Report of the
2004 Stock Assessment Workshop
for the
New Jersey Delaware Bay Oyster Seed Beds

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Executive Summary 2004 Stock Assessment Workshop

The stock assessment workshop utilized data from the historical record, the 2003 seed bed random sampling program, dredge efficiency studies, and a model to develop harvest allocations for the 2004 oyster season. The data and support documentation are provided in the following document.

Status of the Stock:

Oysters- Baywide oyster abundance remained about the same as last year. Market size (≥3") oyster abundance has been maintained on the Market beds (All below Shell Rock except Beadons and Nantuxent Point) by transplantation, and there is a continuing trend toward decreased submarket (2.5 to 2.99") oyster abundance on these beds. Due to poor spat sets and relatively good growth, the percentage of oysters > 2.5" has continued to increase in throughout much of the seed beds in past year. Few small oysters remain to replenish the larger individuals.

Market size oysters continue to be most abundant from Shell Rock up bay to Middle.

Oyster meat (Condition Index) remained about the same as last year.

Spat set was low throughout the bay for the fourth year in a row. The trend toward declining recruitment on beds in the Central portion of the bay (All beds below Shell Rock except for Egg Island and Ledge) is of major concern. In addition, the low spat counts and continued losses to dermo suggest that market and submarket oyster abundance can be expected to decline in 2005 and 2006, and perhaps 2007.

Box count mortality (natural mortality) was lower than last year in all regions of the bay except the Upper (Arnolds, Upper Arnolds and Round Island) area. Mortality became greater the farther down bay one progressed.

Dermo levels were much lower than last year. The reduced dermo intensity levels resulted in lower mortality and has helped sustain oyster abundance in the Central and Upper Central areas. Dermo prevalence remains high throughout the Central and Lower bay regions. As with mortality, percentage of oysters infected and the intensity of the infection became greater the farther down bay one progressed.

Harvest came mostly (88%) from Ship John, Bennies Sand, Shell Rock, Cohansey and Bennies, and reflects an up bay movement of harvest activity. The industry harvested nearly 83,500 bushels, 18.6% more than last year.

Catch per unit effort (CPUE) remained the same for single dredge boats and increased slightly for dual dredge boats, but has been relatively stable for the past two years.

Transplants came from Arnolds, Upper Middle, Middle and Cohansey, and nearly met the 90,000 bu. goal set by the Delaware Bay Shell Fisheries Council. The industry transplanted nearly 85,000 bu. These were planted on Bennies, Bennies Sand and New Beds.

Management Advice:

For model purposes, Direct Market beds are all beds below Ship John except Nantuxent and Beadons. Ship John, Cohansey, and Sea Breeze are Direct Market beds for 2004.

Market beds include both high-mortality and medium-mortality beds.

High-Mortality Direct Market beds are: Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Ledge, and Egg Island.

Medium-Mortality Direct Market beds are: Shell Rock, and additionally for 2004: Ship John, Cohansey, and Sea Breeze.

Direct Market Allocations are mostly based on a constant abundance goal and include, expected recruitment, natural mortality, and fishing mortality.

The majority of oysters available for Direct Market are on Shell Rock. Because the Direct Market allocation of oysters from beds below Shell Rock is so low, those beds are recommended for closure in 2004. To augment the Direct Market allocation, Ship John, Cohansey, and Sea Breeze are included in projections.

Recruitment was very low for the fourth year. Conservation of juveniles is essential.

Augment market beds with juvenile-targeted transplant and spat recruitment programs.

Area Management for Direct Market

1. Close all beds below Shell Rock for 2004.
2. Harvest Shell Rock's projected 18,313 allocated bushels by midsummer, and close Shell Rock for transplant. Re-open 6 weeks after transplant for an additional harvest of 6,911 bu.
3. Use Ship John, Cohansey, Sea Breeze as Direct Market beds to augment fishery and conserve juveniles. Projected allocation of 34,520 bushels. Close after reaching allocation.

Area Management for Transplant-(all transplants must be monitored carefully to verify numbers being moved.)

1. Transplant larger animals from Upper Middle/Middle to Shell Rock to augment 2004 direct market. Close Shell Rock for at least 6 weeks to allow conditioning of transplant.
2. Transplant without culling from Beadons and Nantuxent to closed High Mortality beds. If transplant occurs early (April), evaluate re-opening bed in 2005. If transplant occurs later, evaluate re-opening in 2006.
3. Transplant from Low Mortality beds (Round Island, Upper Arnolds, Arnolds) without culling to High Mortality beds as in 2.

Based on old 40% rule, all beds below Shell Rock would be closed in 2004.

There is no reason to change the 10° C rule to close the fall harvest.

An annual cultch management program is essential for long term resource viability.

Without transplants the high-mortality bed direct-market allocation in 2005 is likely to be zero.

An annual cultch management program to replace those shells being removed from the seed beds is essential for long term resource viability.

2004 Stock Assessment Workshop for the New Jersey Delaware Bay Oyster Seed Beds

Introduction

The natural oyster seed beds of the New Jersey portion of Delaware Bay (Figure 1) have been surveyed yearly, in the fall and/or winter, since the middle 1950's. 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 has been divided into a series of 25-acre grids. These grids fall into one of three strata. The strata consist of test, bed proper and bed margins. The test area typifies the highest quality areas of the bed (a high abundance of oysters 75% or more of the time). The bed proper is those sites at which oysters are abundant 25-75% of the time and the bed margin is areas that have an abundance of oysters less than 25% of the time. In 2002 a fourth strata was added to include the sites transplanted to by the intermediate transplant program. The survey consists of about 100 samples covering the primary and most of the minor seedbeds. 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, 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, and older oysters per composite bushel; the size of live oysters ≥20mm from the composite bushel; condition index and the intensity of dermo and MSX infections in oysters from selected beds. The data are normalized to a 37 quart bushel, because this approximates the size of a US Standard Bushel. Until 1999, the principal data used in management was based on the proportion of live oysters 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 projects have since been undertaken: dredge tow lengths were measured and recorded every 5 seconds by GPS navigation during the survey and separate dredge calibration studies were made. These new data were 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 on the seedbeds that was initiated in 1995. Prior to that time, the seed 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. The sampling on a number of beds was adjusted to 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).

This year we noted a discrepancy in the way the oyster statistics were being calculated between those in the Fegley et al (1994) summary and the way we are now proceeding. The former report utilized log transformations and harmonic means based on 20L while we have been utilizing arithmetic means based on bushel calculations. The former method reduces the impact of excessively large numbers (1972 set), but these data are not comparable to the current data series. We have calculated simple arithmetic means, based on the means of the bed groups, for the previous data for direct comparisons. We did not have time to revert to the entire data set so no 95% confidence limits were calculated. From 1957 to 1989, the bay-wide mean number of oysters per bushel was about 239, with the highest numbers on the upper beds and the lowest, on the lower beds (Table 2). During the past decade (1989 to 2003), the bay-wide overall mean of 143 oysters/bu. has varied little, and the changes, with the exception of the extremes (1989 and 1994), have not been statistically significant (Figure 2). The 1957-89 bay-wide mean spat/bu. was about 239, the same as the mean of oysters/bu., (Table 2), but with the very large 1972 set removed the bay-wide mean was 190 spat/bu. In the last decade and a half the bay-wide overall average has been 92 spat/bu., about half the earlier (1972 excluded) figure. The mean spat count for the 47 year period (1957 to 2003) is 196 spat/bu (161 spat/bu if the 1972 set is excluded). The maximum seed removed from the seedbeds by the industry during the past thirteen years was 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 early 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 oysters from the seedbeds was instituted in 1996, the greatest landings occurred in 1998 (136,000 bu.). The average yearly landing since 1996 has been slightly more than 78,700 bu.

Status of Stock and Fishery

Oyster Resource

Sampling in 2003 was conducted from October 27 to October 29 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. An additional category "transplant" was added to assure that oysters transplanted from Upper or Upper Central beds to Central beds are explicitly accounted for in the allocation of oysters to be harvested.

Because oysters are being sampled along a salinity gradient that reflects spat set, predation, disease and growth, combining the data into bay-wide statistics results in high variances. During the past fifteen years the seed bed region has experienced a nearly a two fold fluctuation in the number of oysters per bushel, but, with the exception of the highest and lowest values, no statistical differences exist (Figure 4). In 2003 there were 115 oysters/bu., about 80% of the 15 year bay-wide average of 143 oysters/bu. The bay-wide average number of 143 oysters/bu. in 2003 was about 68% of the long-term (1957-2003) average of 209 oysters/bu. Based on the "old rule" for bed closure, when a bed has most grids with <40% oyster by volume of an un-culled bushel sample, all beds below Shell Rock should be closed to harvest activities in 2004.

Beds in the Upper and Upper Central segments of the bay continue to support high oyster abundance for the 1989-2003 time series (Table 3). Most of these beds (except Upper Middle and Sea Breeze) have >180 oysters/bu. All beds in the Upper and Upper Central Region had more than half the grids sampled containing >40% oyster. Grids with a high percentage of oyster increased on Middle, Cohansey, and Shell Rock.

Two years ago, oyster abundance on beds in the Central and Lower segments of the bay fell into two groups; those that had retained high to moderate levels (>40%) of oysters (the inshore beds - Nantuxent Point, Hog Shoal, Vexton and Hawks Nest) and the remainder (Table 3). In 2003 only two grids below Shell Rock had > 40% oyster. These were on Bennies Sand and Nantuxent Point. The percentage of the number of oysters in the >2.5 inch categories was >50% on all beds in the Central and Lower areas with the exception of Nantuxent Point and Hog Shoal. The general trend for this increase in percentage of large oysters is continuing. During the past decade the percentage >2.5" had been in the 15 to 20% range on all of these beds. The recent increase in this percentage is primarily due to low recruitment and **not** because more large oysters are present. Last year **all** beds below Bennies Sand had low abundance, high dermo and a high percentage of oysters >2.5". This year the same general trend continues, but dermo levels (weighted prevalence) have declined on most beds

The important areas for the oyster industry are the beds in the Upper Central and Central region. Examination of the trends on the individual seedbeds indicates that these two regions have substantially different processes controlling oyster abundance (Figure 5). The average numbers of oysters on the Upper Central beds for the 1989 to 2003 period was statistically greater than for the Central beds (Figure 5). The spat set was not statistically different over the period (Figure 5); thus some factor or factors affected post-set survival differentially. This phenomenon is a continuation of the historical trend of differentiation between the bed groups and the factors that most affect post set survival are predation and disease.

In 2003 total oysters per bushel on the Upper Central beds and the heavily fished Market beds have remained the same as last year (Table 4, Figure 6). The numbers of market oysters/bu. and submarket oysters > 2.5 /bu. appear to have increased in the Upper Central beds (Figure 7) for the second year in a row. Due to the high variance last year this increase is not statistically significant. Reflecting the good growth of the past few years and regulated harvest to sustain market-size abundance, the numbers of market and submarket oysters on the Market beds remained about the same as last year. The percentage of the number of oysters/bu. > 3" and >2.5" remains high (>45%) in the Upper Central and Market areas of the bay (Figure 8). This reflects the combination of good growth and poor spat set of the last few years. Shell Rock has been of particular importance because this bed produced > 18 % of the direct market landings in 2003, and > 43% in 2002. Appreciable numbers of oysters continue on this bed. Spat set (only 54/bu.) was also highest on this bad. The total numbers of oysters on this bed reflect the reasonably good spat set in 2002 (212/bu.), and this is also evident in the percentage of oysters >2.5" declining from 50% to 36%. Most beds below Shell Rock continue to have few if any grids with > 40% oyster, few oysters/bu, low set, a high percentage of oysters > 2.5" and dermo levels, though down, still at nearly 100% prevalence. Spat set on these beds is only double the adult mortality (mean of 20.6 spat/bu. and mean of 10.1 dead adults/bu.), a recruitment rate not normally sufficient to sustain adult abundance.

Quantitative Estimates

Quantitative estimates of abundance include the high quality, test and transplanted areas only. Low quality areas have not been included in the quantitative data. These estimates generally mirror the trends observed in the oyster/bu. data presented above. An updated value of 317 was utilized to convert market-size and submarket-size abundance to market-bushel equivalents. Market-size oysters were defined as those ≥76.2 mm. Submarket-size oysters were defined according to the three growth rate groupings: 73.2 mm (low growth), 68.1 mm (medium growth), 65.0 mm (high growth). The correction for dredge efficiency used the size-class dependent dredge efficiencies and the differential in dredge efficiency between Upper and Lower beds. If a bed was not sampled in 2003, the value for 2002 was used.

Quantitative bay-wide oyster abundance used all information, but oysters sampled in transplant grids, and remained essentially unchanged from 2002. In 2003 oyster abundance on the Market beds remained about the same as in 2002.

The 1999-2003 quantitative time series, using standardized size classes defined as 20 – 63.4 mm (juveniles), 63.5-76.2 mm (submarkets), and >76.2 mm (markets), shows that market and submarket abundance change little on most beds (Figure 9). Juvenile abundance remained low. Total weighted abundance (markets + (submarkets/2)) computed on a per-bushel basis using the 1989-2003 time series, rose slightly from 2002, reaching the 70th percentile level for the time series, primarily due to transplant activities during 2003.

The 1999-2003 quantitative time series, using standardized size classes defined above shows a decline in market and submarket abundance on the medium mortality beds, primarily due to a drop in abundance on Ship John (Figure 10). Abundance still remains at historical high levels throughout this region. The abundance decline was anticipated based on the ratio of submarket to market-size animals in the 2002 survey. Juvenile abundance continued a 4-year decline. Total weighted abundance (Markets+(submarkets/2)), computed on a per-bushel basis using the 1989-2003 time series, on the Upper Central (medium mortality) transplant beds rose to record highs (Figure 11). The 2003 abundance was at the 100th percentile for the time series and 141% above the 2002 values. This increase was at the 70th percentile rate observed during the time series.

The 1999-2003 quantitative time series, using standardized size classes defined above shows a decline in market and submarket abundance on the low-mortality beds, primarily due to a drop in abundance on Arnolds since 2001(Figure 12). Declines in all size classes were noted on Arnolds since 2002. Total weighted abundance (Markets+(submarkets/2)), computed on a per-bushel basis using the 1989-2003 time series, on the low mortality transplant beds is at the 25th percentile of abundance is low for the time series (Figure 11).

Only a limited number of juvenile oysters remain on some market beds and the number of submarkets continues to decline, as predicted last year (Figure 13). The supply of juveniles is now so meager that natural production on the market beds in 2004 will not sustain a fishery.

The relatively high proportion of market-size animals (relative to the submarket-size animals) is now present over much for the bay from Egg Island upbay to Middle. This type of size-frequency distribution is not sustainable under normal natural mortality rates in the Cohansey-Ship John area and barely sustainable below Shell Rock. The management plan designed to achieve a no net reduction in the number of market size oysters on the market beds at the end of the year has been met reasonably successfully in 2000-2003.

Oyster Condition

On a bay-wide basis, condition index was the same as last year (Figure 14). Data from the Lower area are not available this year because too few oysters were collected.

Spat Set

Spat set in 2003 dropped relative to 2002 (Table 3, Figure 15) and continues the poor setting for the fourth consecutive year. The bay wide 2003 spat counts (mean = 22/bu.) were far below the long term mean of 196 spat/bu., and well below the 92 spat/bu. (1989-2003) mean. Spat set was 50 spat /bu.or higher on only one bed – Shell Rock, and was 35 spat/bu. or higher only on Shell Rock, Bennies Sand and Nantuxent Point (Table 3). Typically, some of the inshore beds of the Central Region (Nantuxent, Hog Shoal, Strawberry, Hawks Nest, Beadons and Vexton) receive a good set, but this did not materialize this year. Only Nantuxent Point received >45 spat/bu. On a longer-term perspective, spat settlement for the period of 1997 to 1999 was at the upper end of the 12-year range with adequate sets in 1994 and 1995 as well (Figures 4 and 15). This was also a decade when the mean spat fall was only 47% (57% if the 1972 data are included) of the 47 year long term average. The past four year period of very low spat set is unprecedented in the 1957 to 2003 time series (Figure 16), but a period of low (*vs* very low) set also occurred from 1959 to 1963 (Figure 16). It is the 1994-1999 period of better than average spat set that has been supporting the current harvests, and is why, with the lack of substantial set in the past four years, the percentage of large oysters is increasing.

Mortality and Disease

Since the onset of the dermo (*Perkinsus marinus*) epizootic in 1990, average mortality on the seed beds, as assessed by total box counts during the fall survey, has fallen into 3 major groups: Upper, Upper Central and Central/Lower. Lowest dermo levels have occurred on the Upper beds, and 2003 was no exception (Table 3, Figure 17). The 1990-2003 mean annual percent mortality was 30% ± 6.5% (95% CI). This year mortality was lower in all regions except the Upper seed beds where it remained low. In the Upper Central region oyster mortality appears to have dropped by about 50% from 2002 to 2003. Mortality also decreased in the Central region, and was <45% on all beds. A cluster of beds including New Beds, Strawberry, Hawk's Nest, Beadons, Vexton and Hog Shoal were the only beds with > 40% mortality and all were in the range of 35 to 44 % mortality (Table 3). Bennies and Bennies Sand experienced somewhat less mortality.

Quantitatively natural mortality rate reached a decadal high on the high mortality beds in 2002, and the natural mortality rate on the medium-mortality beds was at or near average (50th percentile) levels for the 1990-2002 time series in 2002. Natural mortality rate in both these groupings dropped substantially in 2003, coming in at the 33rd percentile in the time series (Figure 18).

The natural mortality rate on the low-mortality beds was below average (near the 25th percentile) levels for the 1990-2002 time series in 2002. Natural mortality rate dropped to the 20th percentile of the time series in 2003 (Figure 18).

Dermo, *P. marinus,* prevalence (the percentage of infected oysters) and weighted prevalence (the average infection intensity of all oysters examined with intensity ranked from zero (uninfected) to 5 (heavily infected)) are measured on most beds during the fall random sampling survey. For both measures the seedbeds continue to fall into three major groupings identified since 1990: Upper (Round Island, Upper Arnolds and Arnolds), Upper Central (Upper

Middle, Middle, Ship John, Cohansey and Shell Rock), Central (all beds below Shell Rock, and including the Lower area of Ledge and Egg Island). The long-term (1990-2003) bed and bay-wide average prevalence and weighted prevalence are depicted in Figures 19 and 20. The mean long-term prevalence of dermo across all beds was 75% ± 11% (95%CI). Mean long-term weighted prevalence of dermo across all beds was 2.2 ± 0.4 (95%CI). The patterns for dermo and mortality are strikingly similar with both increasing from Upper to Lower beds (Figures 17 to 20 and Table 3). The beds in each grouping tend to be similar, and dermo continues to be the primary source of adult oyster mortality on the seedbeds. The similarity among plots highlights the relationship between dermo prevalence, dermo infection intensity and oyster mortality.

Figures 19 and 20 summarize the annual changes in dermo prevalence and weighted prevalence since 1990. In 2003, prevalence remained high on average, but was slightly below the long-term mean on beds in the Upper Central and Central regions. The high prevalence in these regions indicates that the disease will likely remain widespread among oysters in these areas. Prevalence was much lower (27%) in the Upper region. Infection levels were down throughout the beds during 2003 compared with the long-term averages. This decrease was likely a result of a colder and longer winter and a wet spring during 2002-2003.

Harvest and Transplant

Harvest

Based on a provision of a 65,000 or 85,000 bu. spring transplant program from Upper Central bay beds to Central bay beds, the SAW 2003 recommended a prorated harvest limit of between 39,000 and 45,000 bu. This could be supplemented by an additional harvest from Ship John if it was not utilized in the transplant program. An additional fall transplant of 27,000 bu. from the Upper Central region plus some allocation from the medium mortality beds was recommended to augment the 2004 harvest.

