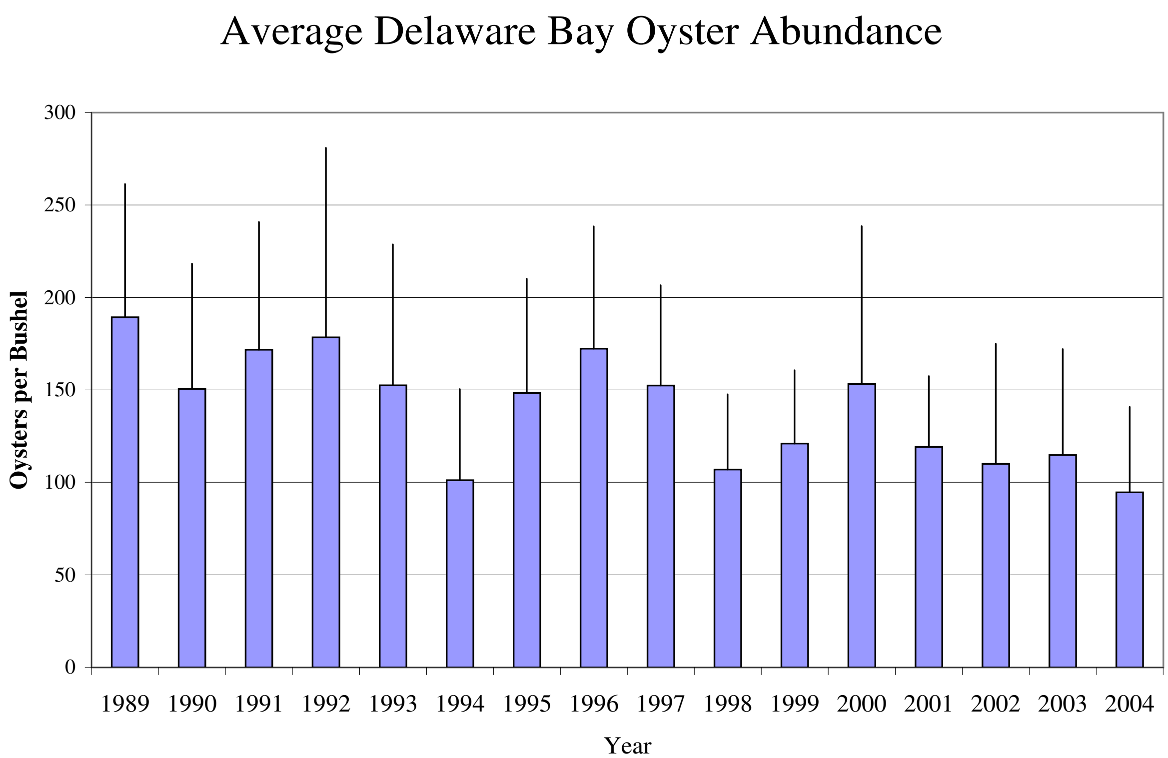

Figure 3. Annual oyster harvest from the natural oyster beds, in bushels.

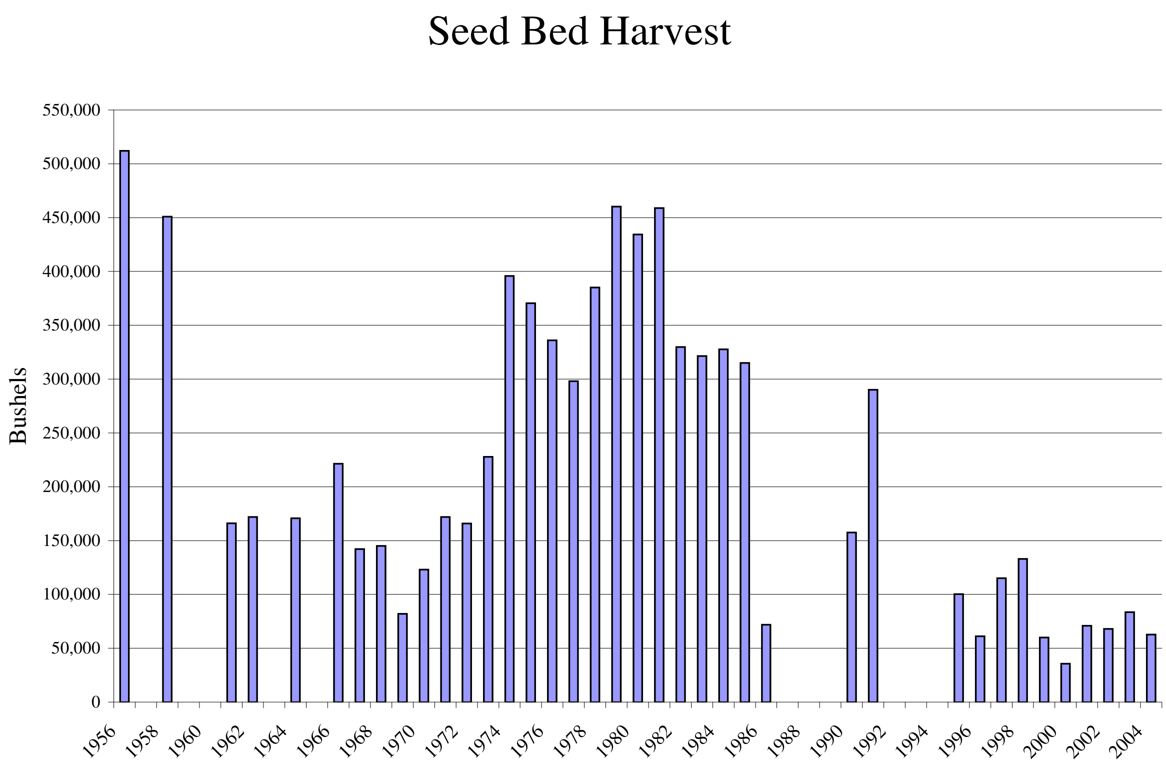

Figure 4. Delaware Bay natural oyster beds showing the locations of the 2004 random sampling sites (white dots)

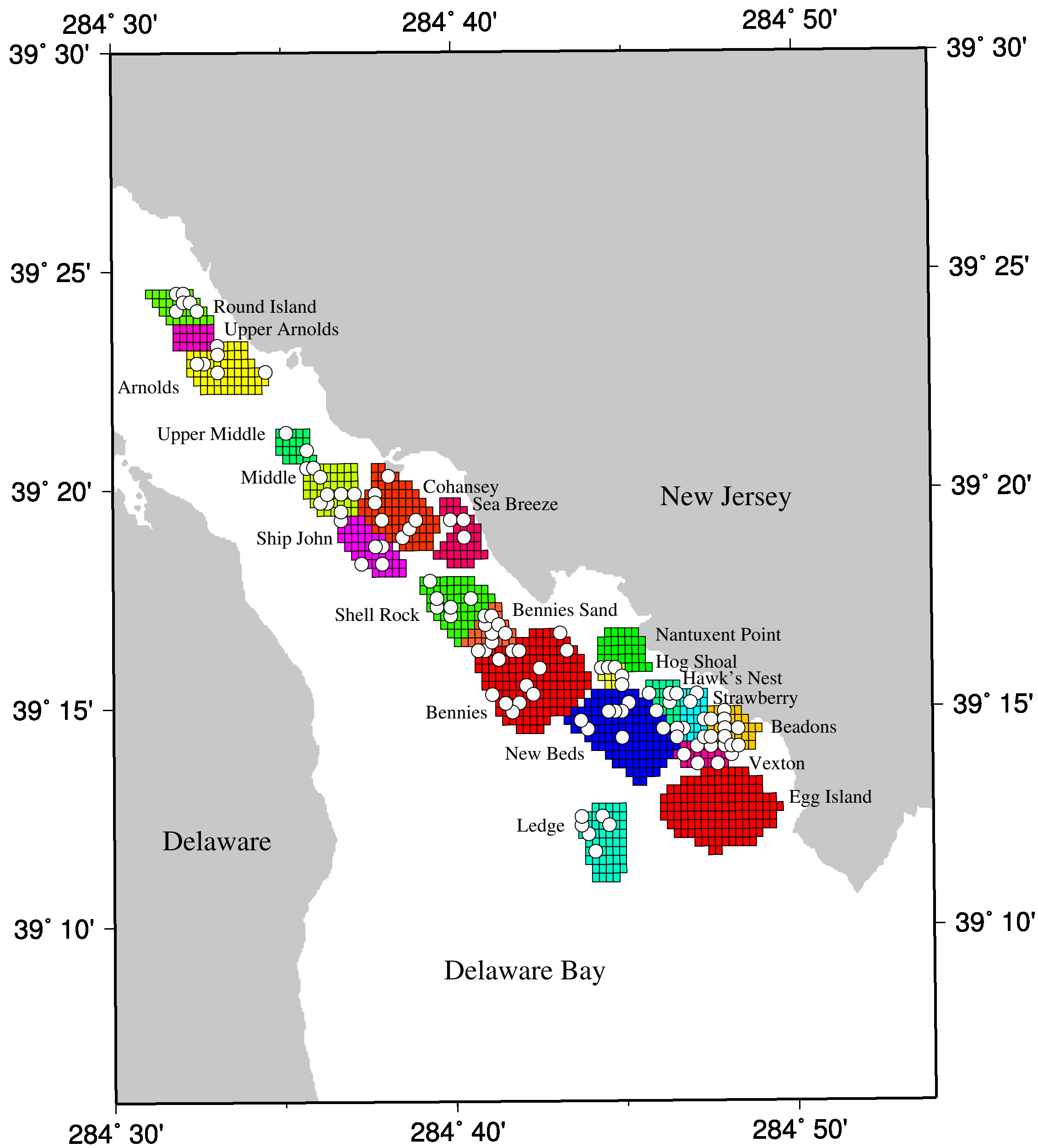

Figure 5. Comparison of catchability coefficients (expressed as the reciprocal of dredge efficiency) for (a) the average of the 2000 and 2003 dredge calibration programs, (b) tow-based estimates obtained during the 2003 survey, and (c) tow-based estimates obtained during the 2004 survey. The 2000/2003 average values were used for estimation of oyster density in this assessment.

