Report of the
2001 Stock Assessment Workshop
for the
New Jersey Oyster Seed Beds

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Executive Summary 2001 Stock Assessment Workshop

The stock assessment workshop utilized data from the historical record, the 2000 seed bed random sampling program, dredge efficiency studies and a model to develop harvest allocations for the 2001 oyster season. The data and support documentation is provided in the following document.

Status of the Stock:

Oysters- Market and submarket (2.5 to 2.99") oyster abundance has rebounded on Cohansey, Ship John, Middle and has maintained itself on Shell Rock and perhaps Bennies Sand.

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

Oyster meat condition was about the same as last year, but with a slight decrease in the oysters from the Upper Central region.

Spat set was poor this on all beds but Ship John and Shell Rock (both moderate) and Hawk's Nest (good).

Box count mortality was lower than last year, especially on the upper beds. Mortality became greater the farther down bay one progressed.

Dermo levels were about the same as last year and levels became higher the farther down bay one progressed. This is in direct correspondence to the mortality.

As recommended by last year's SAW, the industry harvested nearly 37,000 bu. and transplanted 40,000 bu. from Upper Central Beds to Central beds.

Most of the harvest came from Shell Rock, Bennies, Bennies Sand and New Beds.

Most of the transplants came from Middle, Ship John and Cohansey

Management Advice

For model purposes direct Market beds are all beds below Middle 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 are: Cohansey, Seabreeze, Ship John and 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.

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, up to 106,000 bu. are available for harvest.
2. With area management and without a transplant, 84,000 bushels are available for harvest.
3. Without area management and with a transplant, between 54,000 and 58,000 bu. are available for harvest.
4. Without area management and without a transplant, between 32,000 and 35,000 bu. are available for harvest.

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

1.Transplant Arnolds oysters to Shell Rock and Middle oysters to New Beds.
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 10^0C rule to close the fall harvest.

A cultch management program to replace those shells being removed from the seed beds is necessary.

2001 Stock Assessment Workshop for the New Jersey Delaware Bay 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. For the past decade, 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, high quality and low quality areas. The test area typifies the highest quality areas of the bed (a high abundance of oysters 75% or more of the time). The high quality areas are those sites at which oysters are abundant 25-75% of the time and low quality 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, the 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 bushel; the size of live oysters >2 cm from the composite bushel; and the intensity of Dermo and MSX infections in oysters from selected beds. The data are normalized to a standard 37 quart bushel and the amount of material brought up by the dredge was estimated. Until two years ago, 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 very 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 per bushel has varied little, and the changes have not been statistically significant (Figure 2). The 1953-92 bay-wide mean spat per bushel was about 51, with an average bay wide maximum of 2100 (Table 1). In the last decade the bay-wide overall average has been 110 spat per bushel, about twice the earlier figure. The maximum seed taken by the industry during the past decade 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 harvest has been 73,000 bu.

Status of Stock and Fishery

Seed Bed Sampling

Oyster

Sampling in 2000 was conducted on October 23 to October 25, 2000 using donated time on the oyster dredge boat Howard Sockwell with Larry Hickman 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.

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. Thus it is difficult to establish baywide statistical differences from year to year. 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). Bay-wide average number of 150 oysters/bu. in 2000 was the same as for the present decade and 50% higher than the long term average of 100 oysters/bu.

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) have > 200 oysters/bu. Beds in the Upper and Upper Central region continued to have a number of grids (particularly Upper Central beds) with >40% 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 of oysters (Bennies Sand and Hawks Nest) and the remainder that have continued to deteriorate. Of the Central and Lower regions of the bay only Bennies Sand and Hawk's Nest had any grids that contained >40% oyster (Table 2). All other grids had < 30% oyster. There was a relatively large increase in oysters in the 2.5-3" (submarket) category in the Central portion of the bay.

The important areas for the oyster industry are the beds in the Upper Central and Central region. Examination of the trends in the 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 2000 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. The numbers of market size (> 3") oysters on Shell Rock, Bennies Sand, Bennies and New Beds, used to supply the majority of market oysters, remained about the same as last year (Table 3, Figure 6). The decline in the 2.5 to 3" size oysters that had been evident since 1997 was reversed in 2000. This reversal is primarily due to modest increases in this size oysters on Shell Rock (+9 oysters/bu), Bennies Sand (+15) and Bennies (+11). New Beds continued its decline (-7 oysters/bu.). It is important to note that the increase on Shell Rock and Bennies Sand are the result of relatively good sets in 1998 and 1999 (Table 2). Sets on New Beds have not been adequate to replace oysters lost to mortality and harvest, and there has only been one modest set on Bennies in the last three years (Table 2).

The reversal of the overall decline in abundance was not restricted to the heavily fished beds (Figure 7). Proportional increases on the Upper Central beds mirror those of the market beds in both size classes (Figure 8), but recovery was greater in the Upper Central when compared with the Central area

Coupled with the reversal in the decline in abundance, the percentage of the number of oysters/bu. **greater than** 2.5" has generally decreased. This is because of the increase in abundance of smaller oysters. This year it was <20% in the Upper and Upper Central bay areas. The percentage of oysters >2.5" on all Upper and Upper Central Bay beds remained the same (<20%) or decreased from 1998 to 2000 while the numbers of oysters/bu. either remained the same or increased, due, primarily, to the high spat sets in 1998 and 1999 (Table 2). In the Central and Lower bay this situation is generally reversed with low spat settlement and declining numbers of oysters/bu. (with the exception of Hawk's Nest and Bennies Sand). The percentage of the number of oysters/bu. >2.5" was >20% on Bennies Sand and Hawk's Nest and >60% on all other Central and Lower Bay Beds. During the past decade the percentage >2.5" has been about 15% on all of these beds.

Model Data

Table 4 shows the final estimates of abundance after survey quantification. Estimates labeled "high quality" are based on samples taken on the high quality and test areas only. These values were used for all subsequent calculations. Low quality areas were not included in subsequent calculations, as their sampling intensity was insufficient to provide reliable estimates of abundance. Estimates of abundance are provided in terms of bushels using the values 348 and 499 to convert market-size and submarket-size (2.5"-3") abundance to bushel equivalents. In some cases, submarket size was defined as 2.75"-3", in which case these values will be lower than the submarket abundances indicated in Table 4. All calculations, however, were done as individual oysters. If a bed was not sampled in 2000, the value for 1999 was used. The correction for dredge efficiency (q) used the size-class dependent dredge efficiencies and the differential in dredge efficiency between upper and lower beds (Table 5).

Recent trends in settlement, disease mortality and harvest have resulted in the greatest number of market sized oysters on Cohansey (88,000 bu.) followed by Ship John, followed by Middle, each with about half as many market oysters as the previous bed. A group consisting of Bennies, Hawks Nest, Shell Rock and Seabreeze had approximately 10,000 bu. of market size oysters each (Table 4). In contrast to last year, numbers of submarket oysters in the 2.5 to 3" class were present in greater numbers than market oysters on both the market beds and the Upper Central beds (Figure 8). Greatest overall increase in oyster abundance was on Cohansey followed by Ship John, Shell Rock and Bennies Sand. The increase in submarket size oysters and the relatively constant number of market size oysters is reflected in the drop in percent of oysters that are market size (Tables 2 and 3).

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 Lower beds increased while that of the Upper Central area declined somewhat (Figure 9).

Spat Set

Bay wide spat set was near the long term mean of 50 spat/bu., and below the 110 spat/bu decade long mean. Spat set in 2000 was, for the most part, poor (Table 2, Figure 10). Spat set was below 100/bu on all beds but Ship John, Shell Rock and Hawk's Nest, and was below 50 spat/bu on all other beds but Cohansey. 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.

Mortality and Disease

Mortality, assessed as percent total box count falls into 3 major groups Upper, Upper Central and Central/Lower. In 2000 mortality was generally lower in the Upper and Upper Central regions than in the previous two years (Table 2, Figure 11). The mortality in the Central and Lower Bay segments remains high and about the same as in 1998 and 1999 (Figure 11). This may reflect the early sampling, because Dermo prevalence and weighted prevalence remained high and about the same as the last two years (Table 2). Since water temperatures did not decline until well into November, additional fall 2000 mortality might be expected. It is unlikely, however, that additional mortality would bring the 2000 levels up to those of 1999. In a broader perspective baywide Dermo continued a three year period of high weighted prevalence (Figure 12), and these levels are clearly evident in the Central/Lower beds (Figure 13).

Comparison of fall "oyster box count" mortality estimates with those obtained using the method of cumulating recent mortality shows that the two methods give very similar results and indicate that the fall box counts give a reasonable estimate for mortality that has occurred during the summer and fall (when most Dermo caused mortality occurs).

Regression analysis of monthly prevalence and weighted prevalence against fall survey mortality estimates suggests that May Dermo values (particularly prevalence) may predict Dermo caused mortality over the summer and fall.

MSX disease prevalence continued to be insignificant (<10% in October samples).

Harvest and Transplant

Based on a provision of a 40,000 bu. transplant program from Upper Central bay beds to Central bay beds, SAW 2000 recommended harvest limit of 40,000 bu. Spring and fall market harvests were permitted on the seed beds in 2000. Spring harvest was from May 8 to July 21 (11 weeks) and Fall harvest was from August 7 to September 29 (9 weeks). The 20 weeks of fishing this year compare to 26.5 in 1999, 30 in 1998, 17 in 1996, and 25 in 1997. A total of 52 days (304 boat days) was utilized in the spring and 38 days (273 boat days) in the fall. Spring harvest was from 10 beds and totaled 17,335 bu. with 83% of this coming from four beds (Bennies (24%), Bennies Sand (30%), New Beds (21%) and Shell Rock (7%))(Table 6). Fall harvest was also from 10 beds and totaled 18,242 bu. with 75% of this coming from the same four beds (Bennies (14%), Bennies Sand (30%), New Beds (13%) and Shell Rock (18%)) (Table 6).

The total catch for the 2000 season was 35,577 bu (Figure 3). Catch per day was 333 bu. in spring and 481 bu. in fall. Catch per boat day was 57 bu. in spring and 67 bu. in fall. The catch per boat day was about the same as last year (average = 62 bu./day) after dropping markedly in 1999 to 65 bu/per day from 1997 (average = 91 bu/day) and 1998 (average = 81 bu/day).

Transplant

Transplantation of 40,000 bu. from up bay seed beds to replace those being harvested was one of the management recommendations from the 2000 SAW. This appeared to work well in conserving the resource. During the 2000 market season 40,053 bushels of oysters were moved from other seed beds to the market beds (Table 7). Between 1997 and 1999, about 114,000 bu. of oysters were transplanted and in 2000 an additional 34,928 bu. of oysters were moved from Upper Central beds to New Beds and Bennies (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.

Spring transplants were all placed on Bennies bed. These oysters came from three beds: Middle (9,335 bu.), Cohansey (6,572 bu.) and Ship John (4,146 bu.). Fall transplants were moved from two inshore beds, Beadons (4,900 bu.) and Nantuxent (225 bu.) and the Upper Central bay bed Middle (14,875 bu.). These were placed on New Beds (5,125 bu.) and "Inner" Bennies (14,875 bu.). One sampled grid on Bennies received some of these transplanted oysters. This was responsible for 22% of the oysters reported for Bennies in 2000. Another grid that did not receive a transplant was responsible for another 20% of the total.

Other Studies

A number of other studies were completed this year. These include a hopper calibration on the *Howard Sockwell*, a transplantation study, continued dredge calibration and modeling. Information from these is integrated into the stock assessment and management advice. Summaries of these studies are provided in the appendix to this document. Complete study reports are available at Haskin Shellfish Research Laboratory.

Management Advice

- Conservative management of harvest levels in 2000 plus good settlement in the Upper Central grounds in 1998 and 1999 have stemmed the 3 year decline in oyster abundance on those beds. The numbers of submarket oysters increased and there are sufficient 2.5 to 3" oysters in the system to provide for year 2001 harvests. The lower spat set in 2000 suggests that careful attention to spat settlement in 2001 will be a critical factor in evaluating the prospects for continued harvests in 2002-2005. Dermo levels remain high and may be expected to continue to produce heavy mortality.

- Significant variation in natural mortality rate among direct-market beds produced by a salinity-dependent gradient in Dermo intensity and, to a lesser extent, in oyster drill caused mortality, necessitates the distinction of two groups of direct-market beds:
  - (1) High-mortality beds: Bennies, Bennies Sand, New Beds, Hog Shoal, Strawberry, Hawk's Nest, Vexton, Ledge, and Egg Island.
  - (2) Medium-mortality beds: Cohansey, Sea Breeze, Ship John, and Shell Rock.
- Evaluation of the yearly allocation for direct-market beds should include the following assumptions:
  - (1) Due to presumed differential growth between bed groups, oysters 2.5 to 3" on the high-mortality direct-market beds and Shell Rock will recruit to the fishery in 2001. For Cohansey, Sea Breeze, and Ship John, oysters 2.75-3.0" will recruit to the fishery in 2001.
  - (2) Allocations should be set for two separate fishing periods, before and after June 30, to permit reassessment of the predicted natural mortality rate for the second fishing season. This reassessment should be used to update the allocation for the second season. This approach will limit the chance of over-harvesting if the natural mortality rate is initially underestimated. It will also provide for an increased harvest allocation if the natural mortality rate is initially overestimated.
  - (3) The 75^{th} percentile of natural mortality rate should be used for defining the allocation for Season 1. The value for the 75^{th} percentile was obtained from the mortality rates for the period 1989-2000 for each of the two groups of beds (Fig. 14). Example simulations for this and other mortality rates are shown in Fig. 15. The 75^{th} percentile

represents a conservative approach which guards against overfishing in times of high mortality. It is assumed that the projected natural mortality rate for 2001 will be reassessed at the end of May based on the Dermo monitoring program and the relationship between May prevalence and end-of-the-year cumulative mortality. The allocation for Season 2 can be updated based on this new mortality projection.