Most oysters were harvested from the high-mortality direct-market beds prior to 2003. Persistent low recruitment has eliminated surplus production on these beds. As a consequence, the 2003 SAW recommended that direct marketing extend to Ship John and Cohansey, **beds previously reserved for transplant**. Area-management to assure some harvest on Shell Rock and on these 'transplant' beds was successful in 2003.

Beds were harvested almost continually from April 14 to November 22, 2003 with the exception of 3 weeks required for the transplants. The 29 weeks of fishing this year were slightly less than the 33 weeks last year, 20 in 2000, 26.5 in 1999, 30 in 1998, 17 in 1996, and 25 in 1997. In 2003 the beds contributing to the harvest were more evenly distributed, but generally reflected an up bay movement of harvest activity. In 2002 the beds supplying most of the market size (> 3") oysters were: Shell Rock, New Beds, Hog Shoal, Bennies, and Bennies Sand, while in 2003 Ship John, Bennies Sand, Shell Rock, Cohansey, and Bennies supplied most of the oysters (Table 5). Harvest was from 14 beds and totaled 83,497 bushels (Figure 3). Five beds accounted for nearly 88% of harvest (Bennies (12.7%), Cohansey (17.3%), Shell Rock (18.4%), Bennies Sand (19.4%) and Ship John (20.11%))(Table 5). Thirty-five boats participated in the fishery and worked for a total of 1,471 boat days. After dropping for 4 consecutive years, the catch per boat day for dual dredge boats rebounded to nearly 70 bu/day about the 2000 level (Figure 21). The catch per boat day for single dredge boats was similar to that of last year.

Total dredging impact was estimated. Six beds were covered by dredging more than once during 2003: Bennies Sand, Vexton, Bennies, Shell Rock, Ship John and Cohansey. For Bennies Sand, Shell Rock, Ship John and Cohansey, dredge coverage exceeded 3 times the bed area. For Bennies and Bennies Sand, some increased coverage occurred because these beds were deployment beds for the industry transplant program.

Transplant

Transplantation from up bay beds to replace those being harvested was recommended by the 2003 SAW. For 2003 this amount was 30,000 bu. in both April and June (Table 6), and 30,000 bu. for a fall transplant in September. These recommendations were based on the monies available and the spring transplant goals were met, but the fall transplant moved about 80% of the allocation (Table 6). Between 1997 and 2003, about 291,292 bu. of material was moved from Upper Central and inshore Central beds. The Upper Central region supplied all of the transplanted and > 65% of market oysters this past year. Last year it supplied all of the transplants and 46.2 % of the market oysters (43.6 % from Shell Rock). About 66% more oysters were transplanted in 2003 compared to last year (Tables 5 and 6). In 2003 part or all of New Bed (grids 50, 51, 52, 64 and 65), Bennies (grids 86, 97, 98, 99, 100, 101, 111, 112 and 113) and Bennies Sand (grids 12 and 13) were potentially impacted. A new comparison of the effectiveness of culling indicates that it concentrates larger oysters about 2-3 times, but the dredge, as currently used, concentrates small oysters relative to what is on the bottom. The net effect is that the overall deck load resembles what is on the bottom. Thus, transplants involve oysters of all sizes, and not just those in the market and submarket categories. In 2003 oysters were transplanted in April and June and were placed on Bennies and Bennies Sand. These oysters came from three beds: Upper Middle, Middle and Cohansey. Fall transplants in September came from the same beds plus Arnolds and were placed on Bennies and New Beds. Of the grids sampled in 2003, only grid 99 and 86 of Bennies, grid 12 of Bennies Sand and grid 51 of New Beds received oysters. It was not readily apparent that the sample from any of these grids was substantially different from the remainder of the samples based on the number of oysters collected or the size of the oysters in the sample. This condition may be due to at least two factors, the dispersion of oysters over a large area, and/orsome of the grids were open for harvest and numbers of oysters were reduced. The lack of size differentiation is not surprising given that the numbers of oysters sampled was not different and that the size frequency distributions of oysters on these beds are not greatly different (Table 4). The transplant to Bennies Sand grid 12 increased the numbers of oysters and the percentage of oysters to a slightly greater extent than transplants to other grids so it was removed from some summary calculations.

Other Studies

One other study was initiated this year. We investigated the relative benefits of using a traditional oyster dredge and a suction dredge in a transplant program. The traditional oyster dredge, when towed in survey mode, short tows in which the dredge is retrieved without filling the bag, is 15% to >50% efficient. When used in transplant operations, dredge efficiency was lower, ~5%, and about 100 bushels of material was loaded per hectare swept. The tendency for the dredge to preferentially catch larger particles was negated by the amount of time the dredge remained on the bottom. Once on board culling machines caused deck loads contained a factor of 2 to 3 more oysters per bushel than present on the bottom. The suction dredge operated very differently, and without culling the deck loads contained 1 to 3 times as many oysters as were present on the bottom. Catch efficiencies were high, between 19% and 58%. Total swept area per bushel loaded was much lower, about 600 bushels being loaded per hectare swept. Catch efficiencies were highest for small particles.

Dredge efficiency rose markedly after transplanting, from 6% to 28% on the plots worked by the traditional oyster dredge and from 11% to 56% on the plots worked by the suction dredge. Neither method proved deleterious to bottom complexity, cultch availability, or population attributes. To the degree that the sampling program could identify and track the transplanted oysters, oysters transplanted by the two methods did not vary in growth, mortality, or health. In a sustainable transplant, the number of small oysters and amount of cultch moved downbay should be minimized. This goal was not achieved. The suction dredge, by selective removal of smaller particles enriched in juveniles and cultch, risks a long-term decline in live oyster abundance and shell coverage. The traditional oyster dredge has the inherent capability of concentrating larger animals, but, as used in the transplant process, much of the selective advantage disappears. A behavioral shift to exploit the desirable selective advantage of the traditional oyster dredge may improve the efficiency of the transplant program.

A request of the 2003 SAW was to evaluate the long term data for possible spawner recruit relationships. We have provided this diagram for the 1957 to 2003 data (Figure 22). The data will require further evaluation before it can be utilized within context of a management discussion.

Management Advice

2004 Direct-Market Allocation from Direct-Market Beds—Implementation

Projections were made based on the management plan developed by the 2000 SAW (Stock Assessment Workshop). Under this plan, the goal for managing the direct-market beds is to achieve no net reduction in the number of market-size oysters at the end of the year. This is the 'constant market-size abundance' reference point. That is, the number of oysters at the end of the year should 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 goal has been met reasonably successfully in 2000-2003 (Figures 9, 10, 12, 13). This year a unique combination of low recruitment, historically high abundance **and** a highly skewed size frequency distribution has led to and examination of a different allocation scheme on a few selected beds (see below).

The following beds were considered direct-market beds: Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Ledge, and Egg Island. The potential use of Ship John, Cohansey, and Sea Breeze to enhance the direct-market program will be considered in a subsequent section.

Estimates of abundance on the direct-market beds were obtained from the 2003 survey and were based solely on the high quality, test, and transplant grids (Table 8). Low quality areas were not included. A few beds were not sampled in 2003. In these cases, data from 2002 were used without corrections for potential mortality or fishing. The correction for dredge efficiency used the size-class dependent dredge efficiencies and the differential in dredge efficiency between upper and lower beds formulated by the 2001 SAW.

The continued adequacy of the catchability coefficients (= 1/dredge efficiency) were examined for two beds with the highest abundance and greatest change in fishing impact between 2002 and 2003, Cohansey and Ship John. The catchability coefficients for submarket and market-size oysters for the Cohansey/Ship John area from previous measurements were 6.89 and 6.93 respectively. Estimates of dredge efficiency during last year's transplant project on Cohansey yielded a similar average catchability coefficient of 6.04. Updated numbers from a larger experiment are still under analysis, but the average for Ship John and Cohansey market-size oysters is 7.4. As a consequence, updated catchability coefficients have not been used.

Market-size oysters were defined as those ≥76 mm (3 inches). Conversion of numbers of oysters to bushels used an updated value of 317 market-size oysters per bushel from data collected during the Fall of 2001 (2002 SAW) and 2003.

The numerical model used by the 2001- 2003 SAWs was applied to this assessment. The model includes recruitment to the fishery, natural mortality, and fishing mortality. Mortality is introduced into the model as a time-varying function that permits the rate of natural and fishing mortality to vary during the year and independently of each other. The model requires input of the number of market and submarket-size oysters, the periods of mortality, and an anticipated rate of natural mortality. The model then estimates the amount of fishing mortality that would balance abundance over the year. From that, the model provides an estimate of harvest consistent with the management goal described earlier.

Direct-market calculations were made using the assumption that natural mortality was lower on Shell Rock than on the other direct-market beds. Based on recommendations from the 2001 SAW, natural mortality rate was set at the 75th percentile of observed yearly mortality rates since 1989. These percentiles were updated using the entire 1989-2003 time series (Figure 21). The 75th percentiles of natural mortality were: 0.480 yr^{-1} for the high-mortality beds and 0.268 yr^{-1} for Shell Rock. Growth rates, obtained from field observations in 2001, were used to estimate the smallest oyster expected to recruit to the fishery in 2004. This size boundary was set at 65 mm (2.56 inches) for the high-mortality beds and 68 mm (2.68 inches) for Shell Rock. A single fishing scenario was investigated: a continuous season (April 1-November 15). We emphasize that 2001 was apparently a "good" growth year and that a precautionary approach to interpretation of data based on this one study should be applied until additional growth data can be obtained.

A recommendation of the 2003 SAW to develop an estimate of confidence intervals on abundance was implemented using a Monte Carlo scheme. This approach used the results of each of the tows within beds and within strata to develop a series of random combinations or simulated surveys. Randomization of size class data within samples was not included. Each random draw of survey samples was then corrected for dredge efficiency using a randomly chosen efficiency from the list of efficiency measurements from the 2000 SAW. Samples from the 1000 simulated surveys were subsequently averaged over stratum and summed over bed. Based on the standard NOAA stock assessment protocol the 20th and 80th percentile confidence limits were selected and are provided throughout the 2003 assessment. These confidence limits will require regular updating on beds providing a majority of the harvest.

2004 Direct-Market Allocation from Direct-Market Beds—Projections

As predicted by the 2003 SAW, only a minimal allocation of 720 bushels is available this year from natural production on the direct-market beds. The SARC (Stock Assessment Review Committee) recommends that the direct-market beds downbay of Shell Rock be closed for the 2004 harvest season to maintain the constant market-size abundance goal. This includes the September, 2003 transplant which should be used to maintain abundance on these beds through 2004, rather than being harvested.

Shell Rock continues to be productive. The projected 2004 allocation under the constant market-size abundance reference point for Shell Rock is 18,313 bushels.

Abundance Level	Allocation (market-equivalent bushels)
20th Percentile	12,152
Mean	18,313
80th Percentile	19,930

The SARC recommends that the mean value be used in this and all subsequent projections for setting the 2004 allocation. The SARC emphasizes the necessity of limiting fishing on Shell Rock to this recommended level, since Shell Rock contains a large fraction of the total available oysters for harvest and is anticipated to continue to be productive in 2005.

Necessity of Juvenile Conservation During a Period of Low Recruitment

Four years of low recruitment mean that the long-term viability of the industry is in jeopardy. The SARC recommends that emphasis be placed on measures that will conserve juveniles, thereby preserving future surplus production.

Only a limited number of juvenile oysters remain on some direct-market beds and the number of submarkets continues to decline, as predicted at the 2003 SAW. The supply of juveniles is now so meager as to make it likely that natural production on the high-mortality direct-market beds in 2004 will not sustain a fishery in 2005. Continued closure of the high-mortality direct-market beds in 2005 can be anticipated without augmentation of oyster abundance through a significant transplant or shell-planting program. Juvenile oysters on the high-mortality transplant beds could be moved to the market beds without sustaining additional natural mortality losses. This would conserve juveniles and augment the market beds.

Juvenile abundance continues to decline on beds upbay of Shell Rock as well. The short-term viability of the fishery depends on direct marketing from the medium-mortality transplant beds. The use of medium-mortality transplant beds for direct marketing is the most conservative option biologically with the advantage of focusing on the market-size animals that are presently at high abundance on these beds, in combination with transplant. This is only possible because of a unique combination of a fifteen year historical high abundance **and** a size frequency distribution that is highly skewed toward larger animals. Limiting the total number of juveniles transplanted downbay from the medium-mortality beds by including a direct-market program for part of this resource is essential because it limits mortality of the juveniles at a time when they are scarce.

Although difficult to predict precisely, clearly no long-term management strategy exists to maintain industry integrity without an increase in recruitment. Establishment of a recruitment augmentation program is essential if the industry is going to remain viable while natural recruitment rates are low. Otherwise, population stability can only be obtained by reducing fishing mortality to near zero.

Recommended Addition to the 2004 Direct Market Program

The SARC recommends using Cohansey, Ship John, and Sea Breeze as direct-market beds in 2004. This would conserve juveniles on these beds that might otherwise be lost by transplant to a higher mortality bed downbay, yet it would augment the 2004 allocation. These beds are presently characterized by a ratio of submarket-to-market-size animals that will result in a natural decline in market-size abundance in 2004 if the rate of natural mortality is above the 25^{th} percentile of the 1989-2003 time series. As a consequence, setting an allocation somewhat in excess of the constant-abundance reference point is temporarily advantageous. The SARC notes that these beds are presently at the 100^{th} percentile of abundance in the 1989-2003 time series, but that the 75^{th} percentile abundance level is relatively near the 50^{th} percentile abundance level (Figure 11). Thus, the SARC recommends limiting harvest to levels that retain abundance well above the 75^{th} percentile level of the time series. Given the unique characteristics that exist the 80^{th} percentile is considered to be well above the 75^{th} (Figure 23).

Projections for a 2004 allocation from Cohansey, Ship John, and Sea Breeze were run under the conditions used for Shell Rock with two exceptions. Growth rates, obtained from field observations in 2001, were lower on these beds. The size boundary for submarket-size individuals was set at 73 mm (2.87 inches). In addition, the constant market-size abundance reference point was relaxed using the proviso that market-size abundance should not drop below the 80^{th} percentile of abundance in the 1989-2003 time series. The projected 2004 direct-market allocation for these beds is as follows.

Abundance Level	Allocation (market-equivalent bushels)
20th Percentile	29,772
Mean	34,520
80th Percentile	37,310

The SARC recommends setting the allocation at the mean abundance value. In addition, the SARC recommends using an intermediate transplant from Upper Middle and Middle to Shell Rock to augment the 2004 allocation. It is anticipated that Shell Rock will close in mid-summer. This transplant should occur after the closure and the bed should remain closed for no less than an additional six weeks before permitting harvest. Projections for this allocation are provided later under the transplant section.

Recommended 2004 Transplant Program—Implementation of Projections

Transplant beds are divided into three groups based on their natural mortality rates as recommended by the 2001 SAW. These were (1) low mortality beds: Round Island, Upper Arnolds and Arnolds; (2) medium mortality beds: Upper Middle, Middle (Cohansey, Sea Breeze, and Ship John are recommended to be reserved for direct marketing); (3) high mortality beds: Nantuxent Point and Beadons.

Data collected from transplant deckloads during an experiment in 2003 showed that dredging and culling the material concentrates oysters with respect to cultch, but large oysters were not concentrated more than small oysters. The size-frequency distribution in the deckload was nearly the same as that on the bottom, as determined from diver samples. On the other hand, the deck loads were concentrated in live oysters versus cultch. No mechanism exists presently to estimate the concentration factor from bottom to deck *a priori*. We used the average number of oysters per deck-load bushel instead. The average over all three transplants was 370.7 individuals per deck-load bushel. This value was used in further calculations. For transplants targeting market-size animals, the value of 132 submarket + market animals per bushel, derived from the same data set was also used. This value is based on the average numbers from the 2003 transplants. Close monitoring of total oysters moved downbay in 2004 is essential to update per-bushel estimates so that the proper number of animals is moved.

In the absence of a concentration mechanism for large oysters, a precautionary approach must be used to limit total impact on juveniles in any transplant not focused on juvenile augmentation and to achieve population sustainability. The 10% rule would appear to be a reasonable approach. It is based on the fact that average age does not exceed 6 years, so that a 10% replacement rate is well within the beds long-term capacities. This approach was recommended by the 2003 SAW who also noted that median yearly mortality rates are 0.188 (medium-mortality transplant beds) and 0.113 (low-mortality transplant beds). Setting a transplant rate at something less than the natural mortality rate is probably within the replacement capacity of these beds. All transplant projections utilize the 10% removal rate.

The SARC emphasizes the desirability of limiting the amount of cultch and juvenile oysters transplanted downbay unless the transplant is specifically designed as a juvenile augmentation program. The suction dredge, as presently configured, should not be used for transplant unless juvenile augmentation is the goal. If it is, the suction dredge should be considered, because the transplant goal might be achieved at lower cost and the transplant is more easily monitored. In addition, the SARC strongly recommends that any transplant to augment the 2004 season should include at least a 6-week bed closure to permit an increase in condition, and any transplant targeting the movement of juveniles should include minimally a 1-year (full growing season) closure.

Recommended 2004 Transplant Program -- Projections, Goals, and Timing

Any transplant designed to augment the 2004 allocation should target the larger animals on Middle and Upper Middle beds. The SARC recommends that this transplant should move oysters to Shell Rock and should occur shortly after the Shell Rock direct market closes, anticipated to be in mid-summer. This approach will minimize juvenile mortality because rates of natural mortality are lower on Shell Rock than downbay while permitting an increase in condition. A minimal six-week closure would be necessary after this transplant. Because of the bias of the suction dredge in favor of juveniles, this transplant can only be done with a traditional oyster dredge and culling machines.

The projection for a transplant from Middle and Upper Middle to Shell Rock uses the 10% rule and the previously estimated 370.7 oysters per deck-load bushel. Given the uncertainty of the deck-load estimate of 370.7 oysters/bu., the transplant will need to be carefully monitored.

The SARC recommends two transplants for juvenile augmentation designed to provide oysters for marketing in 2005/2006. Both transplants should go to high-mortality, direct-market beds (e.g., Bennies, New Beds) and both should be closed for minimally one full growing season. The SARC notes that the high-mortality direct-market beds are likely to be closed in 2004, thereby accomplishing this goal.

Source beds to be used for juvenile augmentation are Nantuxent Point, Beadons, Arnolds, Upper Arnolds, and Round Island. Projections use the 10% rule and the SARC recommends that a suction dredge be considered. If traditional oyster dredges are used, culling machines should not be used. If the 2004 closure of the high-mortality direct-market beds is also meant to serve as a closure for these transplants, this transplant should occur as early in April as is feasible. If no transplants are placed on the high mortality direct-market beds in spring, continuing the closure into the 2005 season will need to be considered. An alternative is to conduct this transplant in October with the understanding that the receiving beds would be closed during 2005. The SARC reiterates that, because the volume of transplant is estimated from a quantitative stock abundance value converted to bushels by conversions that are highly variable, any transplant must be monitored to make sure that the total number of oysters moved downbay does not exceed recommended quantities. Because of the critical nature of these data and the necessity of using the data in real time during the transplant, a sample should be taken from each deck load and analyzed within 24 hr. All samples must be taken daily and should be a haphazard sample taken from traditional oysters dredge boats and a portion of the deck load from the suction boat.