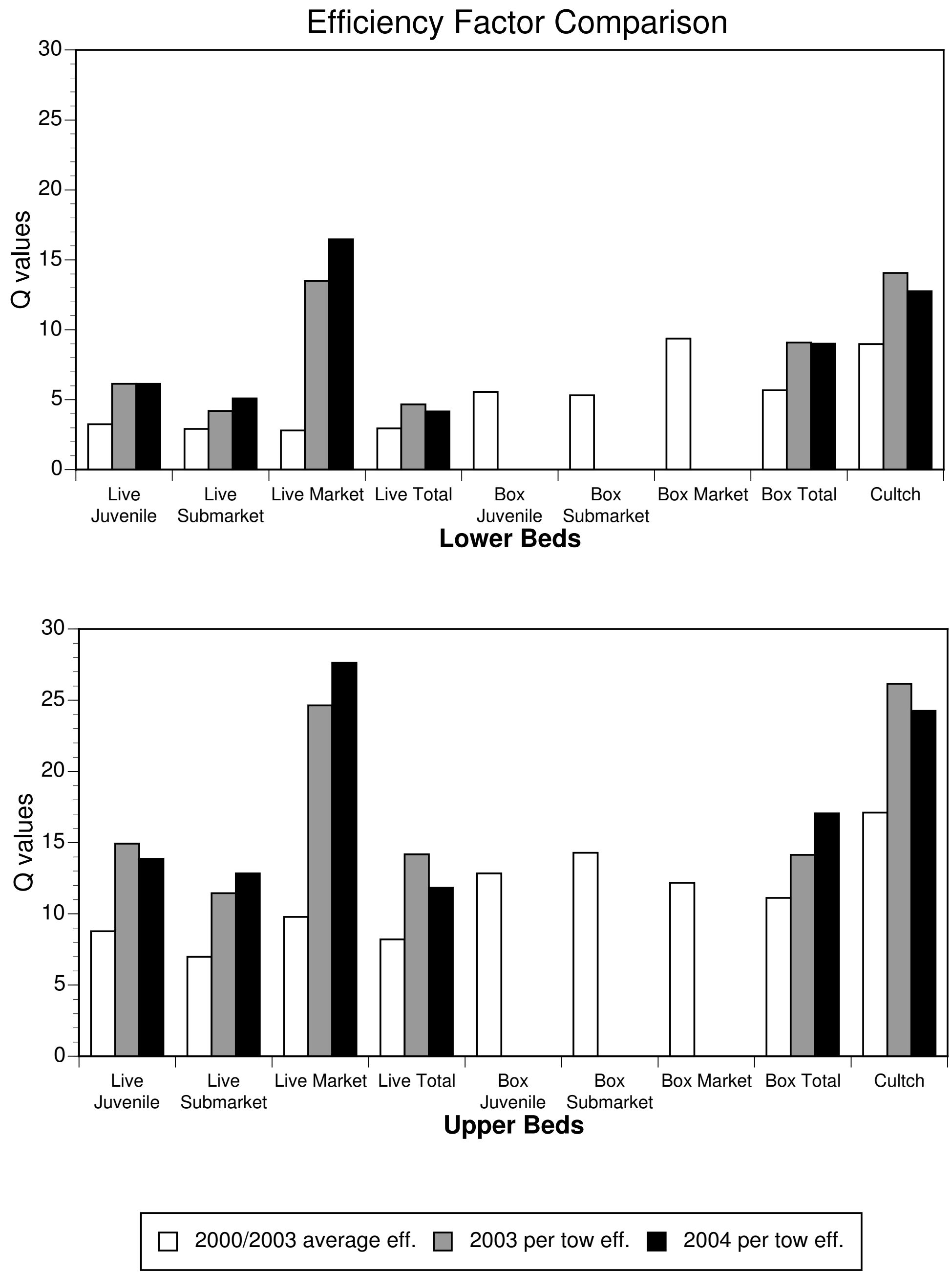

Figure 6. Average annual bay-wide oyster and spat abundance (37-qt. bushel), with 95% Least Significant Difference confidence intervals. Underlined values are not significantly different. Mean = average of annual values. Years are arrayed across the top.

Delaware Bay Seed Beds

Year	**1989**	**1992**	**1996**	**1991**	**2000**	**1993**	**1997**	**1990**	**1995**	**1999**	**2001**	**2003**	**2002**	**1998**	**1994**	**2004**	**Mean**
Oysters	189	178	172	172	153	153	152	151	148	121	119	115	110	107	101	95	**139**
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Year	**1991**	**1999**	**1997**	**1998**	**1995**	**1994**	**1990**	**1989**	**2000**	**2002**	**1993**	**2004**	**1992**	**1996**	**2003**	**2001**	**Mean**
Spat	268	191	151	128	127	124	112	69	55	44	44	27	25	22	22	15	**87**

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Figure 7. Total oysters per 37-qt. bushel from the Upper Central (less Shell Rock) and Market beds (Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Egg Island and New Beds). Error bars are the 95% confidence intervals.

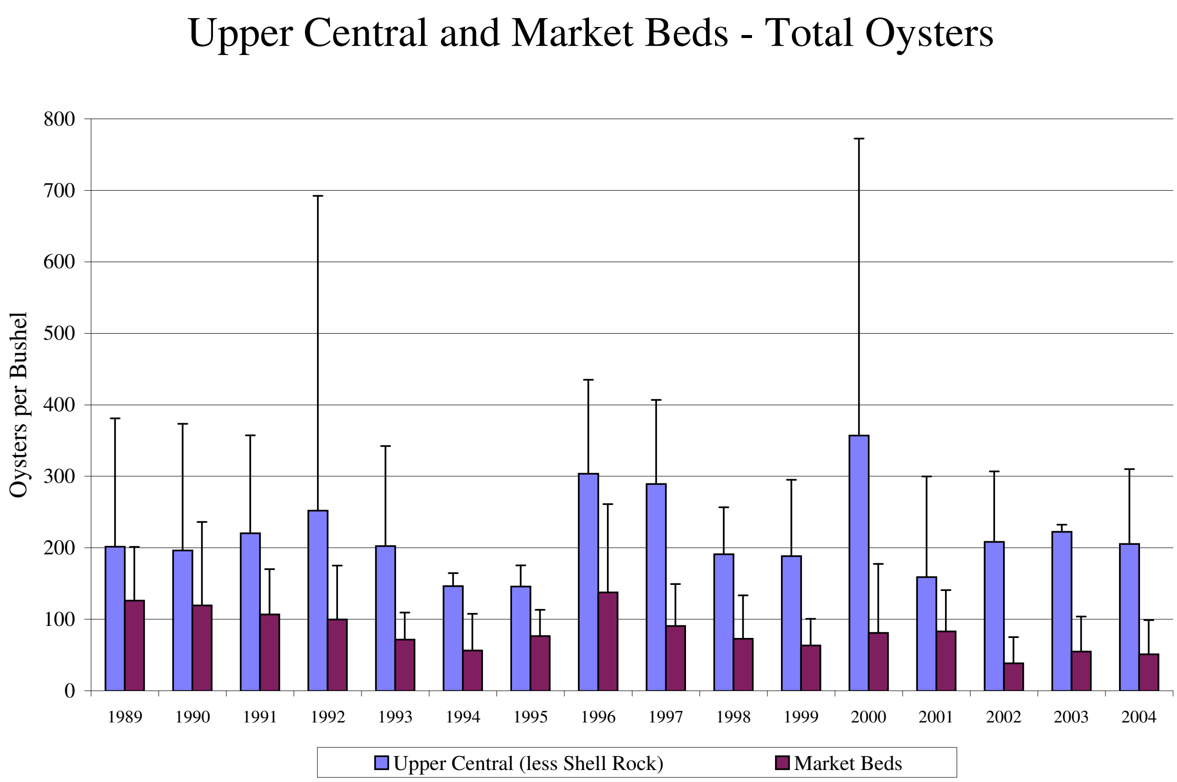

Figure 8. Time series of oyster abundance, cumulatively by bay region. High-mortality transplant: Beadons, Nantuxent Point; high-mortality market: Strawberry, Hog Shoal, Vexton, Hawk's Nest, New Beds, Egg Island, Ledge, Bennies, Bennies Sand; medium-mortality market: Shell Rock; medium-mortality transplant: Ship John, Cohansey, Sea Breeze, Middle, Upper Middle; low mortality: Arnolds, Upper Arnolds, Round Island.

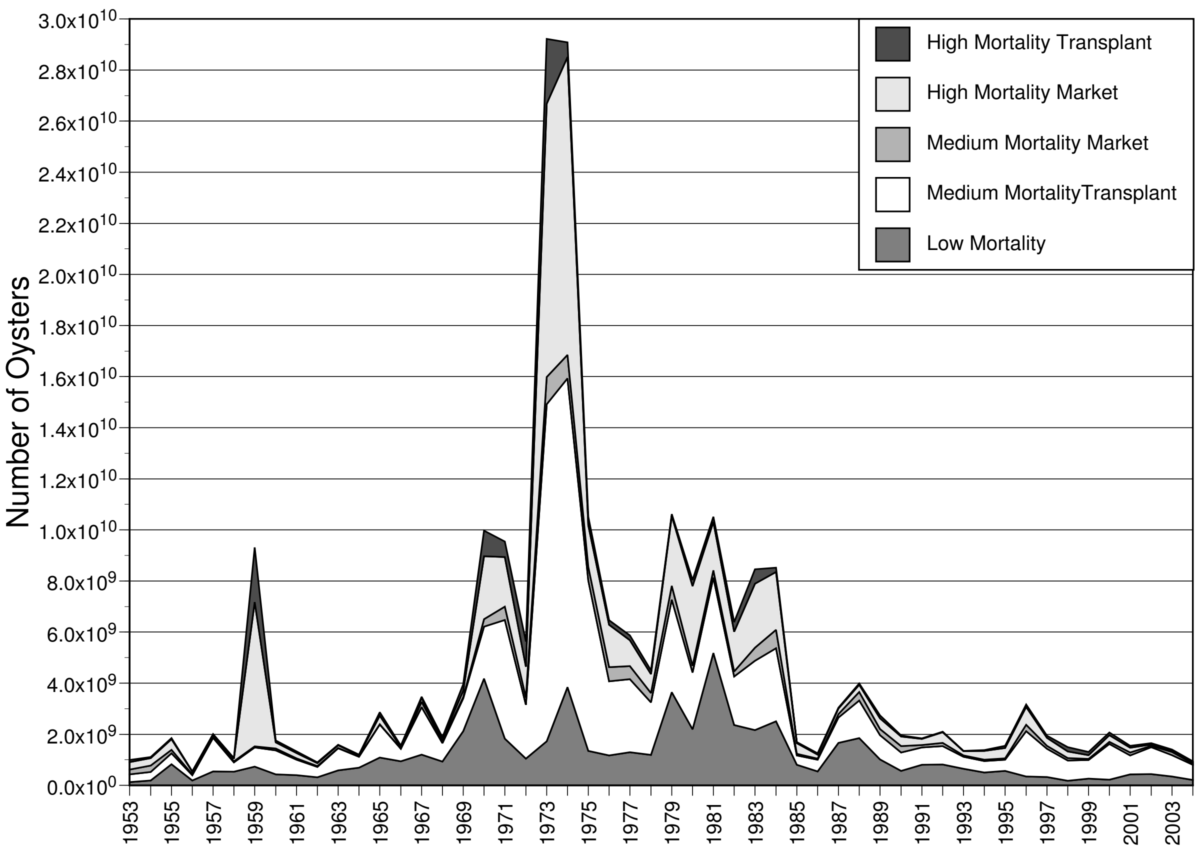

Figure 9. Time series of spawning stock biomass. All strata include the bed margins, as well as the test areas and bed proper. Test+high-quality strata include the test areas and bed proper only.

