# Report of the
# 2002 Stock Assessment Workshop
# for the
# New Jersey Delaware Bay Oyster Seed Beds

## Presenters:

**John Kraeuter**, Haskin Shellfish Research Laboratory
**Eric Powell**, Haskin Shellfish Research Laboratory
**Susan Ford**, Haskin Shellfish Research Laboratory

## Stock Assessment Review Committee:

**Scott Bailey**, Delaware Bay Section of the Shell Fisheries Council
**Joe Dobarro**, Rutgers University
**Steve Fleetwood,** Delaware Bay Section of the Shell Fisheries Council
**Bruce Halgren**, New Jersey Department of Environmental Protection
**Larry Jacobson,** NOAA, NMFS, Woods Hole
**Jim Joseph**, New Jersey Department of Environmental Protection
**Roger Mann**, Virginia Institute of Marine Science
**Tom Soniat**, Nicholls State University

## Editors:

**John Kraeuter**, Haskin Shellfish Research Laboratory
**Eric Powell**, Haskin Shellfish Research Laboratory
**Susan Ford**, Haskin Shellfish Research Laboratory

**Distribution List**
Nancy Sittineri, Chair, Delaware Bay Section of the Shell Fisheries Council
Jim Joseph, New Jersey Department of Environmental Protection
Selected faculty and Staff, Haskin Shellfish Research Laboratory
Oyster Industry Science Steering Committee
Stock Assessment Review Committee

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## Executive Summary 2002 Stock Assessment Workshop

The stock assessment workshop utilized data from the historical record, the 2001 seed bed random sampling program, dredge efficiency studies and a model to develop harvest allocations for the 2002 oyster season. The data and support documentation is provided in the following document.

**Status of the Stock:**

Oysters- Baywide oyster abundance remained about the same a last year. Market size (>3") oyster abundance has been maintained on the Market beds, and there appears to be a modest trend toward increased submarket (2.5 to 2.99") oyster abundance on these beds

Numbers of oyster in all size classes on beds below Bennies Sand have continued to deteriorate.

Oyster meat (Condition Index) was about the same as last year. Meat quality was excellent, but the slight decrease in condition in the Upper regions of the bay continues.

Spat set was very low throughout the bay. The average spat count was the poorest in the last 13 years. The trend toward declining recruitment on some key beds in t he central area of the bay of continuing concern. In addition, the low spat counts this and last year, and continued Dermo mortality suggest that lower market and submarket oyster abundance can be expected in 2004 and 2005.

Box count mortality (natural mortality) was about the same or slightly lower than last year. Mortality became greater the farther down bay one progressed. Because weather was exceptionally warm and dry well into December, it is likely that disease-caused mortality continued after the late October survey period. This implies that the stock condition could be slightly worse than indicated.

Dermo levels were about the same as last year, but there is evidence of a slight reduction on some beds. As with mortality, percentage of oysters infected and the intensity of the infection became greater the farther down bay one progressed.

Harvest came mostly (>89%) from Shell Rock, Bennies, Bennies Sand, Hog Shoal and New Beds. The industry harvested nearly 71,000 bushels out of an allocation of 106,000 bu. recommended by last years SAW.

Catch per unit effort (CPUE) declined for the fifth year in a row. The first year of the direct market effort (1996) had a lower CPUE than the next two years, but the fishery only existed for a portion of the 1996 season.

Transplants came from Arnolds, Middle, Ship John, Cohansey and Nantuxent Point. The industry transplanted slightly more than 52,000 bu. These were moved from the Upper Central beds and Nantuxent Point to New Beds and Bennies Sand.

**Management Advice**

For model purposes direct Market beds are all beds below Ship John except Nantuxent and Beadons.

The Market beds are divided into high-mortality and medium-mortality beds.

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

Medium mortality beds is: Shell Rock.

Allocations from the Market beds are modeled for two fishing periods: Before June 30 and After June 30.

Prior to the After June 30 period, Dermo mortality should be predicted and used to update the second period allocation.

The majority of oysters available for direct market are on Shell Rock, Ship John and Cohansey. Oysters from the latter two beds are not marketable due to poor meat quality.

Area management (the opening and closing specific beds or groups of beds to harvest) will increase the numbers of marketable oysters by permitting better allocation of fishing effort.

**1.** With area management and with a transplant, between 88,000 and 107,000 bu. are available for harvest.
**2.** With area management and without a transplant, 69,000 bushels are available for harvest.
**3.** Without area management and with a transplant, between 102,000 and 83,000 bu. are available for harvest.
**4.** Without area management and without a transplant, 64,000 bu. are available for harvest.

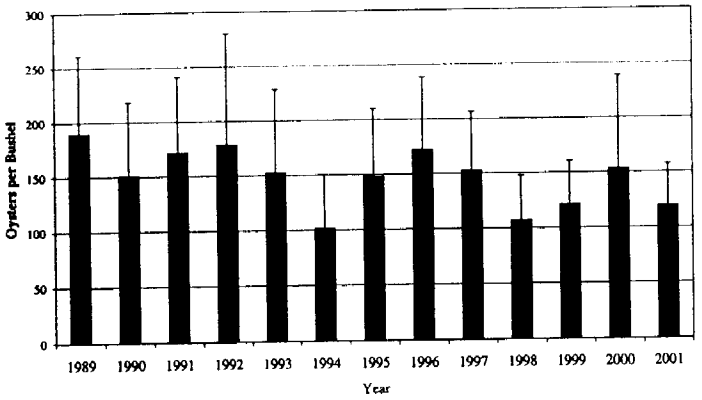
If transplantation is to take place the following should be considered:

**1.**Transplant Upper and Upper Central (except Shell Rock) oysters to New Beds, Bennies or Bennies Sand.
**2.** The inshore Nantuxent/Beadons oysters should be transplanted to New Beds in low Dermo years, but what to do in high Dermo years needs further evaluation.
**3.** Most of the transplant program should take place from mid August through September.

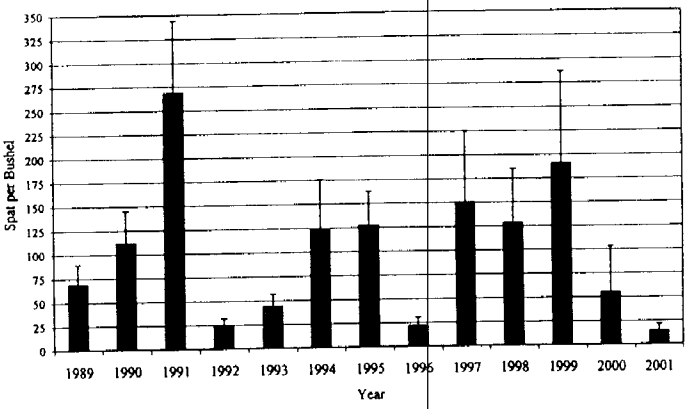
There is no reason to change the $10^0$C rule to close the fall harvest.

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

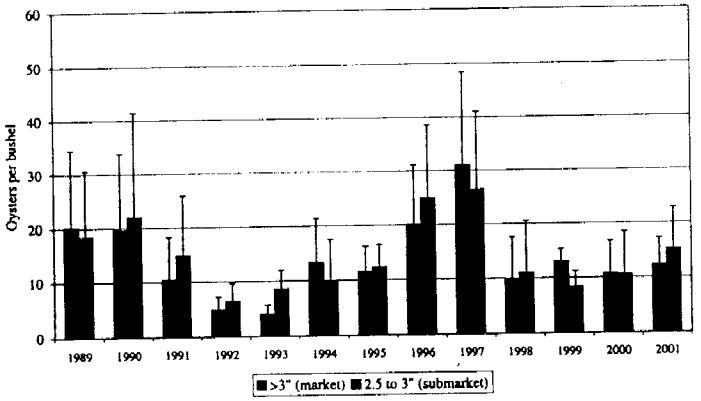
Average Delaware Bay Oyster Abundance



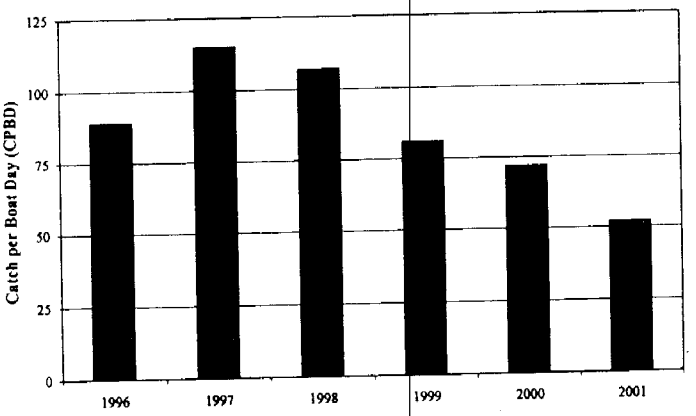

**Average Spat Counts- Delaware Bay Seed Beds**



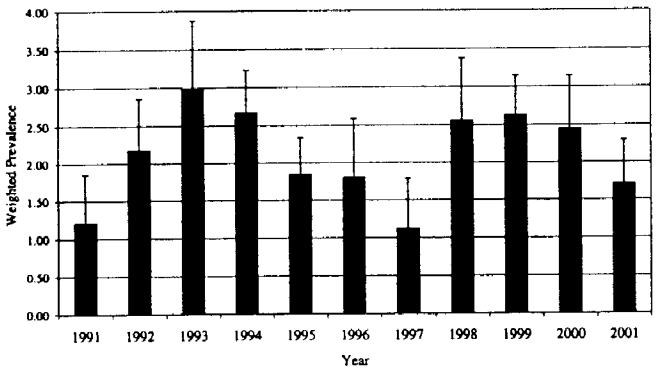

Market Beds - Oysters per Bushel by Size



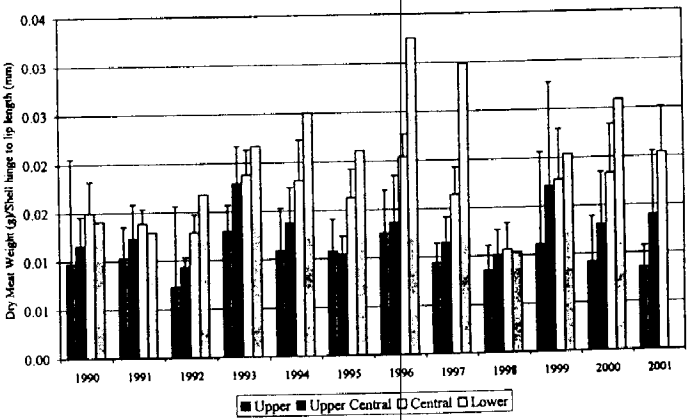

**CPBD - Delaware Bay Market Beds**




Average Dermo (*Perkinsus marinus*)
Delaware Bay Seed Beds




**Delaware Bay Seed Beds - Oyster Condition Index**



# 2002 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 is 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 have an abundance of oysters less than 25% of the time. The survey consists of about 100 samples covering the primary and most of the minor seed beds. Each sample represents a composite of 3 one-third bushels from three one-minute tows within each grid. The current survey instrument is a standard 1.27 m commercial oyster dredge on a typical large Delaware Bay dredge boat, *Howard 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, yearlings, and older oysters per composite bushel; the size of live oysters >20mm from the composite bushel; 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 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 seed

beds 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.

During the period 1953 to 1992, the bay-wide mean number of oysters per bushel was about 100, with a bay-wide average maximum of a little over 600. The highest numbers were on the upper beds and the lowest, on the lower beds (Table 1). During the past decade (1989 to 2000), the bay-wide overall mean of 150 oysters $bu.^{-1}$ has varied little, and the changes have not been statistically significant (Figure 2). The 1953-92 bay-wide mean spat $bu.^{-1}$ was about 51, with an average bay wide maximum of 2100 (Table 1). In the last decade the bay-wide overall average has been 102 spat $bu.^{-1}$, about twice the earlier figure. The mean spat count for the fifty year period is 58 spat $bu.^{-1}$. The maximum seed removed from the seed beds 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 bushels per year were transplanted to the lower bay leased grounds (Figure 3). Since the program of direct landing of oysters from the seed beds was instituted in 1996, the greatest landing occurred in 1998 (136,000 bu.). The average yearly landing since 1996 has been slightly more than 79,000 bu.

## Status of Stock and Fishery

### Seed Bed Sampling

#### Oyster

Sampling in 2001 was conducted from October 29 to October 31 using donated time on the oyster dredge boat *Howard Sockwell* with Sam Elias as captain. Samples were collected from the standard random stratified grid system on each of the major seed beds and a subset of the minor beds. These latter beds are sampled every other year. Samples were taken from the two best grids on Strawberry and Hawk's Nest that were sampled last year. These were added because of the harvesting activity on these beds.

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 decade the seed bed region has experienced a nearly a two fold fluctuation in the number of oysters per bushel, but no statistical differences (Figure 4). The bay-

wide average number of 147 oysters bu.$^{-1}$ in 2001 was statistically the same as for the present decade, but about 50% higher than the long term average of 100 oysters bu.$^{-1}$.

Beds in the Upper and Upper Central segments of the bay continue to support high oyster abundance (Table 2). Most of these beds (except Upper Middle and Middle) have > 150 oysters bu.$^{-1}$. Beds in the Upper and Upper Central region with grids containing >40% oyster varied more this year than in previous ones. Round Island, which experienced little or no fishing, did not have one grid with > 40% oyster while all the grids on the heavily fished Shell Rock continue to support high levels of oyster abundance, and most grids had >40% oyster. Cohansey, after having all grids with > 40% oyster last year, had only 2 grids having a substantial percentage of oyster. Whether this is due to fishing or the random grid selection cannot be determined from the present data, but since only 18,000 bu. were removed and there was no evidence of high mortality, it seems likely that the change in abundance is due to the random grid selection.

Oyster abundance on beds in the Central and Lower segments of the bay fall into two groups; those that have retained high to moderate levels (>40%) of oysters (the inshore beds - Nantuxent Point, Hog Shoal, Vexton and Hawks Nest) and the remainder (Table 2). This latter group has continued to deteriorate with all grids < 31% oyster. The percentage of the number of oysters in the market and submarket categories was >25% on all beds except Hawk's Nest and Nantuxent Point. There is a general trend for this percentage to be increasing on most Central and Lower Bay beds. During the past decade the percentage >2.5" has been about 15% on all of these beds. The increase in this percentage is primarily due to low recruitment and not because more large oysters are present. Within the inshore grids, Beadons is notable because it continues to deteriorate and is beginning to resemble New Beds with low abundance, high Dermo and a high percentage of oysters >2.5".

The important areas for the oyster industry are the beds in the Upper Central and Central region. Examination of the trends on the individual seed beds 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 2001 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.

Last year the data indicated a substantial increase in the numbers of total oysters per bushel on the Upper Central beds, due to the 1998 and 1999 sets, and an extremely high average count on Cohansey. In 2001 total oysters on these beds declined, mostly because Cohansey bed counts returned to long-term levels. The decline trend was not evident on the heavily fished beds (Figure 6). Submarket oysters ( >2.5") have remained about the same in the Upper Central region for the past 4 years, while on the market beds they may show a slight increase (Figure 7). With the exception of Shell Rock (Table 2), the percentage of the number of oysters/bu. **greater than** 2.5" has generally decreased or remained about the same in the Upper Central areas of the bay (Figure 8). Unfortunately, this is not because of an increasing abundance of small oysters, but because the number of oysters > 2.5" has generally declined in these regions (Table 2). Although the percentage of oysters >2.5" on Shell Rock has gone up slightly this is primarily because of the increase in the numbers of oysters in this size class (not recruitment). This suggests that the good growth of the past year, coupled with drop in spat and heavy fishing pressure, may result in declining numbers of oysters on this bed in the next few years. This is particularly important because this bed has produced >30% of direct market landings this past year.

With Shell Rock of the Upper Central region, the Central region supplied the majority of market oysters this past year. The numbers of market size (> 3") oysters on the beds supplying the most market oysters: Bennies Sand, Bennies and New Beds and Hog Shoal, remained about the same as last year (Table 3, Figure 9). The percentage of total oysters in the > 2.5" size class is over 65% on Bennies and New Beds and appears to be increasing on Bennies Sand and slowly increasing on Hog Shoal (Table 2). It is important to note that the relatively good sets on Bennies Sand and many of the inshore beds in 1998 and 1999 were not repeated in 2000 or 2001 (Table 2). New Beds and Bennies Sand received transplanted oysters from the Upper and Upper Central Regions. The majority of the transplants were placed on New Beds, but Bennies Sand received 6,500 bu. of Arnolds stock. The transplants should help maintain market oysters abundance on these beds in the near term in spite of the overall downward trend in recent years.

**Oyster Condition**

On a bay-wide basis, condition index remained about the same as last year (Figure 9), but the condition of the oysters in the Central and Upper Central areas may have increased slightly while that of the Upper area declined somewhat (Figure 10). Data from the Lower area are not available this year because too few oysters were collected.

**Spat Set**

Spat set in 2001 was, extremely poor (Table 2, Figure 11) and was the lowest in the past 13 years. The bay wide spat counts (mean = 14 bu.$^{-1}$) were well below the long term mean of 50 spat bu.$^{-1}$, and far below the 102 spat bu.$^{-1}$decade long mean. Spat set was 50 bu.$^{-1}$ or lower on all beds but Arnolds, Ship John, Shell Rock and Hawk's Nest, and was below 26 spat bu.$^{-1}$ on all other beds. On a longer term perspective, spat settlement for the period of 1997 to 1999 was at the upper end of the 12 year range (Figure 4). This is also a period when the mean spat fall was nearly double the nearly 40 year long term average and the past two year have been at or below the long term average.

**Mortality and Disease**

Since the onset of the Dermo (*Perkinsus marinus*) epizootic in 1990, average mortality on the seed beds, as assessed by box counts during the fall survey, has fallen into 3 major groups: Upper, Upper Central and Central/Lower, with the lowest values on the Upper beds. Over the past two years, however, mortality in the two upper regions has been similar and about 25% of those in the Central/Lower region (Table 2, Figure 12). In all three locations, oyster mortality in 2001 was the same as in 2000, and somewhat lower than in the previous two years. The dividing line between the Upper Central and Central regions is between Shell Rock and Bennies Sand beds, which are close to each other and typically have similar *P. marinus* infection levels. Thus, *P. marinus* levels alone cannot explain this discrepancy.

Prevalence of *P. marinus* continued a modest downward trend that began 3-4 years ago, but detectable infections exceeded 80% in all Upper Central and Central/Lower beds (Fig. 13). An average 30% of oysters had detectable infections in the Upper region. The Weighted Prevalence, which includes infection intensity, showed a clearer gradient in an upbay-downbay direction, averaging 0.4, 1.7, and 2.3 (out of 5.0) from the Upper to Central/Lower beds (Fig. 13). It is noteworthy that both *P. marinus* infection levels and mortality was similar to last year, and lower than the previous two years, despite the fact that the autumn of 2001 was exceptionally warm and dry.

Samples were collected in May 2001 to test a model, developed last year, which suggest that May prevalence could predict *P. marinus*-caused mortality over the summer and fall. Eight beds were sampled: Arnolds, Middle, Cohansey, Ship John, Shell Rock, Bennies Sand, Bennies, and New Beds. Prevalence ranged from 0 at Arnolds to 75% at New Beds. Predicted mortality

was compared with observed box count mortality at the end of October (Table 4). Observed mortality for 5 of the 8 beds (Arnolds, Middle, Bennies Sand, Bennies, and New Beds) was within the predicted 95% confidence intervals. Two, Cohansey and Ship John, fell just below (1-4 percentage points) the lower confidence interval, and one, Shell Rock, fell considerably lower (15 percentage points). These results confirm that, on average, May Dermo prevalences give a reasonable prediction of summer and early autumn seed bed mortality. It would be wise to continue to validate and update the relationship with continued monitoring.

The fishing model allocates oysters using an estimate of mortality on the beds that falls in the 75$^{th}$ percentile of historical values. If the May Dermo prevalence is significantly different from that used in the model simulation, which is made in January, the model could be re-run with the new mortality estimates and new allocations set.