	Oyster Abundance Juveniles 10% Allocation	Oyster Abundance Submarket+Market 10% Allocation	Deck-Load Equivalent Bushels
Low-Mortality Transplant Beds	43,431,219	392,129	118,217
Medium-Mortality Transplant Beds			
Middle/Upper Middle			
370.7 oysters/bu assumed	11,826,333	2,578,793	39,649
132 marketable/bu assumed			19,536
High-Mortality Transplant Beds	2,523,002	520,989	8,211
Estimated Total Deck-Load Bushels			166,077
or using the 132 value			
Estimated Total Deck-Load Bushels			145,964

The rate of natural mortality increases incrementally downbay as salinity increases. The transplanted oysters should be moved as short a distance downbay as possible to reduce the increment in mortality rate. Transplants from Beadons and Nantuxent Point to offshore beds achieve this goal, as does the transplant from Middle/Upper Middle to Shell Rock. The SARC recognizes that the transplant from Arnolds/Upper Arnolds/Round Island will substantially increase mortality rates and recommends that the transplant be placed on beds downbay of Shell Rock with the lowest average mortality rates.

Because the survey now explicitly contains transplant grids as a stratum, the SARC strongly urges NJDEP to continue to designate areas for transplanting using the grid system by buoying off destination grids that avoid using partial grids as much as is fesible. This will permit increased accuracy in estimating the 2005 allocation. Accomplishing this is particularly necessary to adequately assess the results of the juvenile augmentation program recommended herein.

Finally, the SARC considered the relative cost of a marketed bushel from a transplant from Arnolds/Upper Arnolds/Round Island versus the cost of a marketed bushel from a shell planting on, for example, Beadons or Nantuxent Point with a subsequent movement of spatted shell upbay. The SARC recommends that the relative economic benefit of these two options be reviewed prior to carrying out the recommended downbay transplant from Arnolds/Upper Arnolds/Round Island because a shell planting after transplant from Beadons or Nantuxent Point may be more advantageous. Should funds permit both, the SARC strongly recommends the latter be included in this year's juvenile augmentation program.

Recommended 2004 Direct-Market Program—Middle/Upper Middle Transplant

The projection for a transplant from Middle and Upper Middle to Shell Rock uses the 10% rule, an estimated 132 submarket + market-size oysters/deck-load bu., the anticipated mortality rates for Shell Rock, and an average of the Middle/Upper Middle and Shell Rock growth rates. The 75^{th} percentile mortality is used in the projection. Transplant projections for from Middle/Upper Middle to Shell Rock are based on a continuous fishing season beginning six weeks after transplant assumed to occur by July 1, and with the season closing on November 15.

Abundance Level	Allocation (market-equivalent bushels)
20th Percentile	4,803
Mean	6,911
80th Percentile	9,180

Recommended 2004 Direct-Market Program—Projected Totals

Bed Group	Allocation (market-equivalent bushels)
Shell Rock	18,313
Cohansey/Ship John/Sea Breeze	34,520
Shell Rock (Middle/Upper Middle Transplant)	6,911
Total	59,744

Option of Transplanting to Leased Grounds

In a period when juvenile recruitment is low, the additional juvenile mortality incurred in transplanting to leased grounds argues against the procedure. The SARC also notes that transplanting does not concentrate large oysters to the extent previously believed, so that no mechanism of transplanting that would minimize downbay transplant of juveniles is currently available. Under these circumstances, the SARC cannot recommend a transplant program to leased grounds unless conducted within the yearly allocation for harvest (i.e., replanting).

Recommendations for Area Management—Review

Closure of the high-mortality, direct-market beds is recommended for 2004 and for minimally one growing season after transplant for juvenile augmentation. This latter closure should be re-evaluated at the 2005 SAW based on the November 2004 survey.

A significant fraction of the oysters available for harvest are on Shell Rock. Shell Rock will need to be closed after its harvest goal is reached and then reopened no sooner than six weeks after a transplant from Middle/Upper Middle. Harvest of the anticipated transplant from Shell Rock should not occur prior to transplant and a six week closure to avoid over-harvesting the present population. Continued higher-than-average recruitment on Shell Rock makes careful management of this resource essential as Shell Rock will continue to supply a large percentage of the yearly allocation in coming years.

Ship John, Cohansey, and Sea Breeze are recommended to be used as direct-market beds.

Closure should occur following harvest of the recommended allocation from these beds.

Projections 2005 and 2006: Direct-Market Beds

A limited and rapidly decreasing number of juvenile oysters remain on the direct-market beds. For Bennies, Hawk's Nest, Hog Shoal, New Beds, Strawberry, Beadons and Vexton the supply of young is so meager that natural production may not sustain the oyster population. Only on Bennies Sand is the number of young oysters sufficient to sustain the population, but this offers little prospect for continued harvests. There was a substantial transplant in 2003 and it provided a supplement this year, but will not provide much relief in 2004. The only beds with modest numbers of market oysters – Shell Rock, Cohansey and Ship John have not received good set in several years. As a result, the 2005 direct-market allocation is likely to be significantly reduced and a bay-wide closure in 2006 and beyond is likely.

Full implementation of the recommended transplant program, **plus establishment of a shell planting program,** is the only approach to minimize the impact of persistent low recruitment and is the only approach that may permit continuation of the industry.

2004 Science Advice

Based the management discussion and the anticipated program needs in the near future, the SARC recommended consideration of the following science studies. The items were **not** given a priority status.

1. Continue the dermo monitoring program with monthly samples from May to early fall.

2. Utilize aging techniques, intensive size/frequency sampling or experimental methods to develop growth monitoring of oyster populations on transplant source beds as part of an annual growth variability monitoring program

3. Conduct new dredge efficiency studies to be sure that changing conditions (increased effort on the beds) have not affected the base efficiency. These programs should be focused at the beds that have higher catchability coefficients. Use statistical techniques to evaluate variability of the dredge efficiency so some estimate of variance can be made.

4. Evaluate a broodstock-recruitment relationship at the local (bed group) level and investigate a curvilinear broodstock-recruitment relationship that can be used in future assessments.

5. Sample all poor areas to re-evaluate grid distribution among strata and determine how frequently should this be done.

6. Initiate a dock-side monitoring program to acquire information on number and size of oysters going to market.

7. Develop an estimate of fecundity.

8. Initiate a recruitment monitoring program.

9. Develop a shell budget for the transplant beds and other beds.

10. Investigate means of improving the efficiency of concentration of submarket and market-size individuals during transplant.

11. Develop a cultch planting/seed production/seed transportation program, and **specifically compare** the economics of transplanting as a juvenile augmentation program in comparison to shell-planting.

12. Evaluate the possible effect on the survey data integrity that would result from use of another boat and/or captain.

13. Implement a yield per recruit (YPR) model for oysters and examine the efficacy of "f" based reference points for management.

14. Develop a biological threshold reference point for bed group and bay wide harvest closures.

15. Expand the uncertainty estimates to include the 10^{th} and 90^{th} percentiles.

16. Evaluate the time that a grid transplanted to should remain a transplant stratum in the standard random sampling survey.

Figure Legends

Figure 1. Delaware Bay Seed Beds. Division of the beds in groupings based on salinity and biological characteristics.

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

Figure 3. Delaware Bay Seed Beds. Annual seed bed harvest.

Figure 4. Delaware Bay Seed Beds. Average annual bay wide oyster and spat abundance (37 qt. Bushel) and dermo weighted prevalence with 95% Least Significant Difference confidence intervals. Underlined values are not significantly different. Mean = average of annual values. Years are arrayed across the top.

Figure 5. Delaware Bay Seed Beds. Average annual oyster and spat abundance (37 qt. Bushel) for Upper Central and Central seedbeds. 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.

Figure 6. Delaware Bay Seed Beds. Total oysters per 37 qt. Bushel from 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 7. Delaware Bay Seed Beds. Oyster per 37 qt. bushel by market (>3") and submarket (2.5 to 2.99") size classes from Upper Central (less Shell Rock) and Market beds. 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. Delaware Bay Seed Beds. 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 = Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Egg Island and New Beds.

Figure 9. Total numbers of oysters on Low Mortality beds (Round Island, Upper Arnolds, Arnolds), Medium Mortality beds (Upper Middle, Middle, Ship John, Cohansey, Sea Breeze, Shell Rock), and High Mortality beds (Bennies Sand, Bennies, New Beds, Nantuxent, Hog Shoal, Strawberry, Hawk's Nest, Beadons, Vexton, Egg Island, Ledge) 1999 to 2003. Data use the size designations of $\geq$3 inches = market, 2.5 to < 3 inches = submarket, and < 2.5 inches = juvenile.

Figure 10. Total numbers of oysters on Medium Mortality by size class 1999 to 2003. Medium Mortality beds and size designations as in Figure 9.

Figure 11. Weighted numbers of oysters per bushel for 2003 and percentiles of weighted oysters/bu. as calculated from 1989 to 2003 time series. Numbers of oysters per bushel are the averages from bushels collected in the seedbed survey. The weighting is the number of market oysters ($\geq$ 3 inches) + one-half the number of submarket oysters (2.5 inches up to 3 inches) as decided in the 2001 SAW. Bed designations include beds with data for the time series 1989 to 2003. The Central beds include Shell Rock, Bennies Sand, Bennies, and New Beds. The Upper Central beds include Middle, Cohansey and Ship John. The Upper bed is Arnolds.

Figure 12. Total number of oysters on High Mortality beds by size class 1999 to 2003. High Mortality beds and size designations as in Figure 9.

Figure 13. Total number of oysters on Low Mortality beds by size class 1999 to 2003. Low Mortality beds and size designations as in Figure 9.

Figure 14. Delaware Bay Seed Beds. Annual average condition index (dry meat weight (g)/hinge to lip dimension (mm)) by seed 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 15. Delaware Bay Seed Beds. Annual bay wide average spat counts per 37 quart bushel. Error bars are the 95% confidence intervals.

Figure 16. Delaware Bay Seed Beds. Average bay wide historical spat counts per 37 quart bushel (1957-2003)

Figure 17. Delaware Bay Seed Beds. Annual percentage mortality for the past decade by region. Error bars are the 95% confidence intervals. Graphs depict all beds (top), 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 and Ledge is missing because of too few oysters.

Figure 18. Natural mortality for 2003 and percentiles of natural mortality as calculated from the 1989 to 2003 time series for the High Mortality beds (Bennies Sand, Bennies, New Beds, Nantuxent, Hog Shoal, Strawberry, Hawk's Nest, Beadons, Vexton, Egg Island, Ledge), the Medium Mortality beds (Upper Middle, Middle, Ship John, Cohansey, Sea Breeze, Shell Rock), and the Low Mortality beds (Round Island, Upper Arnolds, Arnolds). Natural mortality is expressed as the ratio of dead oysters to total (dead + live) oysters from the seedbed survey samples.

Figure 19. Delaware Bay Seed Beds. Prevalence of dermo (*Perkinsus marinus*) by bed group for the past decade. Error bars are the 95% confidence intervals. Graphs depict all beds (top), 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 and Ledge is missing because of too few oysters.

Figure 20. Delaware Bay Seed Beds. Weighted prevalence of dermo (*Perkinsus marinus)* by bed group for the past decade. Error bars are the 95% confidence intervals. Graphs depict all beds (top), 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 and Ledge is missing because of too few oysters.

Figure 21. Catch per boat day for Delaware Bay Market Beds. The program began in 1996 with a fall harvest only. Single dredge = boats with a single dredge. Dual dredge = boats with two dredges.

Figure 22. Delaware Bay Seed Beds. Relationship between oysters/37 quart bu. sampled in the fall and the spat set/37quart bu. found the following fall. Numbers indicate the years of the sample. Boxes surround current (1989-2003) data.

Figure 23. Percentiles of long term abundance for the medium mortality transplant beds beds (Upper Middle, Middle, Ship John, Cohansey and Sea Breeze), expressed as a fraction of 2003 abundance. Present day abundance (1.0) is at the 100^{th} percentile (see Figure 11).

Table 1. Revised sampling scheme, Delware Bay Seed Beds.

1989-2001		2002-	
Arnolds	6	Arnolds	6
Beadons	10	Beadons	10
Bennnies	12	Bennnies	12
Bennies Sand	5	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
Total	**84**	Strawberry	4
		Vexton	5
		Hog Shoal	4
		Total	**88**
Even Years		**Even Years**	
Hawks Nest	6	Ledge	5
Ledge	8	Upper Middle	2
Strawberry	6	Round Island	5
Upper Mid	2	Sea Breeze	3
	22		15
Odd Years		**Odd Years**	
Hog Shoal	6	Nantuxent	6
Nantuxent	6	Upper Arnolds	2
Upper Arn	2	Egg Island	8
Vexton	7	**Total**	**16**
OL	1		
Total	**22**		

Table 2. Long term (1957- 1989) arithmetic mean of oysters and spat per bushel for the New Jersey Delaware Bay seed beds. Upper = Round Island, Arnolds and Upper Arnolds. Upper Central = Upper Middle, Middle, Cohansey, Ship John and Shell Rock. Central = Bennies Sand, Bennies, Nantuxent, Hog Shoal, Strawberry, Hawk's Nest, Beadons and Vexton. Lower = Ledge and Egg Island.

	Oyster	**Spat**
Bay Average	239	239
Upper	587	435
Upper Central	280	286
Central	191	213
Lower	102	142

Table 3. Results of a random sampling of the Delaware Bay seed beds

A summary of the 2003 seedbed sampling data with similar data for 2001 and 2002. All data were collected between October 27 and October 29, 2003 using a boat and captain donated by Bivalve Packing. Data are displayed from the farthest up bay beds to those down bay. 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 Percent Oyster 2003 indicates the **average** number of bushels brought up by the 3 dredge hauls from each grid using a calibrated the hopper to estimate the numbers of bushels of oysters brought up in the three dredge hauls. For a discussion of this method, see the year 2000 report.

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 the 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. It is italicized and all other sampled grids are shifted down one space. The italicized grid was added as a "Transplant" sample. It is NOT included in the averages for the subsequent information on Bennies.

Because of the emphasis on the direct marketing of oyster from the seedbeds 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 2.5". This is based on the measurements of oysters (Table 3), and can be utilized in conjunction with that table. The percentage column is not the same as the percent oyster in the preceding columns. This former number is the percent of the bushel of material brought on board that was oyster.

The Percentage Mortality figure is based on the number of boxes that were counted in the samples. Due to the influence of Dermo on the industry we have continued the set of columns for Percentage Mortality and data on Percent Prevalence and Weighted Prevalence of Dermo. Prevalence is the percentage of oysters with detectable infections. Weighted Prevalence is the average infection intensity (scored from 0 to 5) of all infected and uninfected oysters.

Summary of the 2003 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2003.

Bed		Bushels/ Haul	Percent			Oysters/Bushel			Yearling/Bushel			Spat/Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence			Size No./bu. >2.5 in.			Size %oysters >2.5 in.		
			2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Round Island		--	--	60.4	36.0																								
Round Island		--	--	57.1	35.0																								
Round Island		--	--	51.1	31.3	--	371	192	--	--	11	--	58	7	--	6	7	--	40	20	--	0.48	0.1	--	14	12	--	4	6
Round Island		--	--	50.7	29.0																								
Round Island		--	--	38.9	6.3																								
Round Island		--	--	27.0	2.6																								
Up. Arnolds		1.4	**58.0**	--	41.4																								
Up. Arnolds	*	0.6	**27.7**	--	19.7	**311**	--	218	--	--	0.6	**12**	--	13	**9**	--	9	**20**	--	20	**0.15**	--	0.15	**32**	--	12	**10**	--	6
Up. Arnolds			--	--	--																								
Arnolds		3.3	**68.3**	65.0	67.6																								
Arnolds		3.2	**62.6**	59.8	64.0																								
Arnolds	*	3.7	**48.2**	50.0	58.0	**272**	383	245	--	--	7	**13**	48	35	**7**	9	9	**33**	33	40	**0.38**	0.73	0.7	**23**	34	16	**8**	9	7
Arnolds		0.1	**28.7**	47.8	44.6																								
Arnolds		0.4	**6.8**	45.1	40.5																								
Arnolds		0.0	**0**	8.9	0.0																								
Up. Middle			--	15.6	--																								
Up. Middle			--	0.0	--	--	58	--	--	--	--	--	0	--	--	15	--	--	70	--	--	1.6	--	--	6	--	--	10	--
Middle		0.5	**78.1**	88.7	67.8																								
Middle		3.7	**63.1**	72.0	46.7																								
Middle		1.7	**62.2**	62.1	37.3																								
Middle	*	2.2	**59.7**	52.2	33.2																								
Middle		1.1	**59.4**	45.8	17.1	**223**	237	133	--	--	3	**19**	31	5	**10**	14	9	**63**	90	33	**0.98**	2.2	0.27	**91**	72	17	**41**	30	16
Middle		2.8	**54.6**	40.0	5.4																								
Middle		1.0	**50.3**	2.1	3.1																								
Middle		0.5	**0**	0.0	0.0																								
Middle		0.0	**0**	--	0.0																								
Cohansey	*	2.7	**70.5**	68.7	81.5																								
Cohansey		2.4	**70.0**	47.7	45.5																								
Cohansey		2.3	**64.6**	41.9	9.6																								
Cohansey		3.4	**64.1**	41.2	0.8	**218**	163	149	--	--	3	**19**	42	3	**12**	20	8	**57**	100	79	**0.95**	3.1	1.61	**99**	50	25	**45**	31	17
Cohansey		0.0	**50.0**	33.4	0.0																								
Cohansey		0.7	**48.5**	6.8	--																								
Cohansey		2.6	**37.0**	3.9	--																								
Cohansey		0.5	**3.3**	--	--																								
Ship John	*	1.5	**68.2**	81.8	78.7																								
Ship John		3.6	**66.0**	74.2	77.3																								
Ship John		1.4	**61.5**	63.2	58.8	**226**	225	220	--	--	20	**24**	57	38	**13**	22	8	**90**	100	95	**1.18**	2.8	2.33	**105**	100	42	**47**	44	19
Ship John		2.8	**48.4**	46.2	46.9																								
Ship John		1.1	**28.4**	14.6	12.4																								

Summary of the 2003 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2003.

Bed		Bushels/ Haul	Percent			Oysters/Bushel			Yearling/Bushel			Spat/Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence			Size No./bu. >2.5 in.			Size %oysters >2.5 in.		
			2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Seabreeze			--	29	37.5																								
Seabreeze			--	22.4	16.6	--	71	91	--	--	0	--	105	7	--	43	15	--	100	70	--	4.6	1.15	--	20	25	--	28	27
Seabreeze			--	2.6	0.18																								
Shell Rock		2.7	**69.4**	69.4	66.7																								
Shell Rock		3.0	**67.7**	40.0	62.7																								
Shell Rock		2.2	**59.0**	30.3	62.2																								
Shell Rock	*	2.7	**55.9**	27.4	54.6	**186**	141	184	--	--	45	**54**	212	32	**12**	20	11	**80**	100	100	**1.25**	3.27	2.48	**68**	70	60	**36**	50	33
Shell Rock		1.6	**52.7**	23.3	45.0																								
Shell Rock		1.0	**46.6**	19.8	43.0																								
Shell Rock		1.3	22.3	--	26.6																								
Bennies Sand	*	2.0	**40.9**	32.5	31.3																								
Bennies Sand		1.3	**33.7**	28.8	31.0																								
Bennies Sand		2.2	**32.7**	28.2	19.1	**140**	98	89	--	--	0	**47**	67	4	**14**	40	16	--	90	90	--	3.13	2.05	**70**	61	39	**50**	62	44
Bennies Sand		1.9	**32.7**	23.5	15.2																								
Bennies		2.2	**26.9**	65.6	27.3																								
Bennies	*	2.5	**21**	28.2	19.1																								
Bennies		1.8	**17.2**	18.4	18.6																								
Bennies		0.4	**15.5**	15.5	15.6																								
Bennies		1.2	**15**	15.4	13.8																								
Bennies		0.5	**8.62**	11.6	5.5																								
Bennies		3.1	**8.06**	4.0	5.0	**19**	16	20	--	--	1	**4**	4	3	**29**	39	43	**85**	90	75	**1.8**	2.76	1.23	**13**	13	13	**68**	81	66
Bennies	*	0.1	**6.25**	2.9	4.2																								
Bennies		0.3	**3.37**	1.5	3.1																								
Bennies		2.6	**0.65**	0.8	2.8																								
Bennies		1.1	**0.58**	0.6	1.4																								
Bennies		0.7	**0.55**	0.3	0.4																								
Bennies		--	--	0.0	--																								
Nantuxent Pt		3.8	**53.2**	--	73.4																								
Nantuxent Pt		2.0	**13.2**	--	54.4																								
Nantuxent Pt		0.9	**7.9**	--	53.5	**74**	--	149	--	--	11	**46**	--	25	**16**	--	31	**95**	--	90	**2.1**	--	3	**21**	--	25	**28**	--	17
Nantuxent Pt	*	2.8	**7.4**	--	27.3																								
Nantuxent Pt		1.1	**1.7**	--	24.2																								
Nantuxent Pt		0.0	**0.0**	--	0.3																								
Hog Shoal		1.5	**23.3**	21.5	60.1																								
Hog Shoal		1.3	**10.8**	6.1	40.0																								
Hog Shoal		3.3	**10.0**	4.4	38.5	**31**	27	108	--	--	5	**18**	32	13	**44**	62	38	**90**	100	100	**3**	3.45	2.95	**14**	20	45	**45**	74	34
Hog Shoal	*	1.8	**9.0**	3.6	35.0																								
Hog Shoal		--	--	--	27.6																								
Hog Shoal		--	--	--	1.0																								

Summary of the 2003 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2003.