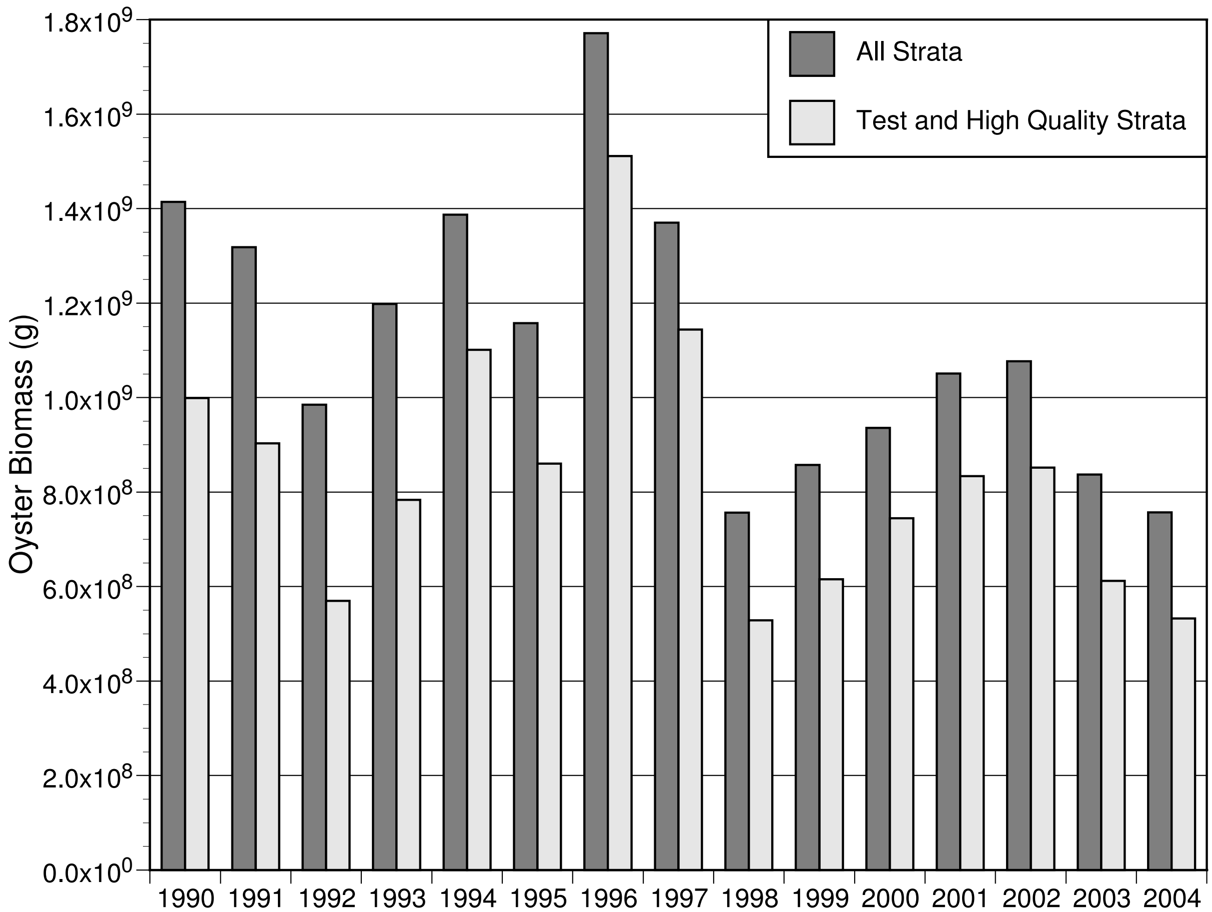

Figure 10. Oyster per 37-qt. bushel by market ($\geq 3''$) and submarket (2.5 to 2.99$''$) size classes from Upper Central (less Shell Rock) and Market beds. Market beds are Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Egg Island and New Beds. Upper Central beds defined in Table 2. Error bars are the 95% confidence intervals.

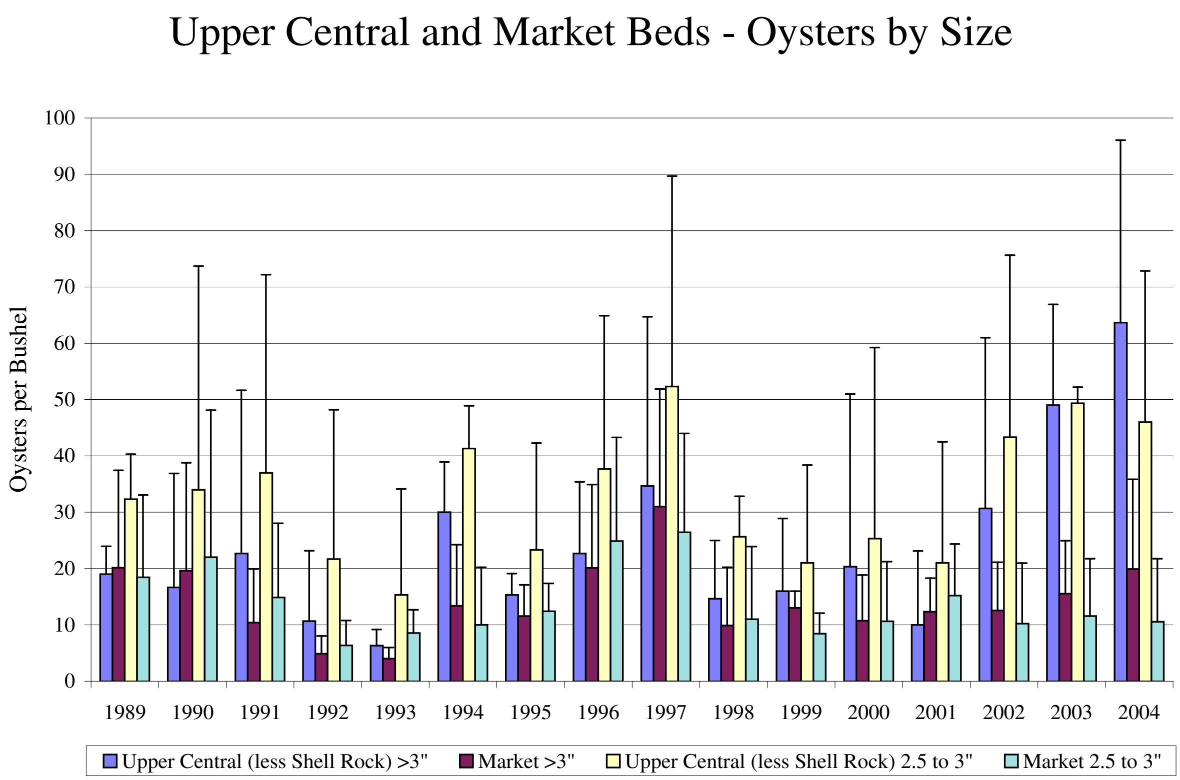

Figure 11. Percent of total oysters in the 2.5″ to 3″ (submarket) and > 3″ (market) categories for the Upper Central (less Shell Rock) and Market beds. Market beds are Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Egg Island and New Beds. Upper Central beds defined in Table 2.

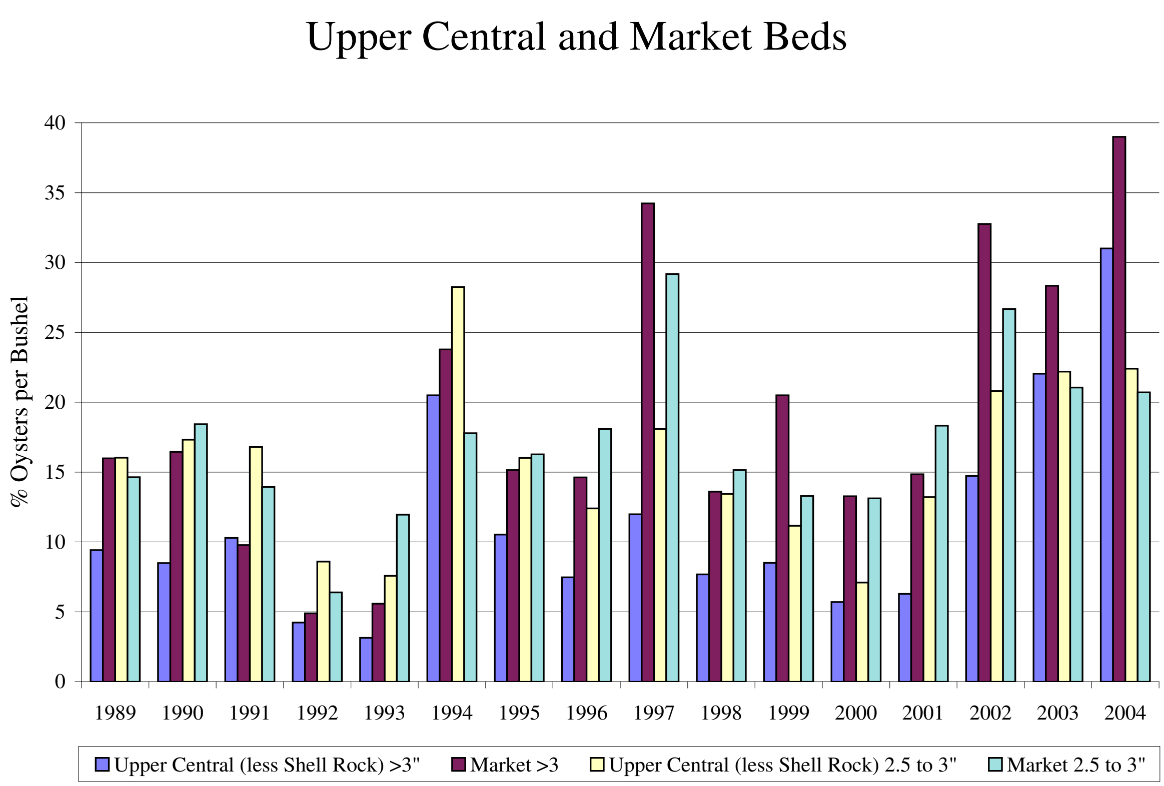

Figure 12. Annual average condition index [dry meat weight (g)/hinge-to-lip dimension (mm)] by bed group. Upper = Round Island, Arnolds, Upper Arnolds. Upper Central = Upper Middle, Middle, Ship John, Cohansey, Shell Rock. Central= Bennies, Bennies Sand, Nantuxent, Hog Shoal, New Beds, Strawberry, Hawk's Nest, Beadons, Vexton. Lower = Egg Island, Ledge. Error bars are the 95% confidence intervals. Interval is missing from Lower because only one bed is sampled in alternate years.

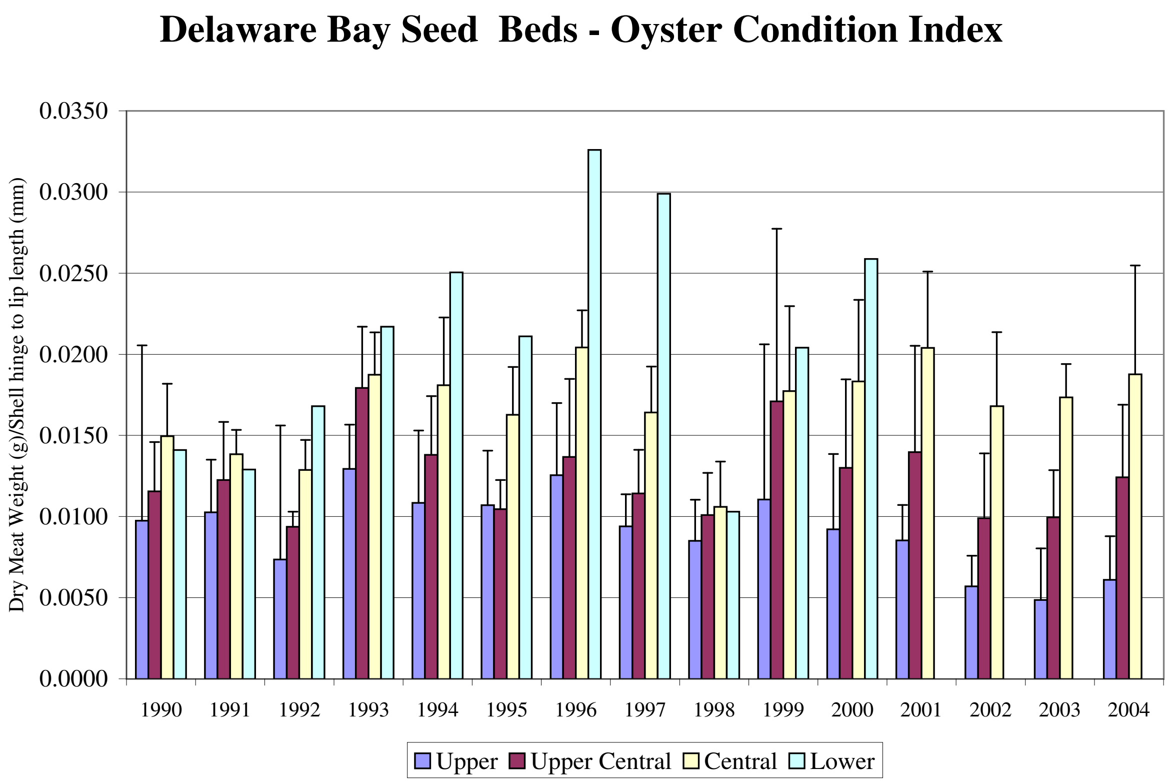

Figure 13. Annual bay-wide average spat counts per 37-quart bushel. Error bars are the 95% confidence intervals.