- Significant increases in submarket size oysters suggest the opportunity to rebuild oyster abundance after the 1998-2000 epizootic. Rebuilding goals should be based on the relationship of the number of market-size oysters present on the direct-market beds in 2000 with the 1989-2000 time series. To develop a rebuilding goal, oyster abundance was recalculated as the weighted mean abundance: mean = number ≥3" + 0.5(number 2.5 to 3"). The rank order of weighted mean abundance (Figure 16) indicates a step function at the 66^{th} percentile, equivalent to about 35 oysters/bu. This value was selected by SARC as the abundance goal because use of the 50^{th} was considered to be insufficiently risk averse. Similarly, the change in weighted abundance from one year to the next for each pair of years of the 1990's was plotted in rank order (Figure 16). Abundance increases occur less frequently than abundance decreases ($P \cong 0.1$). Bed capacity for rebuilding without fishing appears to be about 2. The value that can be achieved with fishing was chosen as the 75^{th} percentile: 1.52. This ratio should be set as the maximum yearly rebuilding ratio. Present weighted mean abundance is a factor of 1.24 below the weighted abundance goal (66^{th} percentile). The value of 1.24 should be used this year to permit rebuilding of abundance to the 66^{th} percentile level.
- The majority of the oysters available for direct-marketing are on Shell Rock, Ship John, and Cohansey. Without area management (opening and closing of specific beds or groups of beds), an allocation based on the abundance of oysters on these three beds combined might actually be removed only from beds downbay because of an industry preference for the higher quality oysters on these downbay beds. This would endanger the stocks on the beds downbay of Shell Rock. Landings records for 1998-2000 indicate that the industry has tended to distribute its effort such that 66% of the oysters were marketed from the high-mortality beds and 34% from the medium-mortality beds (Ship John, Cohansey, and Shell Rock). Without area management, fishing scenarios for 2001 must assume that this historical differential in effort will occur again in 2001. Without area management, the allocation must be reduced

such that the total number of bushels removed from the high-mortality beds does not exceed the amount that can be sustained by the population assuming a 66:34 ratio of industry effort. Figure 17 provides details of one such scenario.

- Consideration should be given in developing an area management program to harvesting the allocation for the high-mortality beds in Season 1 and the allocation for the medium-mortality beds in Season 2. This approach will maximize the allocation to the fishery and minimize the loss to disease.
- Seedbeds to be utilized in the transplant program should be evaluated in three groups distinguished by their natural mortality rates (Figure 14). These are (1) low-mortality beds: Round Island, Upper Arnolds and Arnolds; medium-mortality beds: Upper Middle and Middle; and (3) high-mortality beds: Nantuxent Point and Beadons.

Oyster Transplants

- Evaluation of the yearly allocation for transplant should include the following:
  - (1) For the high-mortality transplant beds, oysters 2.5-3.0" will recruit to the fishery in 2001. For the remaining transplant beds, oysters 2.75-3.0" will recruit to the fishery in 2001.
  - (2) The 75th percentile of natural mortality rate should be used for the initial determination of the allocation to guard against overfishing in times of epizootic mortality. If transplant occurs after June 30, this initial projection can be updated based on the end-of-May reassessment.
  - (3) Consideration should be made of the fact that transplants do not, and cannot, effectively select for size and therefore large numbers of oysters < 2.5" are included in each bushel of transplant.
- The goal of the allocation program should be to stabilize present abundance which is somewhat above the 10-year mean. To assess the need for a rebuilding plan, the weighted mean abundance was calculated as described previously. Because the data seem to plateau at about 40 oysters/bu., that level was chosen as the goal (Figure 18). A maximum one-year rebuilding ratio of 1.52 is consistent with the trends in abundance on these beds as was the case for the direct-market beds (Figure 18). Present abundance is approximately at the abundance goal. Accordingly, the goal of the transplant program should be to stabilize present abundance. A rebuilding plan is not presently necessary for these beds.

- The Arnolds group oysters should be transplanted to Shell Rock to provide an opportunity for an extended growth period at relatively low Dermo mortality rates. The Middle group oysters should be transplanted to New Beds to help rehabilitate that bed. The economics of transplanting the Nantuxent Point/Beadon group needs to be evaluated. A transplant to New Beds should be considered in low-Dermo years.
- Most of the transplant program should occur in the early fall (e.g., mid-August through September) to maximize the time for growth before the next high mortality period in the summer of the following year. However, should Cohansey and Ship John be used to sustain the transplant program rather than for direct-market, the abundance on the high-mortality direct-market beds is insufficient to sustain harvest prior to transplant. Transplant from these two beds, should that option be chosen, must occur prior to the beginning of Season 1.
- Until data are available to characterize the effect of the suction dredge on a bed, transplant should not be conducted using this method because the present allocation is based on the assumption that the culling machines enrich the transplant in the larger size classes.
- There is no reason, at present, to change the 10^0 C rule to close the fall harvest. Results of the research program to evaluate repeated dredging suggest that oysters cannot repair shell damage over the winter.
- Transplant and harvest continue to remove shell from the seedbeds which is not presently being replaced. A cultch management program needs to be instituted to prevent further reduction in bed quality and to increase spat settlement.

Scenarios for Direct-market allocation

The scenarios presented below are based on a model (see Appendix) and assume that natural (mostly Dermo) mortality rate will be high in the coming year. This conservative assumption will be reassessed at the end of May. Season 2 (post June 30) allocation for direct-marketing will then be updated for the period beginning July 1. Accordingly, the scenarios are each broken down into two groupings: (a) an allocation for the period prior to July 1 and (b) an allocation for the period subsequent to July 1 that can be updated at the June Council meeting. The transplant allocations can also be updated at the end of May.

The scenarios outlined below and illustrated in Figure 17 were investigated. Alternate scenarios can be evaluated at the behest of the Council. Two of the scenarios presented do not require area management. Scenario 3, with the higher allocation, assumes area management.

Scenario 1: Fishing season 1: April 1 to June 30. Fishing season 2: July 1 to September 30. All direct-market beds open to fishing throughout the fishing season. This scenario assumes that fishing effort will be distributed between the high-mortality beds and the medium mortality beds in accordance with 1998-2000 landings.

Scenario 2: Fishing season 1: April 1 to June 30. Fishing season 2: August 15 to November 17. All direct-market beds open to fishing throughout the fishing season. This scenario assumes that fishing effort will be distributed between the high-mortality beds and the medium mortality beds in accordance with 1998-2000 landings.

Scenario 3 -- Area management: Fishing season 1: April 1 to June 30. Fishing season 2: July 1 to September 30. High-mortality direct-market beds open to fishing April 1 to June 30. Medium-mortality direct-market beds open to fishing July 1 to September 30. The higher allocation in this scenario originates from the much larger resource present on Ship John, Cohansey and Shell Rock that would be taken without risk to the high-mortality beds downbay under the area-management scenario.

Direct-market Allocation -- without transplant

Scenario * [1]	Season 1 Allocation	Season 2 Allocation[2]	Total Allocation
Scenario 1	21,707	13,900	35,607
Scenario 2	21,057	11,000	32,057
Scenario 3[3]	26,327	57,941	84,313

*All allocations in bushels. All allocations assume Dermo mortality at the 75\th~percentile and a 1.24 rebuilding plan.

[1] Cohansey and Ship John have been defined as direct-market beds. Should the Council wish to use these as transplant beds, the direct-market allocation and the transplant allocation would need to be modified accordingly. However, this would transfer about 39,000 bushels from the direct-market allocation to the transplant allocation. Such a transfer could not be sustained by the high-mortality beds unless the transplant occurred at the beginning, rather than the end, of the year.

[2] Allocation subject to revision during end-of-May re-assessment.

[3] Part of the second season allocation could be transfered to the first season to even out the catch without endangering the stock, provided that the closure of the high-mortality beds also occurred earlier. Based on the difference between the 75\th~percentile and 100\th~percentile of natural mortality, the transfer of about 15,000 bushels to even out the two time periods would be permissible.

Transplant Allocations*

Bed Origin Group	Bed Group Destination	Allocation[2]
Low-mortality beds	Shell Rock	7,070
Medium-mortality beds[1]	New Beds	6,178
High-mortality beds	New Beds	9,310

[1]If all bushels are transplanted, the ratio transplanted to New Beds *versus* Shell Rock is about 1: 0.68. This is similar to the long-term ratio of industry effort and, consequently, the allocations shown in Scenarios 1-3 could be increased by the given amount either in Season 1 or Season 2, regardless of whether area management is implemented. The total additional allocation to the high-market beds, 15,488 bushels, is small in comparison to anticipated Dermo mortality and, consequently, the removal of this many bushels from the high-mortality beds prior to transplant adding them back in the fall can be sustained by the stock.

[2]All allocations in bushels. All allocations assume Dermo mortality at the 75\th~percentile and a 1.0 rebuilding plan (no rebuilding). All assume that transplant would occur between August 15 and September 30. All projections are subject to the end-of-May stock re-assessment.

Total Allocation

The following is a sum of the direct-market and transplant allocations (given in bushels). For simplicity, half of the transplant allocations has been added to each season for Scenarios 1 and 2. The transplant allocation has been added to the appropriate season for the area management

Scenario *	Season 1 Allocation	Season 2 Allocation[1]	Total Allocation
Scenario 1	32,986	25,179	58,165
Scenario 2	32,336	22,279	54,615
Scenario 3	41,860	65,011	106,871

*Cohansey and Ship John have been defined as direct-market beds. Should the Council wish to use these as transplant beds, the direct-market allocation and the transplant allocation would need to be modified accordingly. However, this would transfer about 39,000 bushels from the direct-market allocation to the transplant allocation. Such a transfer could not be sustained by the high-mortality beds unless the transplant occurred at the beginning, rather than the end, of the year.

[1] Allocation subject to revision during end-of-May re-assessment

Science Advice

- Include a growth and condition monitoring program with the disease monitoring program.
- Obtain information on the size-frequency of a typical direct-marketed bushel and a typical transplanted bushel. Apply this information to the determination of the weighted mean abundance used to determine the rebuilding goal and also to better calculate the allocation for transplant.
- Include growth in the fisheries model.
- Include size-dependent mortality in the fisheries model.
- Evaluate tow-based evidence to fine tune dredge efficiency information.
- Add some sampling of all beds to fall survey -- maybe re-sample one `test' area for some beds. Include a measure of tow-based dredge efficiency if one exists.
- Continue to evaluate the `May Dermo correlation' approach to reassessing the management advice.
- Develop a simulation model that permits examination of the probability of occurrence of high *m* combined with limited population resilience (low submarket/market ratio). Apply this model to evaluate the use of a population sensitivity index versus a simple use of a percentile level of *m* in determining the direct-market allocation.
- Examine the biological effects and economics of transplanting including a short-term (e.g., 2-month) transplant to Egg Island to maximize yield.
- 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. Evalute the effect of the suction dredge on bed integrity.
- In support of maintaining the viability of the upper seed beds, evaluate the options associated with cultch management.

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**	
	Average	**Average Maximum**	**Average**	**Average Maximum**
Bay Average	102	613	51	2101
Upper	345	1068	100	2258
Upper Central	151	735	75	2223
Central	66	569	35	1217
Lower	30	242	20	875

Summary of the 2000 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2000.

Bed		Bushels/ Haul	Percent			Size %oysters >2.5 in.			Oysters/Bushel			Yearling/Bushel			Spat/ Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence		
			2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Round Island		1.1	**48.2**	46.6	56.3																					
Round Island	*	1.8	**44.4**	29.0	49.6																					
Round Island		2.1	**27.5**	21.1	26.5	**11**	17	27	**231**	199	146	**24**	13	31	**13**	79	99	**6**	12	24	**20**	30	20	**0.1**	0.7	0.5
Round Island		2	**21.4**	19.2	20.0																					
Round Island		1.8	**16.9**	8.5	12.7																					
Round Island		0.4	**9.6**	5.8	1.1																					
Up. Arnolds			--	53.3	--																					
Up. Arnolds			--	24.6	--	--	21	--	--	192	--	--	19	--	--	93	--	--	17	--	--	--	--	--	--	--
Up. Arnolds			--	18.9	--																					
Arnolds		3.2	**47.6**	64.4	47.9																					
Arnolds		3.5	**35.5**	64.3	43.2																					
Arnolds		3.6	**32.8**	38.3	42.5	**12**	10	23	**222**	205	168	**2**	17	30	**16**	113	90	**8**	22	17	**60**	66	30	**1.2**	1.3	0.5
Arnolds	*	1.5	**25.7**	34.0	39.5																					
Arnolds		1.1	**20.2**	20.0	33.3																					
Arnolds		0.4	**0.0**	0.76	0.0																					
Up. Middle	*	0.04	**16.7**	--	5.2																					
Up. Middle		0.03	**0.0**	--	0.0	--	--	--	**25**	--	0	**0**	--	0	**0**	--	7	**0**	--	0	--	--	--	--	--	--
Middle		7.8	**60.1**	77.5	78.8																					
Middle	*	3.1	**50.2**	75.4	75.8																					
Middle		9.3	**45.2**	54.8	66.7																					
Middle		0.8	**40.6**	20.2	56.1																					
Middle		0.4	**20.4**	17.4	41.6	**11**	17	16	**214**	139	211	**17**	17	62	**47**	306	165	**10**	19	14	**77**	100	90	**1.9**	2.2	3.3
Middle		1.2	**14.0**	6.8	33.3																					
Middle		1.8	**13.8**	5.8	7.0																					
Middle		1.5	**5.3**	3.5	0.0																					
Middle		0.0	**0.0**	0.0	0.0																					
Cohansey		5.8	**87.7**	72.7	72.2																					
Cohansey		3.3	**79.8**	71.0	68.2																					
Cohansey		5.6	**76.5**	59.3	32.8	**14**	23	26	**541**	208	161	**59**	33	38	**56**	561	103	**6**	26	17	**87**	100	100	**1.7**	1.8	3.2
Cohansey	*	7.8	**75.3**	52.6	12.5																					
Cohansey		3.6	**56.5**	34.9	9.1																					
Ship John		2.3	**60.8**	73.0	67.7																					
Ship John		1.5	**54.8**	70.3	57.9																					
Ship John		8.2	**54.0**	70.0	55.4	**12**	18	23	**316**	218	201	**14**	45	89	**156**	330	370	**10**	26	19	**100**	80	--	**2.8**	2.2	--
Ship John	*	6.5	**44.5**	58.2	55.2																					
Ship John		0.2	**15.9**	3.0	22.2																					

Summary of the 2000 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2000.