Bed		Bushels/ Haul	Percent			Oysters/Bushel			Yearling/Bushel			Spat/Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence			Size No./bu. >2.5 in.			Size %oysters >2.5 in.		
			2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
New Beds		4.0	**24.1**	17.5	13.1																								
New Beds	*	2.4	**23.2**	10.7	9.7																								
New Beds		1.5	**10.1**	8.9	8.6																								
New Beds		3.0	**9.4**	6.5	7.0																								
New Beds		2.0	**4.5**	5.5	4.1	**20**	12	12	--	--	2	**16**	5	2	**35**	59	47	**95**	93	95	**1.38**	2.64	1.65	**11**	10	8	**56**	83	70
New Beds		0.3	**3.0**	3.7	3.2																								
New Beds		2.4	**2.4**	2.7	0.9																								
New Beds		0.3	**2.0**	1.9	0.3																								
New Beds		1.4	**1.4**	0.0	0.0																								
Strawberry		2.5	**9.55**	13.1	23.9																								
Strawberry	*	2.8	**7.22**	0.9	1.8																								
Strawberry		1.2	**3.88**	0.3	--	**20**	8	39*	--	--	0*	**13**	4	10*	**35**	59	51*	**90**	90	--	**2**	2.9	--	**14**	5	18	**69**	63	47
Strawberry		3.0	**2.97**	0.0	--																								
Strawberry		--	--	--	--																								
Strawberry		--	--	--	--																								
Hawks Nest		5.8	**18.7**	13.3	56.9																								
Hawks Nest		5.2	**14.9**	8.6	36.6																								
Hawks Nest	*	2.5	**11.3**	1.4	--																								
Hawks Nest		3.2	**8.0**	0.5	--	**53**	16	203*	--	--	11*	**33**	4	46*	**35**	61	28*	**90**	100	--	**1.95**	3.5	--	**35**	9	38	**65**	56	19
Hawks Nest				--	--																								
Hawks Nest				--	--																								
Beadons	*	2.5	**19.7**	23.1	30.8																								
Beadons		1.3	**16.7**	17.4	11.7																								
Beadons		3.0	**6.0**	6.0	11.4																								
Beadons		4.2	**4.5**	4.5	9.4																								
Beadons		2.2	**2.9**	3.3	7.3	**19**	18	25	--	--	7	**14**	53	11	**42**	62	52	**100**	100	100	**3.2**	4.25	3.85	**11**	10	14	**58**	56	56
Beadons		0.8	**2.5**	2.2	6.3																								
Beadons		3.8	**2.2**	1.5	5.2																								
Beadons		2.0	**1.6**	1.5	3.4																								
Beadons		2.3	**0.0**	0.8	3.0																								
Beadons		0.2	**0.0**	0.0	1.8																								
Vexton		2.2	**24.6**	31.2	47.2																								
Vexton		2.8	**11.0**	16.7	35.0																								
Vexton	*	2.5	**10.1**	11.2	25.2																								
Vexton		3.0	**7.1**	11.0	21.2	**21**	26	66	--		5	**15**	30	22	**44**	64	28	**100**	100	80	**4.1**	4.9	1.7	**16**	16	25	**76**	62	38
Vexton		1.7	**0.0**	1.1	8.8																								
Vexton		--	--	--	2.0																								
Vexton		--	--	--	0.3																								

Summary of the 2003 Random Sampling of the Seed Beds

Table 3. Delaware Bay Seed Bed data for 2003.

Bed		Bushels/ Haul	Percent			Oysters/Bushel			Yearling/Bushel			Spat/Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence			Size No./bu. >2.5 in.			Size %oysters >2.5 in.		
			2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001	2003	2002	2001
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Egg Island		6.5	**5.9**	--	3.0																								
Egg Island		2.7	**4.9**	--	2.1																								
Egg Island	*	4.8	**3.1**	--	0.9																								
Egg Island		3.0	**0.7**	--	0.4																								
Egg Island		3.8	**0.5**	--	0.3	**4**	--	2	--	--	0	**0**	--	1	**29**	--	77	**100**	--	71	**2.3**	--	2.21	**3**	--	1	**84**	--	75
Egg Island		1.1	**0.5**	--	0.3																								
Egg Island		2.3	**0.3**	--	0.0																								
Egg Island		0.0	**0.0**	--	0.0																								
Egg Island		--	--	--	0.0																								
Egg Island		--	--	--	0.0																								
Ledge		--	--	4.9	--																								
Ledge		--	--	1.3	--																								
Ledge		--	--	0.6	--																								
Ledge		--	--	0	--	--	1.1	1	--	--	--	--	0	--	--	59	--	--	100	--	--	2.4	--	--	1	--	--	100	--
Ledge		--	--	0	--																								
Ledge		--	--	--	--																								
Ledge		--	--	--	--																								
Ledge		--	--	--	--																								

Table 4. Oyster Seed Beds Size Frequency 2003

	Arnold	Up Arn	Middle	Cohan	Ship Jn	Shell Rk	Ben Snd	Bennie	Nantux	Hog Shl	New Beds	Straw	Hawks N	Beadon	Vexton	Egg Is
0	0	0.0	0	0	0	0	0	0	0	0	0	0	1	0	0	0.0
5	0	0.0	0	0	0	0	1	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
15	0	0.0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.0
20	10	13.4	8	9	6	5	2	0	4	1	0	1	1	1	0	0.1
25	14	14.3	6	10	8	8	2	0	6	1	0	0	1	1	0	0.1
30	15	23.0	5	7	9	18	2	0	8	2	0	0	2	1	0	0.1
35	31	39.2	7	6	4	18	6	0	10	2	1	0	3	1	0	0.0
40	46	45.1	12	9	9	16	8	0	6	1	1	1	3	1	0	0.0
45	47	37.3	16	10	14	13	10	1	3	1	1	1	3	1	0	0.0
50	37	46.0	20	20	18	10	10	1	6	1	1	0	2	1	1	0.0
55	32	34.5	30	17	22	12	13	2	5	3	2	1	1	1	2	0.0
60	17	25.8	28	29	30	18	16	2	6	4	1	1	2	1	1	0.1
65	14	15.2	24	24	26	18	17	2	7	2	2	2	5	2	2	0.0
70	5	9.6	25	24	25	16	18	3	3	3	2	3	6	2	3	0.6
75	**2**	**4**	**20**	**19**	**20**	**12**	**11**	**2**	**4**	**2**	**2**	**2**	**4**	**2**	**3**	**0.1**
80	**1**	**3**	**10**	**9**	**14**	**8**	**10**	**2**	**3**	**2**	**1**	**3**	**6**	**2**	**3**	**0.3**
85	**0**	**0**	**6**	**10**	**12**	**4**	**7**	**2**	**2**	**2**	**1**	**2**	**4**	**1**	**2**	**0.1**
90	**0**	**1**	**3**	**5**	**5**	**4**	**2**	**1**	**0**	**2**	**1**	**1**	**4**	**1**	**1**	**0.1**
95	**0**	**0**	**1**	**3**	**2**	**2**	**3**	**0**	**0**	**1**	**1**	**1**	**4**	**1**	**1**	**0.3**
100	**0**	**0**	**1**	**2**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0.1**
105	**0**	**0**	**0**	**2**	**0**	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0.3**
110	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.7**
115	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**
120	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**
130	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.1**	**0.0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total/Bu.	272	311	223	218	226	186	140	19	74	31	20	20	53	19	21	4
No. Measured	678	325	1174	897	687	1217	650	380	257	118	266	72	188	185	106	25
Greater than 3"	**4**	**7**	**41**	**51**	**55**	**34**	**35**	**9**	**10**	**9**	**7**	**9**	**24**	**7**	**11**	**2**
> 3" 2002	6	--	28	20	44	33	29	10	--	13	7	3	7	6	10	--
> 3" 2001	5	5	6	8	16	24	15	8	12	23	5	9	15	8	11	1
Greater than 2.5"	**23**	**32**	**91**	**99**	**105**	**68**	**70**	**13**	**21**	**14**	**11**	**14**	**35**	**11**	**16**	**3**
> 2.5" 2002	34	--	72	50	100	70	61	13	--	20	10	5	9	10	16	--
> 2.5" 2001	16	12	17	25	42	60	39	13	25	45	8	18	38	14	25	1

Table 5. Seed bed harvest (bu.)of market oysters and bushels of oysters transplanted in 2004. Bennies Sand received 29,723 bu. in June, Bennies received 31,019 bu. in June and 8,850 bu in September and New Beds received 15,200 bu in September. ()= 2002 percent harvest distribution.

Bed	Bushels Harvested	Bushels Replanted	Percent Harvest	Bushels Transplanted
Arnolds			(1.0)	6,458*
Upper Middle			0.3	10,924*
Middle	264			46,897*
Cohansey	13,493	960	17.3 (0.1)	20,513*
Ship John	10,281	6,514	20.1 (0.8)	
Shell Rock	14,992	346	18.4 (43.6)	
Seabreeze	72		0.1	
Bennies	10,604		12.7 (5.8)	
Bennies Sand	15,547	654	19.4 (9.3)	
Nantuxent	420		0.5 (0.1)	
Hog Shoal	405		0.5 (11.1)	
Strawberry	394		0.5	
New Beds	1,554		1.9 (11.8)	
Hawks Nest	2,687	279	3.6 (3.2)	
Beadons	652		0.8 (0.8)	
Vexton	3,379		4.0 (3.9)	
Other			(7.7)	
Total	**74,744**	**8,753**		**84,792**

* Allocation approximate, based on number of grids in Test+Average on each source bed.

Table 6. Source beds and volumes (bu.) for transplanted oysters.

Year	Arnolds	Upper Middle	Middle	Cohansey	Ship John	Nantuxent	Beadons	Total
1997			30,000					30,000
1998				6,000	6,000			12,000
1999			14,650	40,200	17,350			72,200
2000			24,210	4,146	6,572	225	4,900	40,053
2001	6,500		6,395	18,400	14,650	6,250		52,195
2002				6,200	22,416			28,616
2003	6,458*	10,924*	46,879*	20,513*				84,792

* Allocation of bu to beds based on number of grids in Test and Average areas.

Table 7. Industry bottom coverage and catch per unit effort (CPUE). Total coverage = estimated (est.) bottom area covered by oyster dredges in 2003. Fraction of bottom area swept by oyster dredges in 2003. Bu. = bushel. Hectare = 2.47 acres. * = High quality areas only, Submarket+Market oysters.

	Total Coverage (m^2)	**Fraction Covered**	**2003 Harvest (Bu.)**	**2002 Est. Availability (Bu.)***	**CPUE (Bu./hectare)**
Bed					
Round Island					
Upper Arnolds					
Arnolds					
Upper Middle					
Middle	127,213	0.04	264	66,019	21
Ship John	11,071,763	3.75	16,795	165,285	15
Cohansey	10,702,155	3.29	14,491	83,002	14
Seabreeze	74,078	0.07	72	19,112	10
Shell Rock	14,161,913	4.09	15,338	34,495	11
Bennies Sand	13,272,982	16.31	16,201	5,415	12
Bennies	10,830,314	1.94	10,604	21,964	10
New Beds	1,923,512	0.34	1,554	12,998	8
Nantuxent	835,950	0.45	420	16,145	5
Hog Shoal	291,465	0.32	405	4,353	14
Strawberry	392,110	0.26	394	443	10
Hawk's Nest	2,113,551	1.09	2,928	2,951	14
Beadons	630,440	0.26	652	1,660	10
Vexton	2,643,346	1.86	3,379	4,819	13
Egg Island					
Ledge					

Table 8. Summary mean and variability of estimated oyster numbers by size and bed type for the Delaware Bay seed beds.

	SUBMARKETS		
Bed Type	**20th Percentile**	**Mean**	**80th Percentile**
Low Mortality Transplant Beds (Round Island, Upper Arnolds, Arnolds)	574,224	756,622	976,244
Medium Mortality Transplant Beds (Upper Middle,Middle,Sea Breeze,Cohansey, Ship John)	8,818,256	10,864,223	10,437,577
High Mortality Transplant Beds (Beadons, Nantuxent)	1,501,405	3,305,288	4,159,506
Medium Mortality Market Beds (Shell Rock)	6,392,586	8,417,562	9,996,230
High Mortality Market Beds (BenSand,Bennies,NewBeds,Hawk's,Straw,Egg,Ledge,Vexton,Hog)	6,132,621	8,513,067	9,534,267

	MARKETS		
Bed Type	**20th Percentile**	**Mean**	**80th Percentile**
Low Mortality Transplant Beds (Round Island, Upper Arnolds, Arnolds)	2,550,579	3,164,710	3,743,500
Medium Mortality Transplant Beds (Upper Middle,Middle,Sea Breeze,Cohansey, Ship John)	65,850,424	78,446,528	93,130,864
High Mortality Transplant Beds (Beadons, Nantuxent)	1,610,042	1,904,534	2,739,921
Medium Mortality Market Beds (Shell Rock)	4,968,824	5,732,901	6,858,886
High Mortality Market Beds (BenSand,Bennies,NewBeds,Hawk's,Straw,Egg,Ledge,Vexton,Hog)	8,382,444	8,920,777	10,251,460

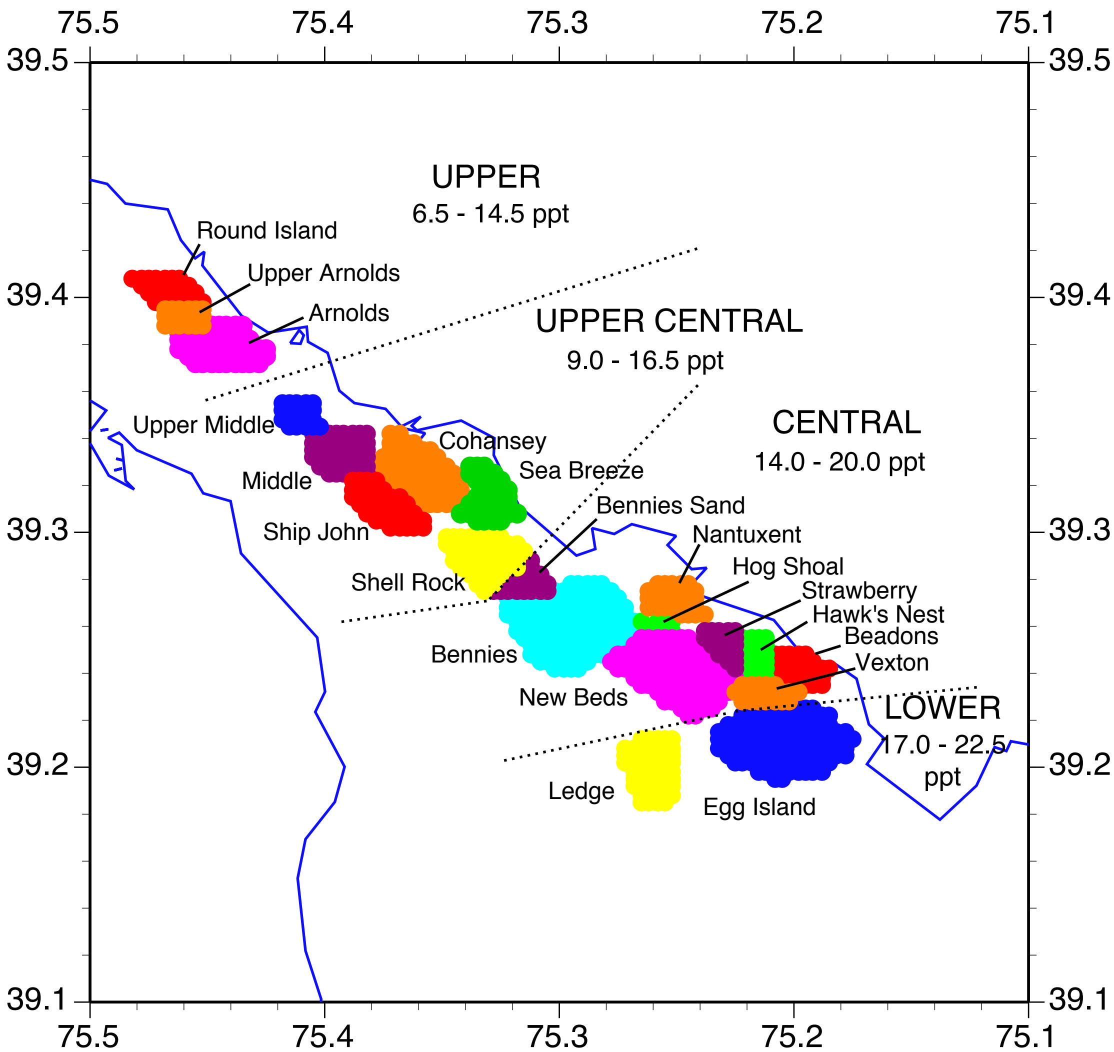

75.5
75.4
75.3
75.2
75.1
39.5
39.4
39.3
39.2
39.1
UPPER
6.5 - 14.5 ppt
UPPER CENTRAL
9.0 - 16.5 ppt
CENTRAL
14.0 - 20.0 ppt
LOWER
17.0 - 22.5
ppt
Round Island
Upper Arnolds
Arnolds
Upper Middle
Middle
Ship John
Cohansey
Sea Breeze
Bennies Sand
Nantuxent
Hog Shoal
Strawberry
Hawk's Nest
Beadons
Vexton
Shell Rock
Bennies
New Beds
Ledge
Egg Island