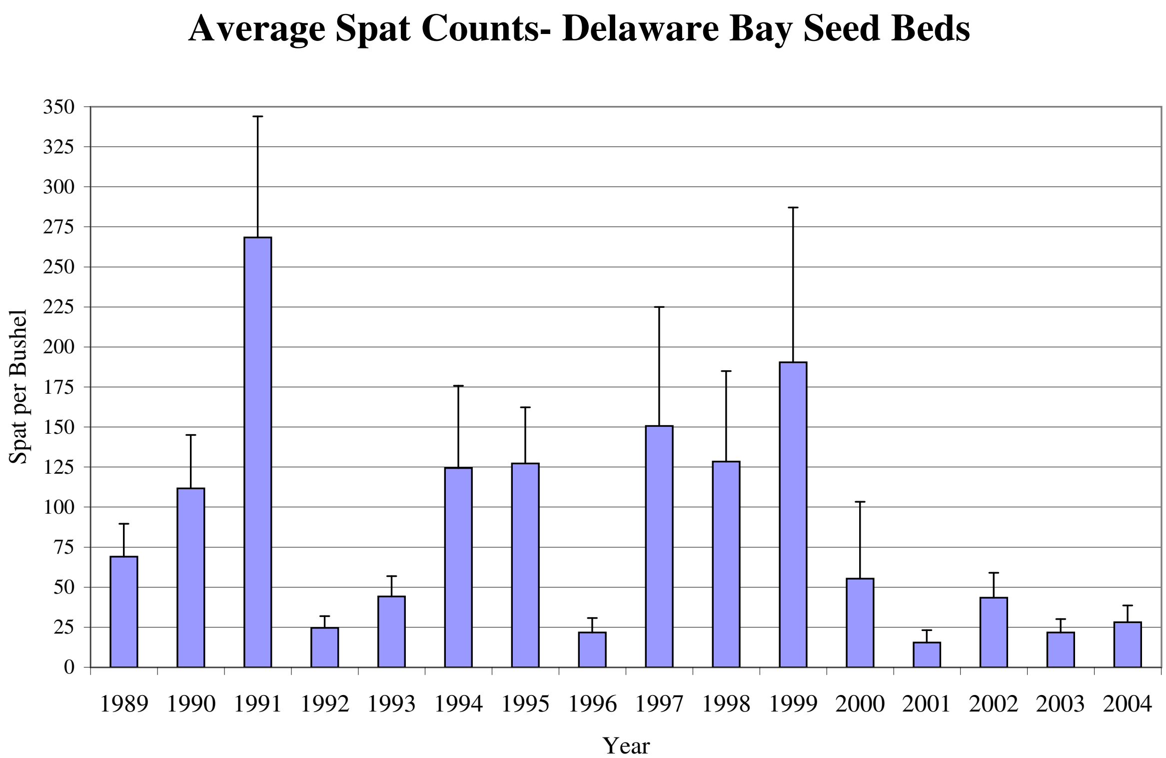

Figure 14. Number of spat recruiting per year for the 1953-2004 time series, cumulatively by bay region. Bay regions are defined in Figure 8.

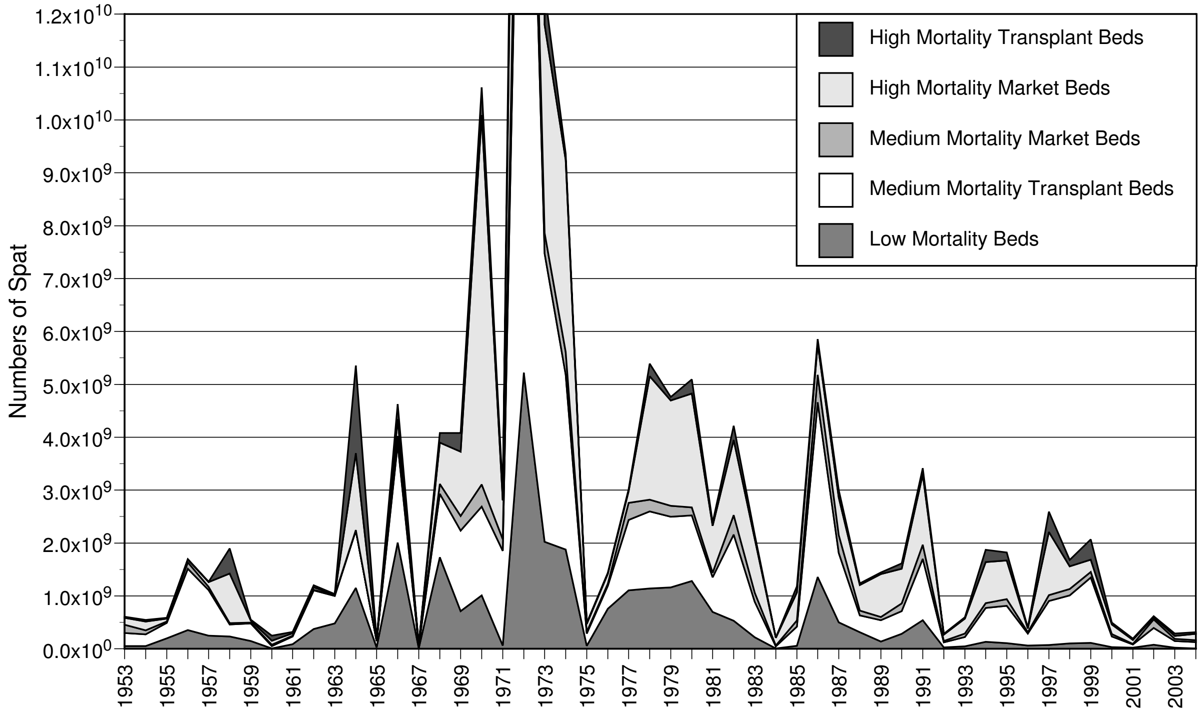

Figure 15. The number of spat recruiting per >20-mm oyster per year. All strata include the bed margins, as well as the test areas and bed proper. Test+high-quality strata include the test areas and bed proper only.

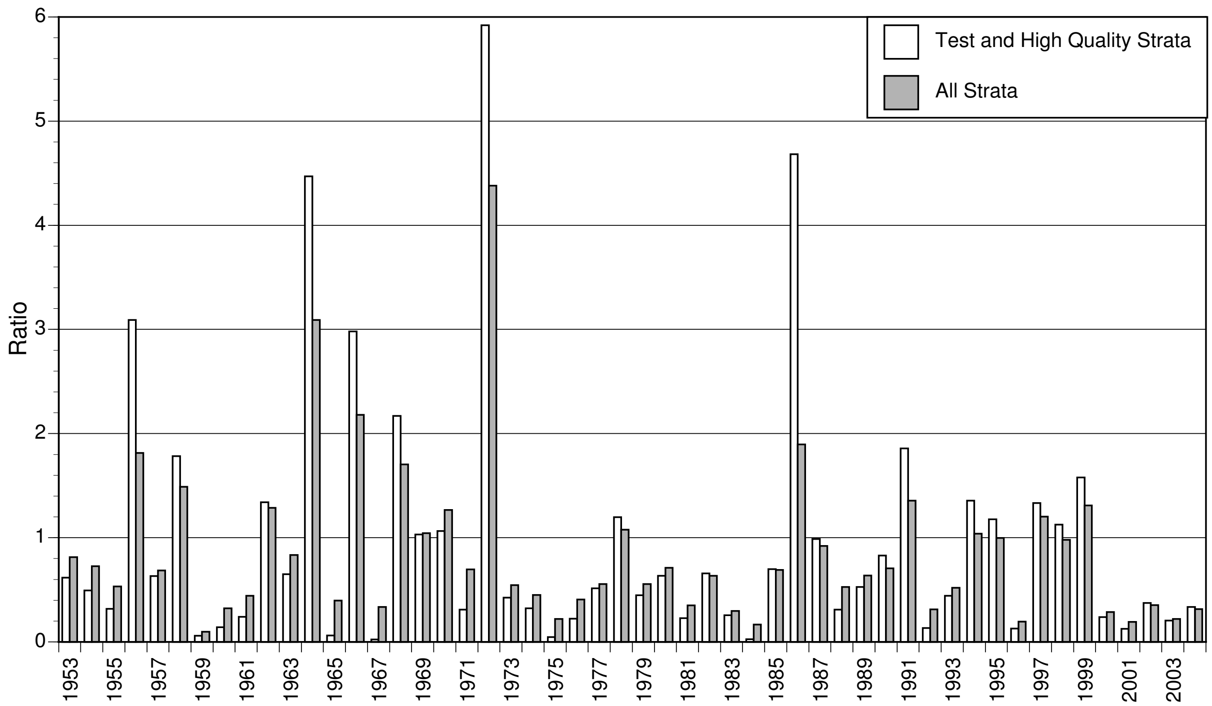

Figure 16. Cumulative number of spat recruiting to 20-oyster-shell bags deployed in the last week of June and collected bi-weekly through September. Colors identify the month of settlement. Circle diameter indicates the number of spat that settled during that time period. Total diameter indicates the cumulative number of spat.