Bed		Bushels/ Haul	Percent			Size %oysters >2.5 in.			Oysters/Bushel			Yearling/Bushel			Spat/ Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence		
			2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998	2000	1999	1998
		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Seabreeze			--	53.0	--																					
Seabreeze			--	20.0	--	--	38	--	--	85	--	--	10	--	--	50	--	--	33	--	--	90	--	--	2.5	--
Seabreeze			--	3.5	--																					
Shell Rock	*	6.8	**59.4**	55.7	64.0																					
Shell Rock		7.3	**57.3**	48.1	60.0																					
Shell Rock		5	**45.0**	47.6	54.1																					
Shell Rock		5.5	**40.5**	46.3	52.4	**19**	27	35	**213**	113	198	**34**	28	41	**130**	208	198	**11**	36	24	**83**	93	100	**1.8**	2.3	2.1
Shell Rock		4.8	**40.5**	33.8	49.3																					
Shell Rock		1.3	**20.3**	27.1	36.8																					
Shell Rock			**19.5**	5.1	29.5																					
Bennies Sand		0.8	**46.9**	52.8	46.9																					
Bennies Sand	*	3.7	**45.2**	40.6	22.6																					
Bennies Sand		0.3	**17.1**	26.6	19.3	**31**	24	11	**133**	110	103	**15**	32	25	**22**	184	264	**18**	36	34	**90**	100	100	**2.3**	2.9	2.4
Bennies Sand		2.1	**15.5**	11.8	0.2																					
Bennies		0.3	**29.7**	13.8	59.1																					
Bennies		5.2	**25.3**	11.6	51.3																					
Bennies		1.8	**22.0**	10.9	42.1																					
Bennies	*	7.3	**20.8**	10.7	38.3																					
Bennies		3.4	**14.3**	9.6	23.1																					
Bennies		5.6	**7.2**	7.9	19.7																					
Bennies		5.2	**6.9**	4.4	14.3	**61**	65	39	**38**	17	75	**2**	2	6	**10**	2	105	**35**	57	40	**100**	97	100	**4**	3	3.1
Bennies		5	**6.6**	3.1	6.7																					
Bennies		1.5	**4.4**	1.0	5.7																					
Bennies		3.7	**4.3**	0.7	2.5																					
Bennies		1.2	**3.5**	0.4	2.3																					
Bennies		0.2	**3.0**	0.3	0.9																					
Nantuxent Pt			--	66.7	--																					
Nantuxent Pt			--	64.7	--																					
Nantuxent Pt			--	62.4	--	--	11	--	--	181	--	--	83	--	--	440	--	--	38	--	**95**	100	--	**3.5**	3	--
Nantuxent Pt			--	48.3	--																					
Nantuxent Pt			--	46.4	--																					
Nantuxent Pt			--	40.7	--																					

Summary of the 2000 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2000.

Bed		Bushels/ Haul	Percent				Size %oysters >2.5 in.				Oysters/Bushel				Yearling/Bushel				Spat/ Bushel				Percent Mortality				Dermo Percent Prevalence				Dermo Weighted Prevalence		
			2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998
		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hog Shoal			--	47.7	--																												
Hog Shoal			--	39.5	--																												
Hog Shoal			--	24.8	--		--	23	--		--	90	--		--	11	--		--	99	--		--	50	--		--	100	--		--	2.9	--
Hog Shoal			--	22.7	--																												
Hog Shoal			--	21.8	--																												
Hog Shoal			--	20.6	--																												
New Beds		3.4	**17.2**	40.8	55.8																												
New Beds		8.4	**12.8**	34.7	37.5																												
New Beds	*	7.8	**7.0**	30.1	21.9																												
New Beds		2.8	**4.5**	15.9	20.9																												
New Beds		5.3	**3.2**	13.5	11.1		**69**	76	36		**13**	34	61		**1**	4	19		**4**	9	41		**51**	66	54		**100**	95	100		**3.5**	2.8	3.5
New Beds		5.5	**1.3**	6.1	10.7																												
New Beds		2.5	**1.1**	3.0	8.0																												
New Beds		1.8	**0.4**	3.0	6.7																												
New Beds		2	**0.0**	1.4	2.6																												
Strawberry	*	6.8	**23.9**	--	43.7																												
Strawberry		7.7	**17.6**	--	39.0																												
Strawberry		1.7	**5.9**	--	37.5		**50**	--	36		**28**	--	67		**2**	--	18		**15**	--	123		**47**	--	52		--	--	--		--	--	--
Strawberry		1.9	**3.7**	--	27.1																												
Strawberry		2.3	**1.8**	--	8.1																												
Strawberry		3.6	**0.73**	--	5.0																												
Hawks Nest		9.3	**73.6**	--	56.1																												
Hawks Nest		8.1	**54.2**	--	27.3																												
Hawks Nest		8.3	**42.7**	--	12.0																												
Hawks Nest		4.5	**34.9**	--	8.2		**20**	--	19		**219**	--	36		**33**	--	38		**318**	--	218		**18**	--	60		**100**	--	**90**		**3.3**	--	**4.4**
Hawks Nest	*	6.7	**24.3**	--	5.6																												
Hawks Nest		1.4	**5.2**	--	2.4																												
Beadons	*	6.2	**22.5**	75.0	77.9																												
Beadons		6.1	**20.8**	59.4	50.0																												
Beadons		4.6	**17.9**	45.6	46.5																												
Beadons		6.1	**15.3**	23.3	33.3																												
Beadons		3	**11.6**	20.8	29.7		**20**	17	10		**46**	64	150		**11**	44	68		**43**	377	127		**31**	45	32		**95**	100	80		**3.7**	4.1	3
Beadons		5.7	**10.9**	17.2	28.0																												
Beadons		7	**10.9**	17.0	14.2																												
Beadons		2.9	**6.4**	6.8	9.9																												
Beadons		5.8	**4.4**	4.8	9.5																												
Beadons		1.8	**2.4**	2.4	4.2																												

Summary of the 2000 Random Sampling of the Seed Beds

Table 2. Delaware Bay Seed Bed data for 2000.

Bed		Bushels/ Haul	Percent				Size %oysters >2.5 in.				Oysters/Bushel				Yearling/Bushel				Spat/ Bushel				Percent Mortality				Dermo Percent Prevalence				Dermo Weighted Prevalence		
			2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998		2000	1999	1998
		--	--	--	--		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vexton			--	46.2	--																												
Vexton			--	40.9	--																												
Vexton			--	27.0	--																												
Vexton			--	25.9	--																												
Vexton			--	8.1	--		--	33	--		--	52	--		--	9	--		--	54	--		--	54	--		--	100	--		--	3.8	--
Vexton			--	6.8	--																												
Vexton			--	2.4	--																												
Egg Island		0.7	**0.80**	48.7	56.5																												
Egg Island		1	**0.71**	14.7	7.9																												
Egg Island		1	**0.48**	8.7	4.6																												
Egg Island		3.3	**0.33**	1.2	3.0																												
Egg Island	*	7.3	**0.32**	0.4	2.8		**75**	25	5		**0.8**	28	37		**0**	0	28		**0.4**	2	13		**73**	35	42		**100**	100	--		**3.6**	3.9	--
Egg Island		6.8	**0**	0.4	2.3																												
Egg Island		4.6	**0**	0.4	0.0																												
Egg Island		0.06	**0**	0.3	0.0																												
Egg Island		1.8	**0**	0	0.0																												
Egg Island		8	**0**	0	0.0																												
Ledge		3	**3.8**	--	10.2																												
Ledge	*	7.8	**2.6**	--	2.7																												
Ledge		6.8	**1.3**	--	1.2																												
Ledge		0.5	**0.39**	--	1.0		**100**	--	75		**3**	--	4		**0.1**	--	0.2		**0.4**	--	3		**62**	--	55		**70**	--	**85**		**1.9**	--	**2.2**
Ledge		2.5	**0**	--	0.68																												
Ledge		1.3	**0**	--	0.65																												
Ledge		1.5	**0**	--	0																												
Ledge		0.08	**0**	--	--																												

Table 3. Number of oysters in each size class (size frequency) on New Jersey's Delaware Bay seed beds, 2000. All data have been adjusted to numbers of oysters collected from an average bushel of unculled material. Oysters approximately 3 inches and larger are indicated in bold face type.

	Round Is	Arnolds	Middle	Cohansey	Ship Jn	Shell Rk	Ben Snd	Bennies	New Beds	Strawberr.	Hawks Nst	Beadons	Egg Is	Ledge
Size (mm)														
20	1	1	2	0	1	0	0	0	0	0	0	0	0.0	0
25	27	9	13	35	14	5	2	1	0	1	11	3	0.0	0
30	32	23	29	52	24	12	6	1	1	1	21	4	0.0	0
35	29	36	43	97	63	20	11	1	0	1	24	5	0.0	0
40	26	34	31	96	59	33	15	2	1	2	26	7	0.0	0
45	26	26	24	79	40	33	19	1	0	2	32	5	0.0	0
50	24	28	20	43	34	27	13	3	0	2	24	6	0.1	0
55	23	19	16	38	21	23	14	3	1	3	21	4	0.1	0
60	17	18	14	27	21	19	12	4	1	2	16	3	0.0	0
65	14	11	8	23	15	11	12	4	1	3	14	3	0.2	0
70	5	6	5	17	8	12	9	6	1	3	9	2	0.1	0
75	**4**	**6**	**5**	**12**	**5**	**6**	**4**	**5**	**2**	**3**	**6**	**2**	**0.1**	**0**
80	**2**	**2**	**3**	**12**	**7**	**5**	**5**	**4**	**2**	**2**	**7**	**1**	**0.1**	**0**
85	**1**	**1**	**2**	**4**	**2**	**3**	**5**	**2**	**1**	**2**	**3**	**1**	**0.1**	**1**
90	**1**	**0**	**0**	**4**	**2**	**2**	**2**	**1**	**0**	**1**	**2**	**0**	**0.0**	**1**
95	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0.0**	**0**
100	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0.0**	**0**
105	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0.0**	**0**
110	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**
115	**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**
125	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**
130	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**
135	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0.0**	**0**
Total/Bu.	231	222	214	541	316	213	133	38	13	28	219	46	0.8	3
Number measured	820	749	974	741	627	1000	388	343	106	163	728	535	19	21
Average Size	42	43	42	43	43	48	52	63	67	58	47	46	66	75
Greater than 3"	**8**	**10**	**10**	**34**	**17**	**18**	**19**	**13**	**7**	**7**	**20**	**4**	**0.3**	**2**
> 3" 1999	8	6	10	19	19	17	13	9	17			5	12	
> 3" 1998	15	12	10	16	18	31	5	16	12	9	3	8	1	2
Greater than 2.5"	26	26	23	74	39	40	41	23	9	14	43	9	0.6	3
> 2.5" 1999	33	21	24	47	40	31	26	11	26			11	19	
> 2.5" 1998	40	38	34	41	47	70	11	29	22	24	7	15	2	3

Table 4. Comparison of the number of bushels of market (>3 inches) and submarket (2.5-3.0 inches) oysters present during the November 2000 survey on the high quality areas and on the entire bed. Asterisks indicate beds surveyed in 1999.

Transplant Beds:	**Survey Abundance – Markets:**		**Survey Abundance – Submarkets:**	
Low Mortality	Total Bed	High Quality Area	Total Bed	High Quality Area
Arnolds	3443	3182	11646	11646
Round Island	4559	1954	7097	3847
** Upper Arnold	4595	3412	14459	12410
Medium Mortality				
Middle	19316	19150	30766	30535
UpperMiddle	0	0	0	0
High Mortality				
Beadons	1490	899	6001	4017
** Nantuxent Pt.	3060	3047	8735	8691
Direct-Market Beds:				
Medium Mortality/Slow Growth				
Cohansey	88668	72936	167365	127380
** Sea Breeze	11226	11226	6326	6246
Ship John	39376	39293	45498	45325
Medium Mortality/Fast Growth				
Shell Rock	11983	8258	27193	21620
High Mortality				
Bennies	8760	7470	18240	16632
Benny Sand	1240	951	2118	1931
Egg Island	462	462	1249	618
Hawk'snest	9478	9447	17030	16774
** Hog Shoal	2141	1681	2155	1857
Ledge	787	787	307	307
New Beds	6226	4840	8528	7626
Strawberry	1279	1279	2651	2651
** Vexton	2559	1815	2599	1857

Table 5. Mean values of q (the reciprocal of dredge efficiency) for each of the size classes of live oysters and boxes, total live oysters, total boxes, and debris for two groups of beds. Group 1 contains Arnolds, Cohansey, Over the Bar, Lower Middle, and Ship John. Group 2 contains Bennies, Shell Rock, Nantuxent Point, Egg Island, and New Beds. Debris includes cultch and other debris. P-values record the results of ANOVA. Analysis comparing the two groups with respect to the variable listed as the colum heading. NS, not significant, a = 0.05.

	Live oysters				Boxes				
Oyster Bed	Juveniles	Submarkets	Markets	Total Live	Juveniles	Submarkets	Markets	Total Box	Debris
Group 1	10.46	6.89	6.93	9.4	11.26	18.98	11	11.47	21.49
Group 2	3.33	2.57	1.54	2.83	6.78	4.03	8.85	6.5	9.55
P-value	0.0009	0.04	0.0001	0.0002	0.04	0.0008	NS	0.02	NS

Table 6. Seed bed harvest of market oysters in 2000.

Bed	**Spring**	**Fall**	**Total**
Middle		1329	1329
Cohansey	581	749	1330
Ship John	862	1398	2260
Seabreeze	25		25
Shell Rock	1247	3326	4573
Bennies	4214	2468	6682
Bennies Sand	5286	5553	10839
Hog Shoal	757	331	1088
New Beds	3605	2358	5963
Beadons		508	508
Vexton	265	127	392
Ledge	9		9
Miscellaneous	484	95	579
Total	**17,335**	**18,242**	**35,577**

Table 7. Bushels of oysters transplanted from Seed Beds.

Year	**Middle**	**Cohansey**	**Ship John**	**Nantuxent**	**Beadons**		
1997	30,000	0	0				
1998	0	6,000*	6,000*				
1999	14,650	40,200	17,350				
2000	24,210	4,146	6,572	225	4,900		

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.

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 group oyster and spat abundance (37 qu. Bushel) for Upper Central and Central seed beds. 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. Oyster per 37 qt. bushel by market (>3") and submarket (2.5 to 2.99") size classes from major market beds. Major market beds = Shell Rock, Bennies, Bennies Sand, New Beds.

Figure 7. Delaware Bay Seed Beds. Total oysters per 37 qt. Bushel from Upper and the major market beds.

Figure 8. Delaware Bay Seed Beds. Oyster per 37 qt. bushel by market (>3") and submarket (2.5 to 2.99") size classes from Upper and major market beds.

Figure 9. 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.

Figure 10. Delaware Bay Seed Beds. Annual bay wide average spat set per 37 quart bushel.

Figure 11. Delaware Bay Seed Beds. Annual percentage mortality for the past decade by region.

Figure 12. Delaware Bay Seed Beds. Annual bay wide average weighted prevalence of Dermo (*Perkinsus marinus*).

Figure 13. Delaware Bay Seed Beds. Weighted prevalence of Dermo (*Perkinsus marinus)* by bed group for the past decade.

Figure 14. Model data. Base data for the ranking of yearly natural mortality by beds grouped into three categories: Low, Medium and High.

Figure 15. Example of the time-dependent rate functions use for fishing and natural mortality rates.