MSX, *Haplosporidium nelsoni*, disease prevalence continued to be insignificant in 2001 (< 7% in October Samples).

**Harvest and Transplant**

**Harvest**

Based on a provision of a 21,000 bu. transplant program from Upper Central bay beds to Central bay beds, SAW 2000 recommended harvest limit of 106,000 bu. Beds were harvested almost continually from April 2, to November 16, 2001. The 33 weeks of fishing this year compare to 20 in 2000, 26.5 in 1999, 30 in 1998, 17 in 1996, and 25 in 1997. Harvest was from 14 beds and totaled 70,800 bushels. Five beds accounted for nearly 90% of harvest (Bennies (13%), Bennies Sand (12%), New Beds (11%) and Shell Rock (33%) and Hog Shoal (21%))(Table 5). Total catch for the 2001 season was 70,800 bu. (Figure 3). Thirty five boats participated in the fishery and worked for a total of 1343 boat days. The catch per boat day dropped to 52 bu.d$^{-1}$ from last year's average of 72 bu.d$^{-1}$. In prior years the average was markedly higher: 1999 - 81bu.d$^{-1}$, 1998 - 107 bu.d$^{-1}$, and1997 - 115 bu.d$^{-1}$. Historic catch per boat day figures have been adjusted based on corrected data supplied by NJ DEP, and may not correspond with data in previous SAW reports. The first year of the direct market fishery had an average catch per boat day of 89, but was only a partial year (Figure 14).

**Transplant**

Transplantation of 21,000 bu. from up bay and inshore high mortality seed beds to replace those being harvested was one of the management recommendations from the 2000 SAW. This

amount was passed by the Delaware Bay Shellfish Council and implemented in the August transplant. This amount was later increased for the October transplant to allow for greater harvest. During 2001 market season 52,195 bushels of oysters and material were moved from other seed beds to the market beds (Table 6). Between 1997 and 2000, about 154,000 bu. of material was moved from Upper Central and inshore Central beds to New Beds (parts of grids 24, 25. 38, and 39) and Bennies Sand (11)(Table 6). It should be noted that transplants of this type involve oysters of all sizes, and not just those in the market and submarket categories. Of the grids sampled in 2001 only grid 11 of Bennies Sand received transplants. August transplants were placed on Bennies Sand (6,500 bu.) and New Beds (12,645 bu.). These oysters came from three beds: Arnolds (6,500 bu.), Middle (6,395 bu.) and Nantuxent Point (6,250 bu.). All of the Arnolds oysters were planted on Bennies Sand and all other oysters were planted on New Beds. October transplants were moved from the Upper Central region beds Cohansey (18,400 bu.) and Ship John (14, 650 bu.). All 33,050 bu. were placed on New Beds.

## Other Studies

A number of other studies were completed this year. These include a growth study on the salinity gradient (Figure 15), continuing attempts to derive a means of predicting summer Dermo related mortality (see above), and a preliminary modeling of carrying capacity (see below). A summer student examined the size composition of oysters selected by the boats participating in the direct market program. Information from these is integrated into the stock assessment and management advice. Complete study reports will be available at Haskin Shellfish Research Laboratory as they are completed.

## Management Advice

### 2002 Direct-Market Allocation from Direct-Market Beds

Projections were made based on the management plan developed by the 2nd SAW. Under this plan, the goal for the direct-market beds is to have the number of market-size oysters at the end of the year equal the number at the beginning of the year. 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 and 2001 (Figures 16-19).

A rebuilding goal for the direct-market beds was set by the 3rd SAW. Because of the recommended expansion of the transplant program (see below), this rebuilding goal has not been

explicitly extended into 2002. However, the SARC notes that the transplant program will enhance abundance on the direct-market beds beyond 2002.

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. Ship John and Cohansey were **not** included in the direct-market program, in contrast to the plan developed by the 3rd SAW, because implementation of that plan did not result in substantial fishing effort directed to those beds in 2001 (Table 7). This decision is, in part, one of the reasons for the lowered estimate of available market oysters.

Estimates of oyster abundance on the direct-market beds were obtained from the 2001 survey and were based solely on the high quality and test areas (Table 8). Low quality areas were not included. A few beds were not sampled fully in 2001. Data for these beds were augmented using the remaining 2000 samplings. 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 3$^{rd}$ SAW (See table 5 in the 2001 report).

Market-size oysters are defined as those >75 mm. This decision was based on selectivity data developed during summer and fall 2001 (Figure 20). Conversion of numbers to bushels used an updated value of 345 oysters per bushel from data developed during the fall of 2001 (Figures 21-22). The conversion was obtained from the average of the six highest per bushel numbers obtained in the fall. The same study found that oysters marketed in the summer tended, on average, to be smaller than oysters marketed in the fall, hence, the conversion is the one most likely to approximate the average during the year.

The same numerical model was used this time as was used by the 3rd SAW. 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 the anticipated rate of natural mortality. The model then estimates the amount of fishing mortality necessary to balance abundance over the year. From that, the model provides an estimate of harvest consistent with the management goal set forth 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

3rd SAW, the natural mortality rate was set at the 75th percentile of observed yearly mortality rates since 1989. These were: 0.461 $yr^{-1}$ for the high-mortality beds and 0.266 $yr^{-1}$ for Shell Rock. Growth rates were obtained from the field growth study of 2001, and used to estimate the smallest oyster expected to recruit to the fishery in 2002 (Table 9). This size boundary was set at 65 mm for the high-mortality beds and 68 mm for Shell Rock.

Two fishing scenarios were investigated: (1) the 2001 scenario implemented by NJDEP in consultation with the Delaware Bay Section of the Shell Fisheries Council and (2) a continuous season without bed closure. The 2001 scenario was as follows. Fishing season: April 1 to October 15. High-mortality direct-market beds open to fishing on April 1 and assumed to close by August 31. Medium-mortality direct-market beds open to fishing April 1 to October 15. High-mortality beds were assumed to close when the allocation for those beds is caught, on or before August 31. Consequently, this scenario conforms to the principals of area management defined by the 3rd SAW and re-recommended in this document. This principal is that the number of bushels taken from the high-mortality beds is restricted to the allocation for those beds.

*Allocation Options*

| | |
|---|---|
| **Option 1.** 2001 Scenario- Area Management | |
| High-Mortality Beds | 45,604 |
| Medium-Mortality Beds (Shell Rock) | 23,143 |
| Total | 68,747 |
| **Option 2.** Continuous Season | |
| High-Mortality Beds | 41,067 |
| Medium-Mortality Beds (Shell Rock) | 22,721 |
| Total | 63,788 |

The difference in these estimates is due to the relative timing of fishing and natural mortality. In the 2001 scenario, most of the oysters on the high-mortality beds are harvested prior to the end of August when Dermo mortality reaches its peak. As a consequence, some oysters can be harvested that would otherwise die naturally. In the continuous season option, these same oysters die from Dermo and are lost to the fishery.

## Long-Range Projections: Direct-Market Beds

Only a limited number of juvenile oysters remain on some direct-market beds. These include New Beds and Bennies, where the supply of juveniles is so meager that natural production on the bed in 2002 may not sustain a fishery in 2003. Other direct-market beds, such as Shell Rock, Hawk's Nest and Bennies Sand are in better shape (Table 8). As a result, the 2003 direct-market allocation is likely to be small without additional transplants in 2002 and beyond.

A projection for 2003 was accomplished by assuming a continuous growth rate of the larger juveniles, the 75th percentile mortality rate for 2002 and 2003, no additional transplants, and that the management goal this year would be met, meaning that the number of market-size oysters on these beds would be conserved in 2002. Because it is likely that the growth rate is somewhat underestimated, it is likely that this projection somewhat underestimates the 2003 direct-market allocation.

*2003 Projection. Continuous Season*

| | |
|---|---|
| High-Mortality Beds | 27,464 |
| Medium-Mortality Beds (Shell Rock) | 11,180 |
| Total | 38,644 |

The reduction over 2002 is due to the low spat settlement rates in 2000 and 2001 that have reduced the total pool of juveniles on the direct-market beds. The SARC recommends the expansion of the transplant program in 2002 to augment the resource for 2003.

## Recommended 2002 Transplant Program

Transplant beds were divided into three groups based on their natural mortality rates as recommended by the 3rd 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; (3) high mortality beds: Nantuxent Point and Beadons.

Evaluation of the 2001 transplant program revealed that culling did not enrich the deckload percentage of larger animals that might be directly marketed. Essentially, the entire size-frequency distribution was moved downbay (Figure 20). Counts taken during the transplant program showed that the number of submarket/market oysters per bushel transplanted was 84.5/bushel.

The SARC investigated several options for determining the volume that might be transplanted downbay. The following were noted:

1. Estimates comparing food requirements to food availability using a carrying capacity model developed by Wilson-Ormond et al.(1997) suggest that oysters on beds such as Cohansey, Ship John, Middle and Arnolds, are food limited. Reduction in abundance might be expected to enhance oyster growth rates on these beds (Table 10).

2. Growth measurements made in 2001 showed low growth rates on Cohansey. Higher growth might be anticipated at lower population densities.

3. Spat counts averaged higher on these beds than on the direct-market beds. Present abundance on these beds exceeds the long-term average abundance.

4. Median yearly mortality rates are 0.28 (Cohansey area) and 0.12 (Arnolds area). Setting a transplant rate at something less than the natural mortality rate is probably within the replacement capacity of these beds.

5. From 1958 through 1986, an average of 80,000 bu. was removed "annually" and transplanted to the planting grounds. The beds and amounts (bu.) were: Arnolds – 7,400, Upper Middle – 4,600, Middle – 15,700, Cohansey – 39,000 and Ship John – 14,500.

The SARC concluded that a 10% removal rate from these beds to support a transplant program was a reasonable goal. Transplant could occur early or late in 2002, depending on the management goal. The following calculations provide guidance as to the number of bushels that might be transplanted. For simplicity, the data are provided in market-size equivalent bushels. Total abundance can be calculated by multiplying each number by 345.

*Option 1. April Transplant.*

Because the oysters would be moved downbay to the high-mortality beds, the size classes have been constructed according to those established by the measured high-mortality-bed growth rates.

| | Juveniles | Submarkets | Markets |
|---|---|---|---|
| Low-Mortality Beds | 1,770,767 | 67,289 | 24,575 |
| Medium-Mortality Beds (without Shell Rock) | 2,118,265 | 202,335 | 144,202 |
| High-Mortality Beds (Nantuxent and Beadons) | 139,249 | 16,427 | 9,056 |
| Total | 4,028,281 | 286,051 | 177,833 |
| 10%: | 402,828 | 28,605 | 17,783 |

At 84.5 submarket/market oysters per bushel of transplanted material, a 10% transplant would require the transplant of 189,395 (95% confidence limits = +/- 36,964) bushels of material.

*Option 2. Late August Transplant.*

Because the oysters would be moved downbay after much of the growing season, the size classes have been constructed according to those established by the measured medium-mortality bed growth rates.

| | Juveniles | Submarkets | Markets |
|---|---|---|---|
| Low-Mortality Beds | 1,517,547 | 57,666 | 21,060 |
| Medium-Mortality Beds (without Shell Rock) | 1,554,807 | 148,513 | 105,844 |
| High-Mortality Beds (Nantuxent and Beadons) | 75,055 | 8,854 | 3,264 |
| Total | 3,147,409 | 215,033 | 130,168 |
| 10%: | 314,741 | 21,503 | 13,017 |

At 84.5 (95% confidence interval = 16.4) market/submarket oysters per bushel of transplanted material, a 10% transplant would require the transplant of 140,940 (+/- 27,507) bushels of material downbay.

| | April Transplant | August Transplant |
|---|---|---|
| Required Transplant Volume: (bushels of material) | 189,395 | 140,940 |

Regardless of the timing, because the mortality rates are different between bed groups, as are the numbers of oysters of submarket size and market size, any transplant should be properly allocated between bed groups.

The SARC was concerned about the impact of the transplant program on the total shell resource. A very conservative estimate of the total shell resource (in bushels), based on the quantity of material taken in the survey, just for the test and bed proper areas, is as follows.

| | Total Shell Resources |
|---|---|
| Low-Mortality Beds | 3,452,778 |
| Medium-Mortality Beds (excluding Shell Rock) | 6,293,812 |
| High Mortality Beds (Nantuxent and Beadons) | 1,321,352 |
| Direct-Market Beds | 9,060,268 |
| Total (upper 3) | 11,067,942 |
| Fraction Moved (April Transplant) | 0.017 |
| Fraction Moved (August Transplant) | 0.013 |

The number of bushels of material to be moved is small in comparison to the estimated volume on the beds. Consequently, in the near term, the transplant program can commence without shell replenishment. However, the SARC **emphasizes** the importance of a shell replenishment program to the long term viability of the industry. Such a program must be developed and implemented within the next few years.

**Impact of 2002 Transplant Program on Direct-Market Allocation**

Projections were based on the continuous fishing season scenario with either an April or late August transplant. Projections were based on the assumption that all marketable oysters would be allocated to the 2002 fishery. Marketable oysters were those oysters surviving natural mortality that began the year at submarket or market size. For the April transplant, the growth and mortality rates for the high-mortality beds were used. For the August transplant, the growth and mortality rates of the medium-mortality beds were used. The latter assumes that transplanting in late August will not significantly increase the natural mortality rate in 2002 for the transplants. Both options assume harvest of transplanted oysters occurs at least 6 weeks after the transplant.

*Option 1. April Transplant.*

| | Direct-Market Bed Production |
|---|---|
| High-Mortality Beds | 41,067 |
| Medium-Mortality Beds | 22,721 |
| Transplants | 38,212 |
| Total | 102,000 |

*Option 2. Late Season (August 15) Transplant*

| | Direct-Market Bed Production |
|---|---|
| High-Mortality Beds | 41,067 |
| Medium-Mortality Beds | 22,721 |
| Transplants | 19,004 |
| Total | 82,792 |

**Long-Range Projections: Direct-Market Beds with Transplant**

Because many smaller oysters are also transplanted downbay, the smaller oysters will provide some degree of rebuilding for these beds for 2003. A crude estimate can be made assuming a 0.461 $yr^{-1}$ mortality rate imposed for 2 years and the growth rate of the high-mortality beds. In addition, assuming a second 10% transplant in 2003 yields some additional oysters

already of submarket size in 2003 (the 2003 transplants).

*2003 Projection with April Transplant. Continuous Season*

| | |
|---|---|
| High-Mortality Beds | 27,464 |
| Medium-Mortality Beds (Shell Rock) | 11,180 |
| 2002 Transplants | 29,123 |
| 2003 Transplants | 38,212 |
| Total | 105,979 |

*2003 Projection with Late August Transplant. Continuous Season*

| | |
|---|---|
| High-Mortality Beds | 27,464 |
| Medium-Mortality Beds (Shell Rock) | 11,180 |
| 2002 Transplants | 36,318 |
| 2003 Transplants | 19,004 |
| Total | 93,966 |

An additional increment would occur in 2004 because not all surviving 2002 juveniles will recruit to the fishery in 2003. There are too many uncertainties to provide specific projections.

## Recommendations for Area Management.

A significant fraction of the oysters available for harvest are on Shell Rock. Some mechanism should be included in the management plan to assure that the high-mortality beds are not overfished and Shell Rock underfished. Closure in August 2001 of the high-mortality beds successfully accomplished this goal in 2001.

Any allocation that includes the transplant of oysters downbay must take into account the insufficient supply of oysters on the direct-market beds to sustain the entire allocation prior to transplant.

Area management within the high-mortality direct-market beds is probably unnecessary, based on last year's fishery. However, consideration should be given to the relatively limited number of bushels on the two biggest beds, New Beds and Bennies, and the particularly small number of juveniles present to sustain out-year harvests. Considerable thought should be given to using one or both beds to receive most of the transplanted oysters as a mechanism of increasing juvenile abundance.

All transplant scenarios should take into account the approximate six week interval required to increase meat yield following transplant. Accordingly, any transplants should be closed to fishing for minimally six weeks post-transplant.

**Transplant to Downbay Leased Grounds.**

From a biological perspective, the impact on the source beds is equivalent for transplanting to leases or direct-market beds. However, transplanting to leases minimizes the long-term benefit to direct-market beds that have a low abundance of juveniles, such as New Beds and Bennies. There is, therefore, a long term impact to the direct-market fishery. Any program that includes transplant to leases will reduce the direct-market allocation in 2002 and can be expected to reduce the direct-market fishery in 2003 and 2004. That impact can be estimated from the current year and out-year estimates of harvestable bushels.

Median Dermo mortality rates on downbay leases exceed 0.5 $yr^{-1}$. The 75th percentile mortality rate exceeds 0.6 $yr^{-1}$. Thus, transplanting to leases minimizes the harvest per bushel of oysters transplanted. A higher growth rate is a potential tradeoff. However, insufficient growth data are available to evaluate this tradeoff substantively. The SARC recommends that additional growth data be obtained on the leased grounds so that a better evaluation of this management option can be obtained. For example, the differential in mortality rate, about a 25% increase on the leased grounds over the New Beds area, would require a greater than 25% increase in growth rate to break even. The only available measurement of growth rate on a lease, made in 2000, showed little growth; however, this was likely a low growth year. An alternate estimate might be obtained by assuming the growth increment between Shell Rock and New Beds was repeated downbay. This growth increment was 25%.

Thus, an example, using an April transplant, yields the following.

| | |
|---|---|
| 2002 Potential Harvest | 43,760 |
| 2003 Potential Harvest from 2002 Transplant | 7,993 |
| | |
| Total | 51,753 |
| Total (if transplanted to New Beds) | 67,335 |

In this case, increased growth rate is inadequate to counteract the increased rate of natural mortality.

## 2002 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 growth and condition index monitoring program with the disease monitoring program. Expand the program to the leased grounds.

2. Obtain additional information on the size-frequency and number of oysters in a typical transplanted bushel to evaluate the efficiency of the transplant program.

3. Evaluate the use of a hydraulic patent tong for the survey.

4. Verify the carrying capacity model through field experimentation as a component of the transplant program.

5. Conduct additional dredge efficiency measurements to assess temporal trends. Particular attention should be given to transplant source beds.

6. Evaluate and repartition survey effort to emphasize beds most important in the direct-market and transplant program. Options include reducing the survey effort on Egg Island and Ledge Beds and reducing survey effort on low-quality areas.

7. Develop an implementation method for the 'May correlation' approach to predicting Dermo mortality rate in the assessment and allocation process.

8. Evaluate the use of the suction dredge for transplant, particularly with respect to the differential in size frequency of the oysters transplanted by suction dredge relative to the oyster dredge/culling machine.

9. Continue development of the aging techniques to determine the age structure of oyster populations on transplant source beds.

10. Develop a broodstock-recruitment relationship for oysters.

11. Include confidence intervals and other like statistics as much as possible in present and in all future stock assessments. Provide estimates of fishing mortality rate.

12. Develop a cost-benefit biological/economic analysis for transplant options including movement of oysters to direct-market beds and to leased grounds.

13. Conduct a retrospective analysis on the survey time series to extend the quantitative abundance estimates back to 1989.

14. Evaluate culling options to increase the efficiency of transplanting.

15. Develop an improved estimate of the shell resource on the low-mortality and medium-mortality beds intended to sustain the transplant program.

16. Develop and implement for the next assessment yearly projections of allocation to future years for long-range planning.

17. Evaluate the resistance of seed bed oysters to Dermo.

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 seed bed region oyster and spat abundance (37 qu. Bushel) for Upper Central and Central seed beds. 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 the Market beds. Market beds = Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Egg Island and Ledge. 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 Ledge. 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 Ledge.

Figure 9. Delaware Bay Seed Beds. Oyster per 37 qt. bushel by market (>3") and submarket (2.5 to 2.99") size classes from Market beds. Market beds = Shell Rock, Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Egg Island and Ledge. Error bars are the 95% confidence intervals.