Figure 1

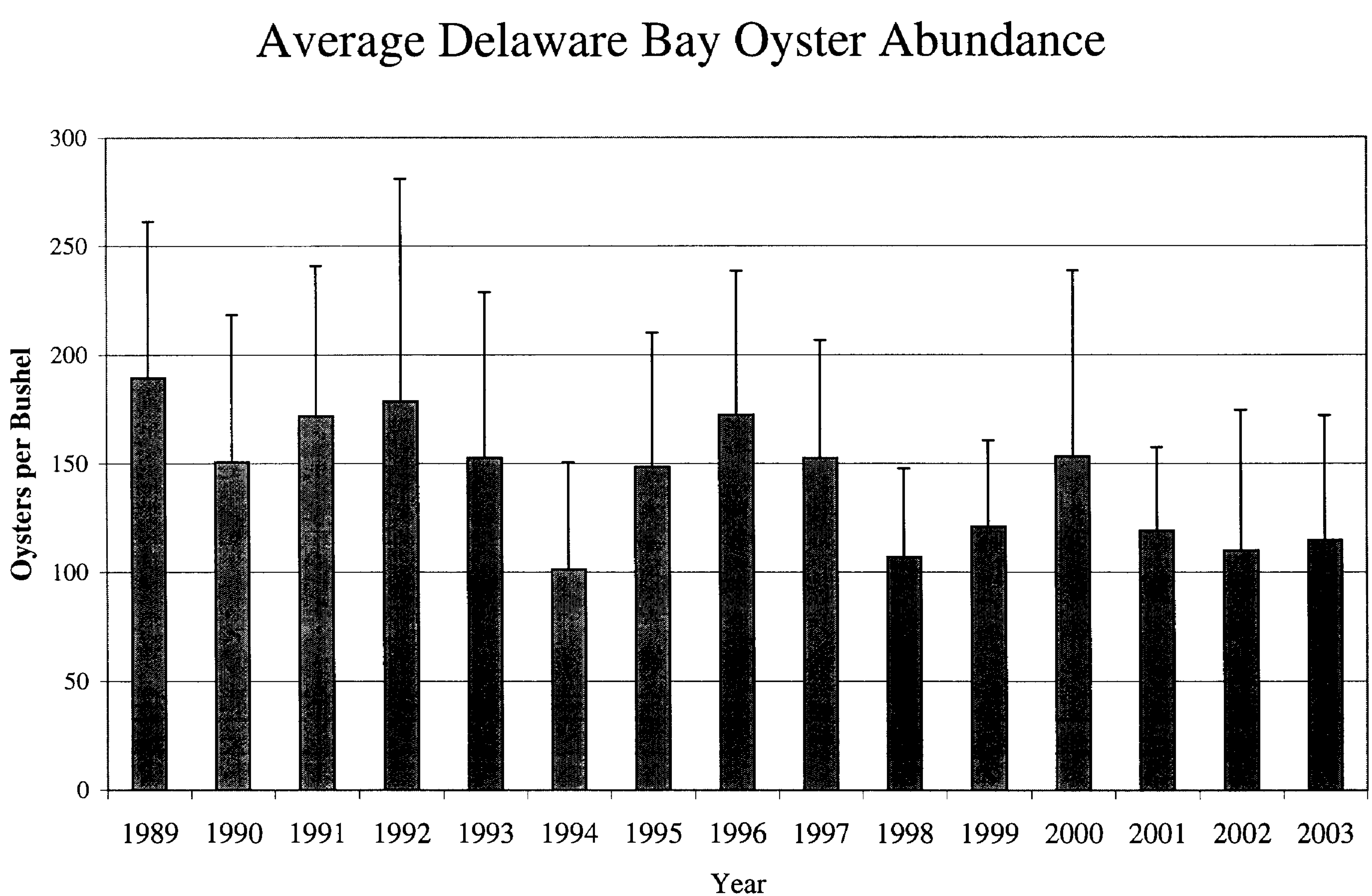

Average Delaware Bay Oyster Abundance
Oysters per Bushel
300
250
200
150
100
50
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Year

Figure 2.

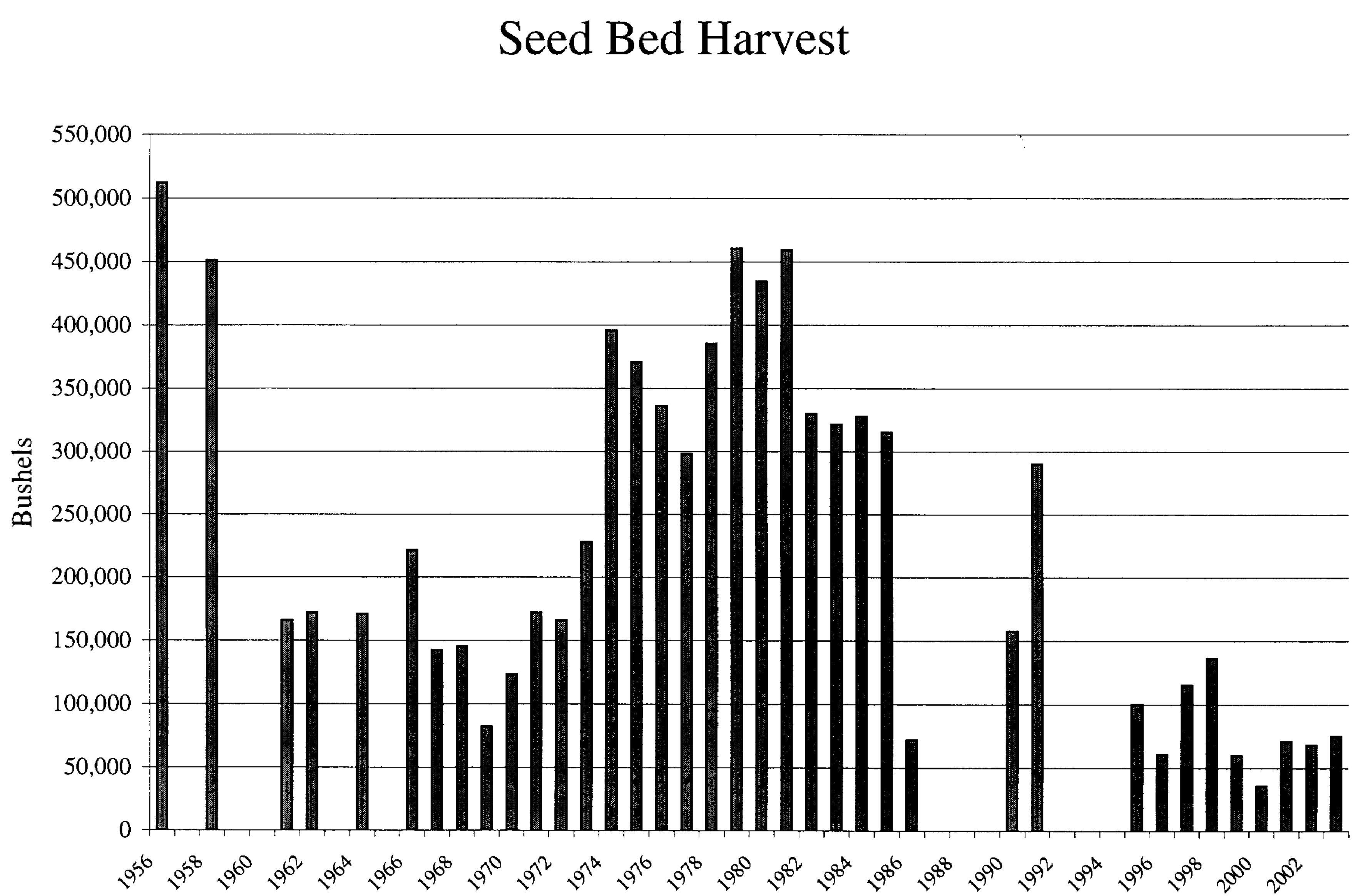

Seed Bed Harvest
Bushels
550,000
500,000
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

Figure 3.

Delaware Bay Seed Beds

Year	1989	1992	1996	1991	2000	1993	1997	1990	1995	1999	2001	2003	2002	1998	1994	Mean
Oysters	189	178	172	172	153	153	152	151	148	121	119	115	110	107	101	143

Year	1991	1999	1997	1998	1995	1994	1990	1989	2000	1993	2002	1992	1996	2003	2001	Mean
Spat	268	191	151	128	127	124	112	69	55	44	43	25	22	22	14	92

Year	1993	2002	1994	1999	1998	2000	1992	1995	1996	2003	2001	1991	1997	Mean
Dermo WP	2.99	2.87	2.67	2.63	2.56	2.45	2.18	1.84	1.81	1.78	1.71	1.2	1.12	2.18

Figure 4.

Upper Central Beds

Year	1997	2000	1996	1991	1989	2003	1992	1993	1990	2001	1999	1998	2002	1995	1994	Mean
Oysters	265	262	247	222	214	213	195	190	184	172	170	155	149	138	124	193*

Central Beds

Year	1996	1989	1995	1990	1997	1992	1991	1998	2000	1999	2001	1993	1994	2003	2002	Mean
Oysters	153	105	95	91	91	91	84	80	80	78	67	55	52	44	28	79*

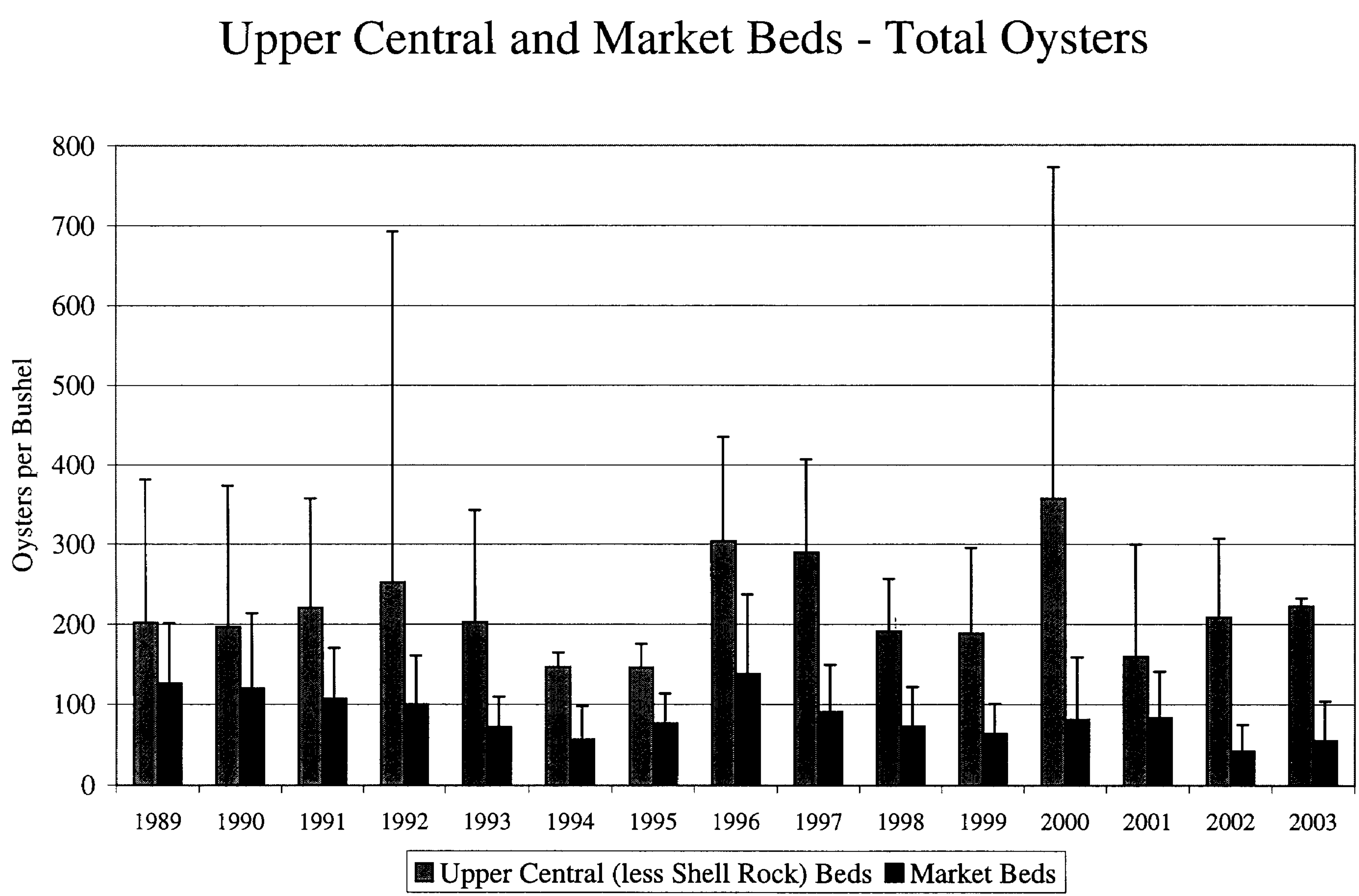
Upper Central Beds

Year	1991	1999	1995	1998	1994	1997	1990	2000	2002	1989	1993	2003	1996	1992	2001	Mean
Spat	307	291	179	169	140	113	103	78	75	70	60	29	28	28	17	113

Central Beds

Year	1991	1997	1999	1994	1998	1995	1990	1989	2000	1993	2003	1992	2002	1996	2001	Mean
Spat	273	221	166	166	146	137	107	70	69	46	23	21	20	16	11	100

Figure 5.



Upper Central and Market Beds - Total Oysters
Oysters per Bushel
800
700
600
500
400
300
200
100
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Upper Central (less Shell Rock) Beds
Market Beds

Figure 6.

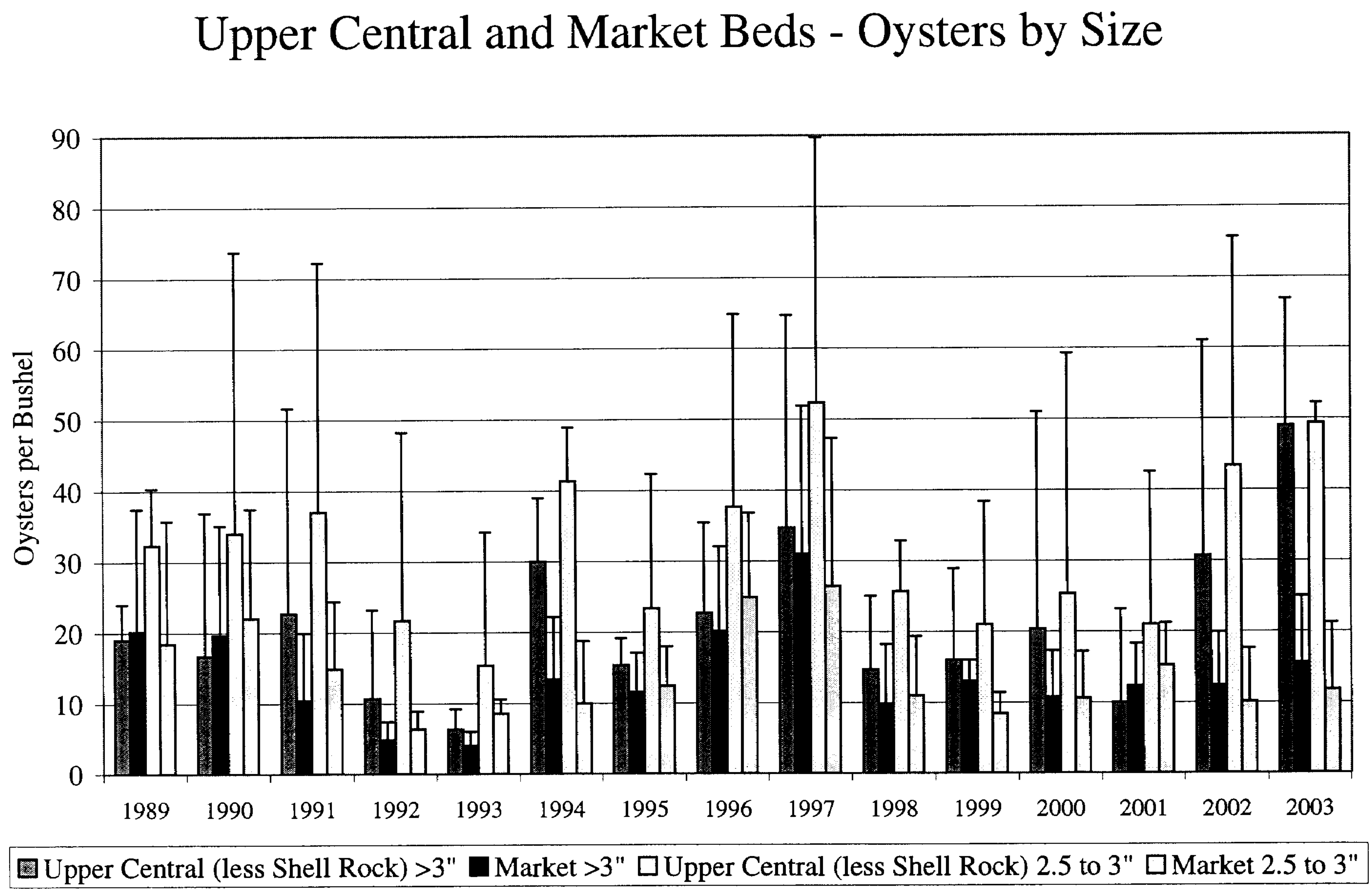

Upper Central and Market Beds - Oysters by Size
Oysters per Bushel
90
80
70
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Upper Central (less Shell Rock) >3"
Market >3"
Upper Central (less Shell Rock) 2.5 to 3"
Market 2.5 to 3"

Figure 7.

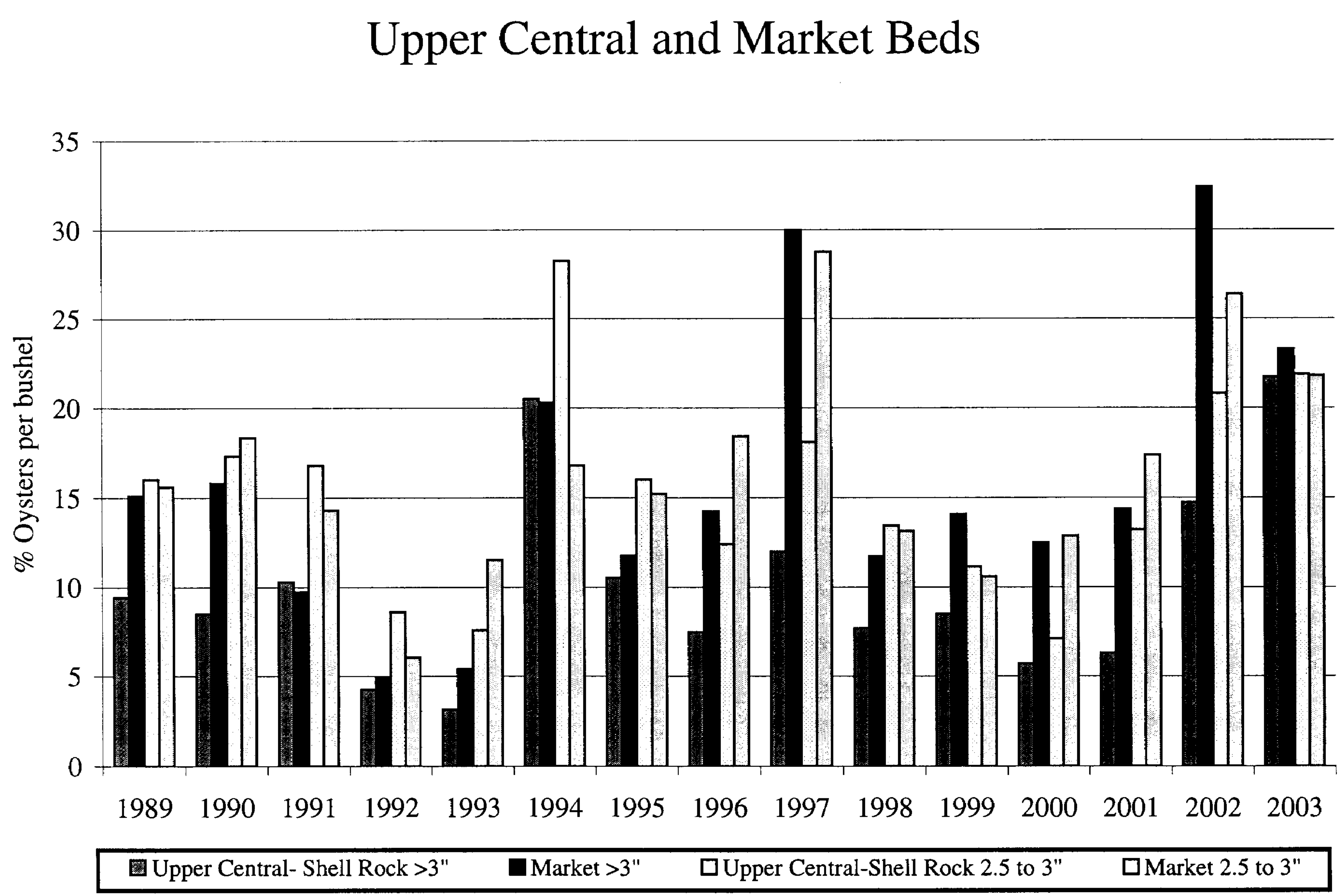

Upper Central and Market Beds
% Oysters per bushel
35
30
25
20
15
10
5
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Upper Central- Shell Rock >3"
Market >3"
Upper Central-Shell Rock 2.5 to 3"
Market 2.5 to 3"

Figure 8.