Figure 16. Model data. Rank order of oyster abundance for the high-mortality direct-market beds for 1989-2000. Rank order of market oyster abundance for 1989-2000 in terms of oysters per bushel.

Figure 17. Model output of bushel allocations for the direct-market beds under three fishing scenarios without a penalty for differential fishing effort. Scenario 1= Continuous season, Scenario 2 = Discontinuous fishing season, Scenario 3 = Area management.

Figure 18. Model data. Rank order of oyster abundance for the medium-mortality direct-market beds for 1989-2000. Rank order of market and half submarket oyster abundance for 1989-2000 in terms of oysters per bushel.

Figure 19. Delaware Bay Seed Beds. Least squares regression comparison of bushels of oysters collected during the 2000 seed bed sampling in a calibrated hopper (hopper) and subsequent estimate by collecting the same oysters in bushel baskets on deck. N = 315 paired samples. The reciprocal regression is Hopper = 0.0492+1.1532*Bushel. Data are plotted with 95 % confidence intervals.

Figure 20. Delaware Bay Seed Beds. Mean +/- Standard Error (t= 0.05) for dry meat weight and condition index (dry meat weight/hinge to lip measure) by standard bay segment. Data from fall surveys 1990 to 2000.

Figure 21. Delaware Bay Seed Beds. Ratio Lower/Central beds and Lower/Upper Central Beds for dry weight and condition index (dry meat weight/hinge to lip measure) by year.

Figure 22. Examples of the time-dependent rate functions used for model fishing and natural mortality rates.

Appendix

Hopper Calibration

In order to provide quantitative estimates of oysters on individual beds three pieces of information are needed, the dredge efficiency, the dredge width, the length of the tow and the number of bushels collected. Measuring the number of bushels requires collecting all the material in some measured container, and in prior years all oysters were collected in bushel baskets on deck. Handling all the oysters in this fashion requires a minimum deck crew of three individuals. All oysters coming onto the dredge boat enter a hopper and then are moved by a series of conveyor belts. To reduce the requirements for a 3 person deck crew and the physical strain of lifting all the bushels of oysters, the hopper on the *Howard Sockwell* was calibrated by filling it with bushels of oysters. Marks were made along the side of the hopper indicating each 1 bushel increment. The hopper calibration was evaluated by comparing the numbers of bushels per dedge haul, estimated to be in the hopper, with the numbers of bushels collected in bushel baskets after the conveyor belt system. In general, there was good correspondence between the Hopper and the Bushel estimates. Bay wide, 335 dredge samples were evaluated (Upper, 41), Upper Central (89), Central (146) and Lower (59). In all cases, the hopper estimate was higher, but statistically insignificant (Appendix Table 1) than the bushel estimate (Figure 19). The difference was probably due to losses on the belt system and attributable to spillage during the catching process. Relatively less work is required to estimate from the hopper; therefore,it is recommended that this method become the primary method for estimation of material collected.

Transplant Experiment

Historically, seed oysters were moved from the seed beds to lower bay planting grounds. These oysters were left for varying periods of time to increase in size before marketing. Typically transplanting was conducted in the spring of each year (April/May). A prior study evaluated the efficacy of transplanting in seasons other than spring, and suggested that transplantation in other months might provide higher yields. The Advisory Council wanted to examine these options in another year and for other months. A brief summary of that study is presented below, and the entire report is available at Haskin Shellfish Research Laboratory.

Oysters were transplanted from Shell Rock bed to leased ground 554 D in March, May, September and October, 1999. Approximately 1800 bushels of culled oysters were moved on each transplant. Additionally, oysters of 3 sizes (2.5 to 2.75", 2.76-2.99"and >3") were tethered on racks to monitor size specific mortality. Oysters were sampled monthly after transplant for growth, mortality and Dermo levels. In general, the results mirrored those of an earlier similar study with the exception that shell growth was extremely poor in 1999. Dermo-related mortality was high and growth was poor so transplants from all four periods had approximately the same number of market oysters available for harvest at the end of the study in November. In spite of the poor shell growth (probably due to low chlorophyll all summer) and high mortality, oyster meat weight (and condition) increased within one month of (with the exception of the March) transplant. The increase in meat exactly mirrored that of the earlier study. In terms of commercial production, the month of transplant made no difference in the numbers of market oysters available. Only the increased meat weight (for shucked oysters) could add significant commercial value.

There is a possibility that increases in meat weight could be made by simply moving oysters from the Upper Central or Central beds to the Lower beds. While we have no direct experimental evidence, the dry meat weight and condition index (CI = dry meat weight/shell hinge to lip distance) data from the seed beds can be utilized for a first approximation. These data were examined by year (1990 to 2000) and by standard bay segment group (Upper, Upper Central, Central, Lower and Bay total). There are statistically significant differences in both the dry meat weight and the condition index by bay segment (Figure 16). Greatest meat weight and greatest condition index are found in the Lower bay segment and the worst in the Upper bay segment. To evaluate the year-to-year variation in potential improvement obtained by moving oysters from the Upper Central or Central beds to the Lower area, a ratio of lower bay to Upper Central/ Central bay condition index and meat dry weight was calculated. A ratio >1 for either of these parameters suggests potential improvement and the magnitude of that improvement.

A Lower/Central bed ratio was >1 in 8 of the 11 years for CI and 9 of the 11 years for meat (Figure 20). A similar analysis for the Lower/Upper Central beds indicated ratios >1 in all years (CI) and 10 of the 11 years (meat) (Figure 21). Potential gains were less in years with poorest overall condition index. This is probably because the differential in condition between the bay segments is typically compressed in years of poor condition (Figure 9). These data suggest a potential for substantial meat quality improvement by transplanting in many years and spectacular improvement in some years. Of course similar or greater improvement could be accomplished by movement of oysters to leased grounds.

Modeling

The model to produce the simulations used an oyster-Dermo disease fisheries model. Fishing mortality, Dermo mortality, and recruitment were included using the following governing equation:

$$d N_m/dt = [- f_1 (t) - f_2 (t) - m(t) + R(t)] N_m$$

where N_m is the number of market-size oysters present, t is time, f_1 and f_2 are the daily rates of fishing mortality for the two fishing seasons, m is the daily rate of natural mortality, and R is the recruitment rate. In subsequent calculations, the two fishing rates were assumed to be equivalent: $f_1 = f_2$.

The time dependency B for each mortality factor used the following formulation:

$$B(t : t_1 , t_2) = 0.5 [\tanh \{(t - t_1)/a\} - \tanh \{(t - t_2)/a\}]$$

where a controls the rate at which mortality ramps up and down. An example of the shape of the mortality curves used is given in Figure 22. For stock rebuilding plans, the model was modified to:

$$N_m(t) = N_m \; e^{[A(t) - \log_e(\eta)]}$$

where A is the sum of the various mortality and recruitment rates already described and η sets the desired ratio of market-size oysters between December 31 and the previous January 1 of a given year. Thus, $\eta = 2$ would result in a doubling of the market-size population at the end of the year. The model requires (1) the size that oysters recruit to the fishery, (2) the natural mortality rate and (3) the rebuilding ratio.

Appendix Table 1. Comparison of bushels of oysters collected in a calibrated hopper (hopper) aboard the *Howard Sockewell* during seed bed sampling 2000 with those subsequently collected in bushel baskets (bushel) on deck. Data are presented for the whole bay, Upper, Upper Central, Central and Lower seed bed groups. There were no significant differences in any of the data sets.

	Total Beds		**Upper**		**Upper Central**		**Central**		**Lower**	
	Bushel	Hopper	Bushel	Hopper	Bushel	Hopper	Bushel	Hopper	Bushel	Hopper
Mean	**3.16**	**3.69**	**1.56**	**1.74**	**3.2**	**3.79**	**3.59**	**4.27**	**2.9**	**3.2**
SD	2.49	2.96	1.35	1.69	2.67	3.15	2.36	2.82	2.54	2.9
SE	0.14	0.17	0.21	0.26	0.28	0.33	0.2	0.23	0.33	0.38
N	320	320	41	41	89	89	146	146	59	59
Mean +	**3.43**	**4.02**	**1.99**	**2.27**	**3.76**	**4.45**	**3.98**	**4.73**	**3.56**	**3.94**
Mean -	**2.88**	**3.36**	**1.14**	**1.2**	**2.64**	**3.13**	**3.21**	**3.81**	**2.23**	**2.43**

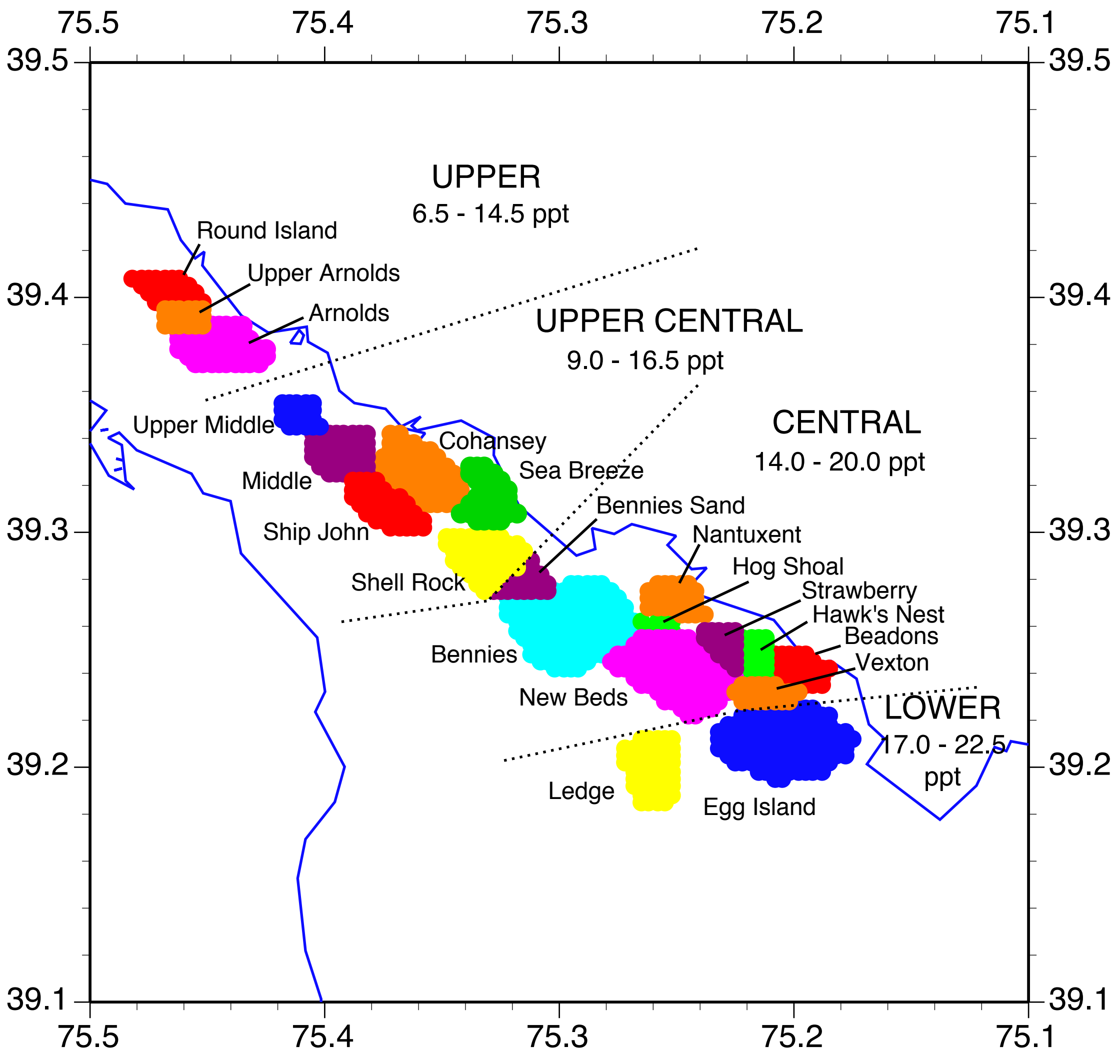

75.5
75.4
75.3
75.2
75.1
39.5
39.4
39.3
39.2
39.1
UPPER
6.5 - 14.5 ppt
UPPER CENTRAL
9.0 - 16.5 ppt
CENTRAL
14.0 - 20.0 ppt
LOWER
17.0 - 22.5
ppt
Round Island
Upper Arnolds
Arnolds
Upper Middle
Middle
Ship John
Cohansey
Sea Breeze
Bennies Sand
Nantuxent
Hog Shoal
Strawberry
Hawk's Nest
Beadons
Vexton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

Figure 1

Figure 2

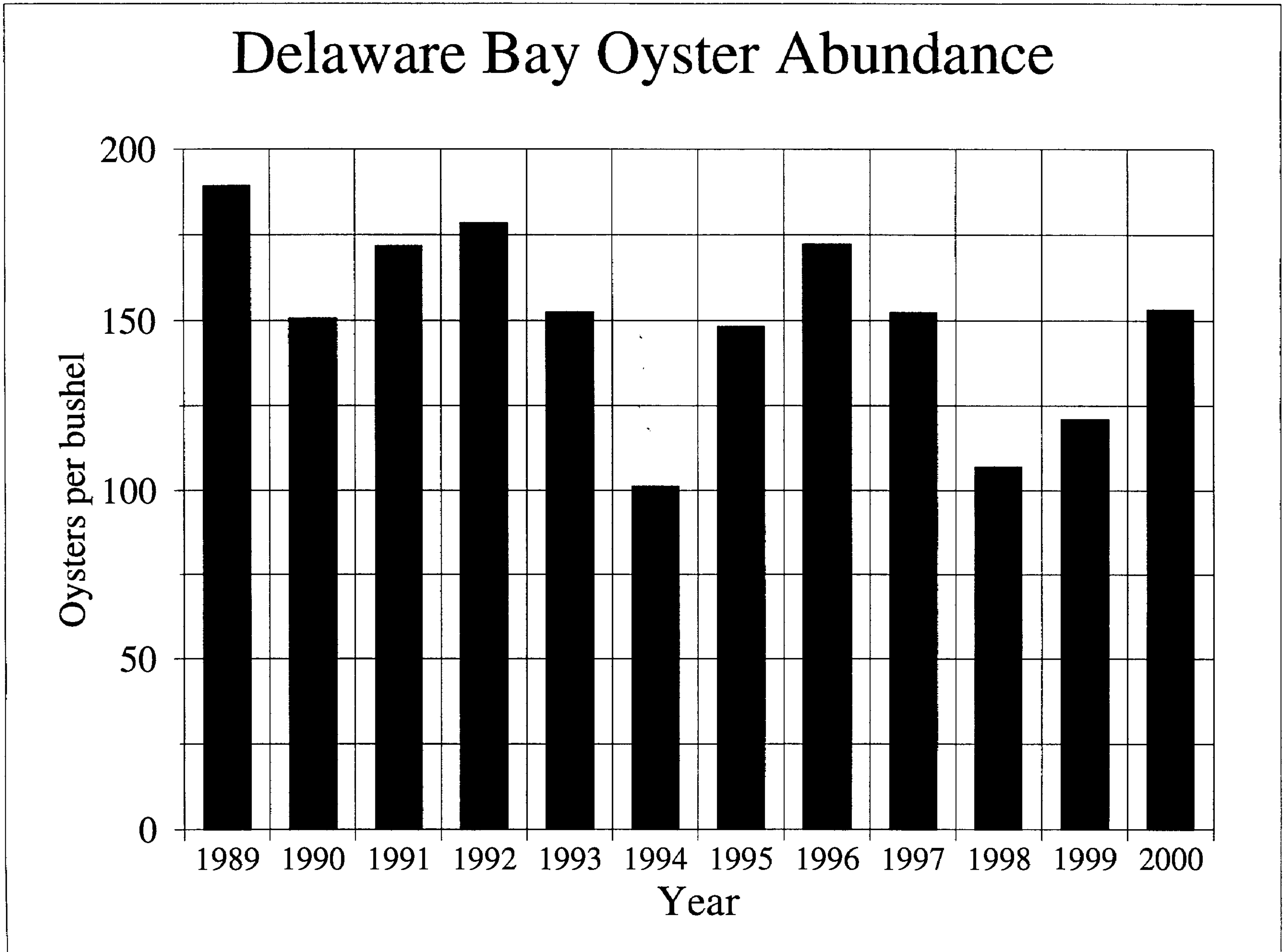

Delaware Bay Oyster Abundance
Oysters per bushel
200
150
100
50
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year