Figure 10. 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 are missing from Lower because only one bed is sampled in alternate years.l

Figure 11. Delaware Bay Seed Beds. Annual bay wide average spat counts per 37 quart bushel. Error bars are the 95% confidence intervals.

Figure 12. Delaware Bay Seed Beds. Annual percentage mortality for the past decade by region. Error bars are the 95% confidence intervals.

Figure 13. Delaware Bay Seed Beds. Prevalence of Dermo (*Perkinsus marinus*) by bed group for the past decade. Error bars are the 95% confidence intervals.

Figure 14. Delaware Bay Seed Beds. Weighted prevalence of Dermo (*Perkinsus marinus)* by bed group for the past decade. Error bars are the 95% confidence intervals.

Figure 15. Catch per boat day for Delaware Bay Market Beds. The program began in 1996 with a fall harvest only.

Figure 16. Growth of oysters tethered to racks on three Delaware Bay seed beds. Those from Cohansey and New Beds were out from April to November, Shell Rock data are from June to November. Three size classes were followed in each area (2.5" to 2.75" hinge to lip (length), 2.25" to 2.49", and 2" to 2.24"). Data are mean growth with 95% confidence intervals.

Figure 17. Total number of oysters on Low, Medium and High mortality seed beds – 1999 to 2001.

Table 1. Long term (1956- 1992) average and average maximum numbers of oysters and spat per bushel for the New Jersey Delaware Bay seed beds. B = Bay wide, 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** | 102 | 51 |
| **Upper** | 345 | 100 |
| **Upper Central** | 151 | 75 |
| **Central** | 66 | 35 |
| **Lower** | 30 | 20 |

Table 2. Results of a random sampling of the Delaware Bay seed beds

Attached is a summary of the 2001 seed bed sampling data with similar data for 1999 and 2000. All data were collected between October 29 and October 31, 2001 using a boat and captain donated by Bivalve Packing. This information is provided based on a stratified random sampling of grids from the seed beds. The strata (groups) from which the samples were selected are: Test area, general bed, marginal areas. One sample was taken from one of the test area strata, and no more than two samples were taken from the marginal strata of the beds. The remainder of the samples were from the general bed. All data were adjusted to a 37 quart bushel.

The data format is the same as in the past years, with the exception of the addition of a Size series which was initiated last year (see below). 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 2000 indicates the **average** number of bushels brought up by the 3 dredge hauls from each grid. This year we have relied on the 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 last years 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.

Because of the emphasis on the direct marketing of oyster from the seed beds we have continued the Size columns. These column 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. It 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 2001 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2001.

| 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. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 |
| Round Island | * | 5.1 | **36.0** | 48.2 | 46.6 | | | | | | | | | | | | | | | | | | | | | | | |
| Round Island | | 5.0 | **35.0** | 44.4 | 29.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Round Island | | 7.5 | **31.3** | 27.5 | 21.1 | **192** | 231 | 199 | **11** | 24 | 13 | **7** | 13 | 79 | **7** | 6 | 12 | **20** | 20 | 30 | **0.1** | 0.1 | 0.7 | **12** | 26 | 33 | **6** | 11 | 17 |
| Round Island | | 6.0 | **29.0** | 21.4 | 19.2 | | | | | | | | | | | | | | | | | | | | | | | |
| Round Island | | 0.3 | **6.3** | 16.9 | 8.5 | | | | | | | | | | | | | | | | | | | | | | | |
| Round Island | | 1.4 | **2.6** | 9.6 | 5.8 | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Up. Arnolds | | 4.8 | **41.4** | -- | 53.3 | | | | | | | | | | | | | | | | | | | | | | | |
| Up. Arnolds | * | 1 | **19.7** | -- | 24.6 | **218** | -- | 192 | **0.6** | -- | 19 | **13** | -- | 93 | **9** | -- | 17 | **20** | -- | -- | **0.15** | -- | -- | **12** | -- | 40 | **6** | -- | 21 |
| Up. Arnolds | | | | -- | 18.9 | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Arnolds | | 5.7 | **67.6** | 47.6 | 64.4 | | | | | | | | | | | | | | | | | | | | | | | |
| Arnolds | | 7.6 | **64.0** | 35.5 | 64.3 | | | | | | | | | | | | | | | | | | | | | | | |
| Arnolds | | 5.3 | **58.0** | 32.8 | 38.3 | **245** | 222 | 205 | **7** | 2 | 17 | **35** | 16 | 113 | **9** | 8 | 22 | **40** | 60 | 66 | **0.7** | 1.2 | 1.3 | **16** | 33 | 21 | **7** | 12 | 10 |
| Arnolds | | 8.0 | **44.6** | 25.7 | 34.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Arnolds | * | 5.3 | **40.5** | 20.2 | 20.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Arnolds | | 0.6 | **0.0** | 0.0 | 0.76 | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Up. Middle | | -- | -- | 16.7 | -- | | | | | | | | | | | | | | | | | | | | | | | |
| Up. Middle | | -- | -- | 0.0 | -- | -- | 25 | -- | -- | 0 | -- | -- | 0 | -- | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | * | 9.0 | **67.8** | 60.1 | 77.5 | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | | 4.7 | **46.7** | 50.2 | 75.4 | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | | 4.7 | **37.3** | 45.2 | 54.8 | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | | 7.4 | **33.2** | 40.6 | 20.2 | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | | 1.6 | **17.1** | 20.4 | 17.4 | **133** | 214 | 139 | **3** | 17 | 17 | **5** | 47 | 306 | **9** | 10 | 19 | **33** | 77 | 100 | **0.27** | 1.9 | 2.2 | **17** | 23 | 24 | **16** | 11 | 17 |
| Middle | | 0.5 | **5.4** | 14.0 | 6.8 | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | | 1.6 | **3.1** | 13.8 | 5.8 | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | | 1.3 | **0.0** | 5.3 | 3.5 | | | | | | | | | | | | | | | | | | | | | | | |
| Middle | | 0.2 | **0.0** | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cohansey | * | 9.5 | **81.5** | 87.7 | 72.7 | | | | | | | | | | | | | | | | | | | | | | | |
| Cohansey | | 4.7 | **45.5** | 79.8 | 71.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Cohansey | | 0.7 | **9.6** | 76.5 | 59.3 | **149** | 541 | 208 | **3** | 59 | 33 | **3** | 56 | 561 | **8** | 6 | 26 | **79** | 87 | 100 | **1.61** | 1.7 | 1.8 | **25** | 74 | 47 | **17** | 14 | 23 |
| Cohansey | | 1.9 | **0.8** | 75.3 | 52.6 | | | | | | | | | | | | | | | | | | | | | | | |
| Cohansey | | 0.3 | **0.0** | 56.5 | 34.9 | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ship John | | 9.2 | **78.7** | 60.8 | 73.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Ship John | ol | 7.2 | **77.3** | 54.8 | 70.3 | | | | | | | | | | | | | | | | | | | | | | | |
| Ship John | | 6.5 | **58.8** | 54.0 | 70.0 | **220** | 316 | 218 | **20** | 14 | 45 | **38** | 156 | 330 | **8** | 10 | 26 | **95** | 100 | 80 | **2.33** | 2.8 | 2.2 | **42** | 39 | 40 | **19** | 12 | 18 |
| Ship John | * | 7.5 | **46.9** | 44.5 | 58.2 | | | | | | | | | | | | | | | | | | | | | | | |
| Ship John | | 0.3 | **12.4** | 15.9 | 3.0 | | | | | | | | | | | | | | | | | | | | | | | |
| Ship John | | 1.0 | **5.6** | | | | | | | | | | | | | | | | | | | | | | | | | |

# Summary of the 2001 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2001.

| 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. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 |
| | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Seabreeze | * | 6.3 | **37.5** | -- | 53.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Seabreeze | | 0.2 | **16.6** | -- | 20.0 | **91** | -- | 85 | **0** | -- | 10 | **7** | -- | 50 | **15** | -- | 33 | **70** | -- | 90 | **1.15** | -- | 2.5 | **25** | -- | 32 | **27** | -- | 38 |
| Seabreeze | | 5.0 | **0.18** | -- | 3.5 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Shell Rock | * | 9.2 | **66.7** | 59.4 | 55.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Shell Rock | | 1.3 | **62.7** | 57.3 | 48.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Shell Rock | | 2.7 | **62.2** | 45.0 | 47.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| Shell Rock | | 6.3 | **54.6** | 40.5 | 46.3 | **184** | 213 | 113 | **45** | 34 | 28 | **32** | 130 | 208 | **11** | 11 | 36 | **100** | 83 | 93 | **2.48** | 1.8 | 2.3 | **60** | 40 | 31 | **33** | 19 | 27 |
| Shell Rock | | 2.8 | **45.0** | 40.5 | 33.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| Shell Rock | | 0.3 | **43.0** | 20.3 | 27.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Shell Rock | | 0.4 | **26.6** | 19.5 | 5.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies Sand | * | 7.3 | **31.3** | 46.9 | 52.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies Sand | | 3.0 | **31.0** | 45.2 | 40.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies Sand | | 3.8 | **19.1** | 17.1 | 26.6 | **89** | 133 | 110 | **0** | 15 | 32 | **4** | 22 | 184 | **16** | 18 | 36 | **90** | 90 | 100 | **2.05** | 2.3 | 2.9 | **39** | 41 | 26 | **44** | 31 | 24 |
| Bennies Sand | | 1.5 | **15.2** | 15.5 | 11.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 5.9 | **27.3** | 29.7 | 13.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 4.9 | **19.1** | 25.3 | 11.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 4.8 | **18.6** | 22.0 | 10.9 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 3.7 | **15.6** | 20.8 | 10.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 2.6 | **13.8** | 14.3 | 9.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 3.8 | **5.5** | 7.2 | 7.9 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 8.0 | **5.0** | 6.9 | 4.4 | **20** | 38 | 17 | **1** | 2 | 2 | **3** | 10 | 2 | **43** | 35 | 57 | **75** | 100 | 97 | **1.23** | 4 | 3 | **13** | 23 | 11 | **66** | 61 | 65 |
| Bennies | | 2.9 | **4.2** | 6.6 | 3.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 5.3 | **3.1** | 4.4 | 1.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | * | 7.7 | **2.8** | 4.3 | 0.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 0.7 | **1.4** | 3.5 | 0.4 | | | | | | | | | | | | | | | | | | | | | | | | |
| Bennies | | 0.6 | **0.4** | 3.0 | 0.3 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Nantuxent Pt | | 6.8 | **73.4** | -- | 66.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Nantuxent Pt | | 7.3 | **54.4** | -- | 64.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Nantuxent Pt | | 9.0 | **53.5** | -- | 62.4 | **149** | -- | 181 | **11** | -- | 83 | **25** | -- | 440 | **31** | -- | 38 | **90** | 95 | 100 | **3** | 3.5 | 3 | **25** | -- | 20 | **17** | -- | 11 |
| Nantuxent Pt | | 1.6 | **27.3** | -- | 48.3 | | | | | | | | | | | | | | | | | | | | | | | | |
| Nantuxent Pt | * | 8.2 | **24.2** | -- | 46.4 | | | | | | | | | | | | | | | | | | | | | | | | |
| Nantuxent Pt | | 6.3 | **0.3** | -- | 40.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hog Shoal | * | 10.2 | **60.1** | -- | 47.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Hog Shoal | | 7.6 | **40.0** | -- | 39.5 | | | | | | | | | | | | | | | | | | | | | | | | |
| Hog Shoal | | 6.3 | **38.5** | -- | 24.8 | **108** | -- | 90 | **5** | -- | 11 | **13** | -- | 99 | **38** | -- | 50 | **100** | -- | 100 | **2.95** | -- | 2.9 | **45** | -- | 21 | **34** | -- | 23 |
| Hog Shoal | | 9.0 | **35.0** | -- | 22.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Hog Shoal | | 3.8 | **27.6** | -- | 21.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| Hog Shoal | | 7.8 | **1.0** | -- | 20.6 | | | | | | | | | | | | | | | | | | | | | | | | |

# Summary of the 2001 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2001.

| 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. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 |
| | | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| New Beds | | 5.2 | **13.1** | 17.2 | 40.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| New Beds | | 1.0 | **9.7** | 12.8 | 34.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| New Beds | * | 3.1 | **8.6** | 7.0 | 30.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| New Beds | | 3.0 | **7.0** | **4.5** | 15.9 | | | | | | | | | | | | | | | | | | | | | | | | |
| New Beds | | 11.0 | **4.1** | 3.2 | 13.5 | **12** | 13 | 34 | **2** | 1 | **4** | **2** | 4 | 9 | **47** | 51 | 66 | **95** | 100 | 95 | **1.65** | 3.5 | 2.8 | **8** | 9 | 26 | **70** | 69 | 76 |
| New Beds | | 8.3 | **3.2** | 1.3 | 6.1 | | | | | | | | | | | | | | | | | | | | | | | | |
| New Beds | | 2.4 | **0.9** | 1.1 | 3.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| New Beds | | 0.7 | **0.3** | 0.4 | 3.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| New Beds | | 4.0 | **0.0** | 0.0 | 1.4 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Strawberry | * | 10.3 | **23.9** | 23.9 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Strawberry | | 6.5 | **1.8** | 17.6 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Strawberry | | | | 5.9 | -- | **39*** | 28 | -- | **0*** | 2 | -- | **10*** | 15 | -- | **51*** | 47 | -- | -- | -- | -- | -- | -- | -- | **18** | 14 | -- | **47** | 50 | -- |
| Strawberry | | | | 3.7 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Strawberry | | | | 1.8 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Strawberry | | | | 0.73 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hawks Nest | | 8.5 | **56.9** | 73.6 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Hawks Nest | * | 8.8 | **36.6** | 54.2 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Hawks Nest | | | | 42.7 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Hawks Nest | | | | 34.9 | -- | **203*** | 219 | -- | **11*** | 33 | -- | **46*** | 318 | -- | **28*** | 18 | -- | -- | 100 | -- | -- | 3.3 | -- | **38** | 43 | -- | **19** | 20 | -- |
| Hawks Nest | | | | 24.3 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Hawks Nest | | | | 5.2 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | * | 3.3 | **30.8** | 22.5 | 75.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 4.1 | **11.7** | 20.8 | 59.4 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 6.7 | **11.4** | 17.9 | 45.6 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 6.5 | **9.4** | 15.3 | 23.3 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 5.6 | **7.3** | 11.6 | 20.8 | **25** | 46 | 64 | **7** | 11 | 44 | **11** | 43 | 377 | **52** | 31 | 45 | **100** | 95 | 100 | **3.85** | 3.7 | 4.1 | **14** | 9 | 11 | **56** | 20 | 17 |
| Beadons | | 2.4 | **6.3** | 10.9 | 17.2 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 5.2 | **5.2** | 10.9 | 17.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 1.2 | **3.4** | 6.4 | 6.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 2.3 | **3.0** | 4.4 | 4.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| Beadons | | 5.8 | **1.8** | 2.4 | 2.4 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vexton | | 9.0 | **47.2** | -- | 46.2 | | | | | | | | | | | | | | | | | | | | | | | | |
| Vexton | | 6.7 | **35.0** | -- | 40.9 | | | | | | | | | | | | | | | | | | | | | | | | |
| Vexton | | 10.3 | **25.2** | -- | 27.0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Vexton | * | 10.7 | **21.2** | -- | 25.9 | | | | | | | | | | | | | | | | | | | | | | | | |
| Vexton | | 6.8 | **8.8** | -- | 8.1 | **66** | -- | 52 | **5** | -- | 9 | **22** | -- | 54 | **28** | -- | 54 | **80** | -- | 100 | **1.7** | -- | 3.8 | **25** | -- | 17 | **38** | -- | 33 |
| Vexton | | 8.0 | **2.0** | -- | 6.8 | | | | | | | | | | | | | | | | | | | | | | | | |
| Vexton | | 4.3 | **0.3** | -- | 2.4 | | | | | | | | | | | | | | | | | | | | | | | | |

# Summary of the 2001 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2001.

| 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. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 | 2001 | 2000 | 1999 |
| | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Egg Island | 4.5 | **3.0** | 0.80 | 48.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 0.6 | **2.13** | 0.71 | 14.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 0.5 | **0.88** | 0.48 | 8.7 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 3.2 | **0.35** | 0.33 | 1.2 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 9.8 | **0.34** | 0.32 | 0.4 | **2** | 0.8 | 28 | **0** | 0 | 0 | **1** | 0.4 | 2 | **77** | 73 | 35 | **71** | 100 | 100 | **2.21** | 3.6 | 3.9 | **1** | 0.6 | 19 | **75** | 75 | 25 |
| Egg Island | 9.2 | **0** | 0 | 0.4 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 1.7 | **0** | 0 | 0.4 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 0.8 | **0** | 0 | 0.3 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 7.3 | **0** | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| Egg Island | 0.2 | **0** | 0 | 0 | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ledge | -- | -- | 3.8 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Ledge | -- | -- | 2.6 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Ledge | -- | -- | 1.3 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Ledge | -- | -- | 0.39 | -- | | 3 | -- | -- | 0.1 | -- | -- | 0.4 | -- | -- | 62 | -- | -- | 70 | -- | -- | 1.9 | -- | -- | 3 | -- | -- | 100 | -- |
| Ledge | -- | -- | 0 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Ledge | -- | -- | 0 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Ledge | -- | -- | 0 | -- | | | | | | | | | | | | | | | | | | | | | | | | |
| Ledge | -- | -- | 0 | -- | | | | | | | | | | | | | | | | | | | | | | | | |

| Table 3. Oyster Seed Beds Size Frequency 2001 | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Round Is | Up Arn | Arnold | Middle | Cohan | Ship Jn | Seabrz | Shell Rk | Ben Snd | Bennie | Nantux | Hog Shl | New Beds | Straw | Hawks N | Beadon | Vexton | Egg Is. |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 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 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 3 | 5 | 6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 1 | 0 | 1 | 0 |
| 25 | 18 | 19 | 13 | 2 | 1 | 1 | 1 | 2 | 0 | 0 | 6 | 1 | 0 | 1 | 8 | 0 | 2 | 0 |
| 30 | 34 | 35 | 34 | 7 | 10 | 9 | 5 | 6 | 2 | 0 | 13 | 5 | 0 | 1 | 10 | 0 | 2 | 0 |
| 35 | 37 | 35 | 40 | 10 | 15 | 21 | 7 | 12 | 2 | 0 | 18 | 9 | 0 | 1 | 20 | 1 | 2 | 0 |
| 40 | 28 | 40 | 45 | 15 | 18 | 23 | 12 | 20 | 6 | 0 | 21 | 12 | 0 | 2 | 26 | 1 | 4 | 0 |
| 45 | 23 | 35 | 33 | 17 | 25 | 34 | 10 | 19 | 6 | 0 | 20 | 10 | 0 | 2 | 30 | 1 | 6 | 0 |
| 50 | 14 | 17 | 26 | 17 | 20 | 34 | 12 | 20 | 7 | 1 | 18 | 19 | 0 | 6 | 29 | 2 | 6 | 0 |
| 55 | 13 | 11 | 17 | 13 | 23 | 29 | 10 | 22 | 10 | 2 | 14 | 17 | 1 | 5 | 24 | 3 | 11 | 0 |
| 60 | 8 | 8 | 15 | 9 | 10 | 25 | 9 | 23 | 17 | 2 | 11 | 14 | 2 | 4 | 18 | 3 | 7 | 0 |
| 65 | 4 | 3 | 6 | 6 | 9 | 16 | 6 | 23 | 14 | 2 | 9 | 12 | 1 | 4 | 13 | 3 | 7 | 0 |
| 70 | 4 | 4 | 5 | 5 | 8 | 10 | 5 | 13 | 10 | 3 | 5 | 10 | 2 | 6 | 10 | 2 | 7 | 0 |
| **75** | **1** | **1** | **3** | **3** | **4** | **7** | **4** | **10** | **6** | **2** | **3** | **8** | **1** | **6** | **5** | **2** | **3** | **0** |
| **80** | **2** | **1** | **1** | **2** | **3** | **4** | **2** | **7** | **6** | **2** | **4** | **5** | **2** | **2** | **6** | **2** | **3** | **0** |
| **85** | **0** | **1** | **1** | **1** | **1** | **2** | **3** | **2** | **1** | **1** | **2** | **4** | **1** | **1** | **3** | **2** | **2** | **0** |
| **90** | **0** | **1** | **0** | **1** | **0** | **1** | **2** | **2** | **2** | **1** | **1** | **3** | **1** | **1** | **1** | **1** | **2** | **1** |
| **95** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **2** | **0** | **1** | **1** | **2** | **1** | **0** | **0** | **0** | **1** | **0** |
| **100** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **0** | **0** | **1** | **0** | **1** | **1** | **0** | **0** | **0** | **1** | **0** |
| **105** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **110** | **0** | **1** | **0** | **0** | **0** | **0** | **1** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1** | **0** |
| **115** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **120** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| | | | | | | | | | | | | | | | | | | |
| Total/Bu. | 192 | 218 | 245 | 108 | 149 | 220 | 91 | 184 | 89 | 20 | 149 | 133 | 12 | 39 | 203 | 25 | 66 | 2 |
| No. Measured | 769 | 324 | 982 | 747 | 321 | 686 | 133 | 928 | 311 | 260 | 653 | 500 | 110 | 70 | 277 | 241 | 368 | 12 |
| **Greater than 3"** | **3** | **5** | **5** | **6** | **8** | **16** | **13** | **24** | **15** | **8** | **12** | **23** | **5** | **9** | **15** | **8** | **11** | **1** |
| > 3" 2000 | 8 | | 10 | 10 | 34 | 17 | | 18 | 19 | 13 | | | 7 | 7 | 20 | 4 | | 0.3 |
| > 3" 1999 | 8 | | 6 | 10 | 19 | 19 | 22 | 17 | 13 | 9 | 9 | 13 | 17 | | | 5 | 11 | 12 |
| | | | | | | | | | | | | | | | | | | |
| **Greater than 2.5"** | **12** | **12** | **16** | **17** | **25** | **42** | **25** | **60** | **39** | **13** | **25** | **45** | **8** | **18** | **38** | **14** | **25** | **1** |
| > 2.5" 2000 | 26 | | 26 | 23 | 74 | 39 | | 40 | 41 | 23 | | | 9 | 14 | 43 | 9 | | 0.6 |
| > 2.5" 1999 | 33 | | 21 | 24 | 47 | 40 | 32 | 31 | 26 | 11 | 20 | 21 | 26 | | | 11 | 17 | 19 |