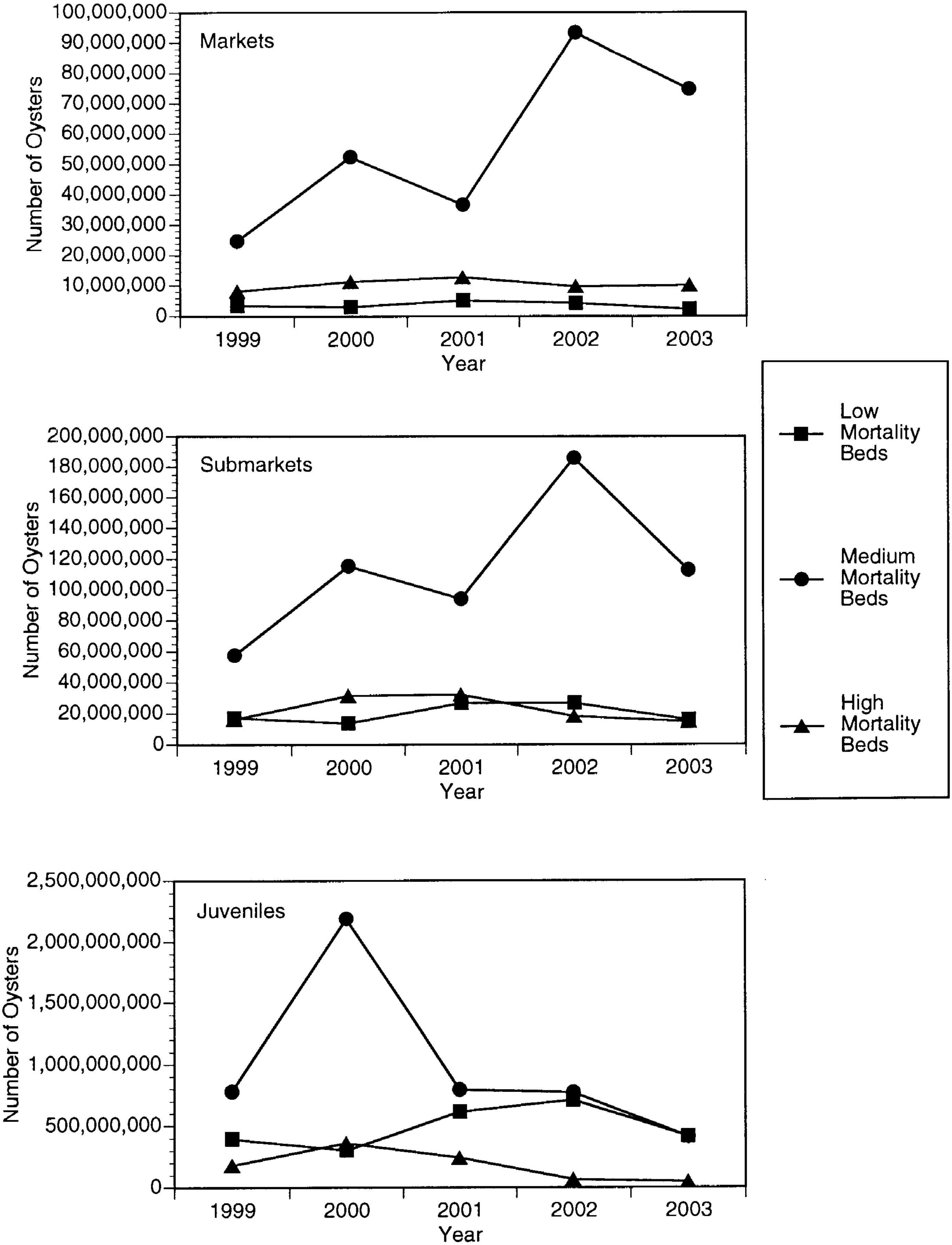

Markets
Submarkets
Juveniles
Number of Oysters
Year
1999
2000
2001
2002
2003
0
10,000,000
20,000,000
30,000,000
40,000,000
50,000,000
60,000,000
70,000,000
80,000,000
90,000,000
100,000,000
20,000,000
40,000,000
60,000,000
80,000,000
100,000,000
120,000,000
140,000,000
160,000,000
180,000,000
200,000,000
500,000,000
1,000,000,000
1,500,000,000
2,000,000,000
2,500,000,000
Low Mortality Beds
Medium Mortality Beds
High Mortality Beds

Figure 9.

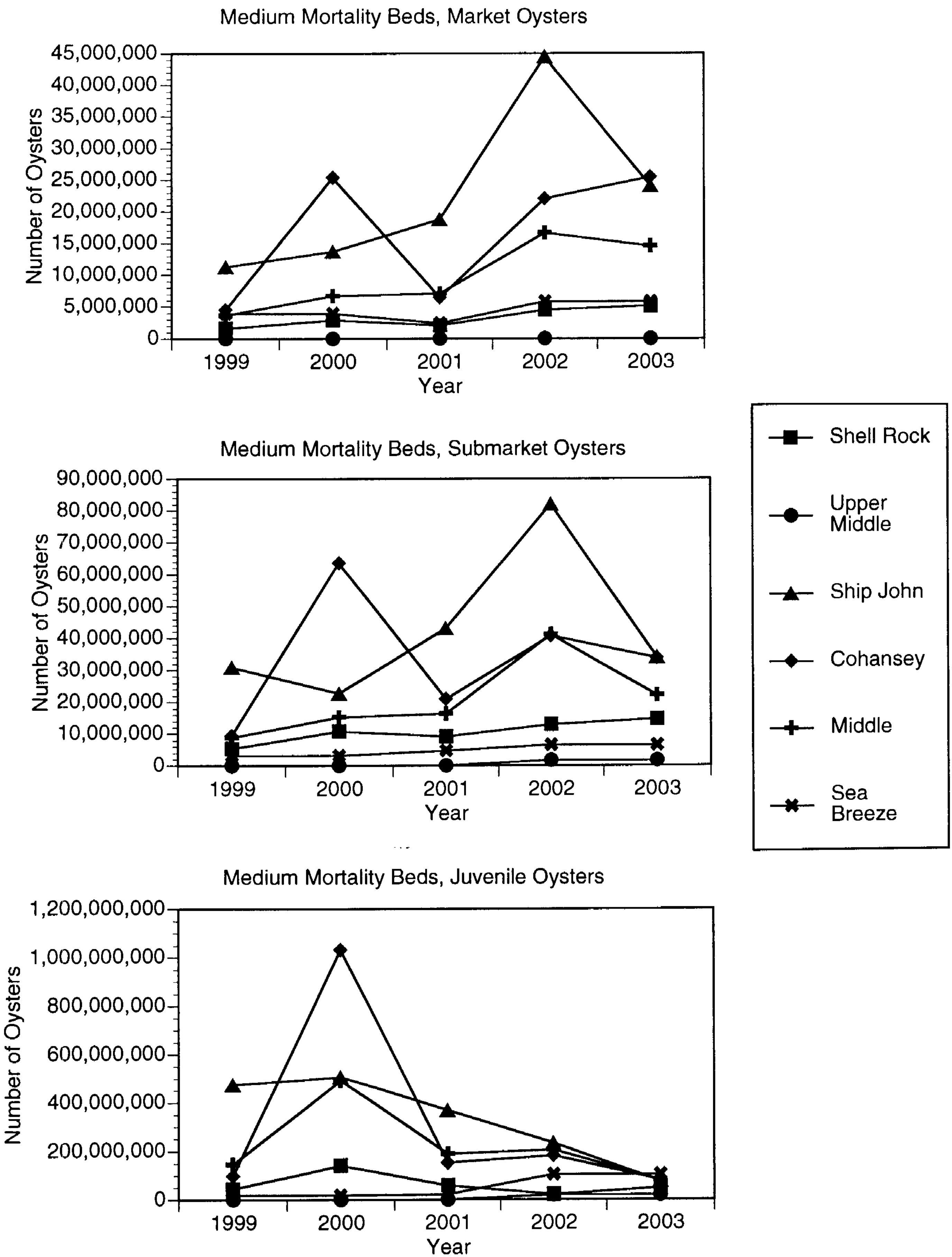
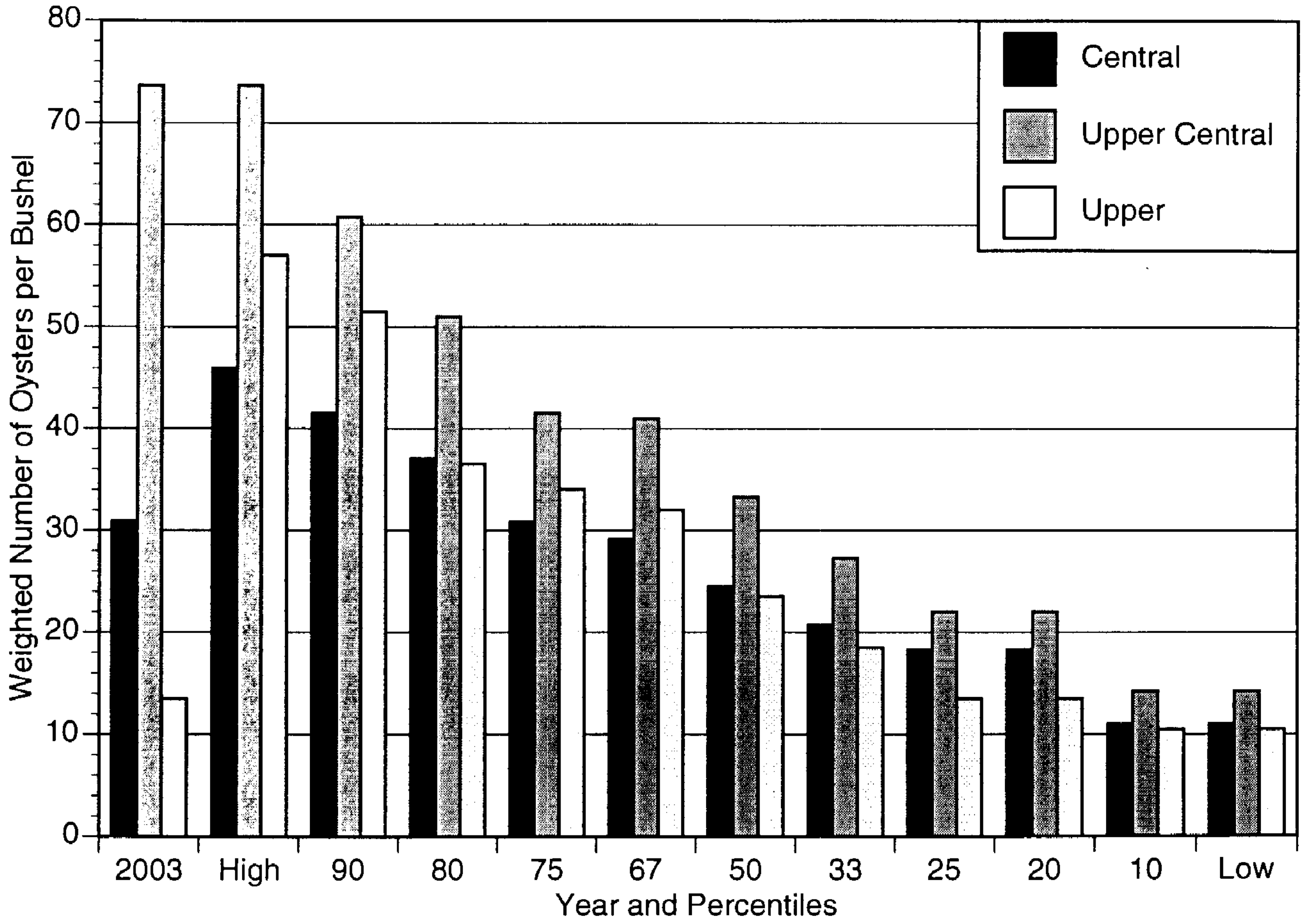

Medium Mortality Beds, Market Oysters
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Number of Oysters
1999
2000
2001
2002
2003
Year
Medium Mortality Beds, Submarket Oysters
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Number of Oysters
1999
2000
2001
2002
2003
Year
Medium Mortality Beds, Juvenile Oysters
1,200,000,000
1,000,000,000
800,000,000
600,000,000
400,000,000
200,000,000
0
Number of Oysters
1999
2000
2001
2002
2003
Year
Shell Rock
Upper Middle
Ship John
Cohansey
Middle
Sea Breeze

Figure 10.



Central
Upper Central
Upper
Weighted Number of Oysters per Bushel
80
70
60
50
40
30
20
10
0
2003
High
90
80
75
67
50
33
25
20
10
Low
Year and Percentiles

Figure 11.

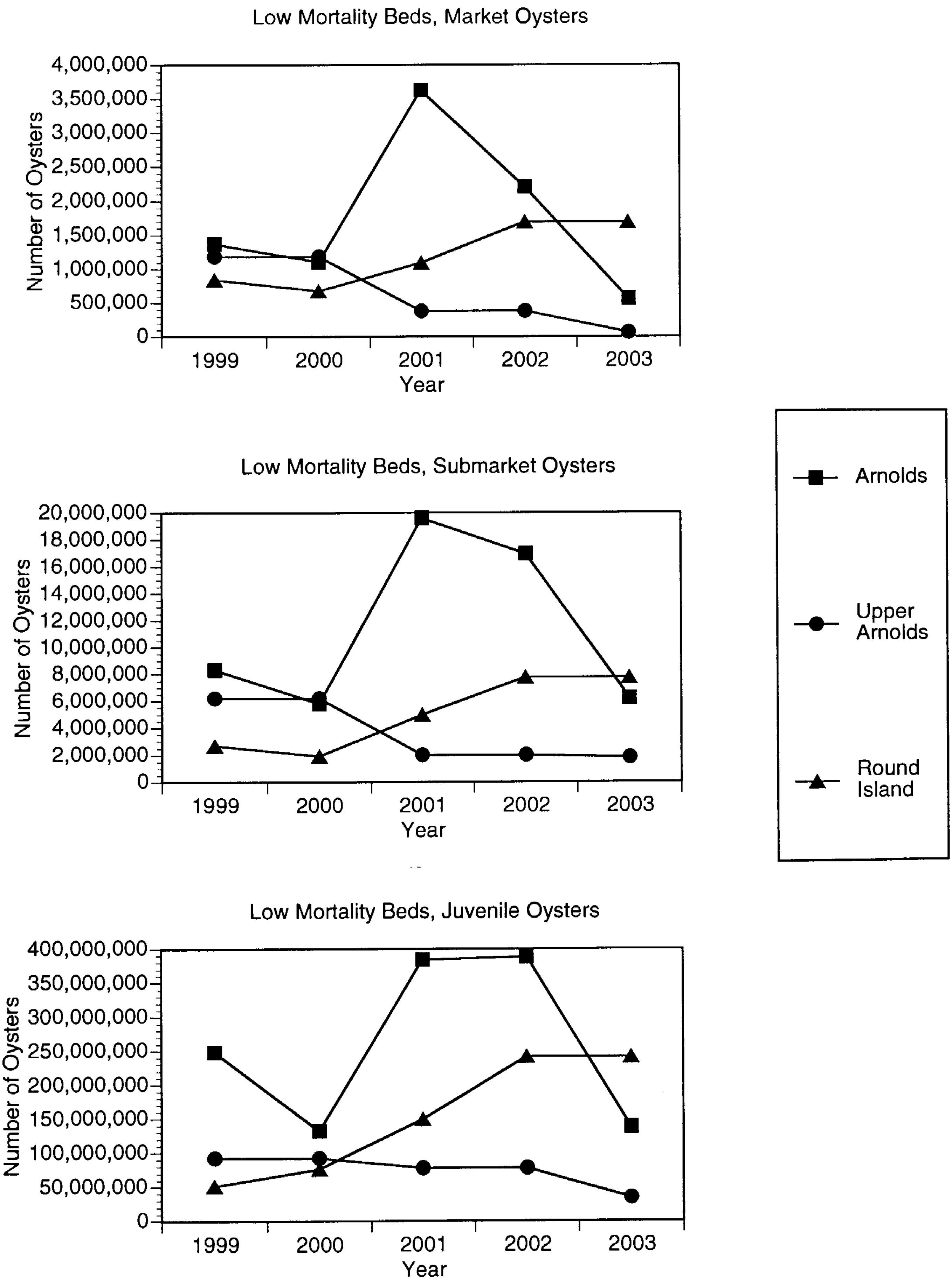
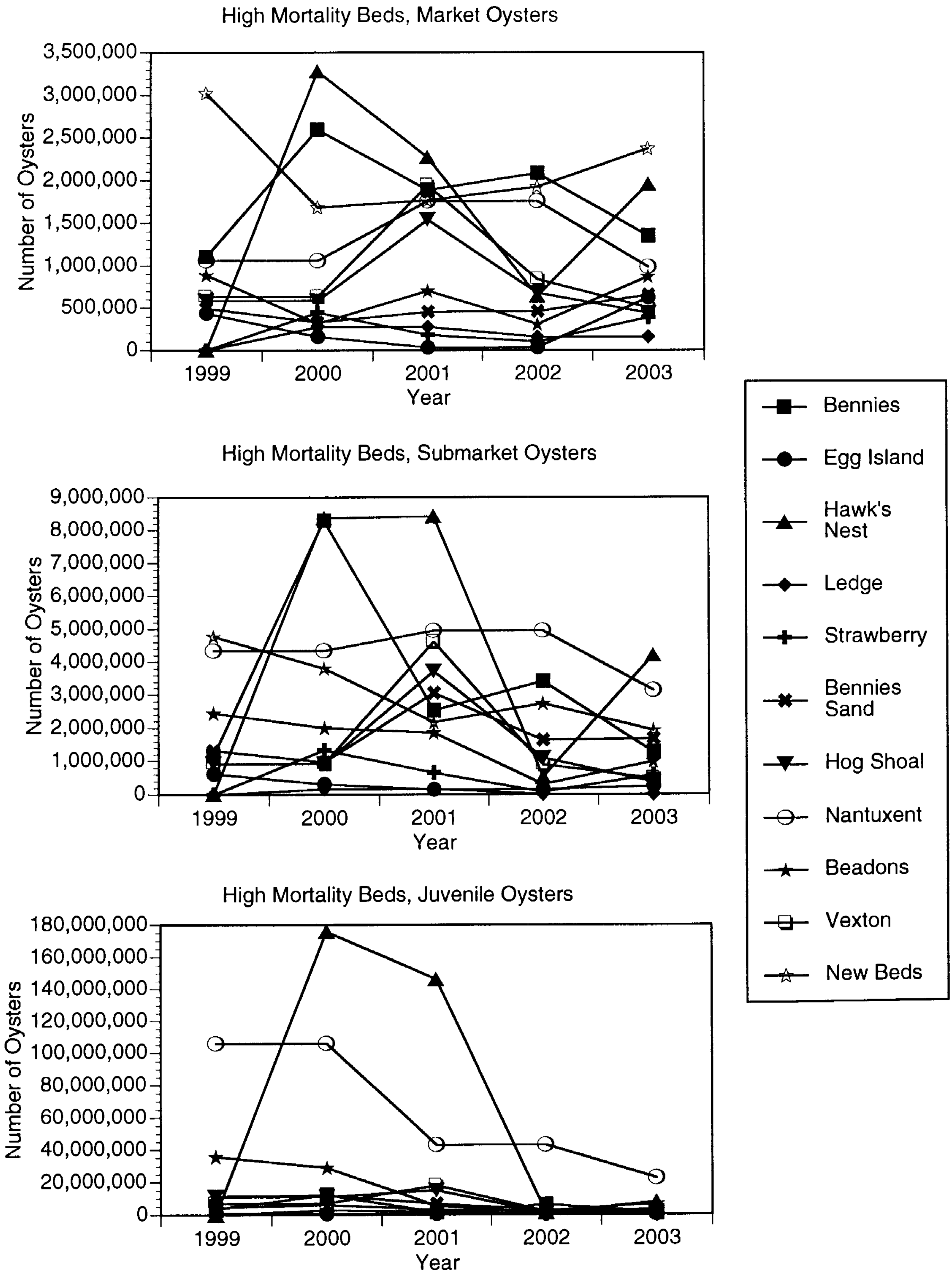

Low Mortality Beds, Market Oysters
Number of Oysters
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1999
2000
2001
2002
2003
Year
Low Mortality Beds, Submarket Oysters
Number of Oysters
20,000,000
18,000,000
16,000,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
1999
2000
2001
2002
2003
Year
Low Mortality Beds, Juvenile Oysters
Number of Oysters
400,000,000
350,000,000
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
0
1999
2000
2001
2002
2003
Year
Arnolds
Upper Arnolds
Round Island

Figure 12.