Figure 3

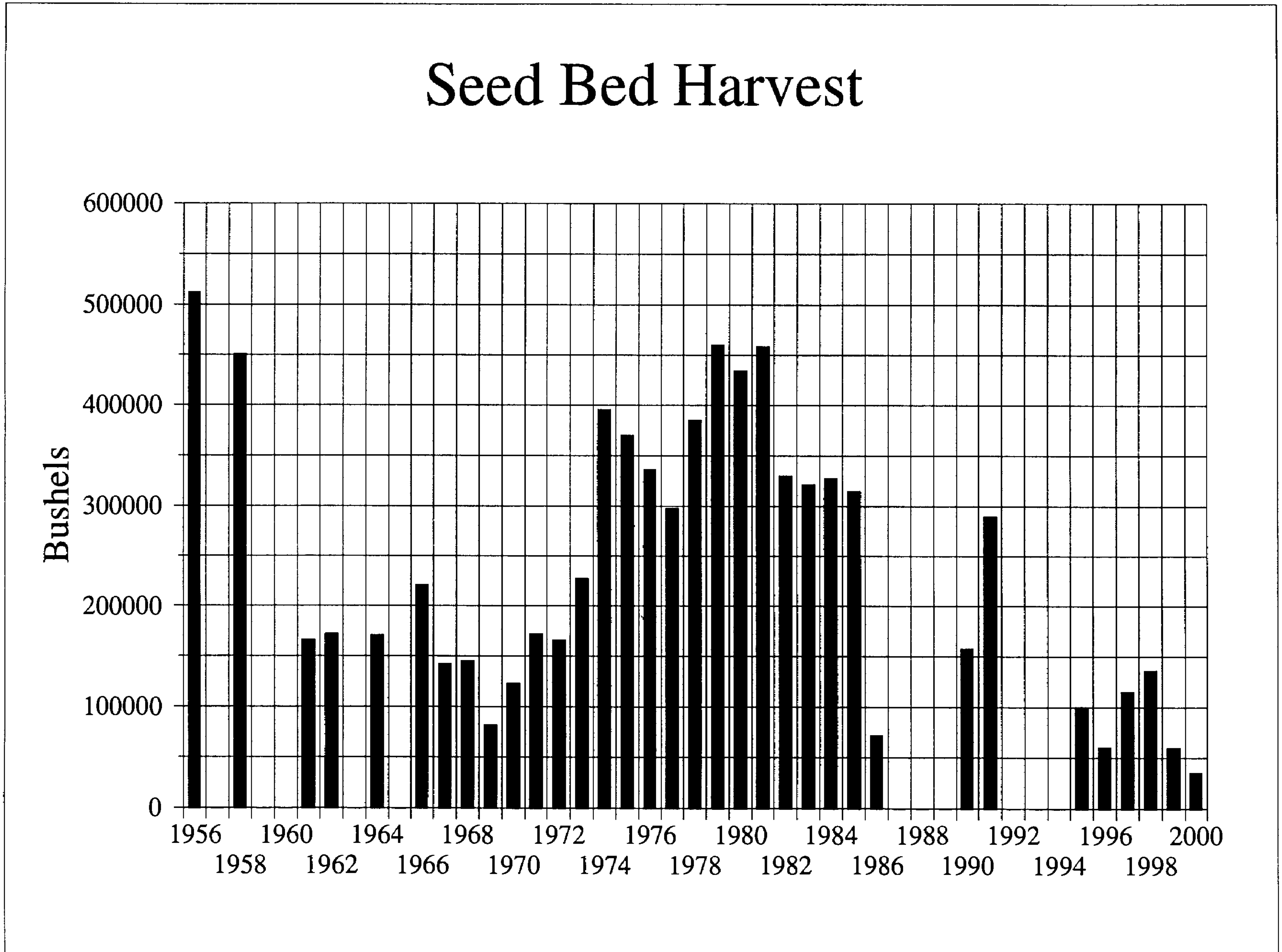

Seed Bed Harvest
Bushels
600000
500000
400000
300000
200000
100000
0
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000

Figure 4

Delaware Bay Seed Beds

Year	**89**	**92**	**96**	**91**	**0**	**93**	**97**	**90**	**95**	**99**	**98**	**94**	**Mean**
Oysters	189	178	172	172	153	153	152	151	148	123	107	101	**150**

Year	**91**	**99**	**97**	**98**	**95**	**94**	**90**	**89**	**0**	**93**	**92**	**96**	**Mean**
Spat	268	190	151	128	127	124	112	69	55	44	25	22	**110**

Year	**93**	**94**	**99**	**98**	**0**	**92**	**95**	**96**	**91**	**97**	**Mean**
Dermo WP	2.99	2.67	2.63	2.56	2.45	2.18	1.84	1.81	1.2	1.12	**2.19**

Figure 5

Upper Central Beds

Year	**0**	**96**	**97**	**92**	**90**	**91**	**89**	**98**	**93**	**99**	**94**	**95**	**Mean**
Oysters	321	309	265	243	225	222	214	193	190	170	143	138	**219***

Central Beds

Year	**96**	**89**	**95**	**90**	**97**	**92**	**91**	**98**	**0**	**99**	**93**	**94**	**Mean**
Oysters	153	105	95	91	91	91	84	80	80	78	55	52	**88***

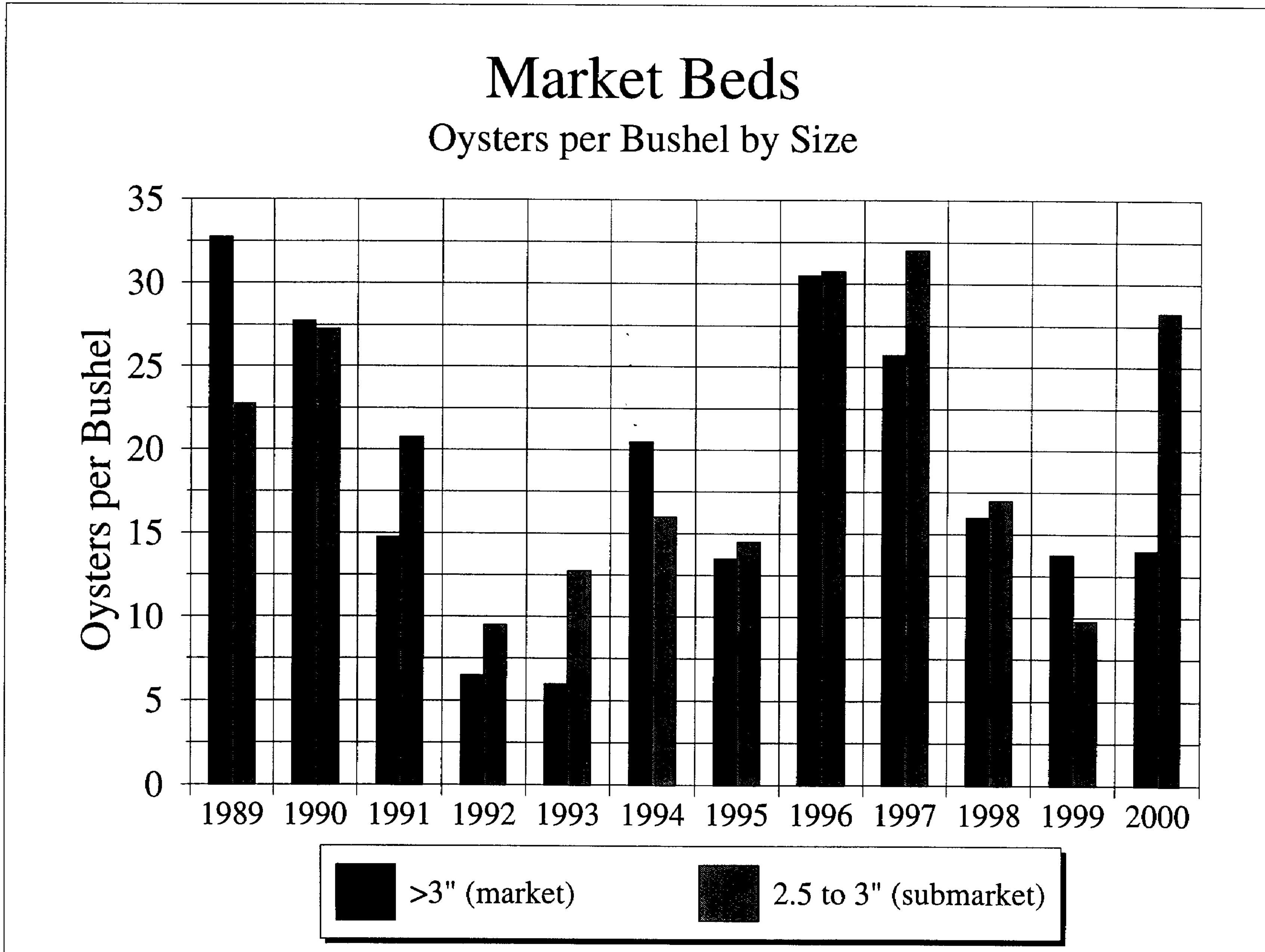
Upper Central Beds

Year	**99**	**91**	**98**	**95**	**94**	**90**	**97**	**0**	**89**	**93**	**96**	**92**	**Mean**
Spat	351	295	209	179	164	122	113	97	70	60	36	31	**144**

Central Beds

Year	**91**	**97**	**99**	**94**	**98**	**95**	**90**	**89**	**0**	**93**	**92**	**96**	**Mean**
Spat	273	221	175	166	146	137	107	70	69	46	21	16	**121**

Figure 6



Market Beds
Oysters per Bushel 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
>3" (market)
2.5 to 3" (submarket)

Figure 7

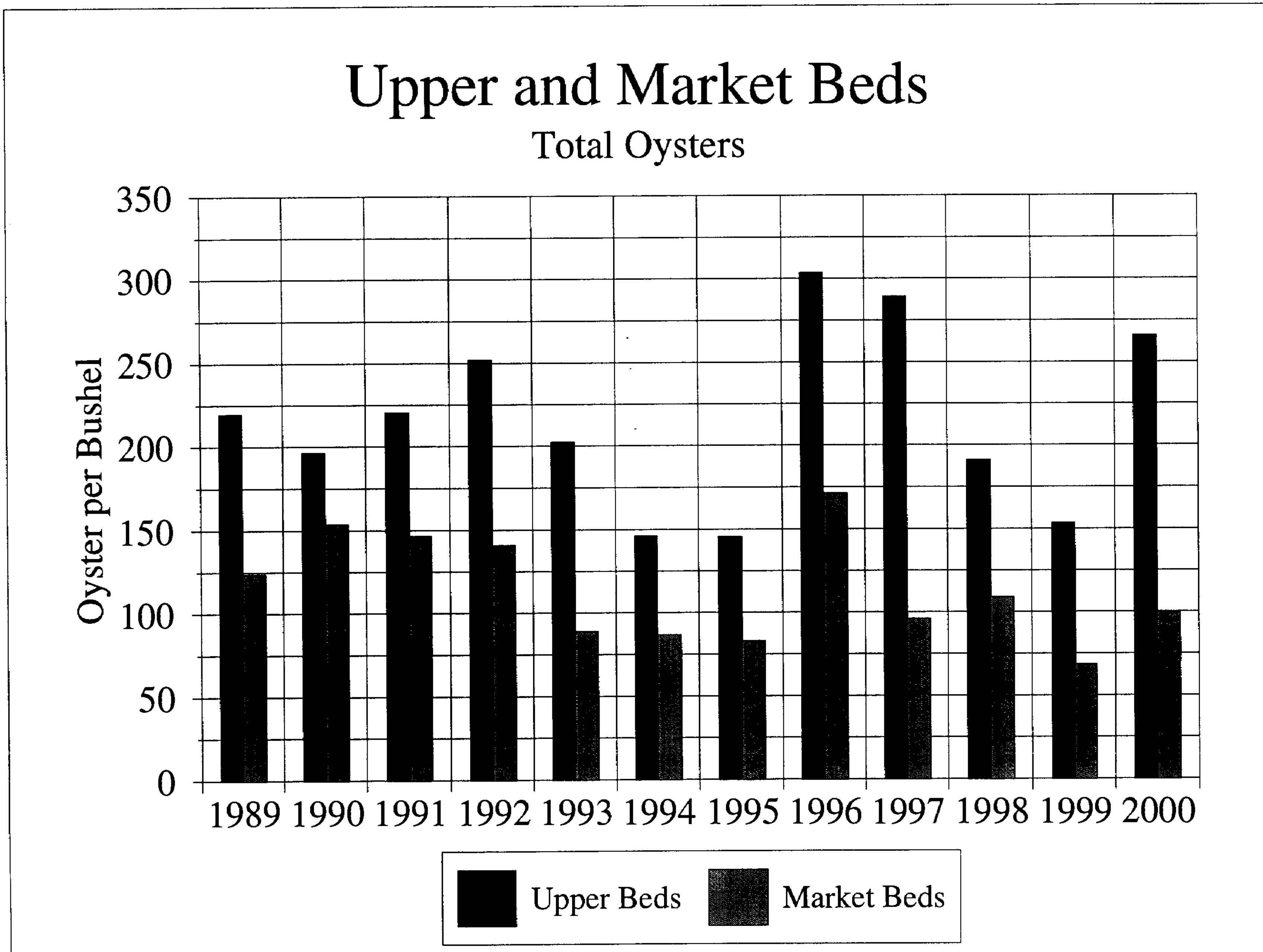

Upper and Market Beds
Total Oysters
Oyster per Bushel
350
300
250
200
150
100
50
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Upper Beds
Market Beds