Table 4. Comparison of observed summer/autumn mortality of oysters on Delaware Bay seed beds with that predicted from May *P. marinus* prevalences.

| | | PREDICTED MORTALITY | | | |
|---|---|---|---|---|---|
| BED | MAY PREVALENCE | MEAN | LOWER 95% CI | UPPER 95% CI | OBSERVED MORTALITY |
| ARNOLDS | 0 | 0.113 | 0.047 | 0.199 | 0.09 |
| MIDDLE | 0.05 | 0.147 | 0.090 | 0.220 | 0.09 |
| COHANSEY | 0.1 | 0.180 | 0.117 | 0.242 | 0.08 |
| SHIP JOHN | 0.05 | 0.146 | 0.090 | 0.220 | 0.08 |
| SHELL ROCK | 0.3 | 0.315 | 0.258 | 0.379 | 0.11 |
| BENNIES SAND | 0.1 | 0.180 | 0.117 | 0.242 | 0.16 |
| BENNIES | 0.45 | 0.416 | 0.329 | 0.500 | 0.43 |
| NEW BEDS | 0.75 | 0.619 | 0.448 | 0.780 | 0.47 |

Table 5. Seed bed harvest (bu.)of market oysters and bushels of oysters transplanted in 2001. All transplants were moved in August except for those from Cohansey and Ship John. These were moved in October.

| Bed | Bushels Harvested | Percent | Bushels Transplanted |
|---|---|---|---|
| **Arnolds** | | | 6,500 |
| **Middle** | | | 6,395 |
| **Cohansey** | 80 | 0.1 | 18,400 |
| **Ship John** | 577 | 0.8 | 14,650 |
| **Seabreeze** | 1,535 | 2.2 | |
| **Shell Rock** | 23,029 | 32.5 | |
| **Bennies** | 9,502 | 13.4 | |
| **Bennies Sand** | 8,618 | 12.2 | |
| **Nantuxent** | 560 | 0.8 | 6,250 |
| **Hog Shoal** | 14,790 | 20.8 | |
| **New Beds** | 7,592 | 10.7 | |
| **Strawberry** | 154 | 0.2 | |
| **Hawks Nest** | 1,238 | 1.7 | |
| **Beadons** | 110 | 0.2 | |
| **Vexton** | 3,015 | 4.3 | |
| | | | |
| **Total** | **70,800** | | **52,195** |
| | | | |

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

| Year | Arnolds | 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 |

Table 7. Delaware Bay Seed beds. Total area in grids (square meters), fraction estimated to be covered by harvest activities based on available and harvested bushels.

| Bed | Total Coverage ($m^2$) | Fraction Covered | 2001 Harvest (Bushels) | 2000 Available (Bushels)* |
|---|---|---|---|---|
| Arnolds | 0 | 0.000 | 0 | 20,054 |
| Beadons | 254,426 | 0.104 | 110 | 6,717 |
| Bennies | 6,495,215 | 1.161 | 9,486 | 31,591 |
| Bennies Sand | 6,093,413 | 7.486 | 8,618 | 3,752 |
| Cohansey | 127,213 | 0.039 | 80 | 257,810 |
| Egg Island | 0 | 0.000 | 0 | 1,360 |
| Hawk's Nest | 784,220 | 0.406 | 1,238 | 33,791 |
| Hog Shoal | 6,644,150 | 7.255 | 14,800 | 4,382** |
| Ledge | 0 | 0.000 | 0 | 1,238 |
| Middle | 0 | 0.000 | 0 | 63,482 |
| Nantuxent | 402,581 | 0.220 | 560 | 15,644** |
| New Beds | 4,821,283 | 0.846 | 7,580 | 15,912 |
| Sea Breeze | 1,711,750 | 1.529 | 1,535 | 20,358** |
| Shell Rock | 8,854,280 | 2.559 | 23,029 | 39,600 |
| Ship John | 1,091,002 | 0.370 | 577 | 105,192 |
| Strawberry | 174,723 | 0.114 | 154 | 5,124 |
| Vexton | 1,303,543 | 0.915 | 3,015 | 4,517** |

*High Quality Areas Only

**Sampled 1999

Table 8. Estimated market bed oyster abundance in market size equivalents.

| Bed | Juveniles (market-size equivalents | Submarket market-size equivalents | Market market-size equivalents |
|---|---|---|---|
| **Bennies** | 4,040 | 6,266 | 6,072 |
| **Bennies San** | 19,121 | 8,065 | 1,769 |
| **Egg Island** | 1,356 | 400 | 88 |
| **New Beds** | 7,740 | 5,300 | 5,692 |
| **Shell Rock** | 168,685 | 23,973 | 7,332 |
| **Hawk's Nest** | 423,862 | 20,886 | 8,674 |
| **Ledge** | 786 | 443 | 793 |
| **Strawberry** | 4,210 | 1,529 | 722 |
| **Hog Shoal** | 42,801 | 9,029 | 5,478 |
| **Vexton** | 51,213 | 11,682 | 6,610 |

Table 9. Estimated growth rates from 2001 experimental oysters on specific beds. April to November are used for two beds, but data are provided for comparison to Shell Rock which had to be re-established in June.

| **Season** | **Bed** | **Large** (63.5-69.6mm) | **Medium** (57.0-63.2mm) | **Small** (50.8-56.9mm) |
|---|---|---|---|---|
| **April-November** | **Cohansey** | 1.82 | 2.82 | 4.31 |
| " | **New Beds** | 10.89 | 10.86 | 15.05 |

| **Season** | **Bed** | Large | Medium | Small |
|---|---|---|---|---|
| **June-November** | **Shell Rock** | 6.31 | 7.34 | 9.61 |
| " | **Cohansey** | 1.74 | 2.39 | 2.55 |
| " | **New Beds** | 9.68 | 9.54 | 13.74 |

Table 10. Fractional decrease in ingestion because of high oyster abundance
This assumes oysters can remove food 10 cm above the bottom.

| **Seed Bed** | Fractional decrease in ingestion |
|---|---|
| Arnolds | 0.2052 |
| Round Island | 0.1289 |
| Upper Arnolds | 0.1108 |
| Cohansey | 0.1800 |
| Middle | 0.2024 |
| Ship John | 0.4053 |
| Sea Breeze | 0.1134 |
| Beadons | 0.0510 |
| Nantuxent | 0.0978 |

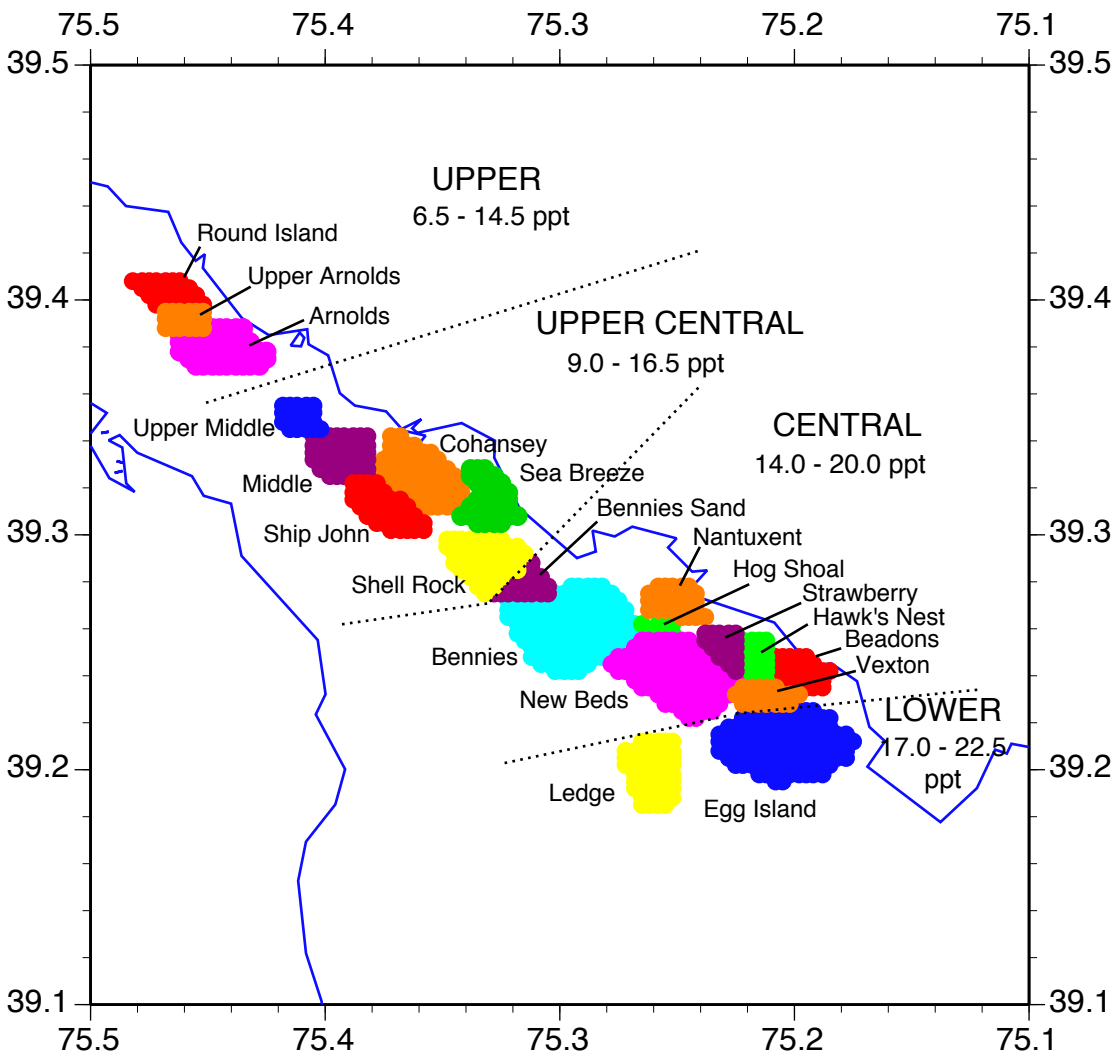

75.5
75.4
75.3
75.2
75.1
39.5
39.4
39.3
39.2
39.1
UPPER
6.5 - 14.5 ppt
Round Island
Upper Arnolds
Arnolds
UPPER CENTRAL
9.0 - 16.5 ppt
CENTRAL
14.0 - 20.0 ppt
Upper Middle
Cohansey
Sea Breeze
Middle
Bennies Sand
Ship John
Nantuxent
Hog Shoal
Shell Rock
Strawberry
Hawk's Nest
Beadons
Bennies
Vexton
New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

Figure 1

Figure 2

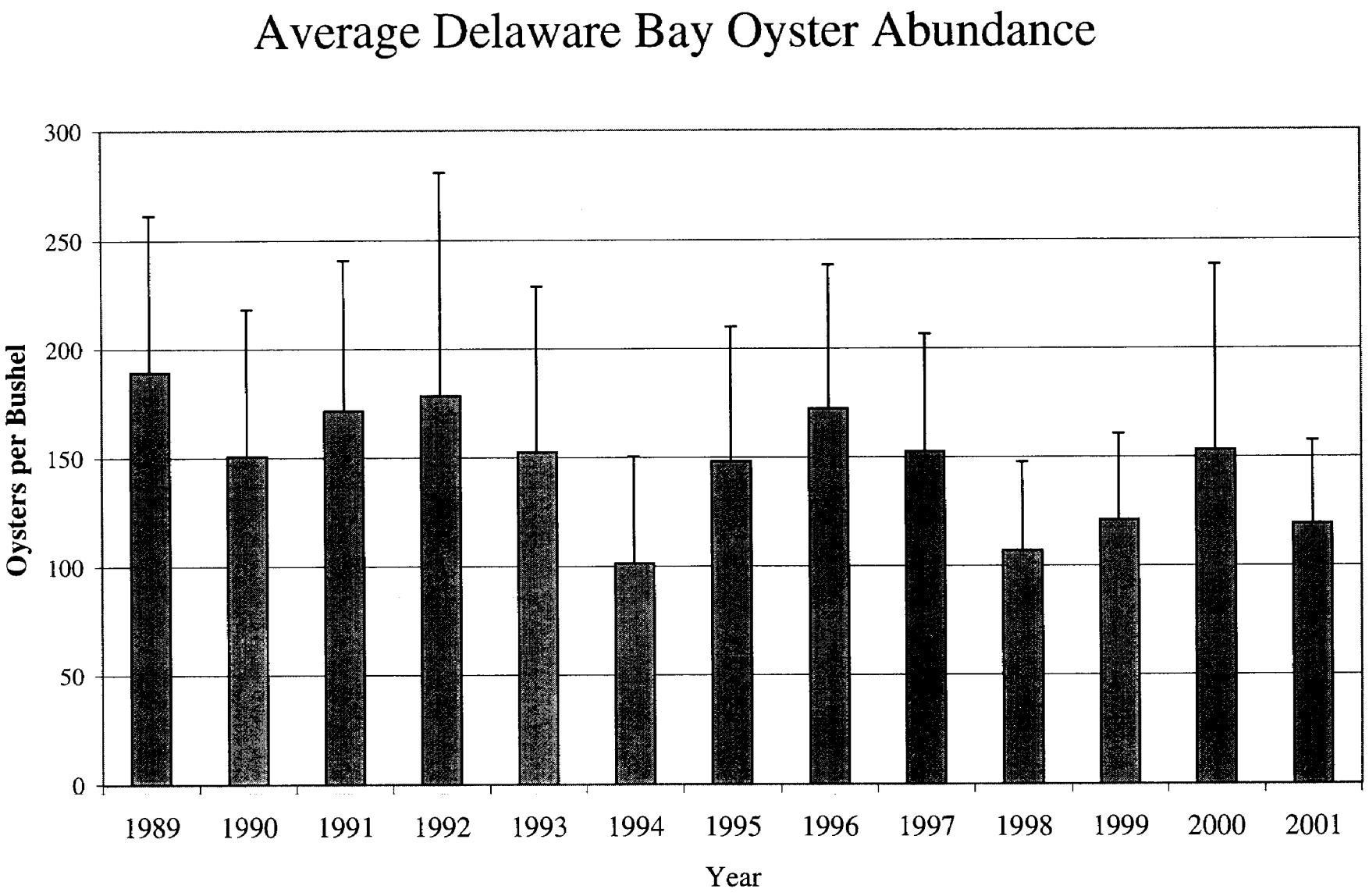

Average Delaware Bay Oyster Abundance
Oysters per Bushel
300
250
200
150
100
50
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

Figure 3

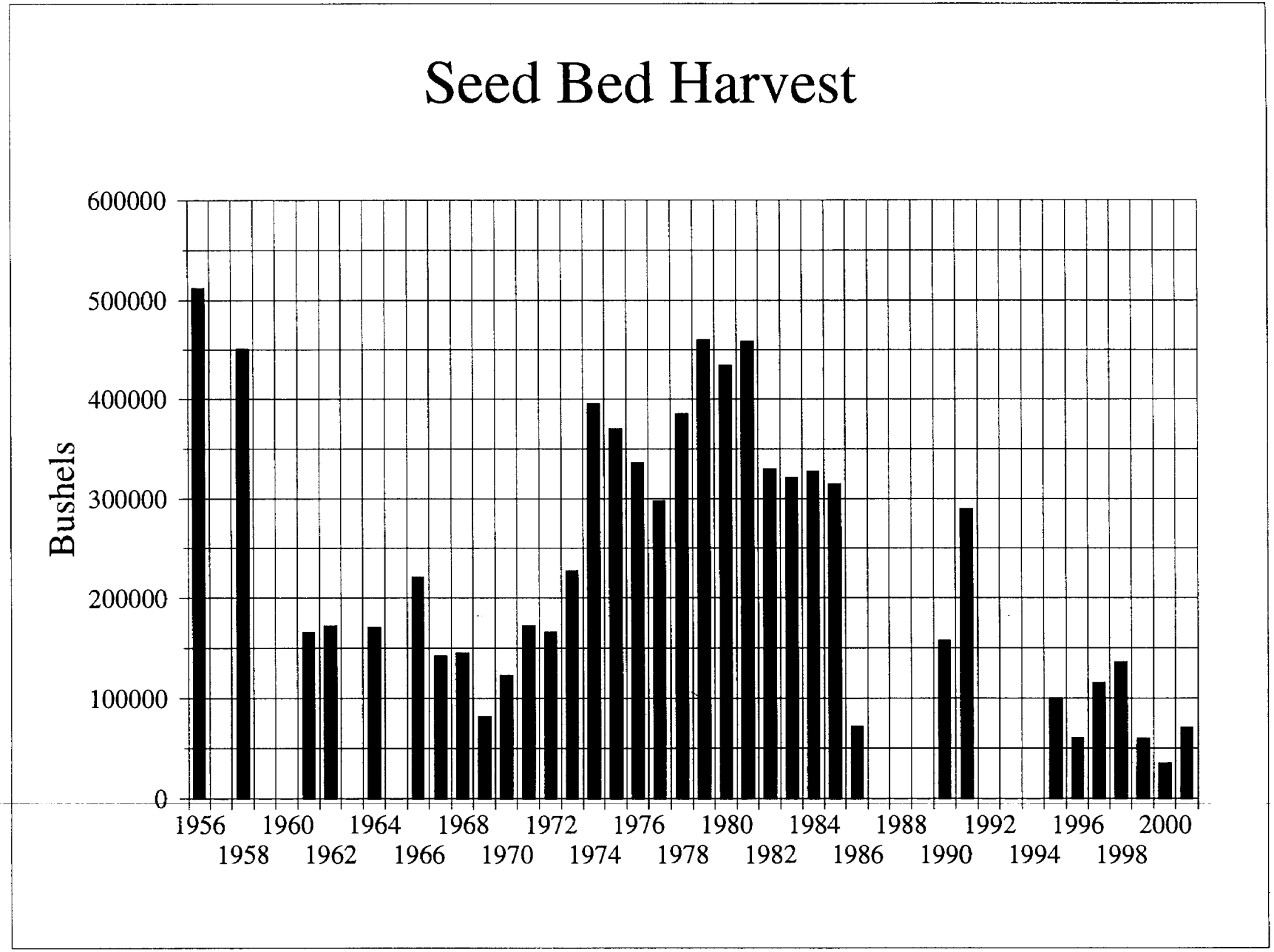

Seed Bed Harvest
Bushels
600000
500000
400000
300000
200000
100000
0
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