High Mortality Beds, Market Oysters
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Number of Oysters
1999
2000
2001
2002
2003
Year
High Mortality Beds, Submarket Oysters
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
0
Number of Oysters
1999
2000
2001
2002
2003
Year
High Mortality Beds, Juvenile Oysters
180,000,000
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
Number of Oysters
1999
2000
2001
2002
2003
Year
Bennies
Egg Island
Hawk's Nest
Ledge
Strawberry
Bennies Sand
Hog Shoal
Nantuxent
Beadons
Vexton
New Beds

Figure 13.

Delaware Bay Seed Beds - Oyster Condition Index

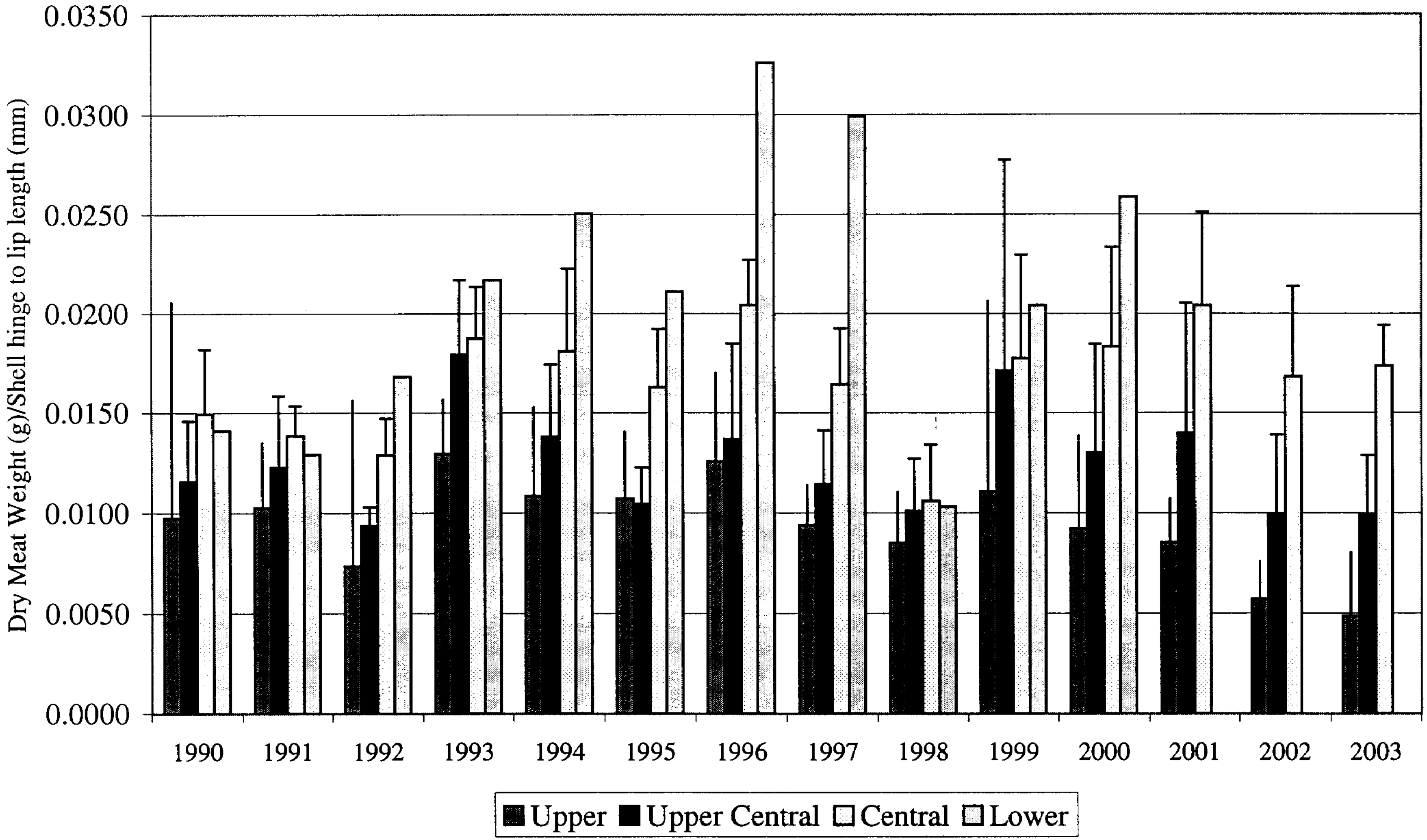


Figure 14.

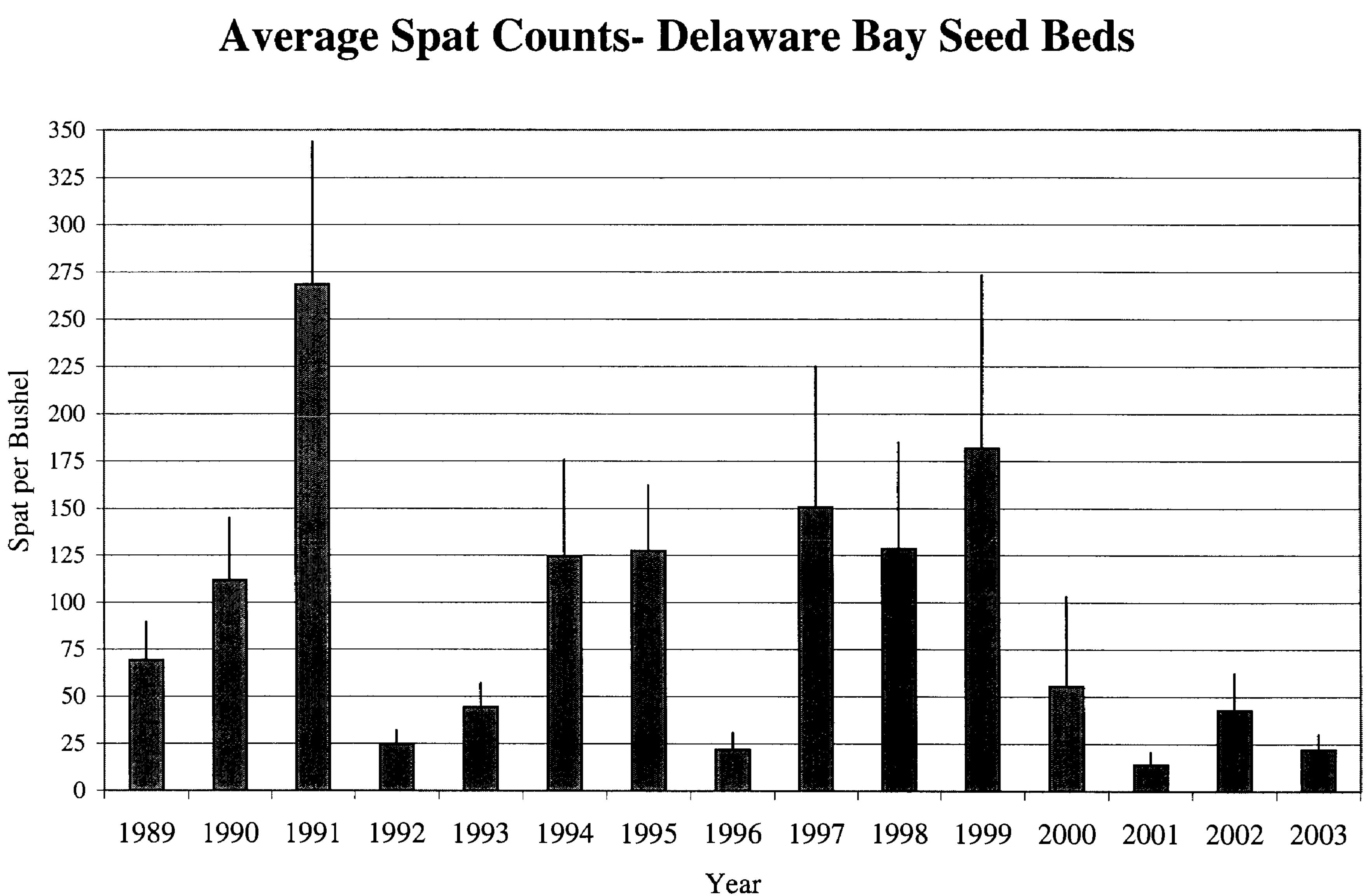

Average Spat Counts- Delaware Bay Seed Beds
Spat per Bushel
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Year

Figure 15.

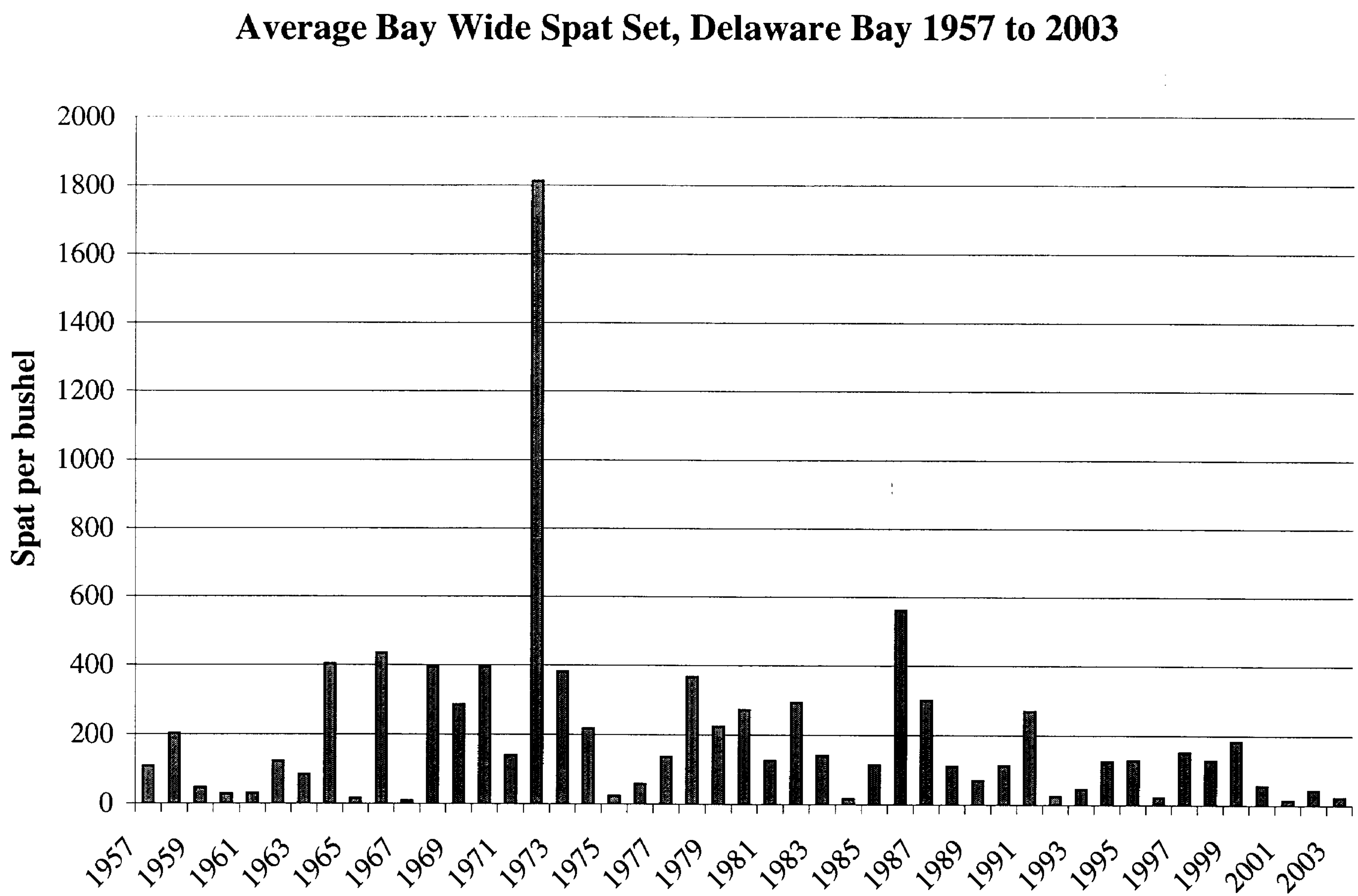
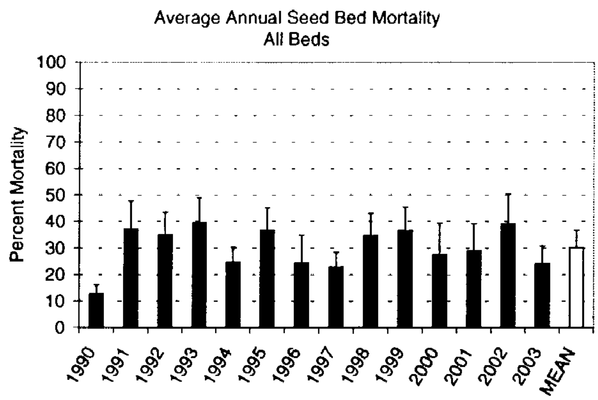
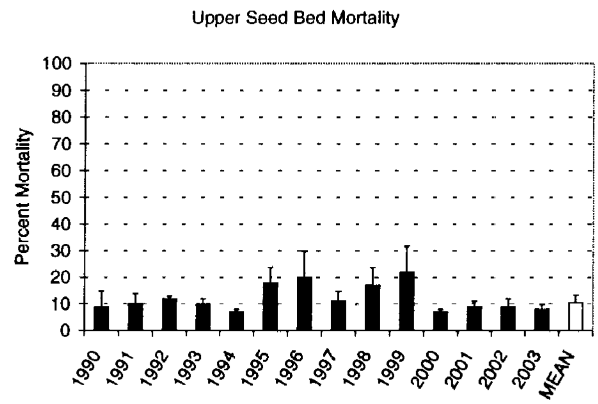
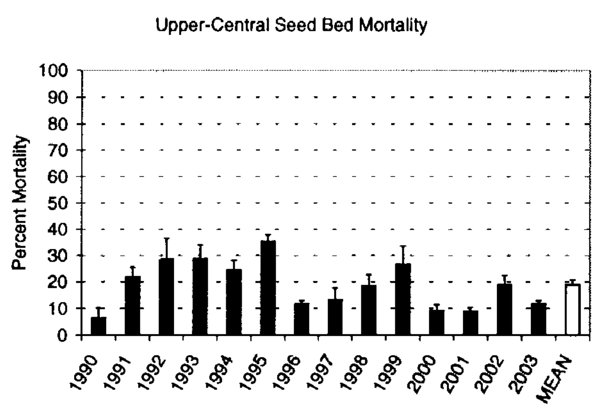

Average Bay Wide Spat Set, Delaware Bay 1957 to 2003
Spat per bushel
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003

Figure 16.


Average Annual Seed Bed Mortality
All Beds
Percent Mortality
100
90
80
70
60
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
MEAN


Upper Seed Bed Mortality
Percent Mortality
100
90
80
70
60
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
MEAN


Upper-Central Seed Bed Mortality
Percent Mortality
100
90
80
70
60
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
MEAN

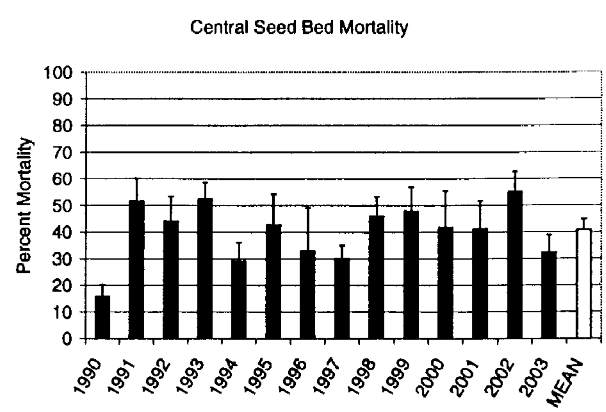
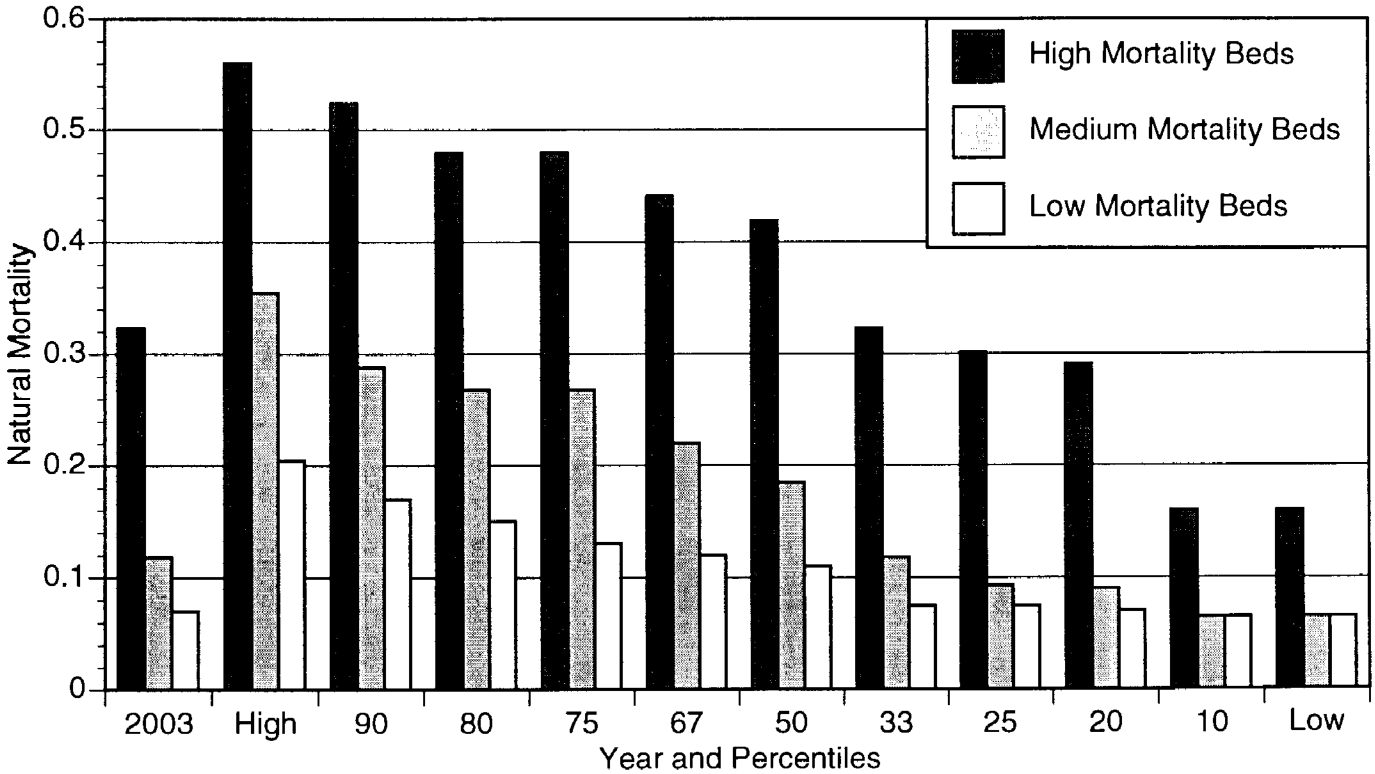

Central Seed Bed Mortality
Percent Mortality
100
90
80
70
60
50
40
30
20
10
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
MEAN

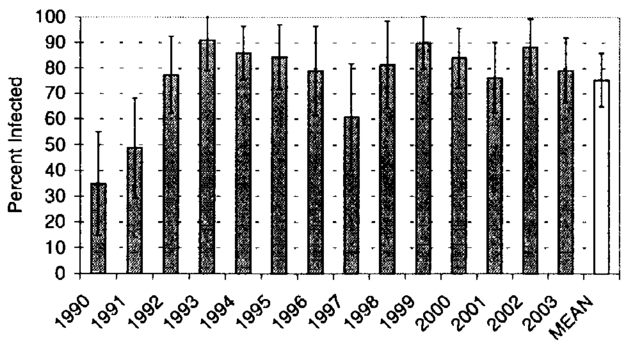
Figure 17.