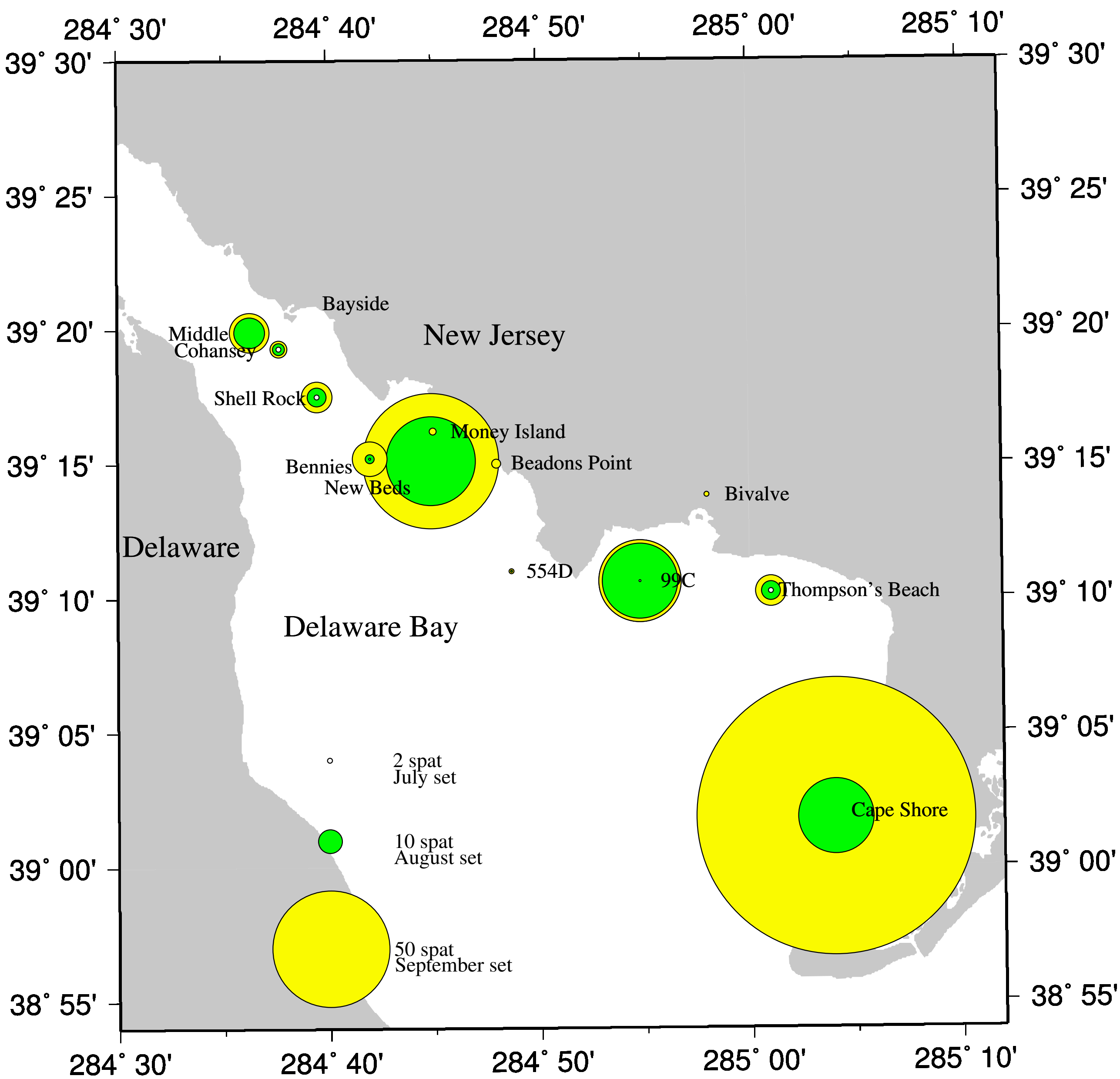

Figure 17. Relationship between Fall Dermo infection intensities and Fall mortality as measured by box counts. Each point corresponds to a measurement from one bed for one year. The regression is significant at $P < 0.05$.

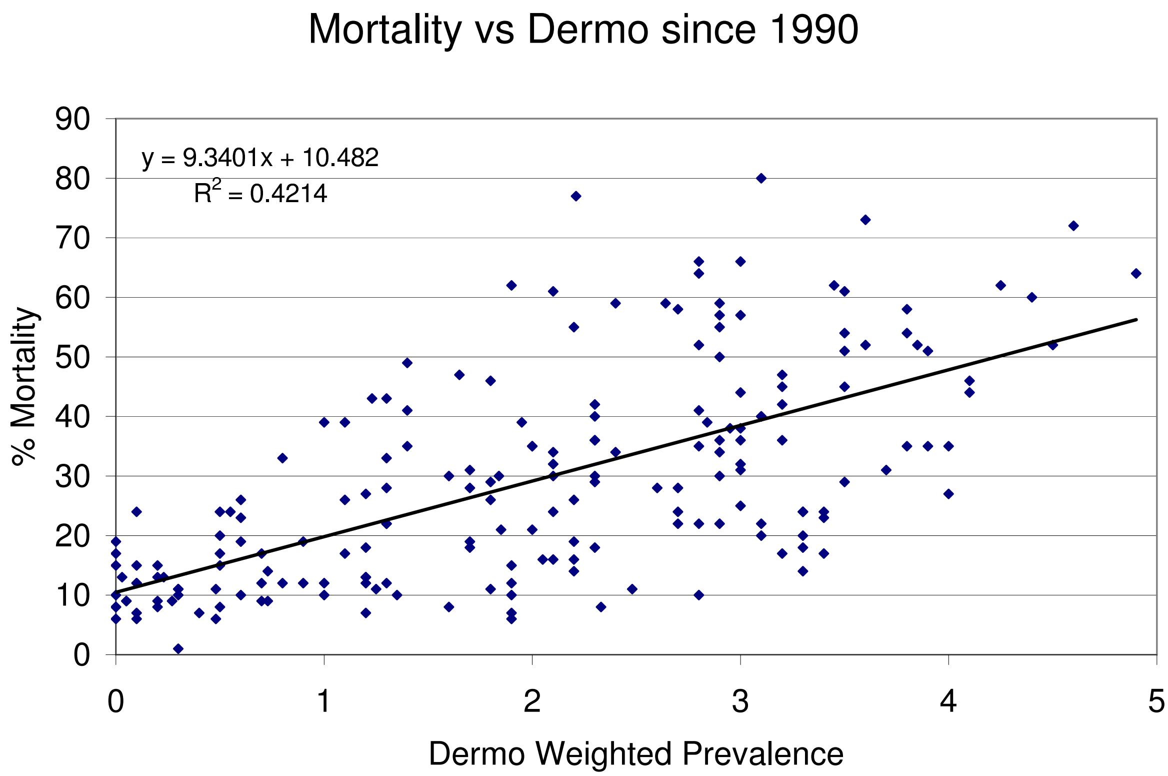

Figure 18. The relationship between oyster abundance and box-count mortality for the 1953-2004 time period for the natural oyster beds of Delaware Bay.

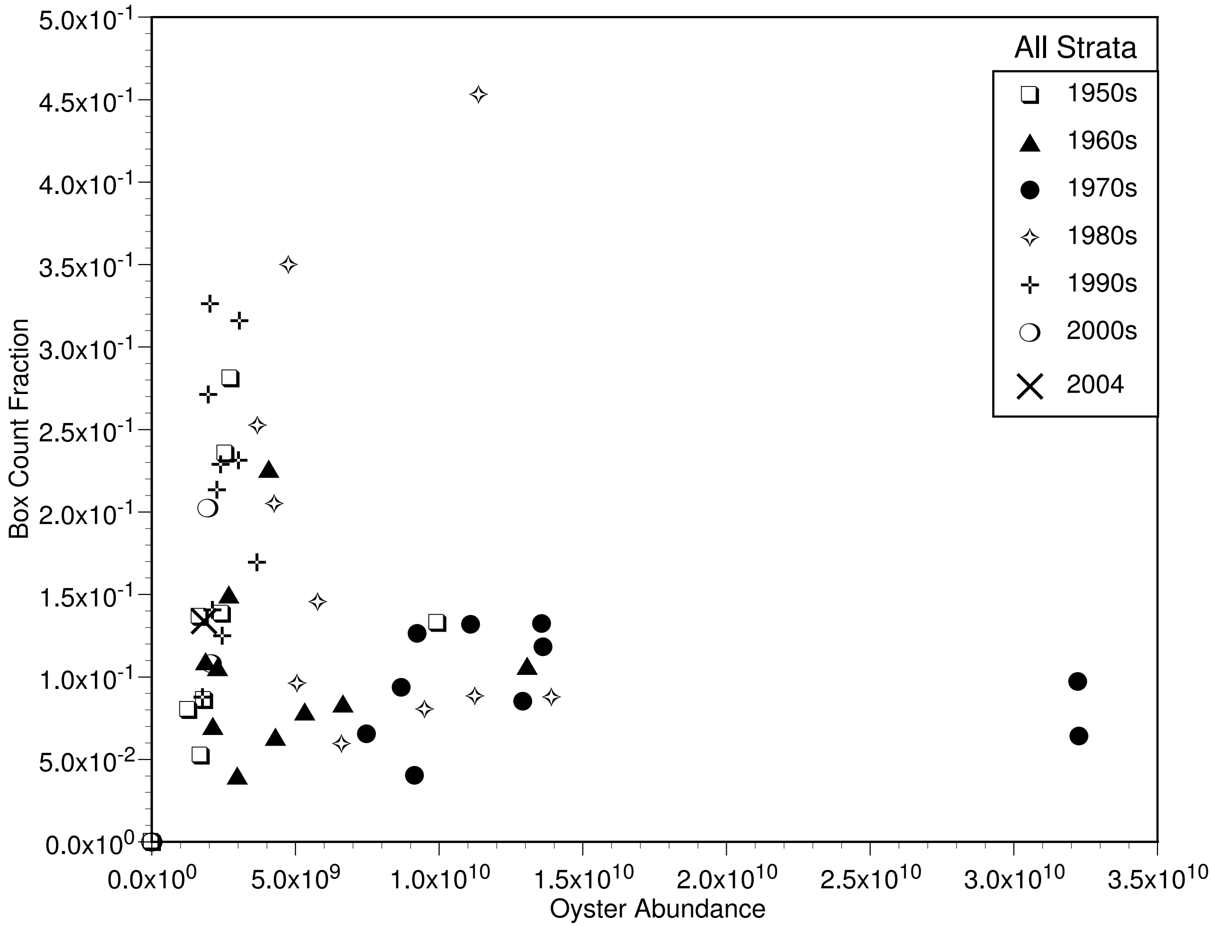

Figure 19. Mean and 2004 Dermo prevalence in oysters on New Jersey Delaware Bay oyster beds. Error bars are 95% confidence intervals.