Figure 8

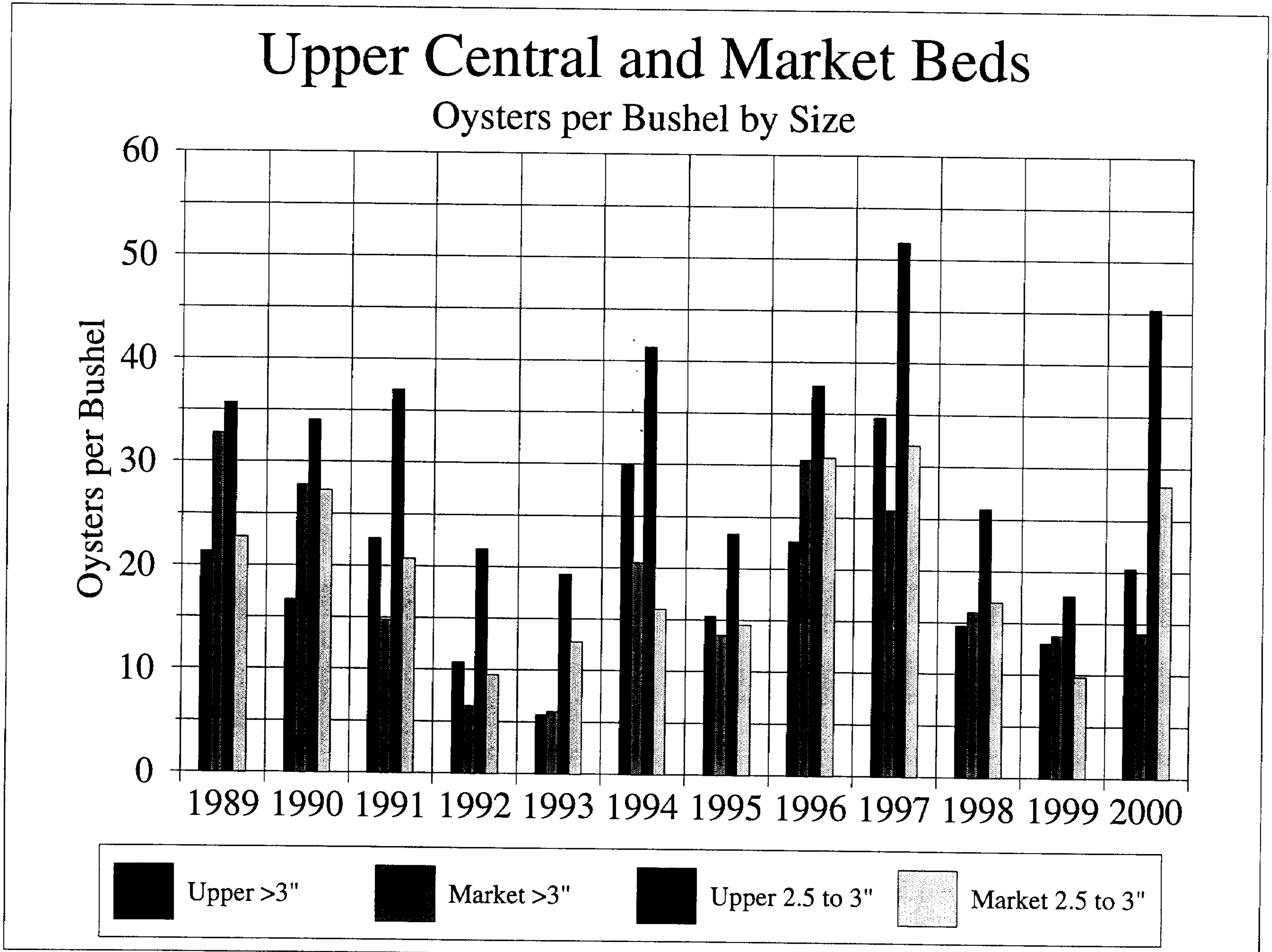

Upper Central and Market Beds
Oysters per Bushel by Size
Oysters per Bushel
60
50
40
30
20
10
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Upper >3"
Market >3"
Upper 2.5 to 3"
Market 2.5 to 3"

Figure 9

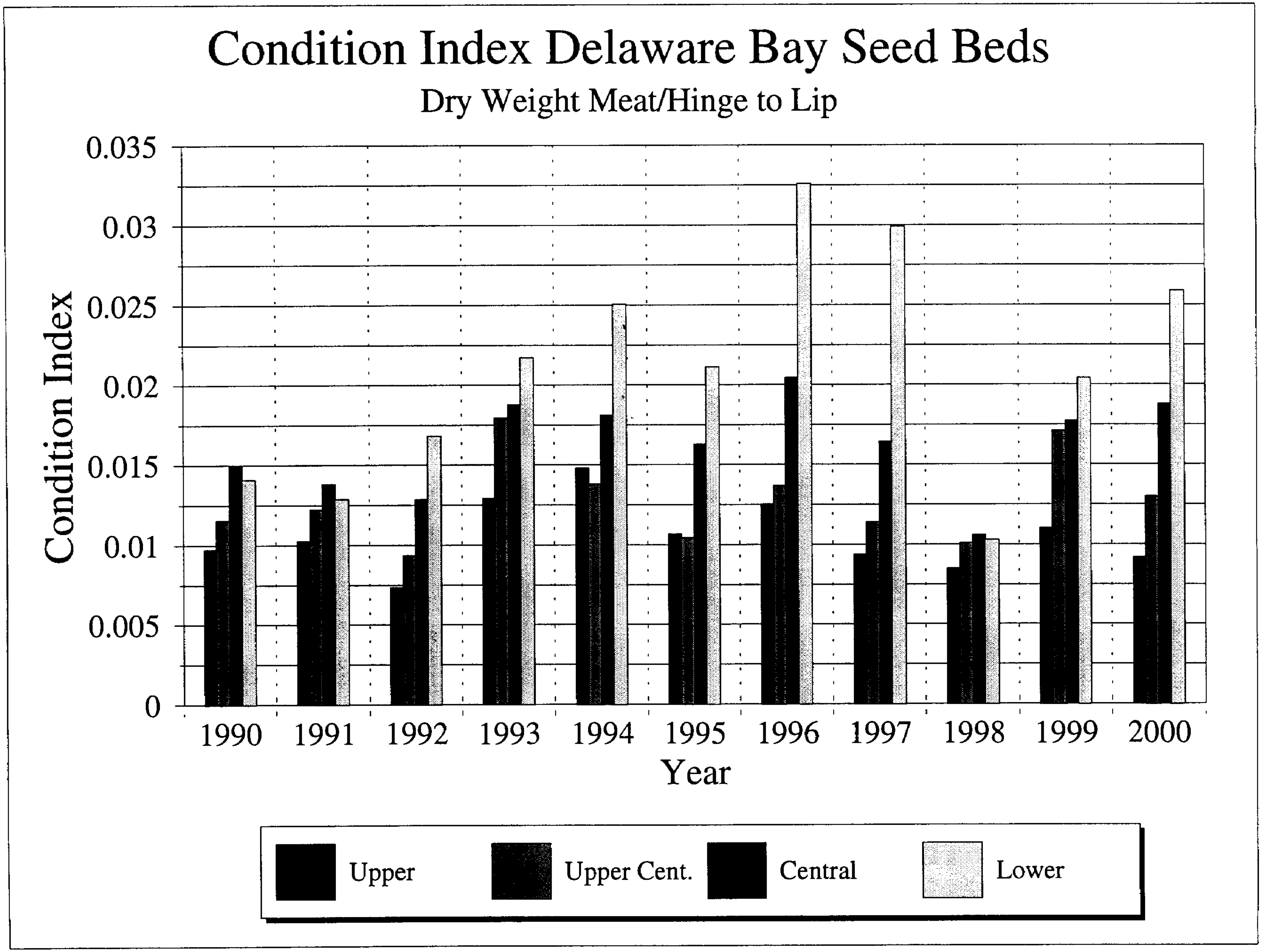

Condition Index Delaware Bay Seed Beds
Dry Weight Meat/Hinge to Lip
Condition Index
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year
Upper
Upper Cent.
Central
Lower

Figure 10

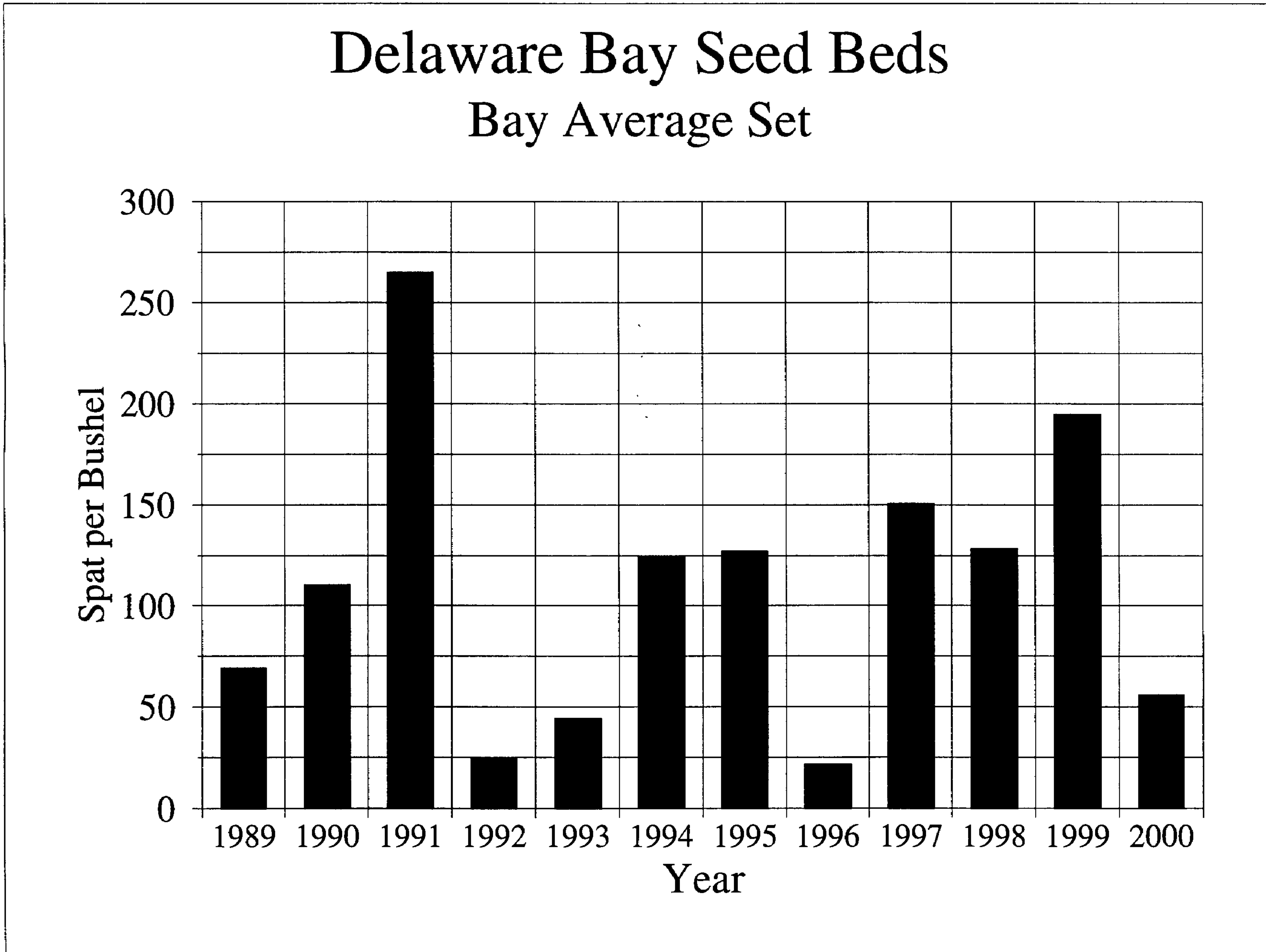
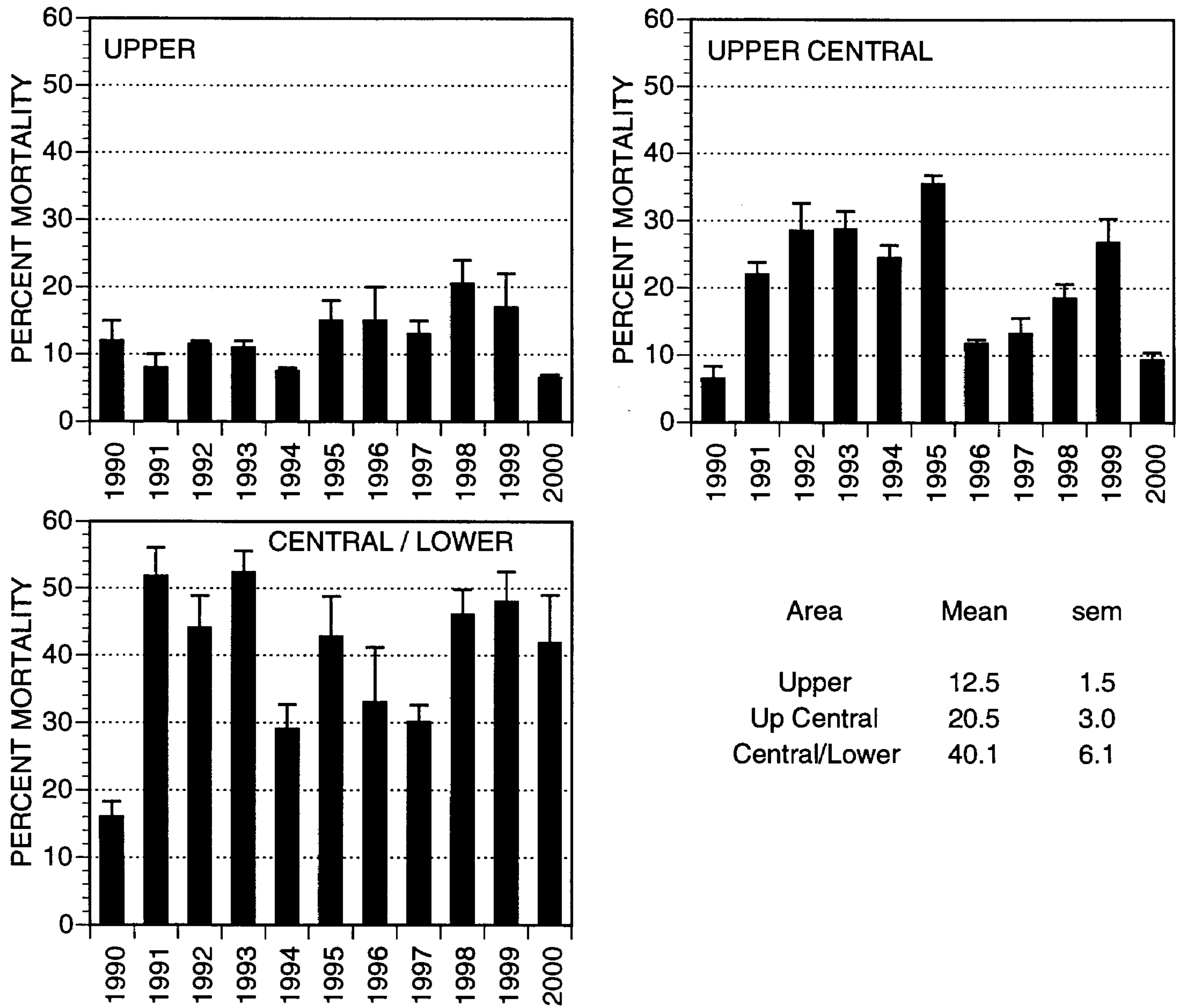