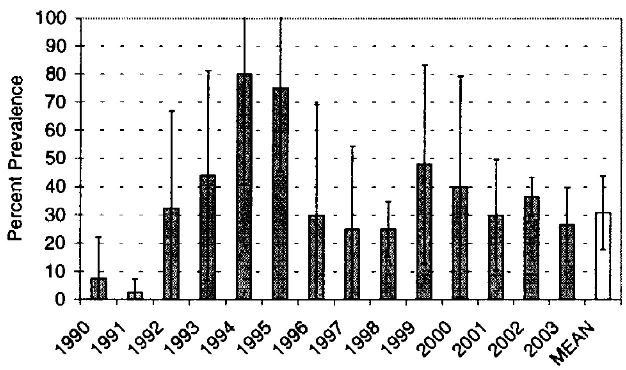
0.6
0.5
0.4
0.3
0.2
0.1
0
Natural Mortality
High Mortality Beds
Medium Mortality Beds
Low Mortality Beds
2003
High
90
80
75
67
50
33
25
20
10
Low
Year and Percentiles

Figure 18.

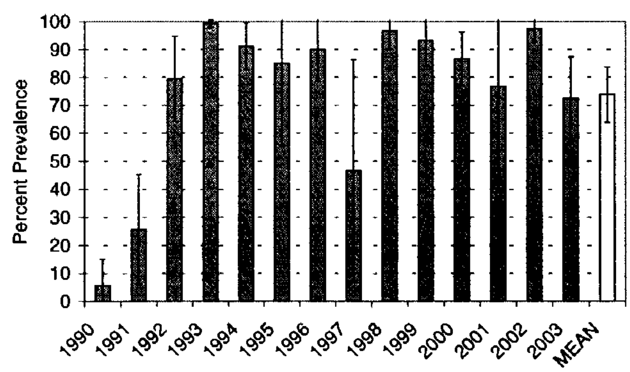
Annual Dermo Prevalence
All Seed Beds



Dermo Prevalence Upper Seed Beds



Dermo Prevalence Upper Central Seed Beds



Dermo Prevalence Central Seed Beds

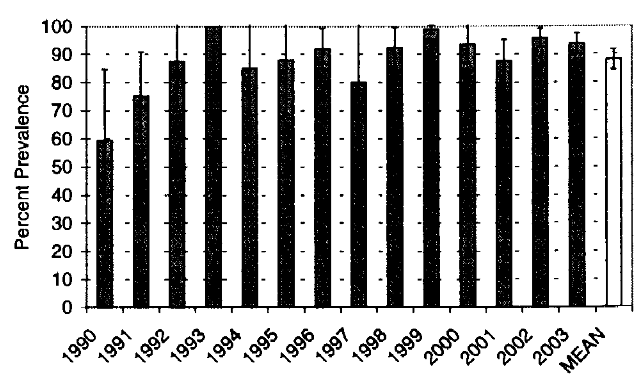


Figure 19.

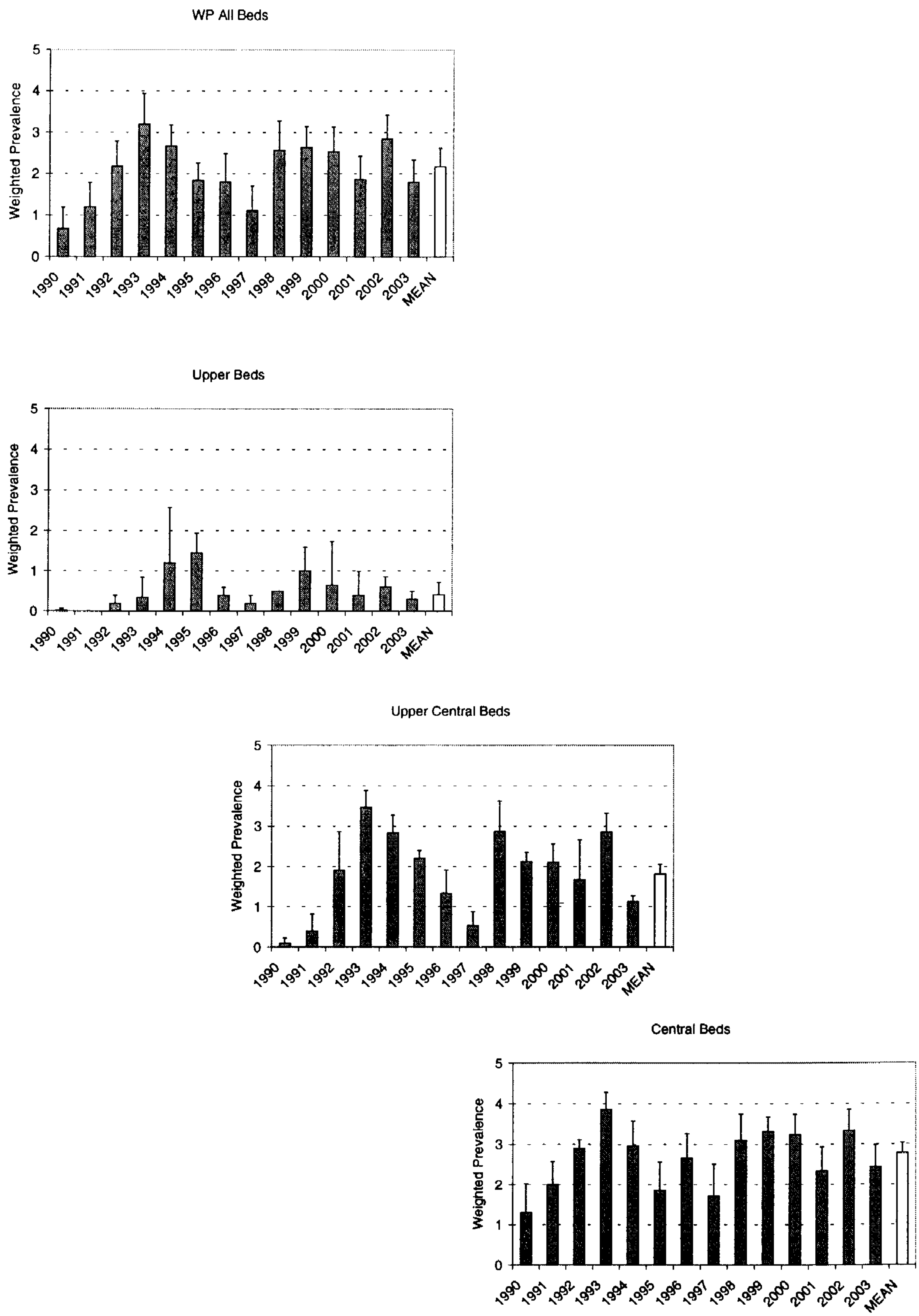

WP All Beds
Upper Beds
Upper Central Beds
Central Beds
Weighted Prevalence
0
1
2
3
4
5
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
MEAN

Figure 20.

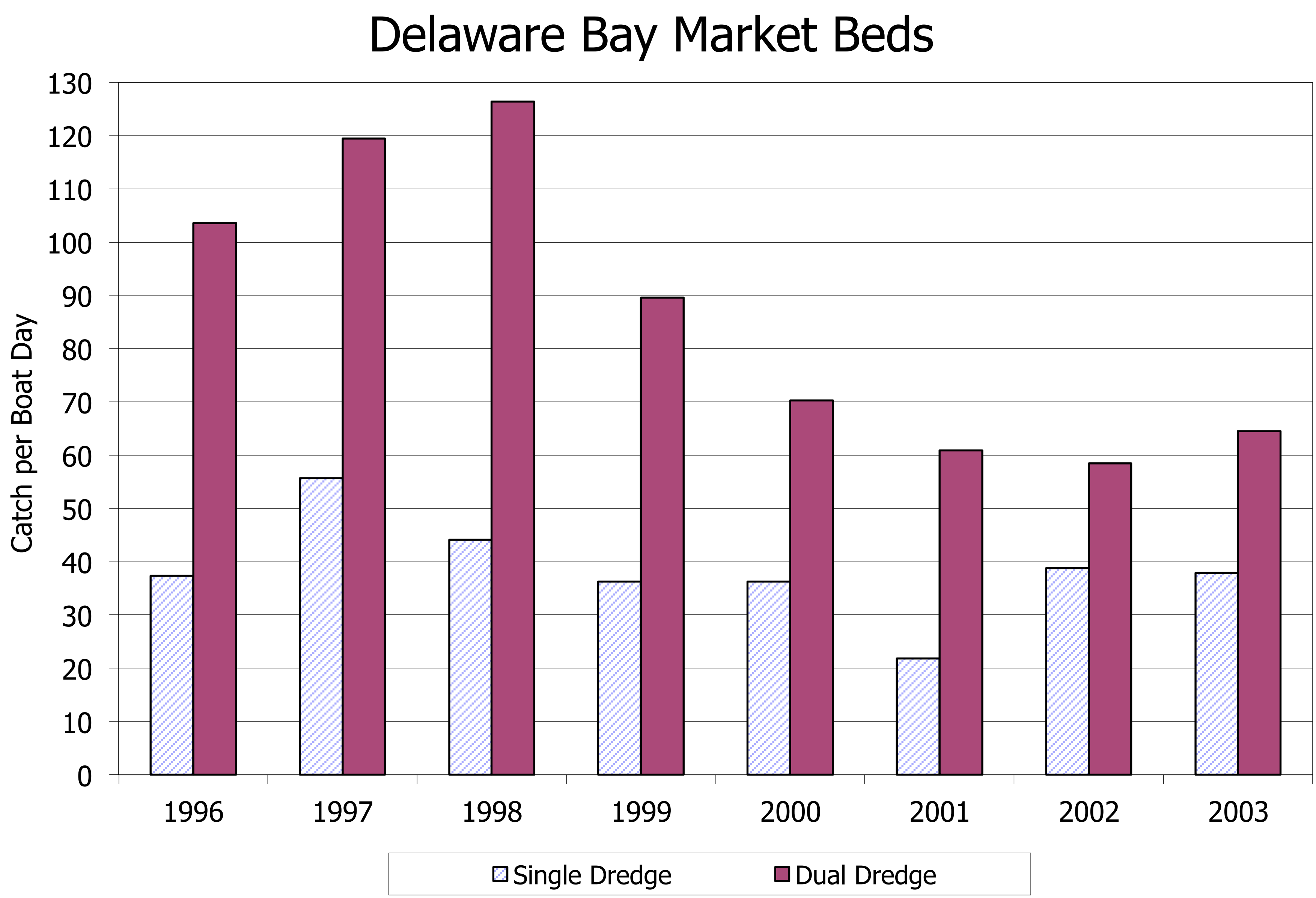

Delaware Bay Market Beds
Catch per Boat Day
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1996
1997
1998
1999
2000
2001
2002
2003
Single Dredge
Dual Dredge

Figure 21

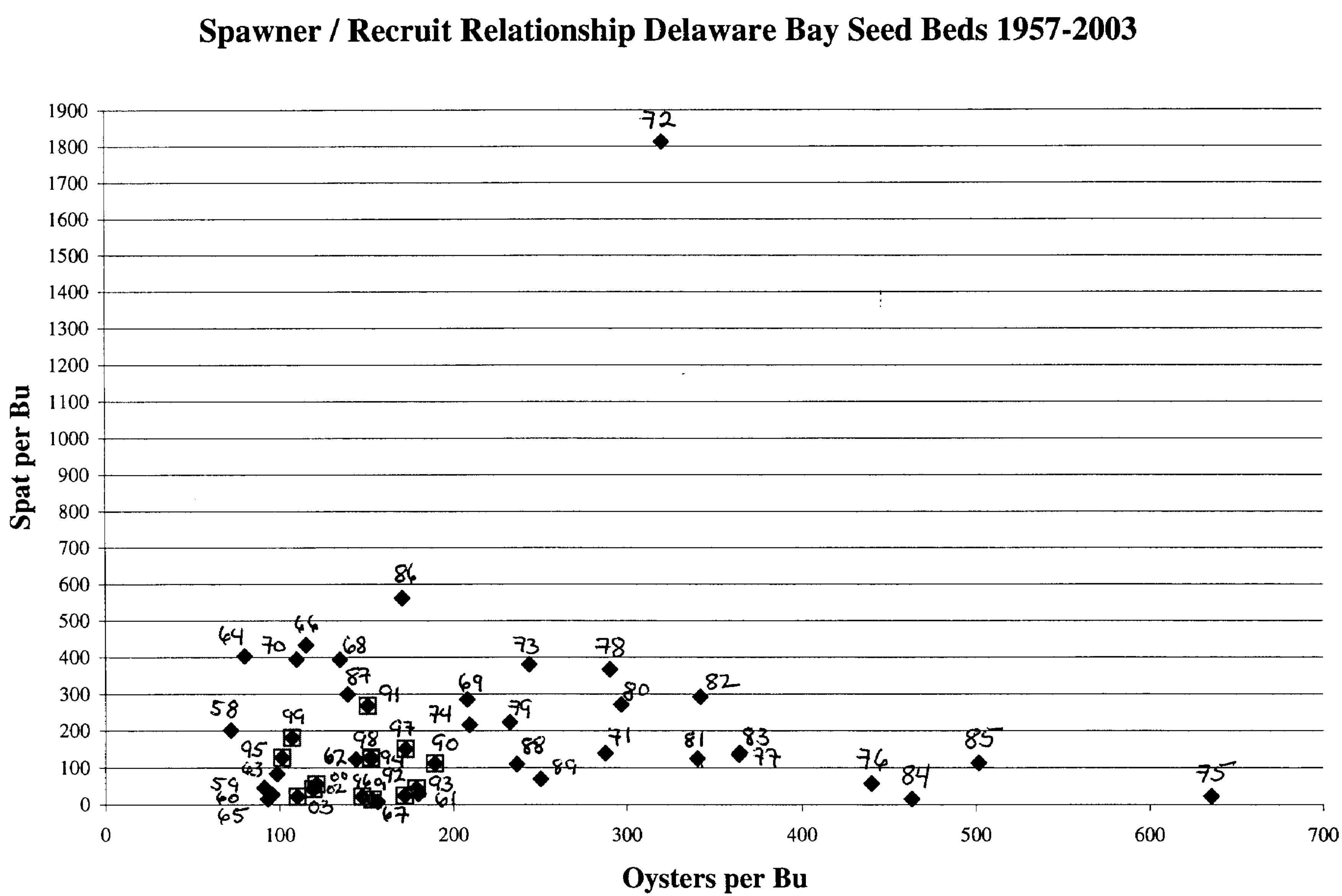
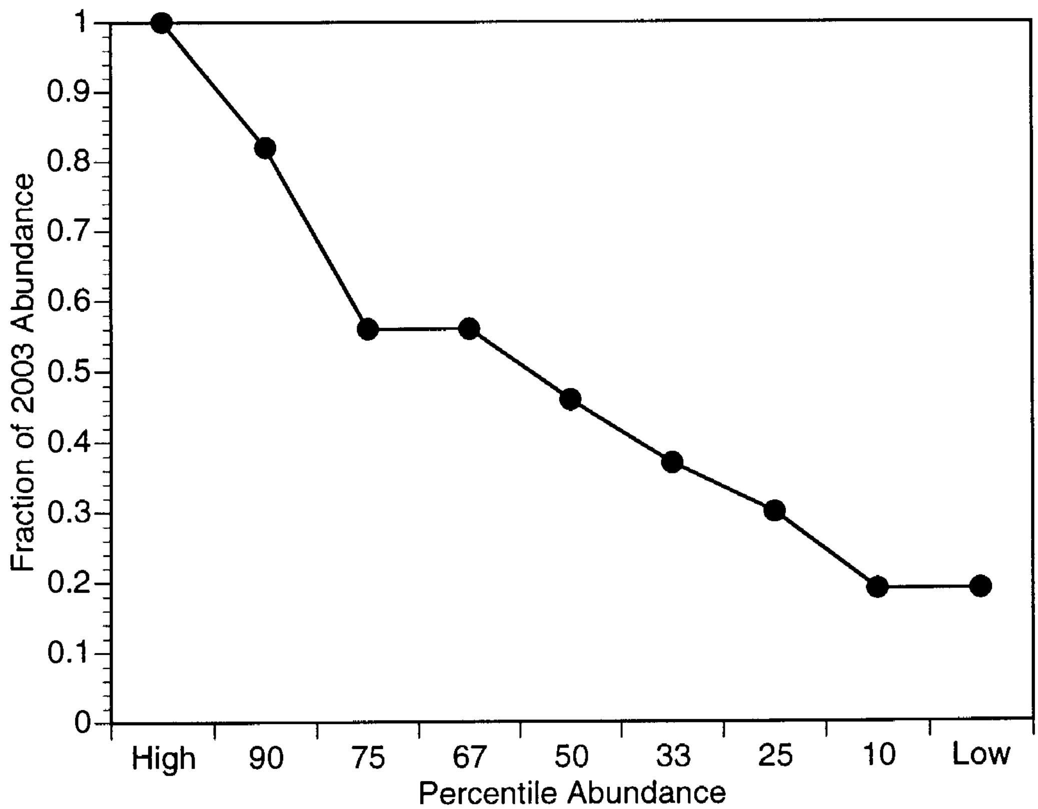

Spawner / Recruit Relationship Delaware Bay Seed Beds 1957-2003
Spat per Bu
Oysters per Bu
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900

Figure 22.



1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Fraction of 2003 Abundance
High
90
75
67
50
33
25
10
Low
Percentile Abundance

Figure 23.