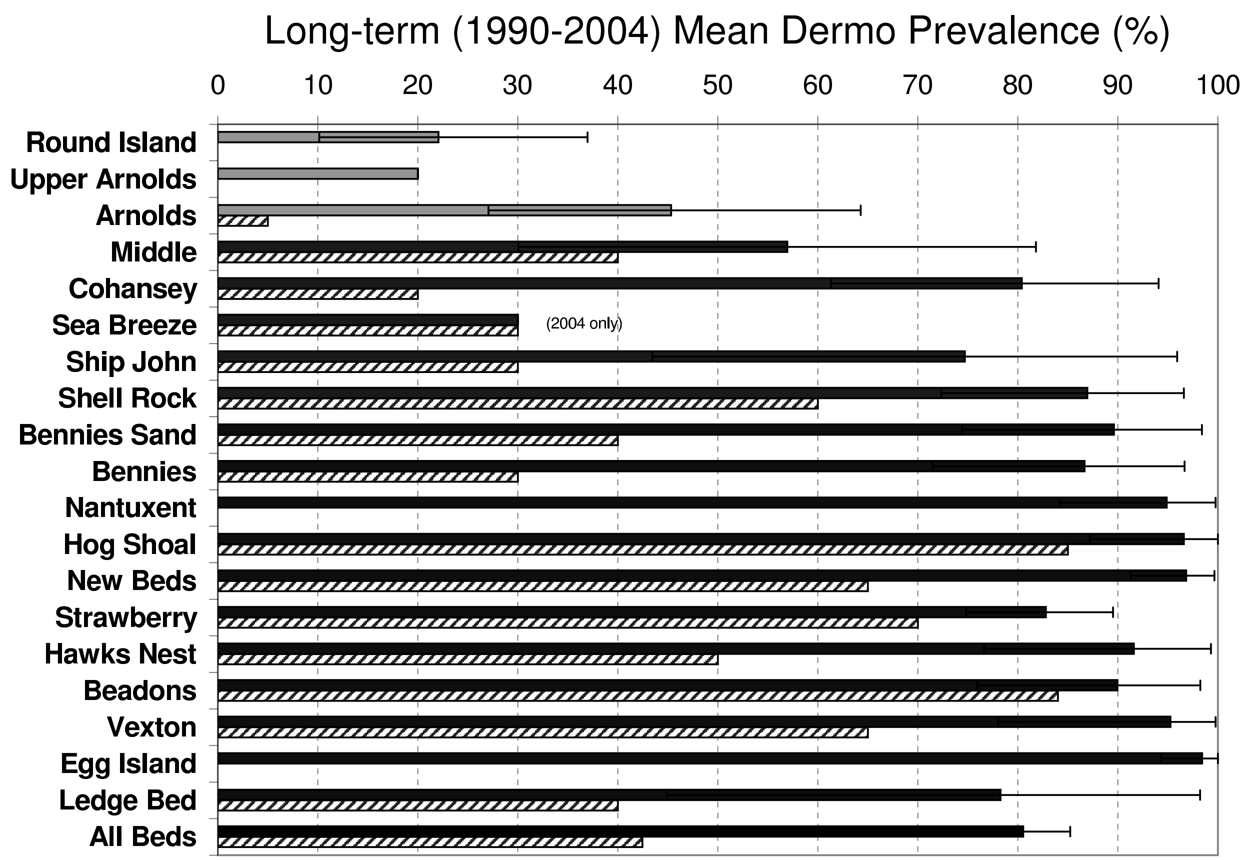

Figure 20. Mean and 2004 weighted prevalences of Dermo disease on New Jersey Delaware Bay oyster beds. Error bars are 95% confidence intervals.

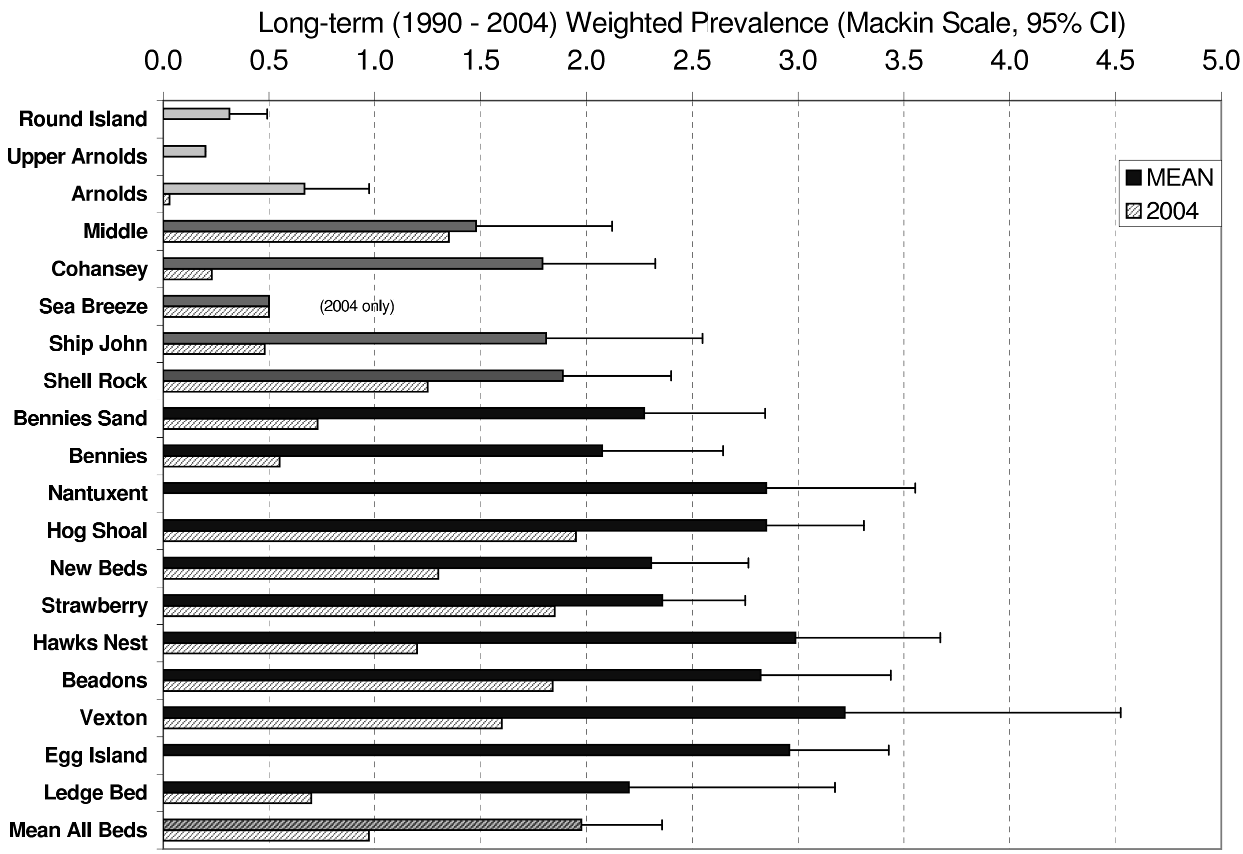

Figure 21. Mean and 2004 box-count mortality on New Jersey Delaware Bay oyster beds, rendered as the percent of beginning year abundance that died. Error bars are 95% confidence intervals.

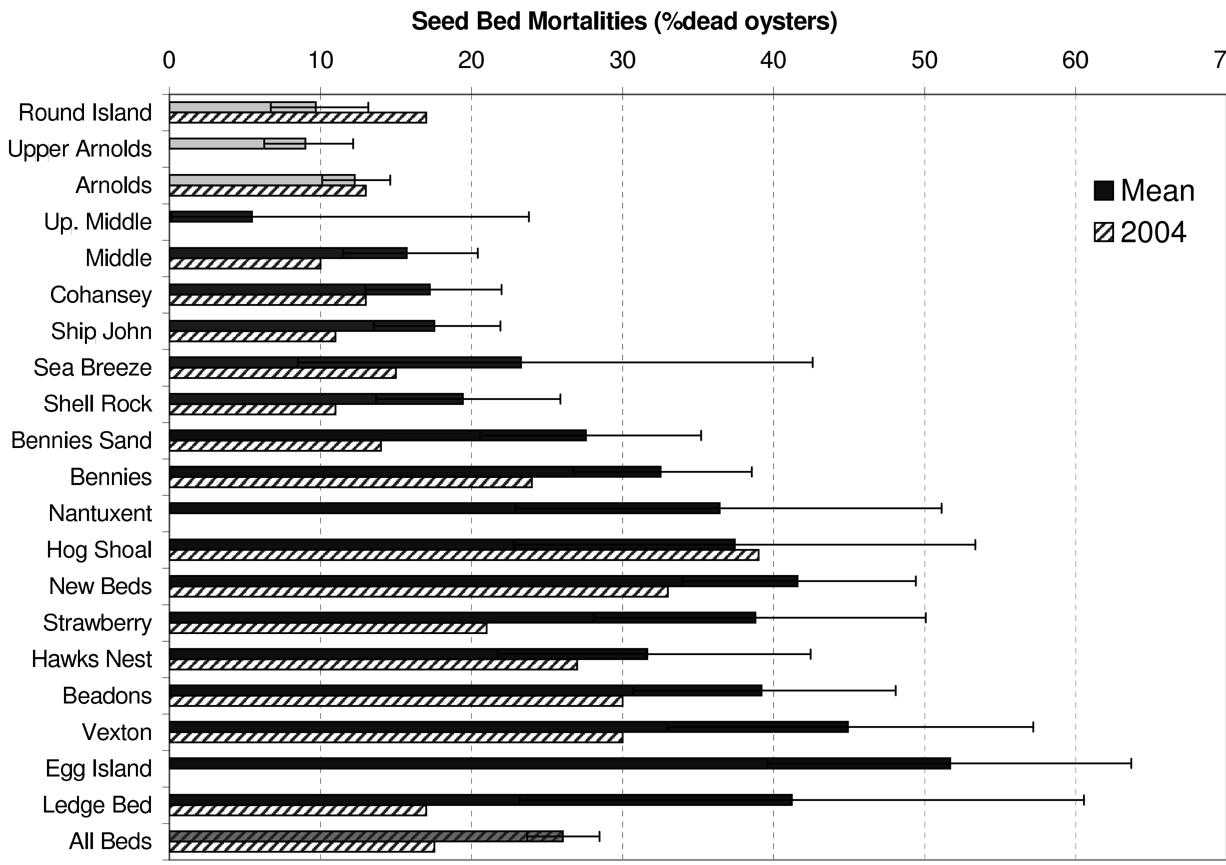

Figure 22. The fraction of bay-wide mortality contributed by each bay section. The cumulated total is the total mortality for the entire bay as a fraction of the abundance for that year. Individual bay-region values are the proportion of total bay mortality represented by mortality in that bay region. Bed groups defined in Figure 8.

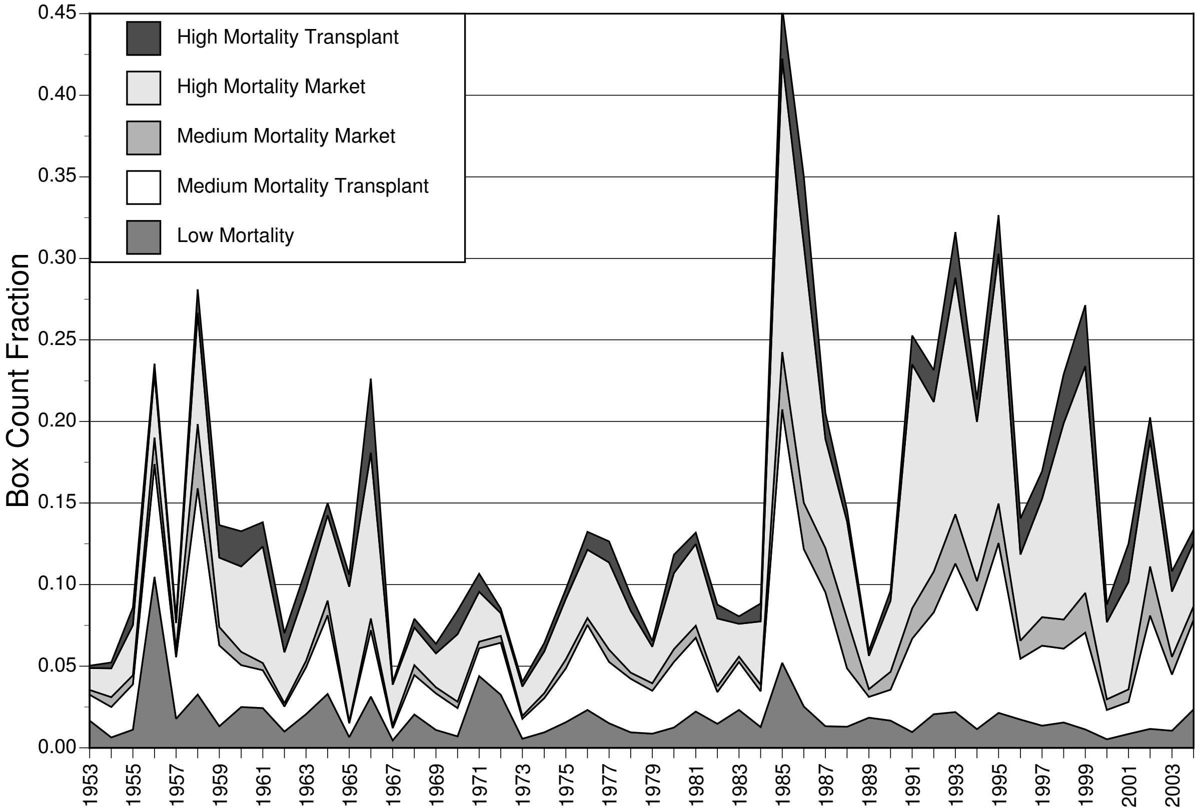

Figure 23. Broodstock-recruitment relationship for the 1953-2004 time period for the natural oyster beds of Delaware Bay.