Figure 4

# Delaware Bay Seed Beds

| Year | 1989 | 1992 | 1996 | 1991 | 2000 | 1993 | 1997 | 1990 | 1995 | 1999 | 2001 | 1998 | 1994 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oysters | 189 | 178 | 172 | 172 | 153 | 153 | 152 | 151 | 148 | 121 | 119 | 107 | 101 | 147 |

| Year | 1991 | 1999 | 1997 | 1998 | 1995 | 1994 | 1990 | 1989 | 2000 | 1993 | 1992 | 1996 | 2001 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spat | 268 | 191 | 151 | 128 | 127 | 124 | 112 | 69 | 55 | 44 | 25 | 22 | 14 | 102 |

| Year | 1993 | 1994 | 1999 | 1998 | 2000 | 1992 | 1995 | 1996 | 2001 | 1991 | 1997 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dermo WP | 2.99 | 2.67 | 2.63 | 2.56 | 2.45 | 2.18 | 1.84 | 1.81 | 1.71 | 1.2 | 1.12 | 2.14 |

Figure 5

**Upper Central Beds**

| Year | 2000 | 1996 | 1997 | 1992 | 1990 | 1991 | 1989 | 1998 | 1993 | 2001 | 1999 | 1994 | 1995 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oysters | 321 | 309 | 265 | 244 | 225 | 222 | 214 | 193 | 190 | 172 | 170 | 143 | 138 | 216* |

**Central Beds**

| Year | 1996 | 1989 | 1995 | 1990 | 1997 | 1992 | 1991 | 1998 | 2000 | 1999 | 2001 | 1993 | 1994 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oysters | 153 | 105 | 95 | 91 | 91 | 91 | 84 | 80 | 80 | 78 | 67 | 55 | 52 | 86* |

**Upper Central Beds**

| Year | 1999 | 1991 | 1998 | 1995 | 1994 | 1990 | 1997 | 2000 | 1989 | 1993 | 1996 | 1992 | 2001 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spat | 351 | 307 | 209 | 179 | 164 | 126 | 113 | 97 | 70 | 60 | 36 | 31 | 20 | 136 |

**Central Beds**

| Year | 1991 | 1997 | 1999 | 1994 | 1998 | 1995 | 1990 | 1989 | 2000 | 1993 | 1992 | 1996 | 2001 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Spat | 273 | 221 | 166 | 166 | 146 | 137 | 107 | 70 | 69 | 46 | 21 | 16 | 11 | 113 |

Figure 6

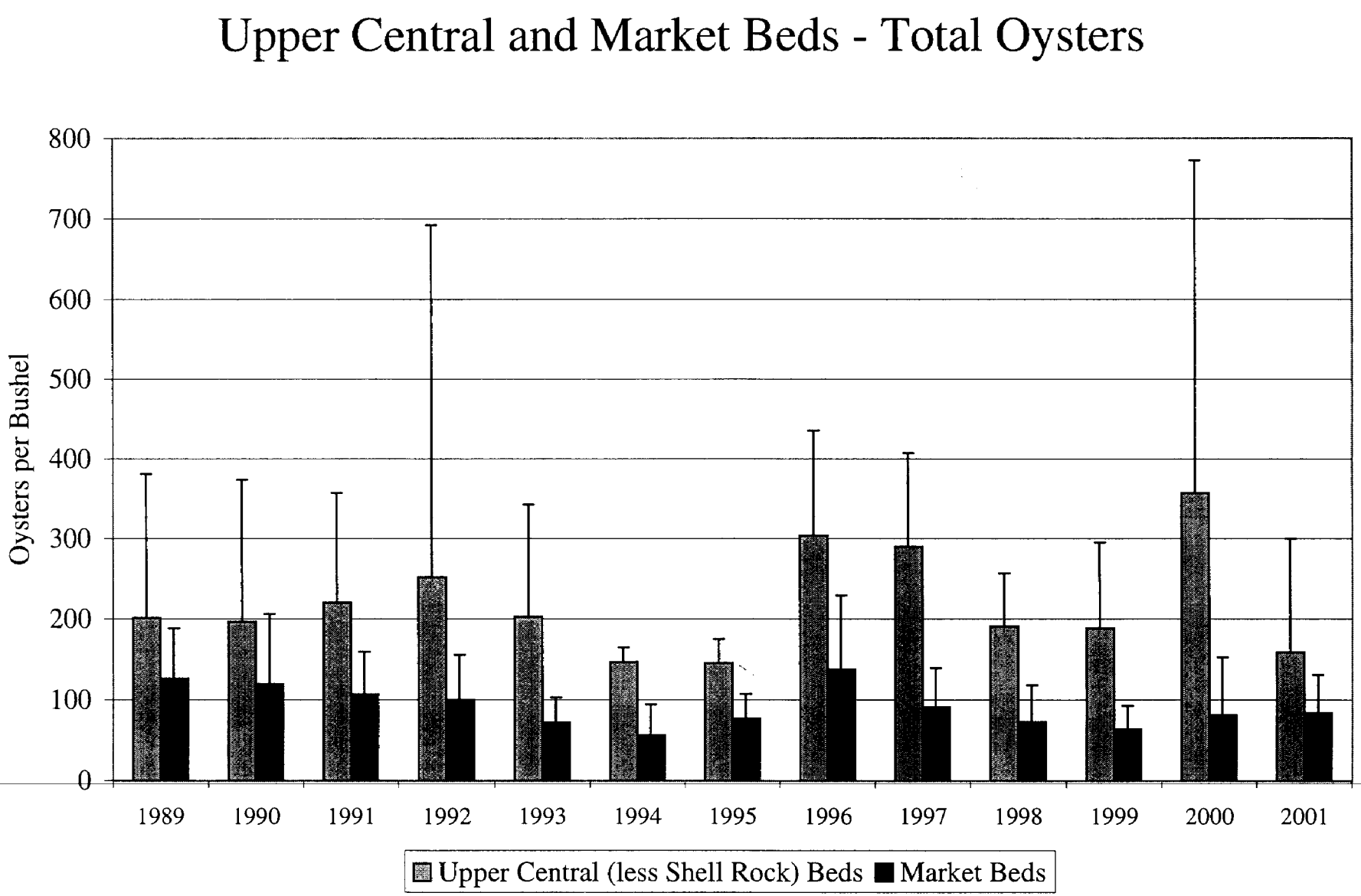

Upper Central and Market Beds - Total Oysters
Oysters per Bushel
800
700
600
500
400
300
200
100
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Upper Central (less Shell Rock) Beds
Market Beds

Figure 7

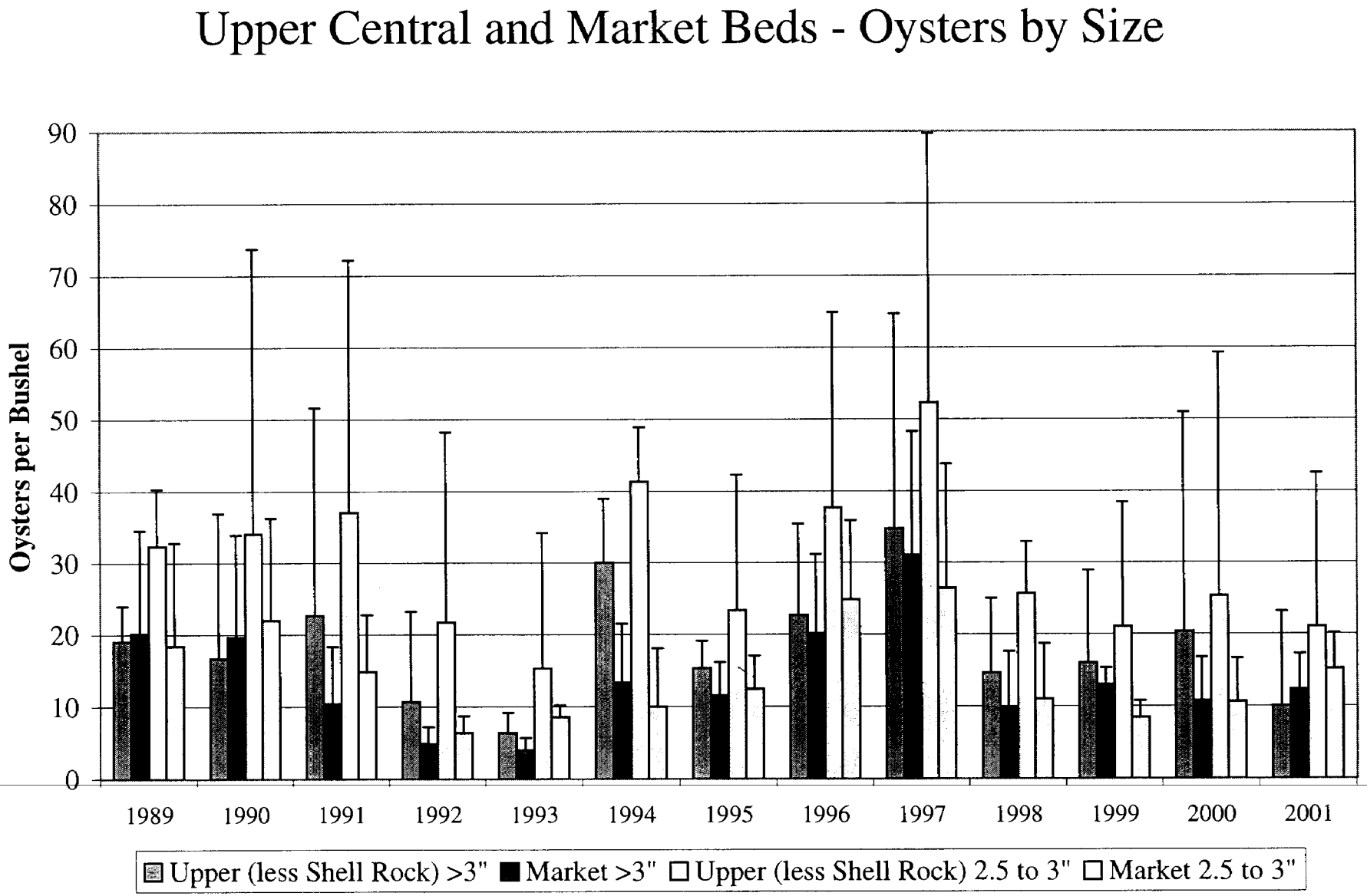

Upper Central and Market Beds - Oysters by Size
Oysters per Bushel
90
80
70
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Upper (less Shell Rock) >3"
Market >3"
Upper (less Shell Rock) 2.5 to 3"
Market 2.5 to 3"

Figure 8

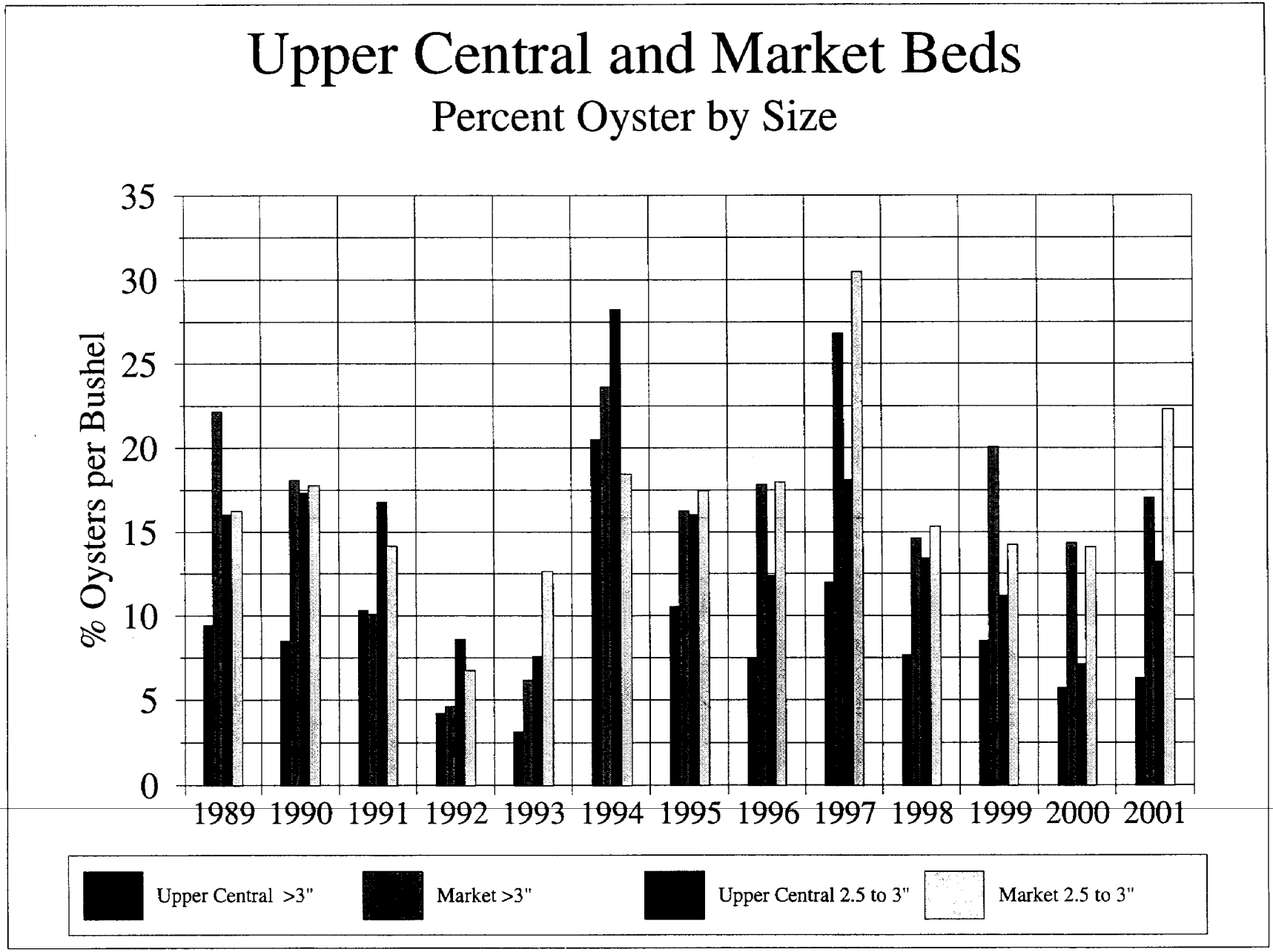

Upper Central and Market Beds
Percent Oyster by Size
% Oysters per Bushel
35
30
25
20
15
10
5
0
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001
Upper Central >3"
Market >3"
Upper Central 2.5 to 3"
Market 2.5 to 3"

Figure 9

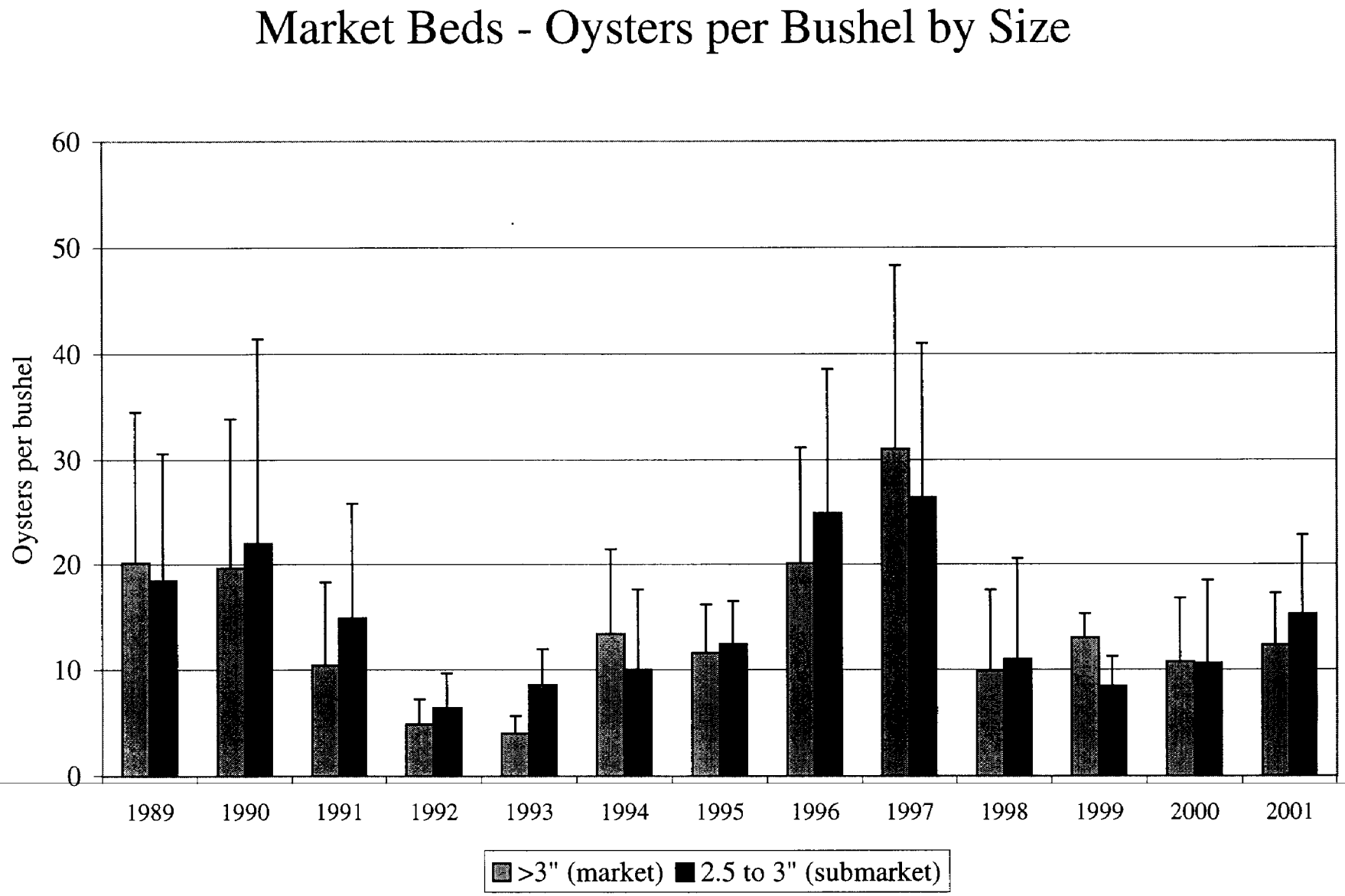

Market Beds - Oysters per Bushel by Size
Oysters per bushel
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
>3" (market)
2.5 to 3" (submarket)