Delaware Bay Seed Beds
Bay Average Set
Spat per Bushel
300
250
200
150
100
50
0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Year

Figure 11



Area	Mean	sem
Upper	12.5	1.5
Up Central	20.5	3.0
Central/Lower	40.1	6.1

Figure 12

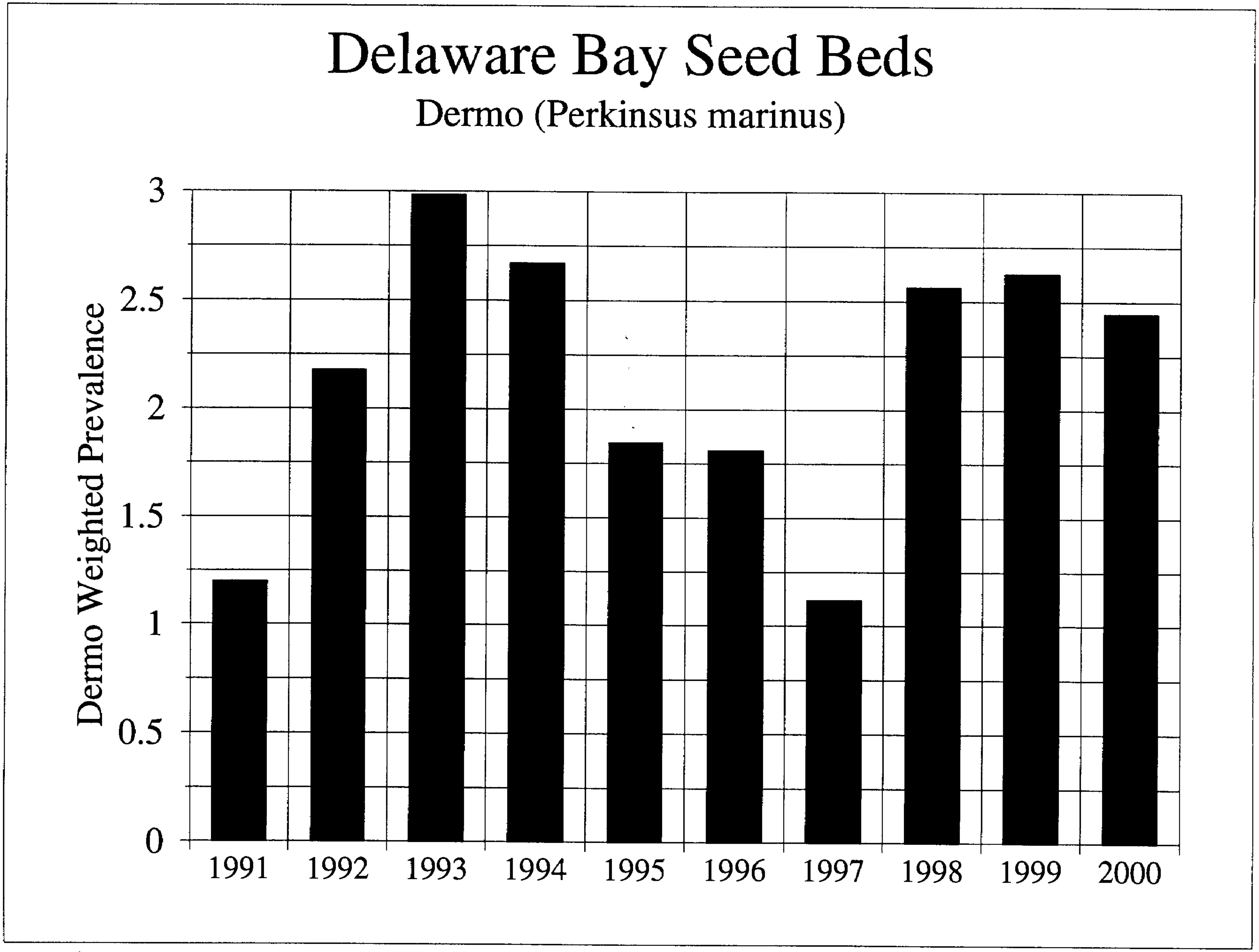
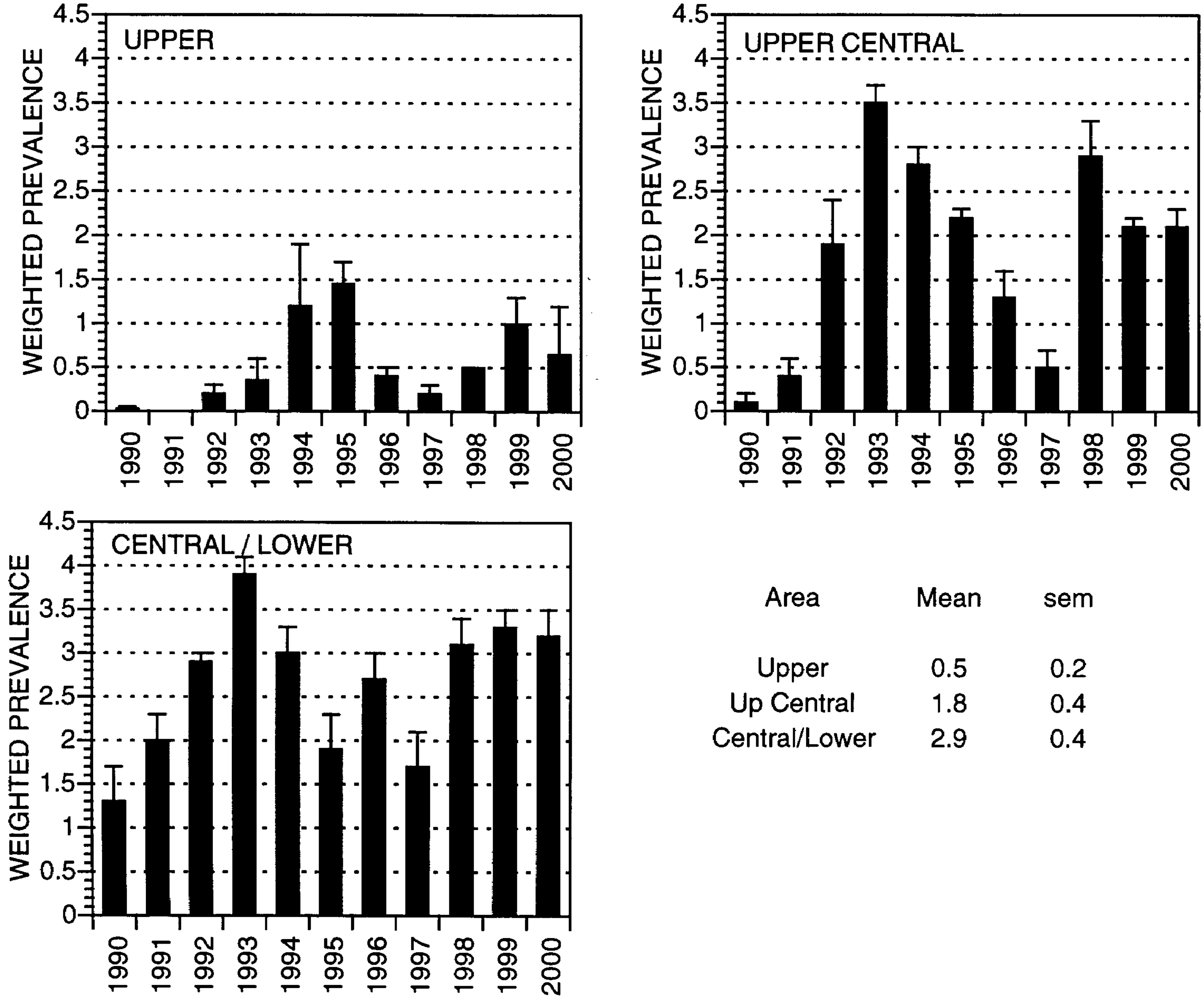

Delaware Bay Seed Beds
Dermo (Perkinsus marinus)
Dermo Weighted Prevalence
3
2.5
2
1.5
1
0.5
0
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

Figure 13



Area	Mean	sem
Upper	0.5	0.2
Up Central	1.8	0.4
Central/Lower	2.9	0.4

Figure 14
Rank order of yearly natural mortality rates.

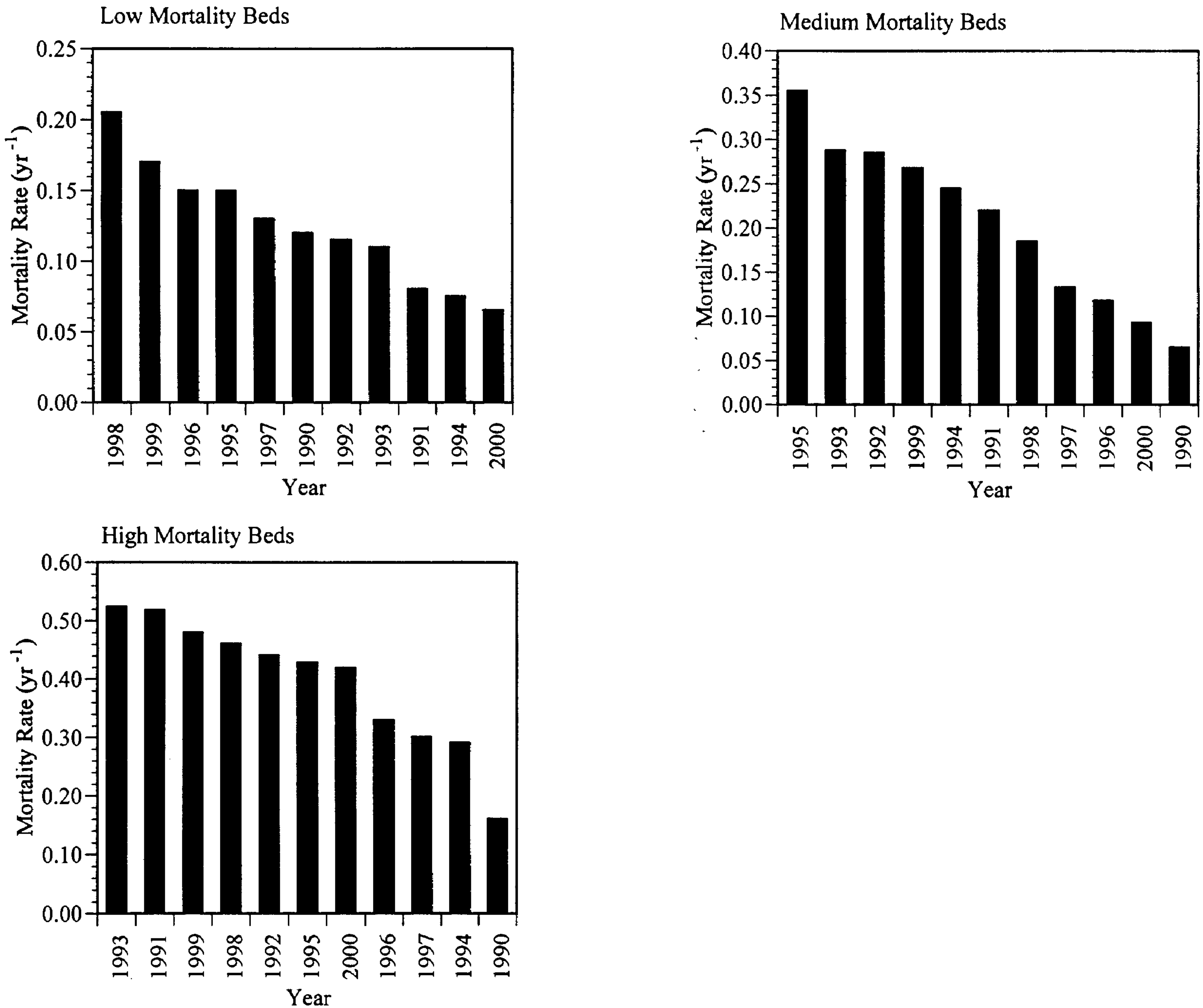


Figure 15

Bushel allocation for direct-market beds under three fishing scenarios without a penalty for differential fishing effort. Details for the fishing scenarios are in the text.