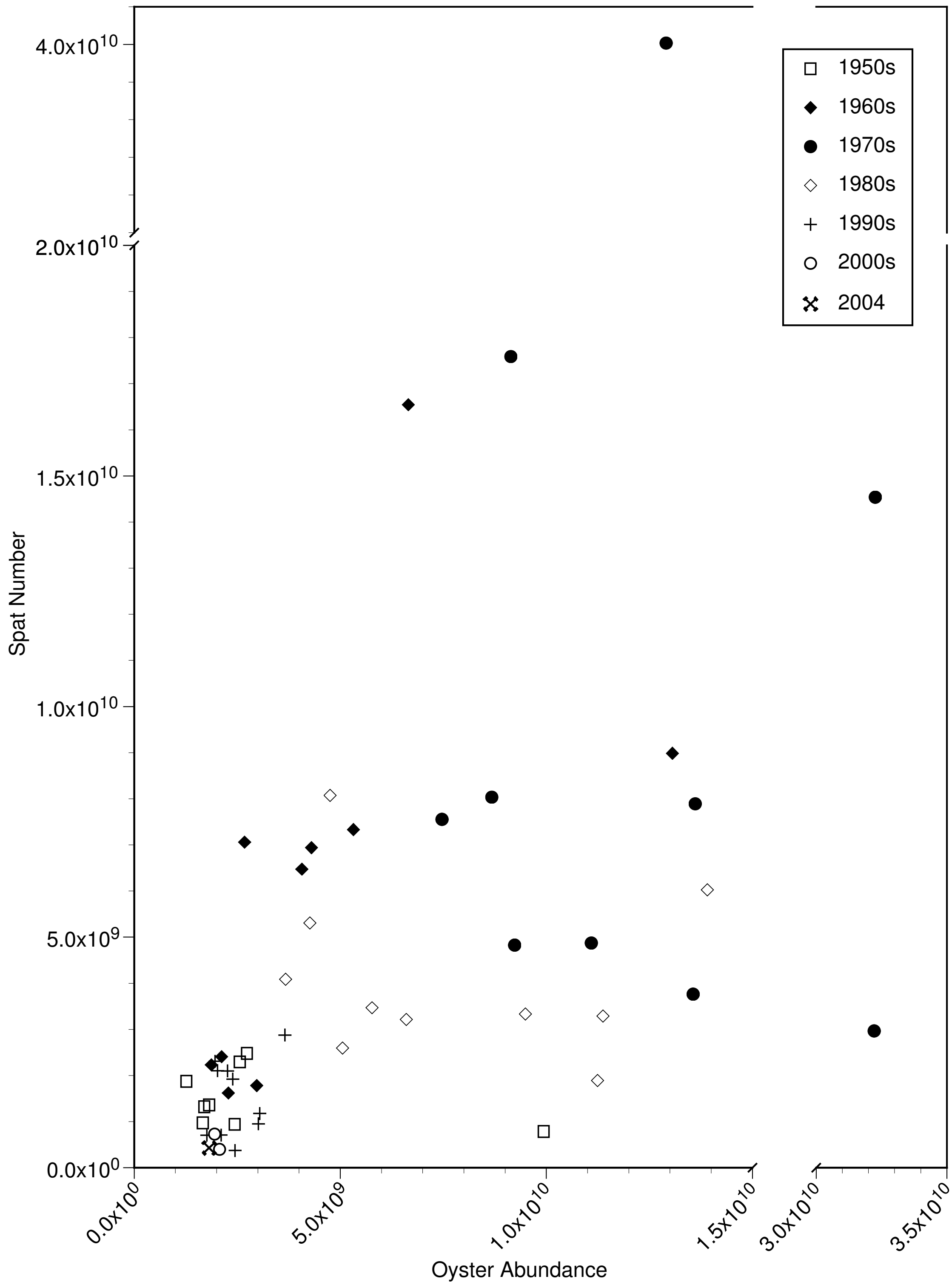

Figure 24. The relationship between recruitment and box-count mortality for the 1953-2004 time period for the natural oyster beds of Delaware Bay.

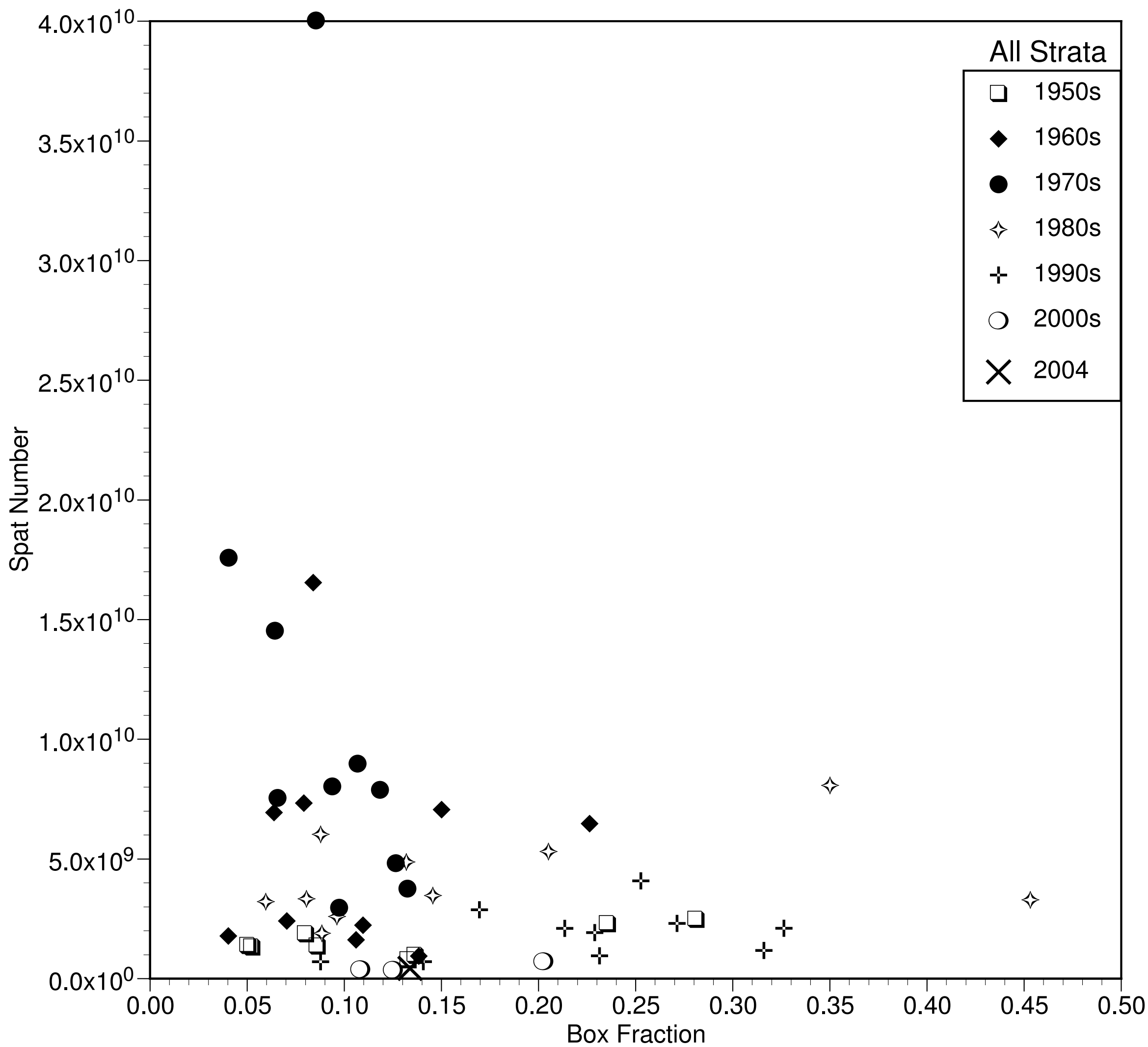

Figure 25. Average annual oyster and spat abundance (37-qt. bushel) for the Upper Central and Central region for the 1989-2004 time period. Upper Central = Upper Middle, Middle, Ship John, Cohansey, Shell Rock. Central = Bennies, Bennies Sand, Nantuxent, Hog Shoal, New Beds, Strawberry, Hawk's Nest, Beadons, Vexton. Underlined values are not significantly different according to 95% Least Significant Difference confidence intervals. Mean = average of annual values. * = means that are significantly different.

Upper Central Beds

Year	**2000**	**1996**	**1997**	**1992**	**1990**	**1991**	**1989**	**2003**	**1998**	**1993**	**2004**	**2002**	**2001**	**1999**	**1994**	**1995**	**Mean**
Oysters	321	309	265	244	255	222	214	213	193	190	180	167	155	153	143	138	206*
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Central Beds

Year	**1996**	**1989**	**1995**	**1990**	**1997**	**1992**	**1991**	**1998**	**2000**	**2001**	**1999**	**1993**	**1994**	**2003**	**2004**	**2002**	**Mean**
Oysters	153	105	95	91	91	91	84	80	80	79	78	55	52	44	38	28	76*
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Upper Central Beds

Year	**1999**	**1991**	**1995**	**1998**	**1994**	**1997**	**1990**	**2000**	**2002**	**1989**	**1993**	**2004**	**2003**	**1996**	**1992**	**2001**	**Mean**
Spat	351	307	179	169	140	113	103	78	75	70	60	34	29	28	28	17	106
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Central Beds

Year	**1991**	**1997**	**1999**	**1994**	**1998**	**1995**	**1990**	**1989**	**2000**	**1993**	**2004**	**2002**	**2003**	**1992**	**1996**	**2001**	**Mean**
Spat	273	221	166	166	146	137	107	70	69	46	29	25	23	21	16	15	92
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Figure 26. Number of oysters harvested from the natural oyster beds of Delaware Bay. Prior to 1996, the bay-season fishery removed oysters from the beds and transplanted them downbay to leased grounds. The direct-market fishery began in 1996. In 1997, an intermediate transplant program began. In this figure, since 1996, the total stock manipulation, including transplant and direct-market is identified as the apparent harvest; those oysters landed are identified as the real harvest. Zeros represent years of fishery closure.