Figure 10

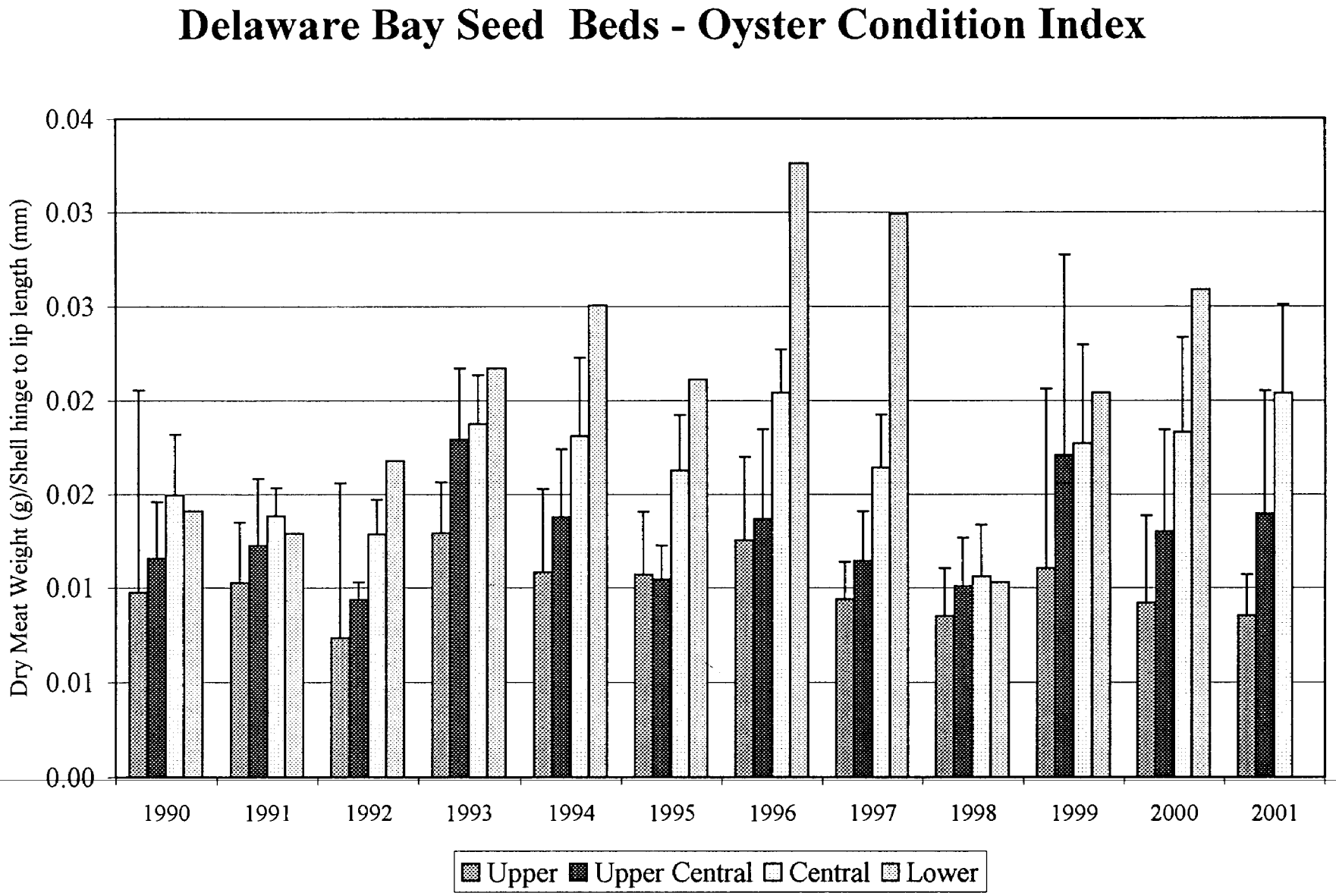
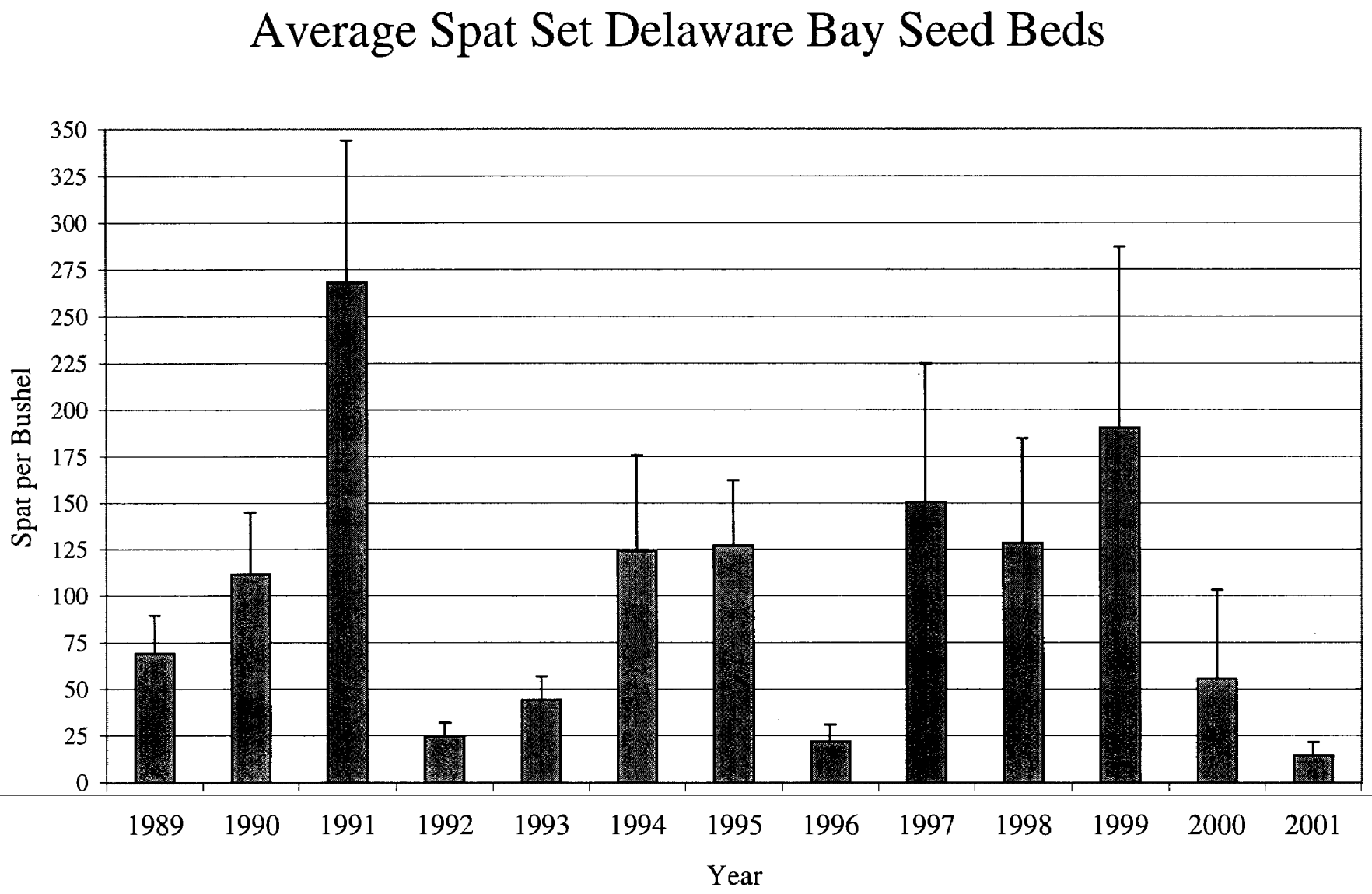
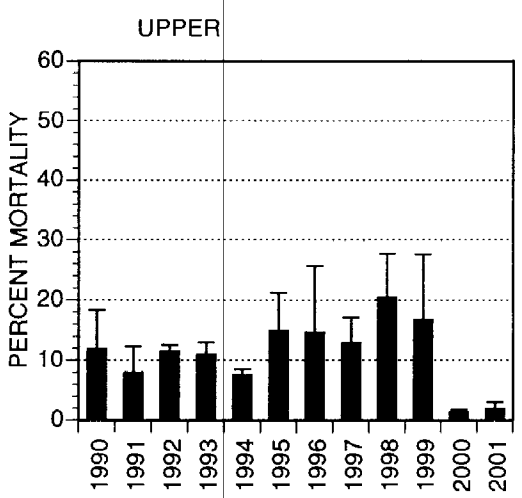
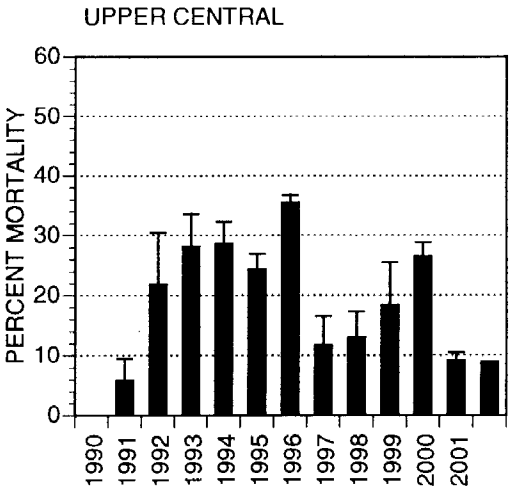
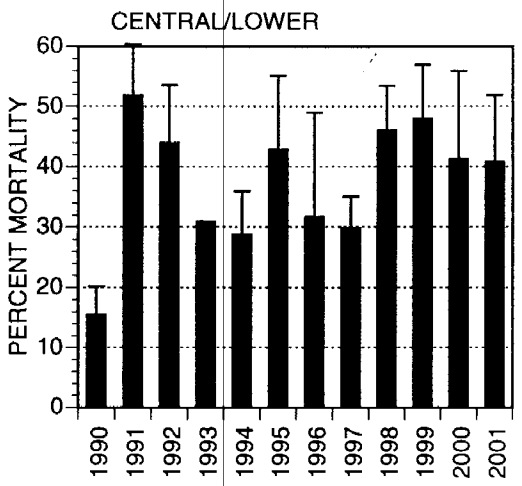

Delaware Bay Seed Beds - Oyster Condition Index
Dry Meat Weight (g)/Shell hinge to lip length (mm)
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Upper
Upper Central
Central
Lower

Figure 11

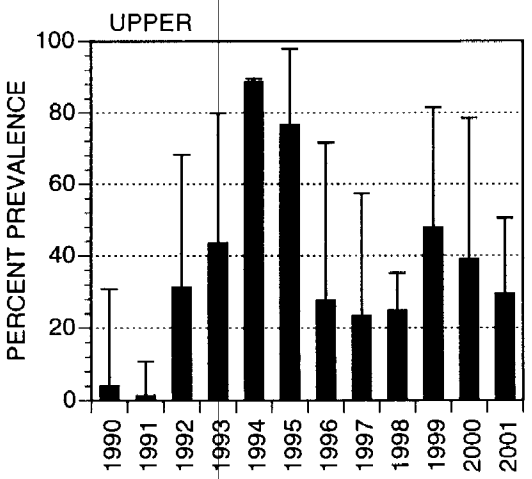

Average Spat Set Delaware Bay Seed Beds
Spat per Bushel
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year

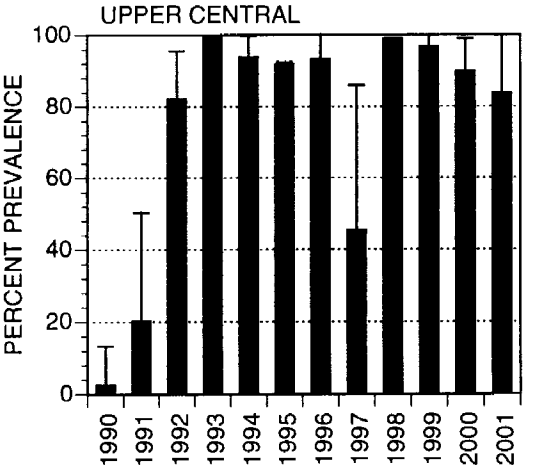


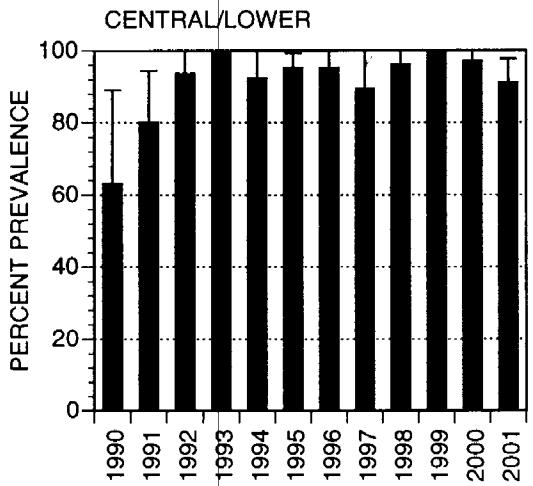



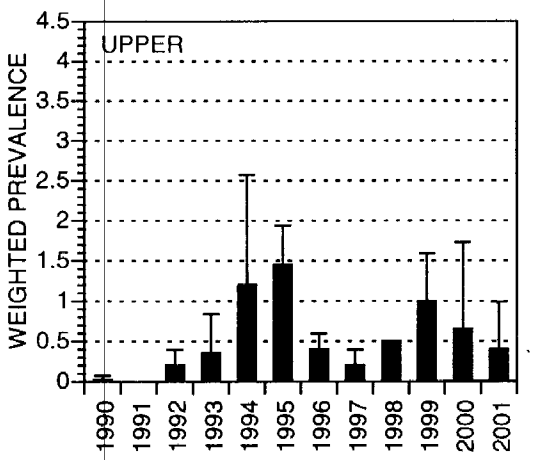

| Area | Mean | sem | 95%CI |
|---|---|---|---|
| Upper | 10.2 | 0.5 | 1.1 |
| Up Central | 18.4 | 0.8 | 1.7 |
| Central/Lower | 39.8 | 2.1 | 4.2 |

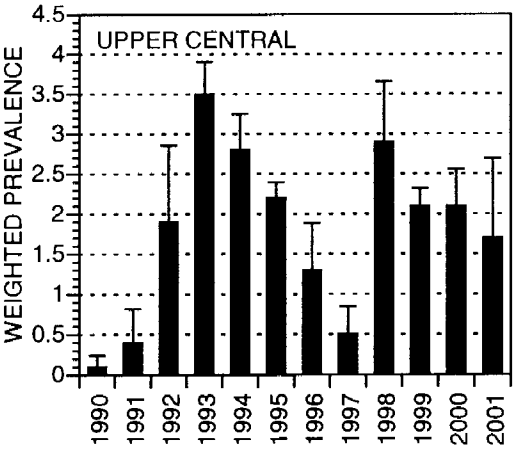


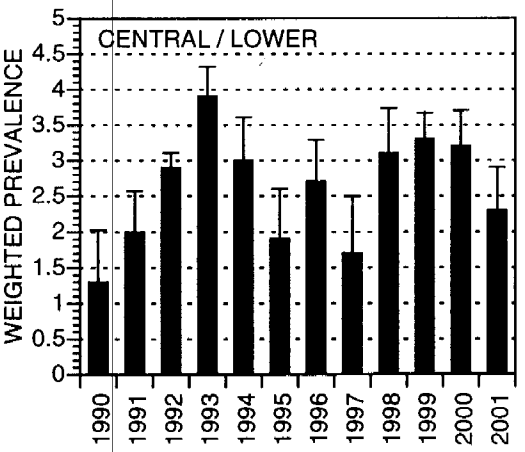




| Area | Mean | sem | 95%CI |
|---|---|---|---|
| Upper | 34.3 | 11.0 | 21.8 |
| Up Central | 77.6 | 6.7 | 12.1 |
| Central/Lower | 92.5 | 1.9 | 3.4 |




| Area | Mean | sem | 95% CI |
|---|---|---|---|
| Upper | 0.5 | 0.2 | 0.4 |
| Up Central | 1.8 | 0.1 | 0.2 |
| Central/Lower | 2.7 | 0.1 | 0.2 |

Figure 15

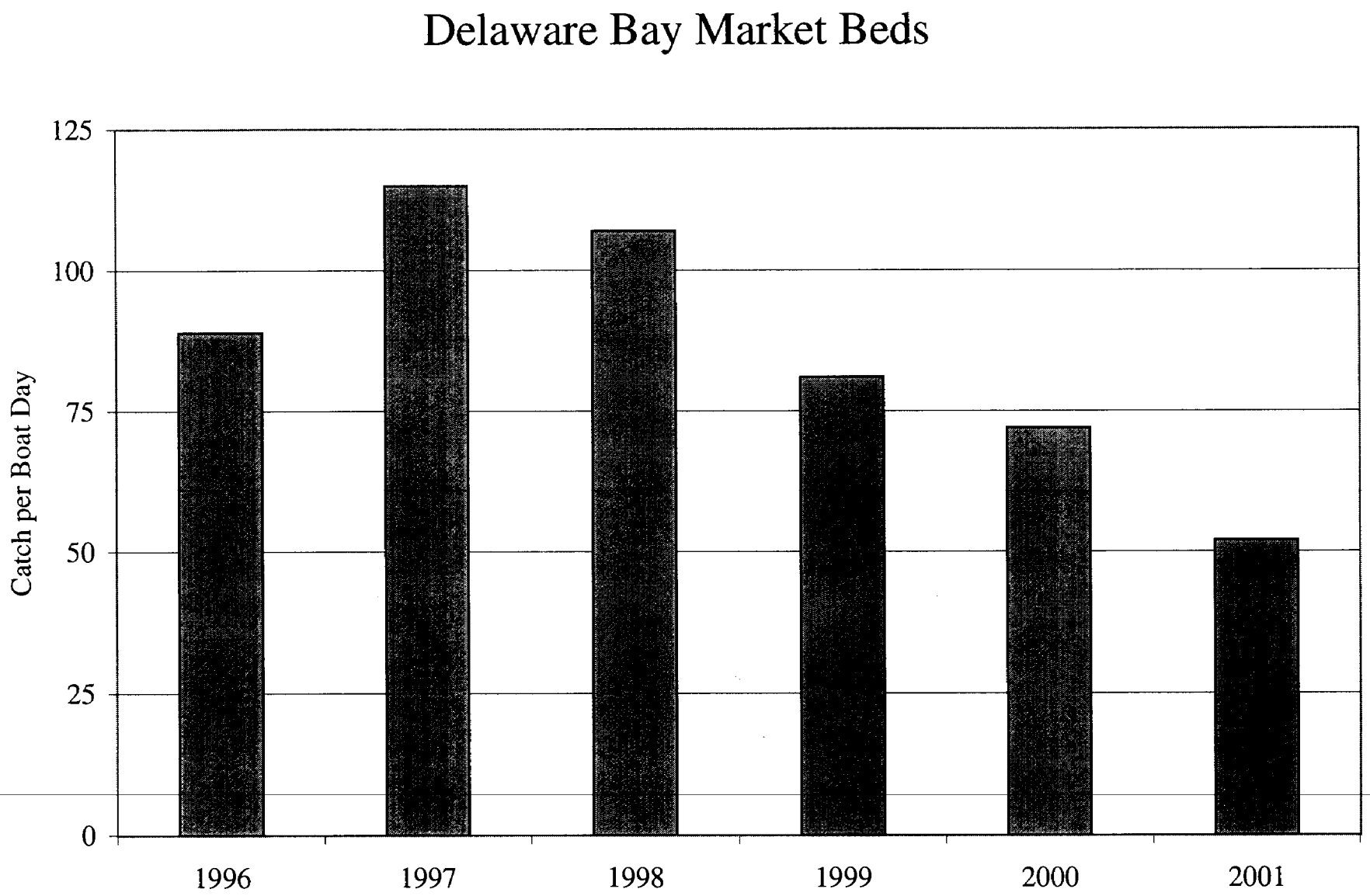

Delaware Bay Market Beds
Catch per Boat Day
125
100
75
50
25
0
1996
1997
1998
1999
2000
2001

Figure 16

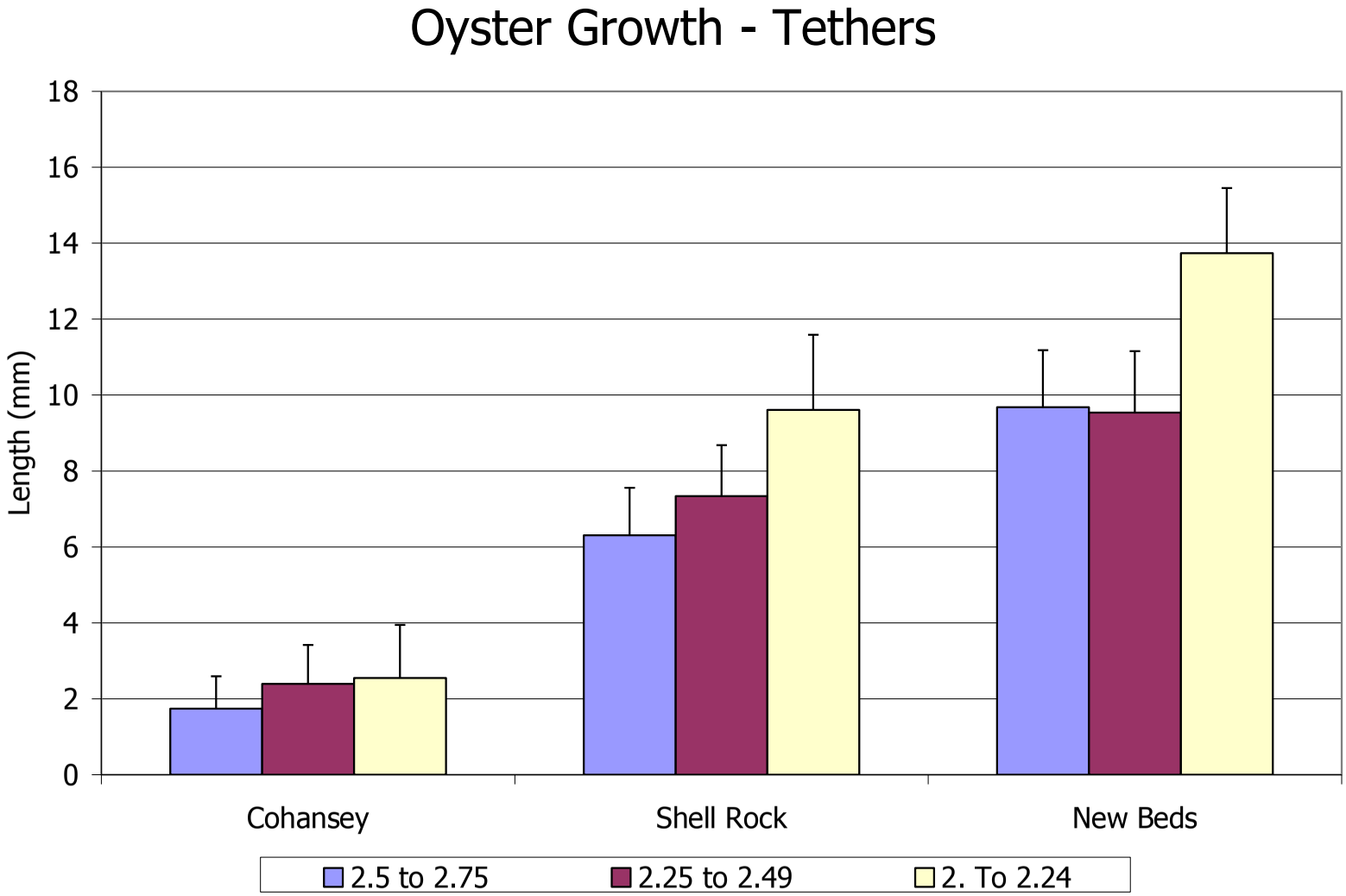

Oyster Growth - Tethers
Length (mm)
18
16
14
12
10
8
6
4
2
0
Cohansey
Shell Rock
New Beds
2.5 to 2.75
2.25 to 2.49
2. To 2.24

Figure 17

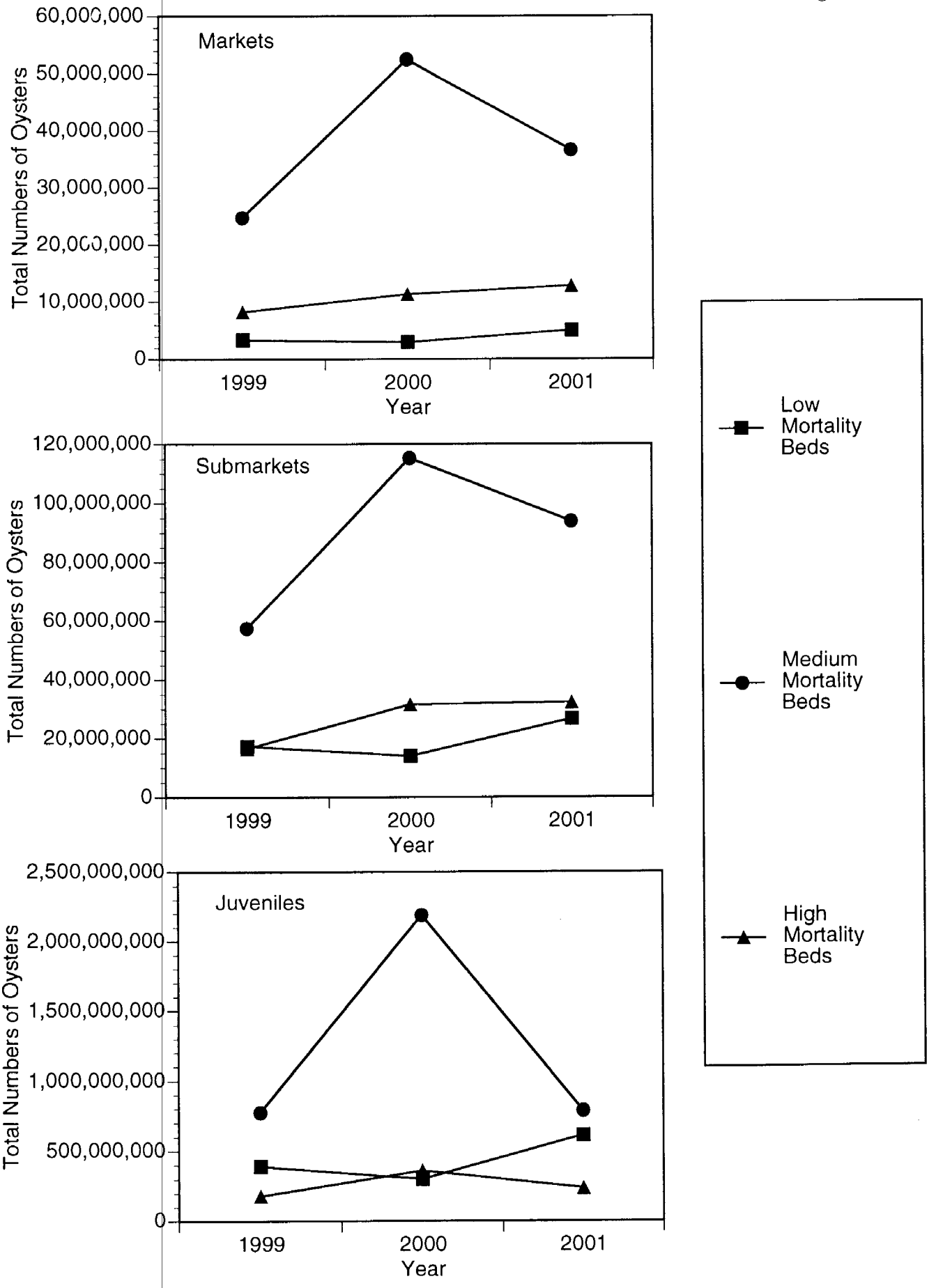
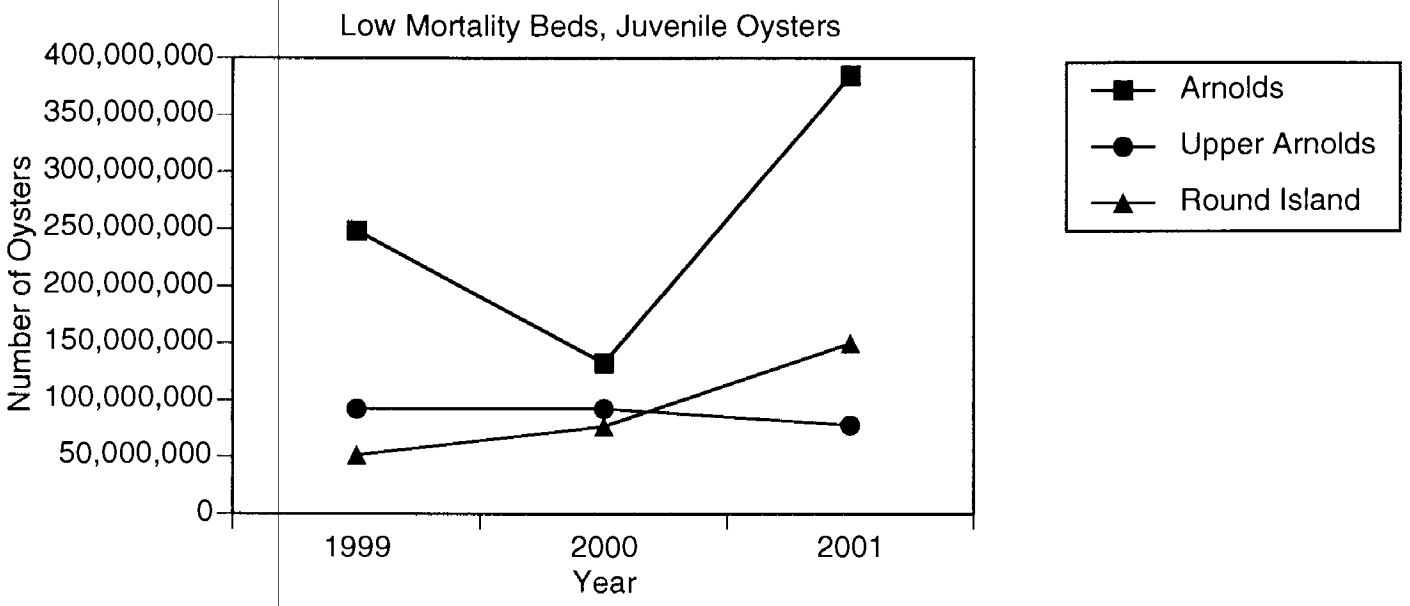
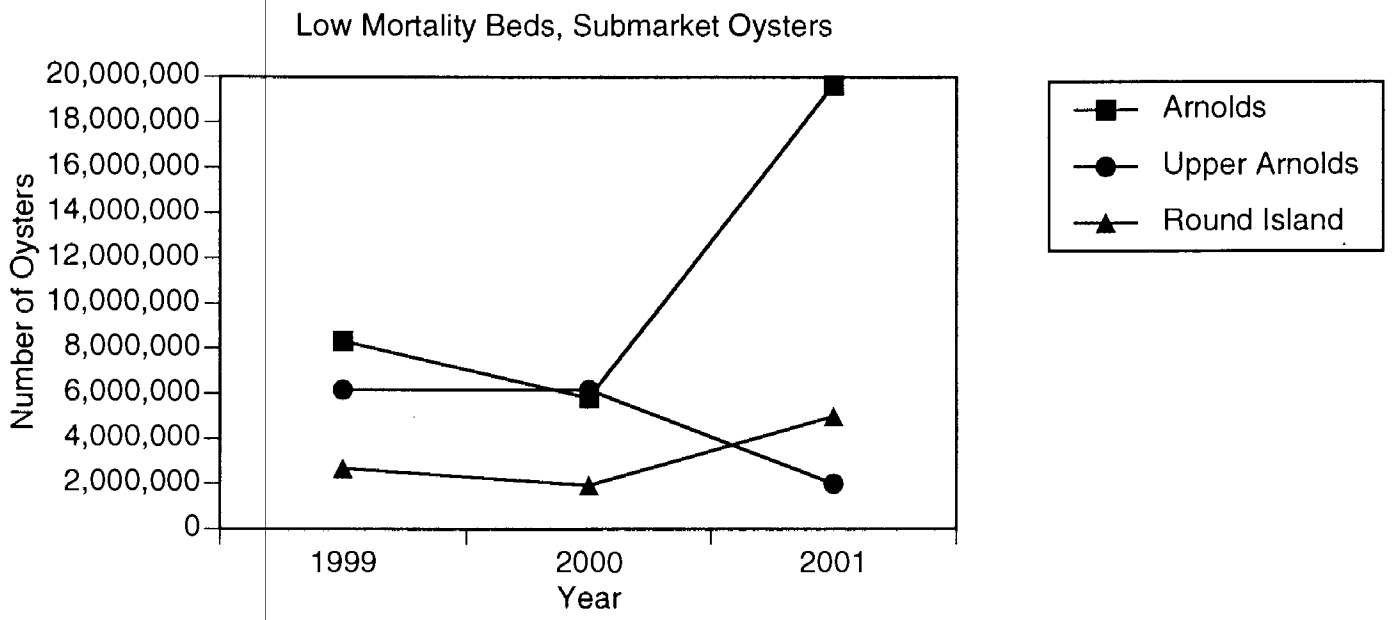

Markets
Total Numbers of Oysters
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1999
2000
2001
Year
Submarkets
Total Numbers of Oysters
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
1999
2000
2001
Year
Juveniles
Total Numbers of Oysters
2,500,000,000
2,000,000,000
1,500,000,000
1,000,000,000
500,000,000
0
1999
2000
2001
Year
Low Mortality Beds
Medium Mortality Beds
High Mortality Beds

Figure 18


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
Year
Arnolds
Upper Arnolds
Round Island


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
Year
Arnolds
Upper Arnolds
Round Island

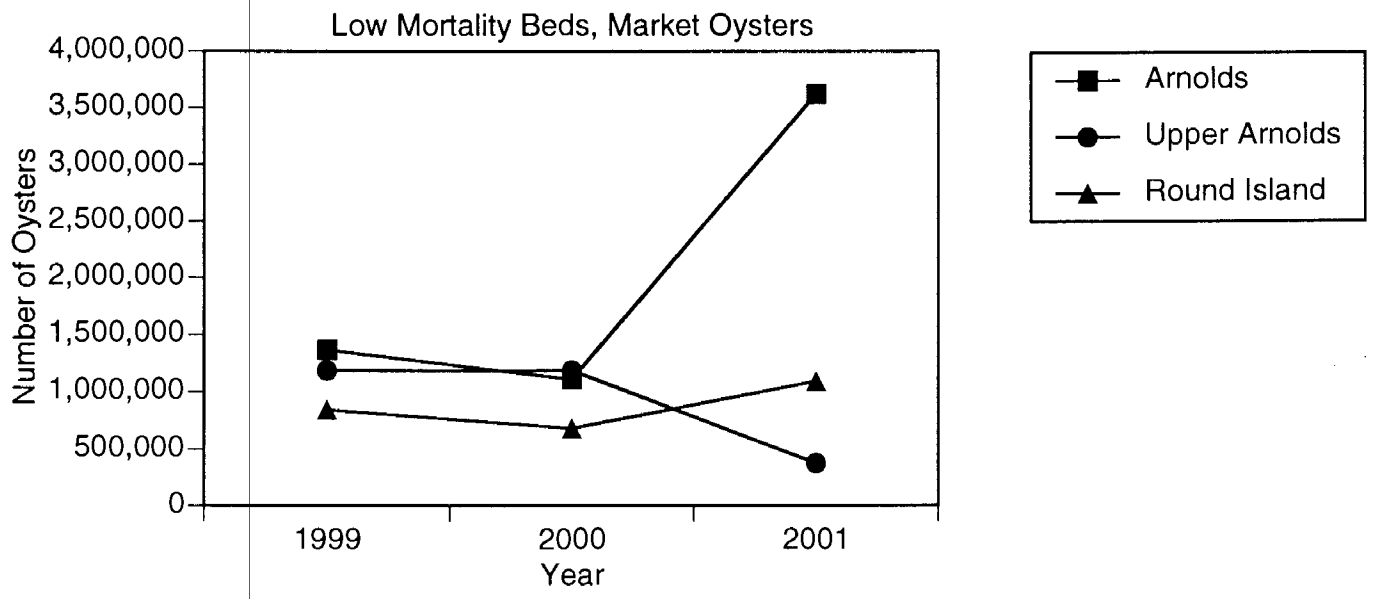
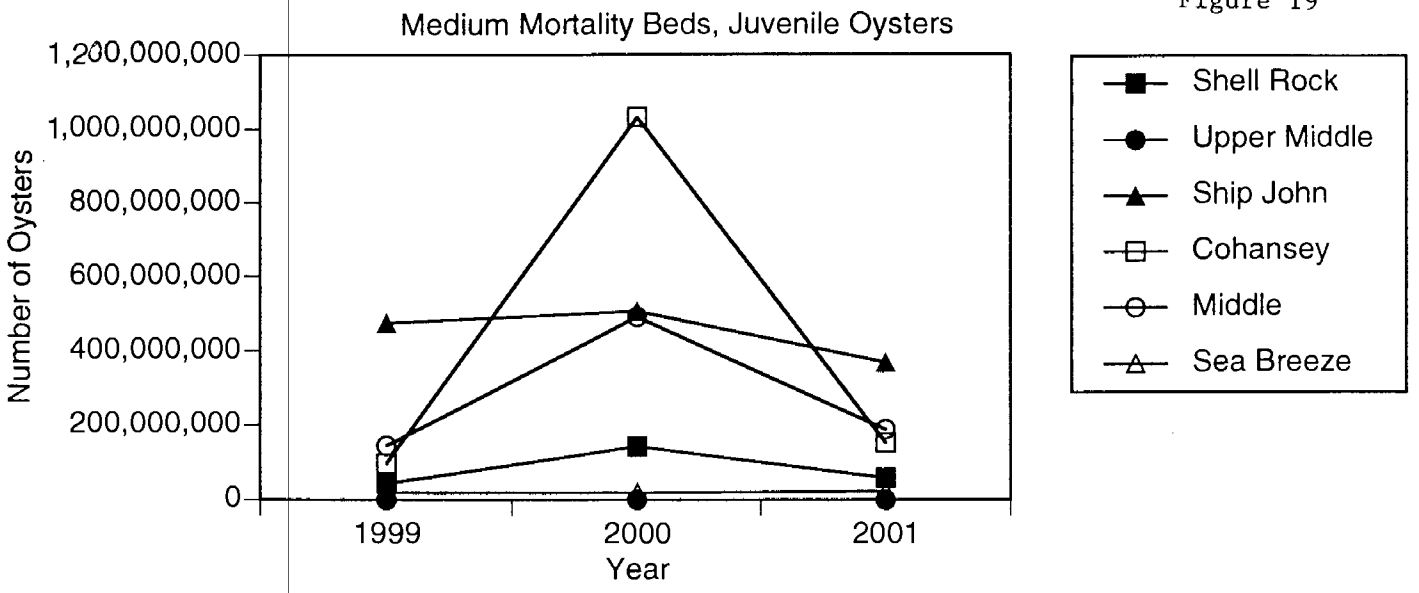
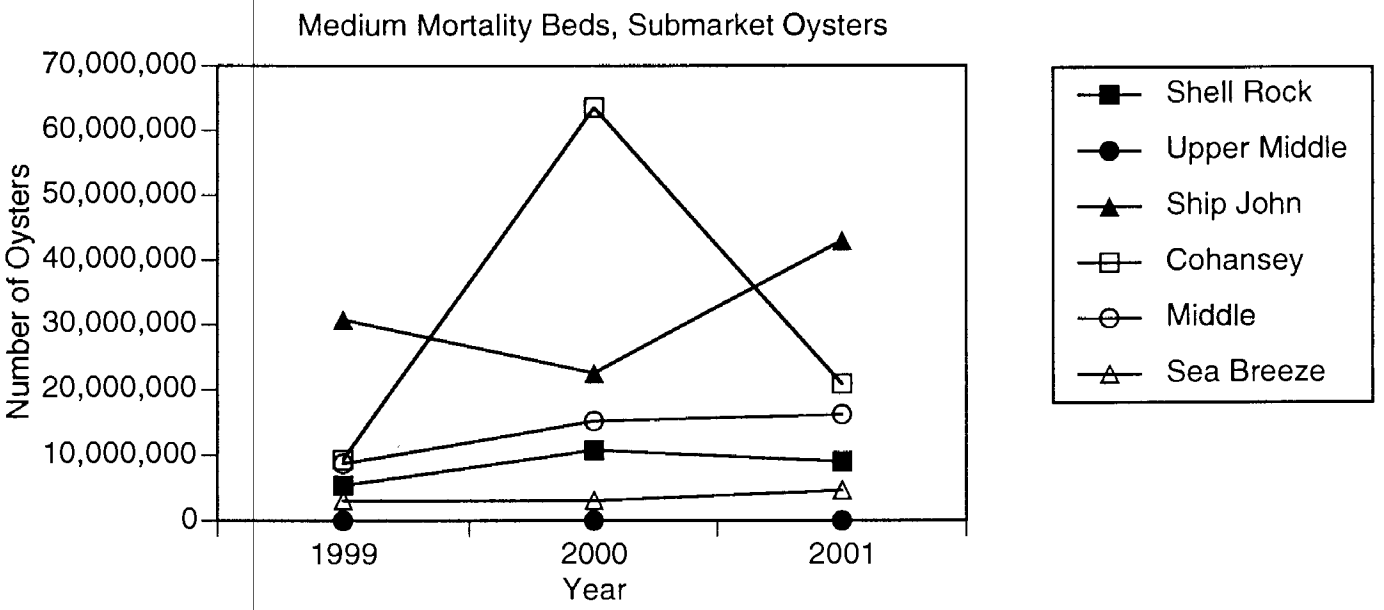