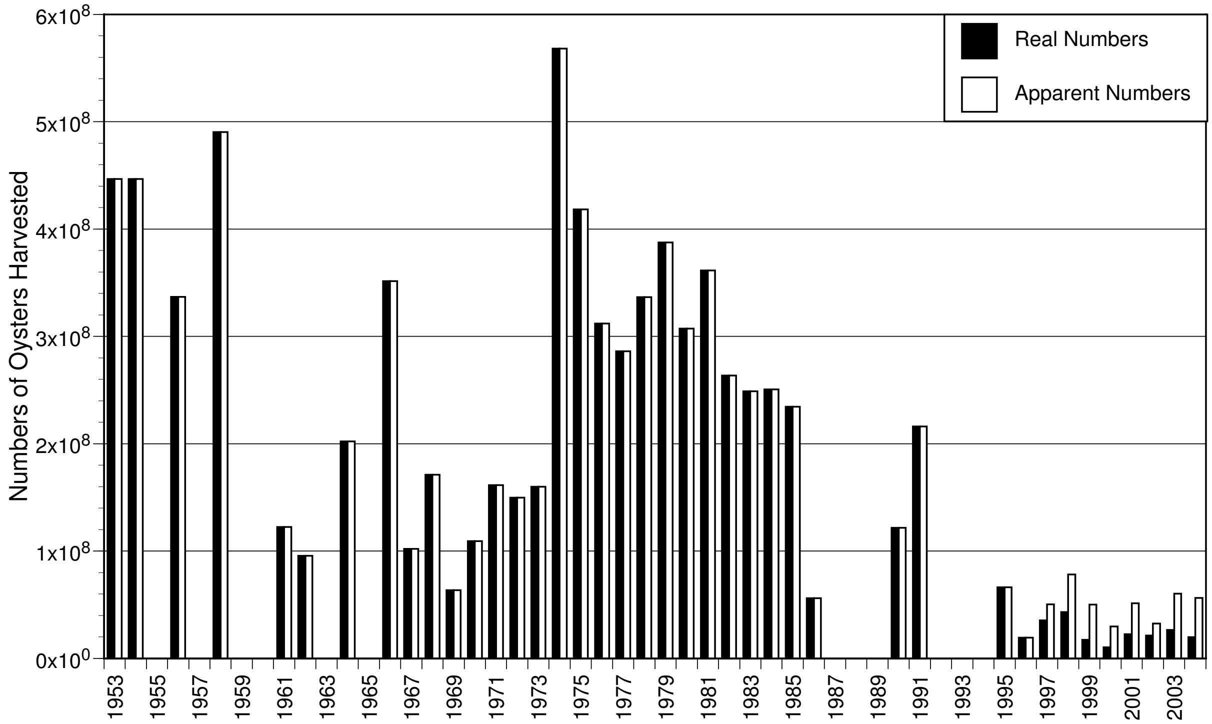

Figure 27. Weeks fished per year in the New Jersey oyster fishery in Delaware Bay.

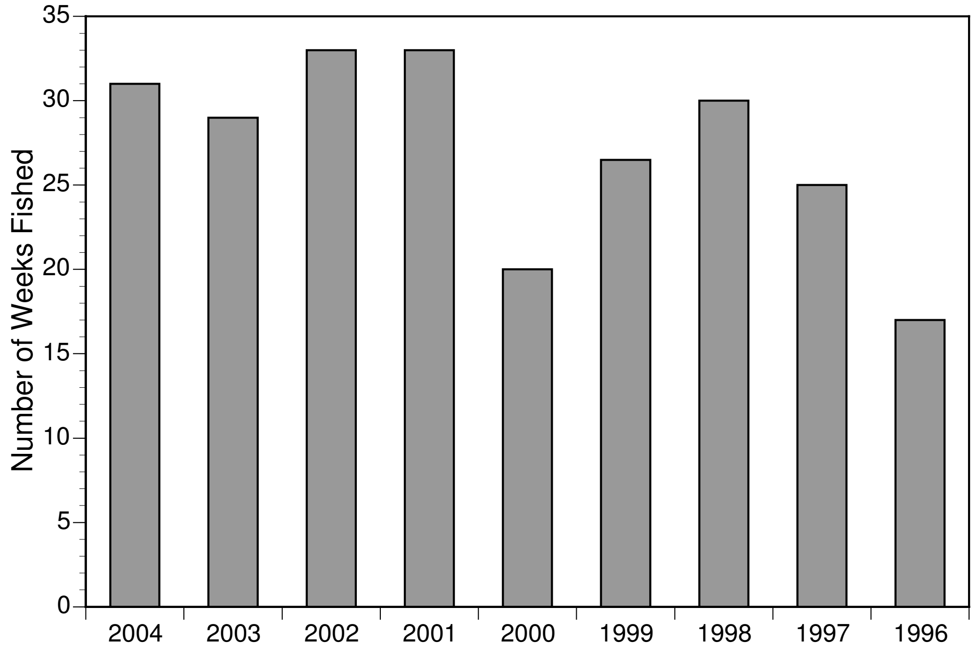

Figure 28. Catch (in bushels) per boat day.

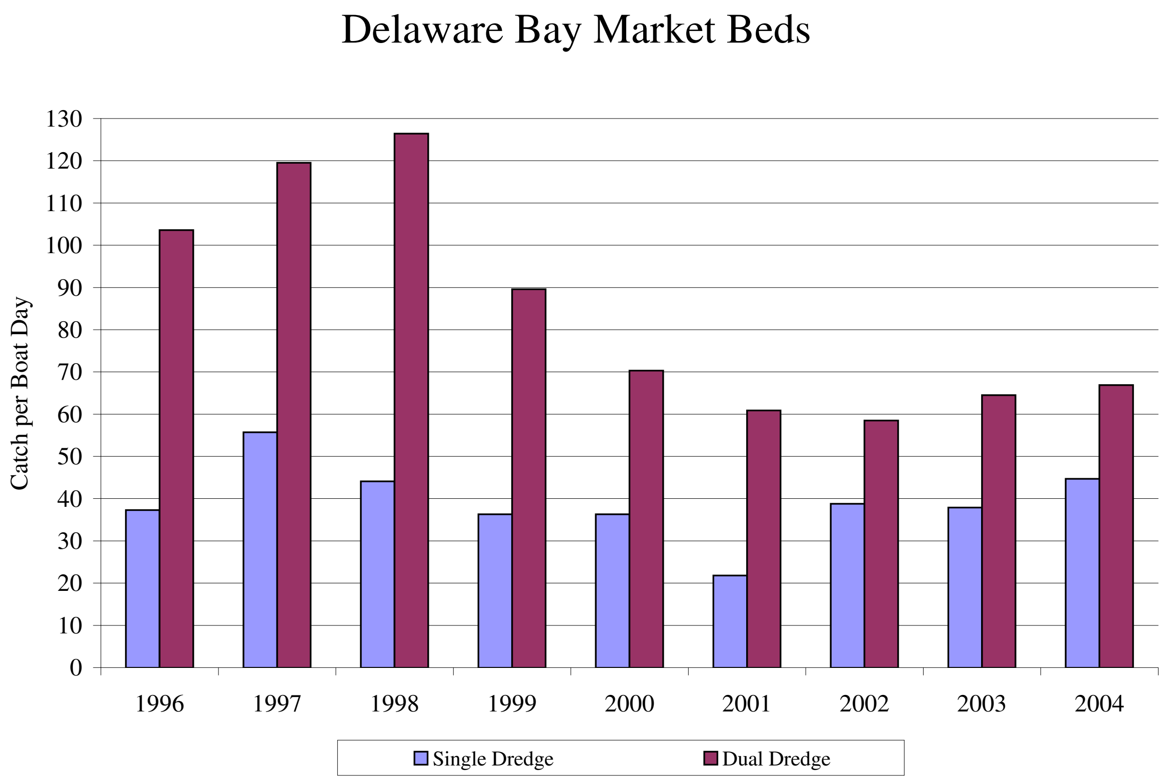

Figure 29. Oyster removals by bay region during the 1953-2004 time period. After 1996, the total reflects both the direct-market removals and those transplanted by the intermediate transplant program. Bed groups defined in Figure 8.

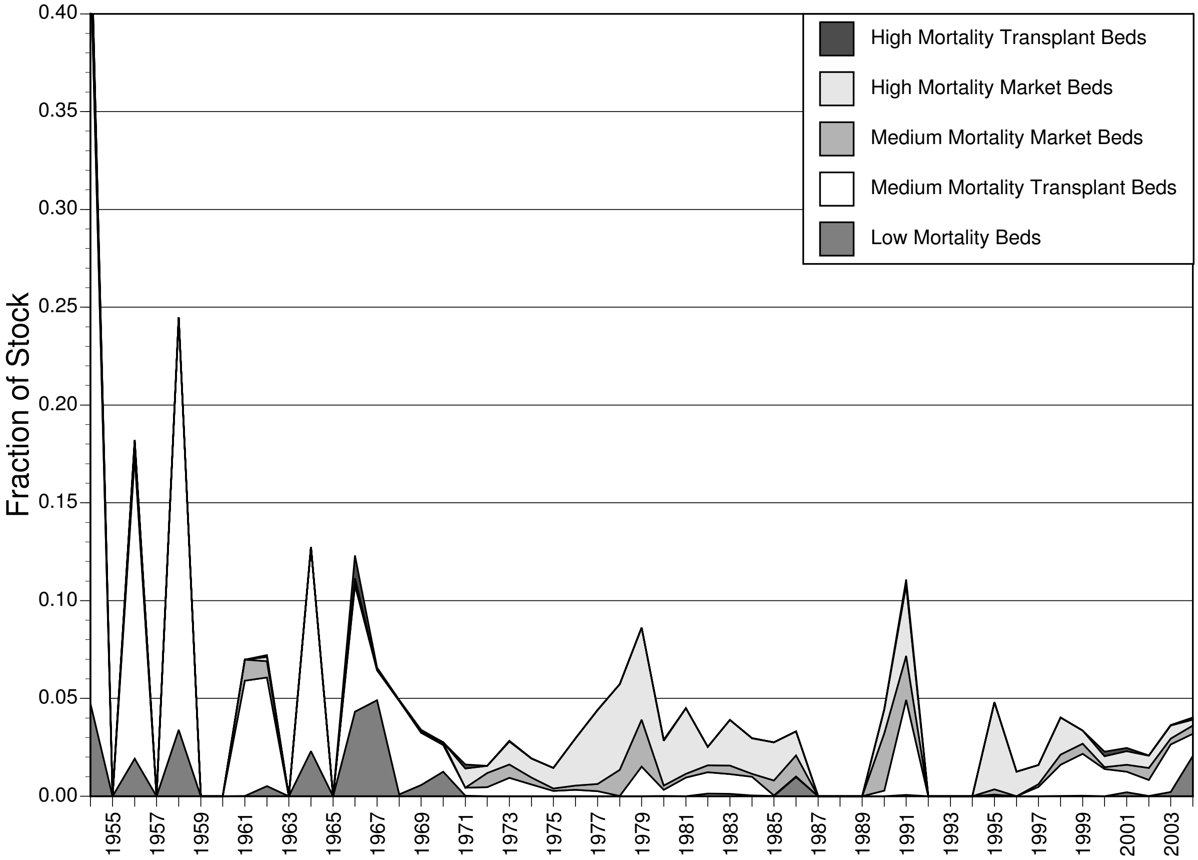

Figure 30. The fraction of the oyster population landed (real) and the fraction of the oyster population manipulated either by harvest or transplant (apparent).