Low Mortality Beds, Market Oysters
Number of Oysters
4,000,000
3,500,000
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1999
2000
2001
Year
Arnolds
Upper Arnolds
Round Island

Figure 19


Medium Mortality Beds, Juvenile Oysters
Number of Oysters
1,200,000,000
1,000,000,000
800,000,000
600,000,000
400,000,000
200,000,000
0
1999
2000
2001
Year
Shell Rock
Upper Middle
Ship John
Cohansey
Middle
Sea Breeze


Medium Mortality Beds, Submarket Oysters
Number of Oysters
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1999
2000
2001
Year
Shell Rock
Upper Middle
Ship John
Cohansey
Middle
Sea Breeze

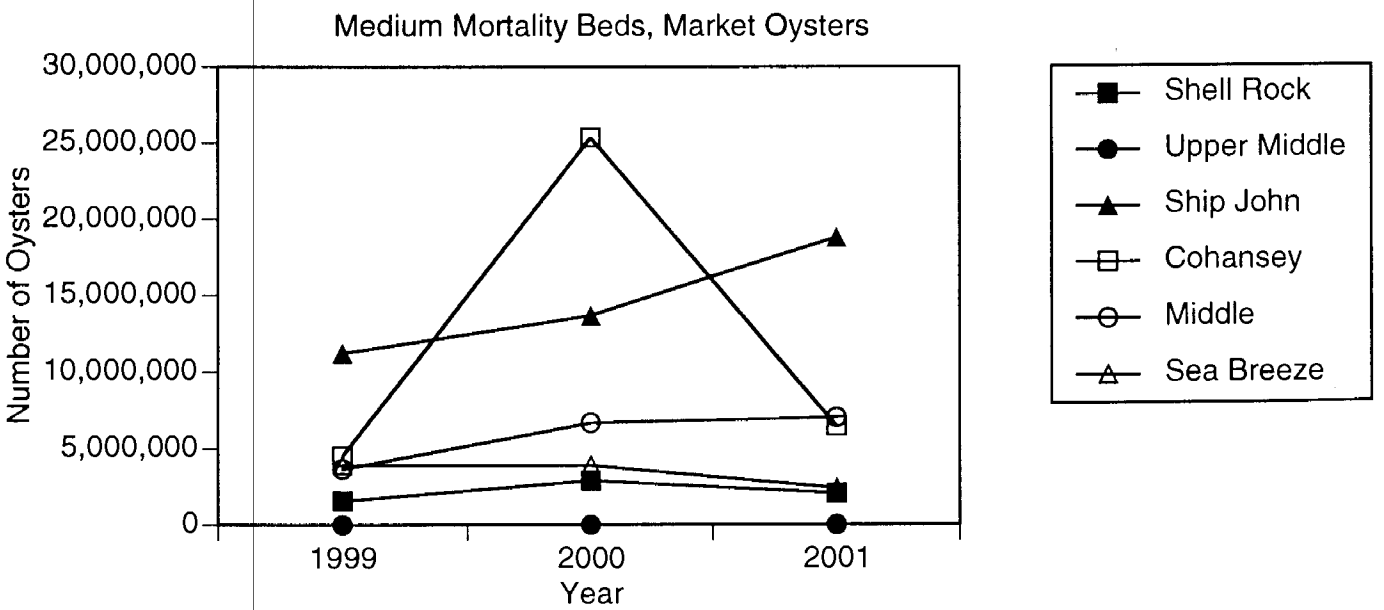

Medium Mortality Beds, Market Oysters
Number of Oysters
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
1999
2000
2001
Year
Shell Rock
Upper Middle
Ship John
Cohansey
Middle
Sea Breeze

Figure 20

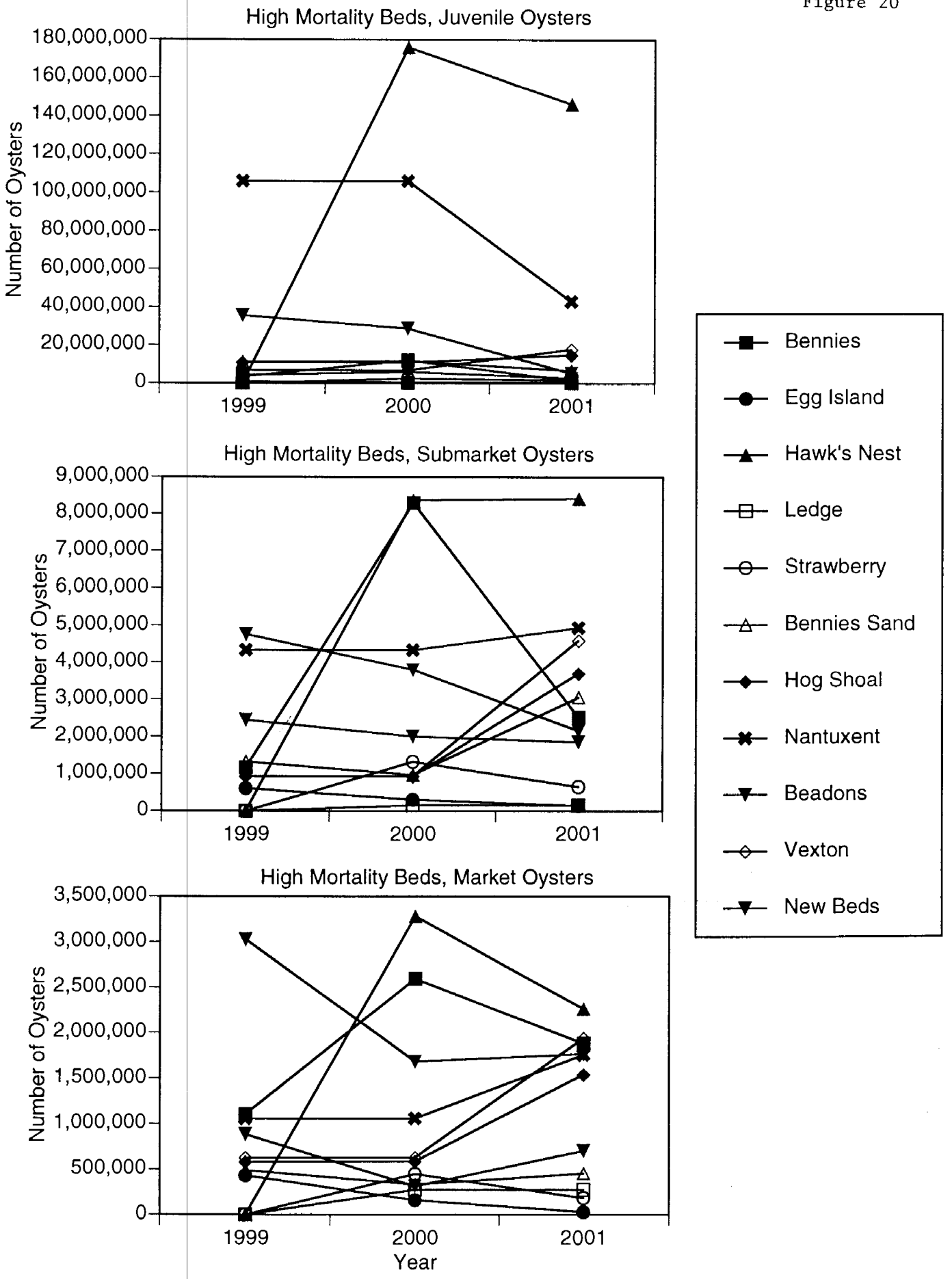

High Mortality Beds, Juvenile Oysters
Number of Oysters
180,000,000
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
1999
2000
2001
High Mortality Beds, Submarket Oysters
Number of Oysters
9,000,000
8,000,000
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000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

Figure 21

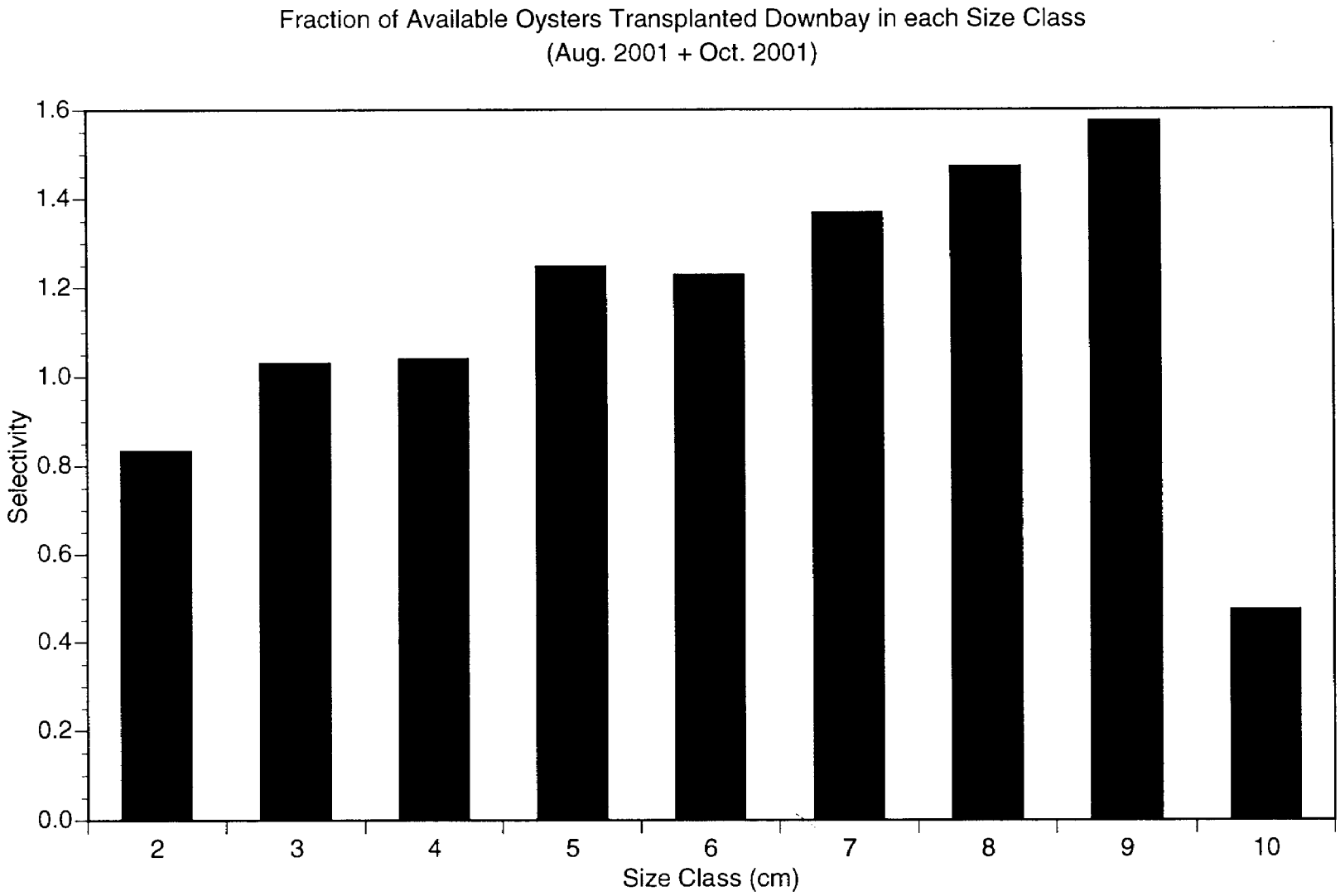

Fraction of Available Oysters Transplanted Downbay in each Size Class
(Aug. 2001 + Oct. 2001)
Selectivity
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2
3
4
5
6
7
8
9
10
Size Class (cm)

Figure 22

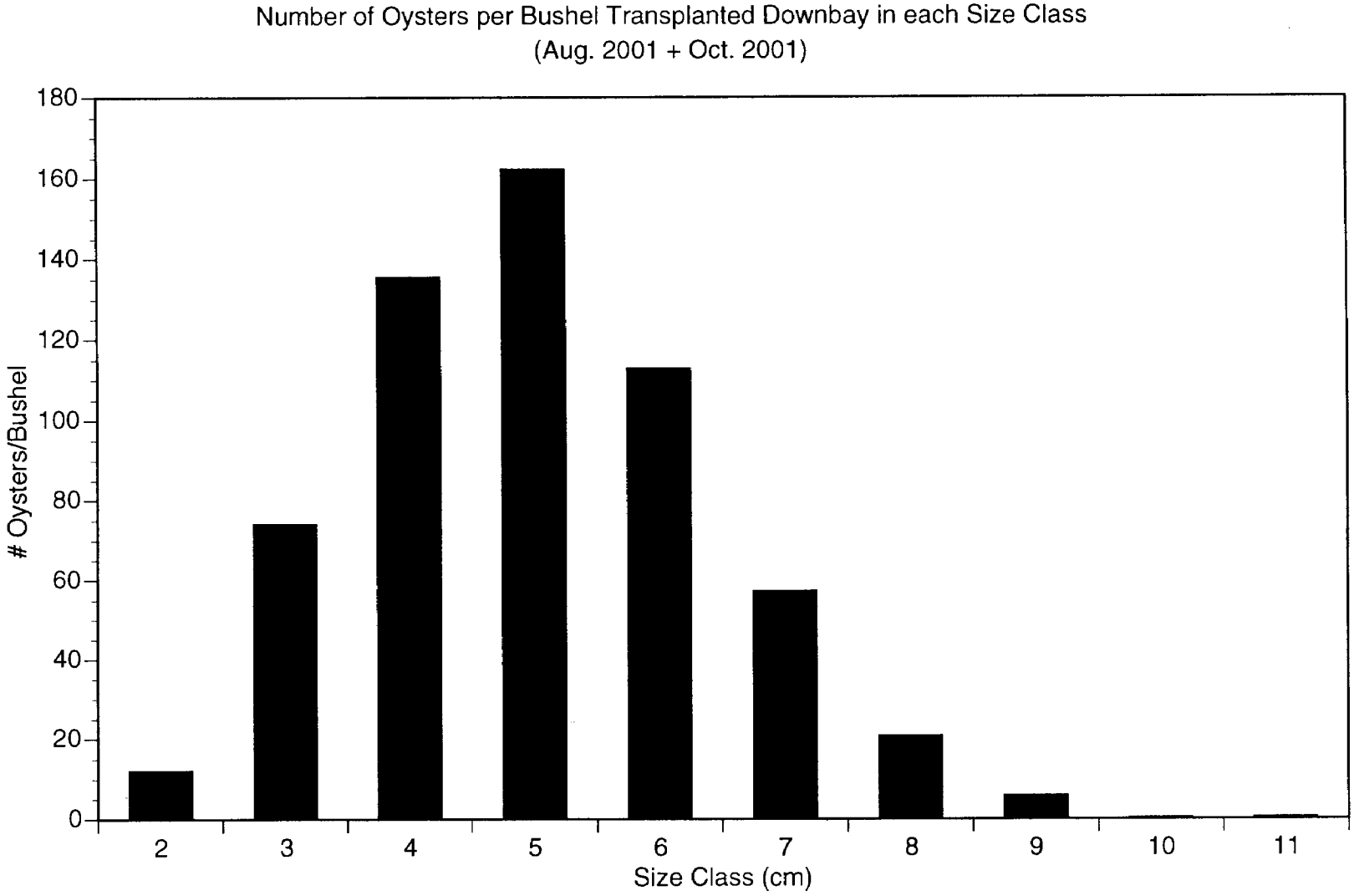
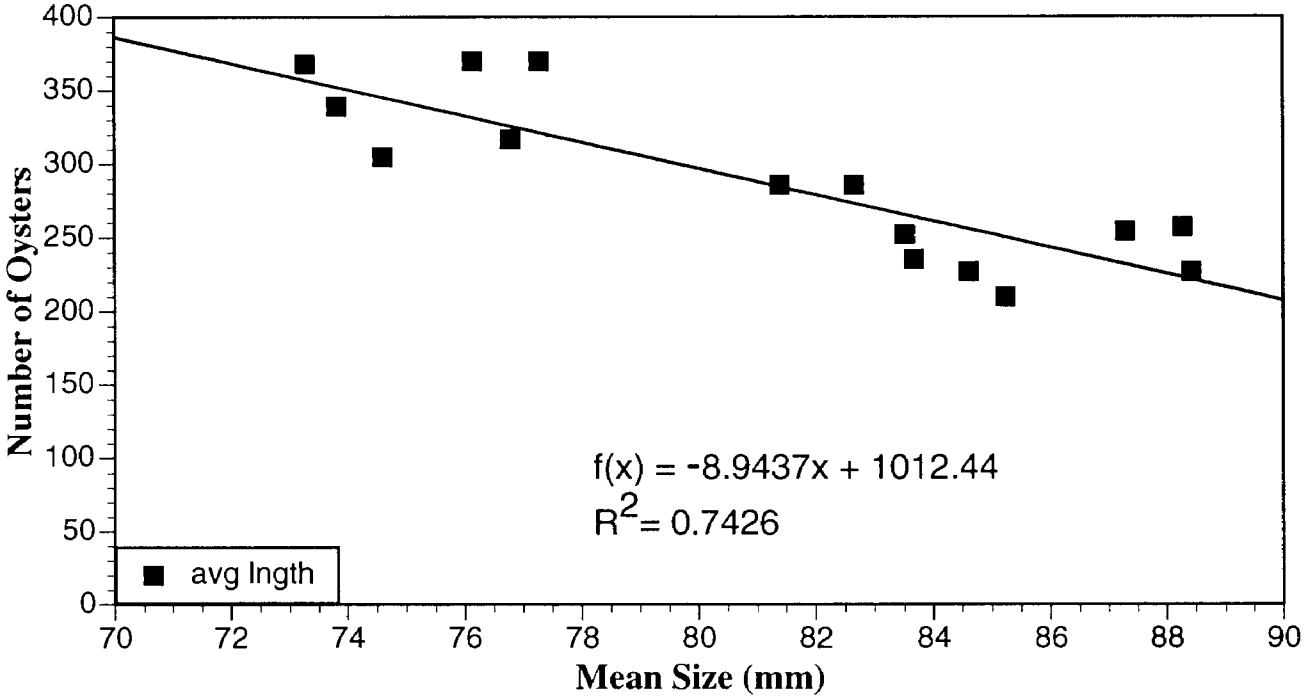

Number of Oysters per Bushel Transplanted Downbay in each Size Class
(Aug. 2001 + Oct. 2001)
# Oysters/Bushel
180
160
140
120
100
80
60
40
20
0
2
3
4
5
6
7
8
9
10
11
Size Class (cm)

Figure 23

Mean sizes and normalized number of market oysters for each of 15 bushels




Average Number of Oysters per Bushel = 287
(normalized to a 37 qt bushel)
Range 210-368 oysters