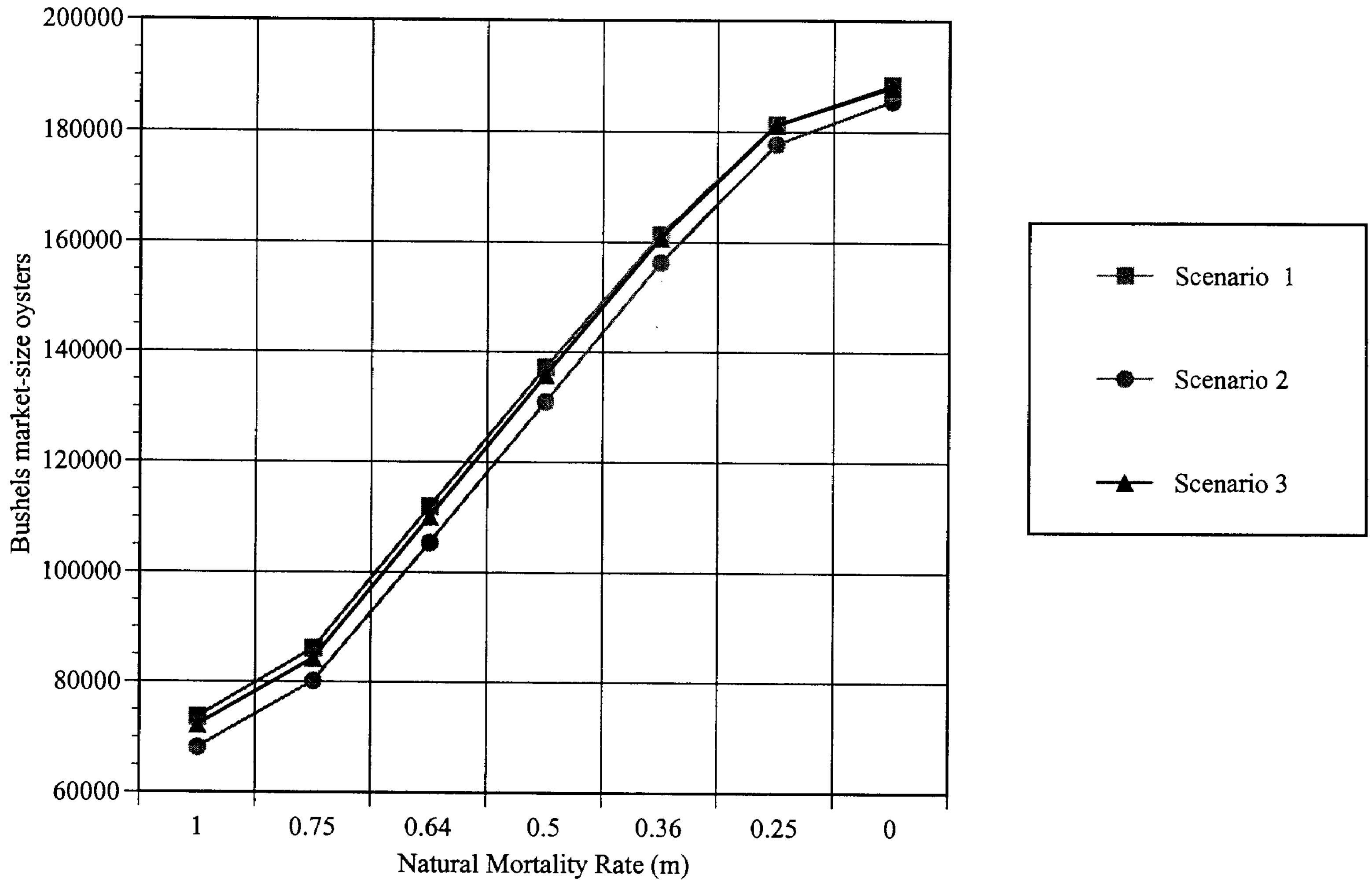
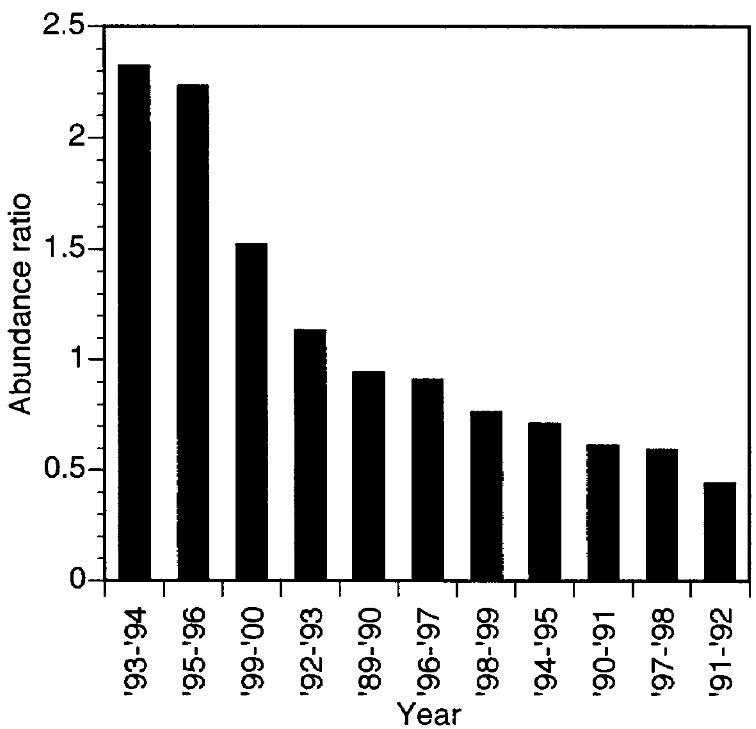


Figure 16

Rank order of the ratio of weighted mean abundance (T+1/T) for the high-mortality direct-market beds for 1989 - 2000.



Rank order of weighted mean abundance in 1989-2000 for the high-mortality direct market beds calculated for the period 1989-2000.

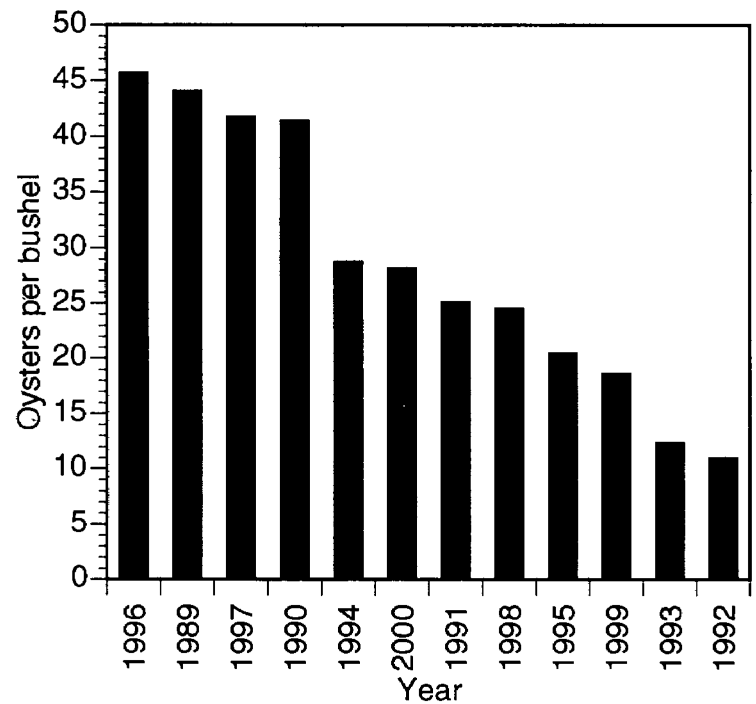


Figure 17

Bushel allocation for direct-market beds under three fishing scenarios, but with a penalty for differential fishing effort and imposed on the two scenarios (1 and 2) without area management. Scenario 3 includes area management. Additional details given in the text.

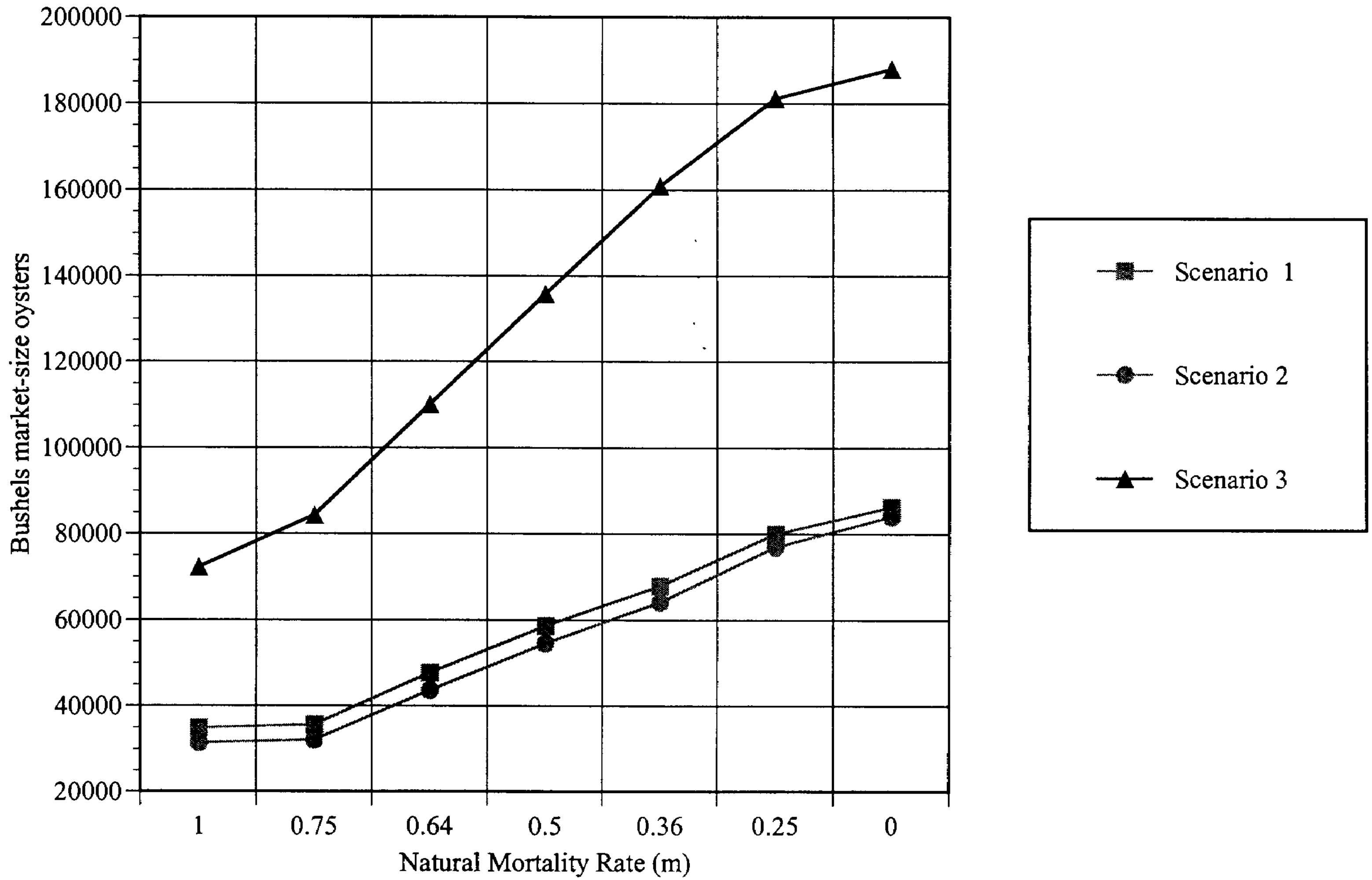
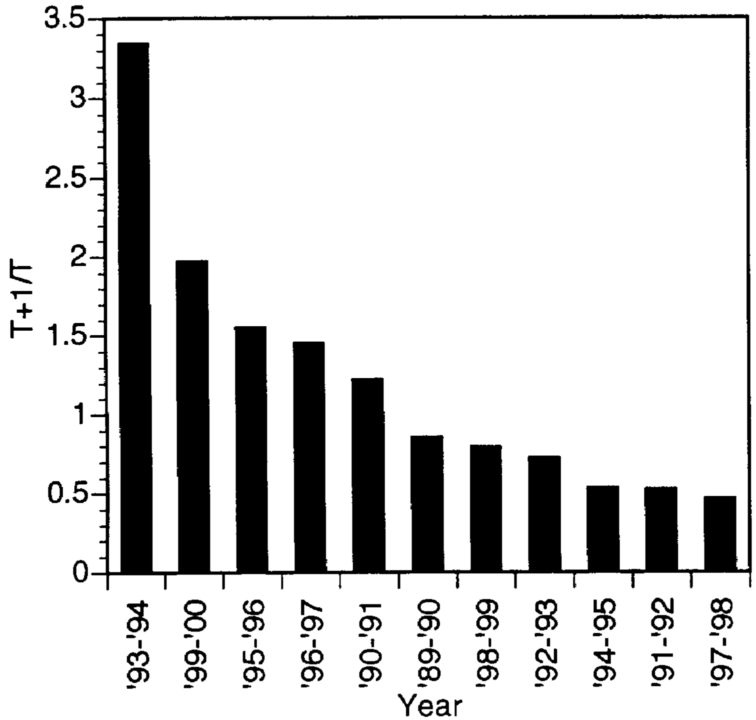


Figure 18

Rank order of the ratio of weighted mean abundance (T+1/T) for 1989-2000 on medium-mortality beds.



Rank order of weighted mean abundance from 1989-2000 on medium-mortality beds calculated as # $\geq$ 3"+0.5(#2.5-3.0")

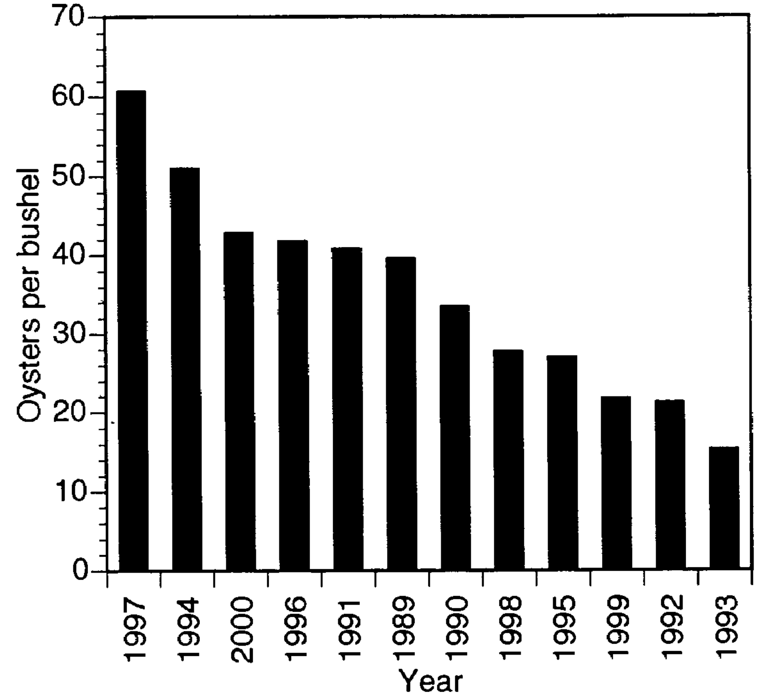
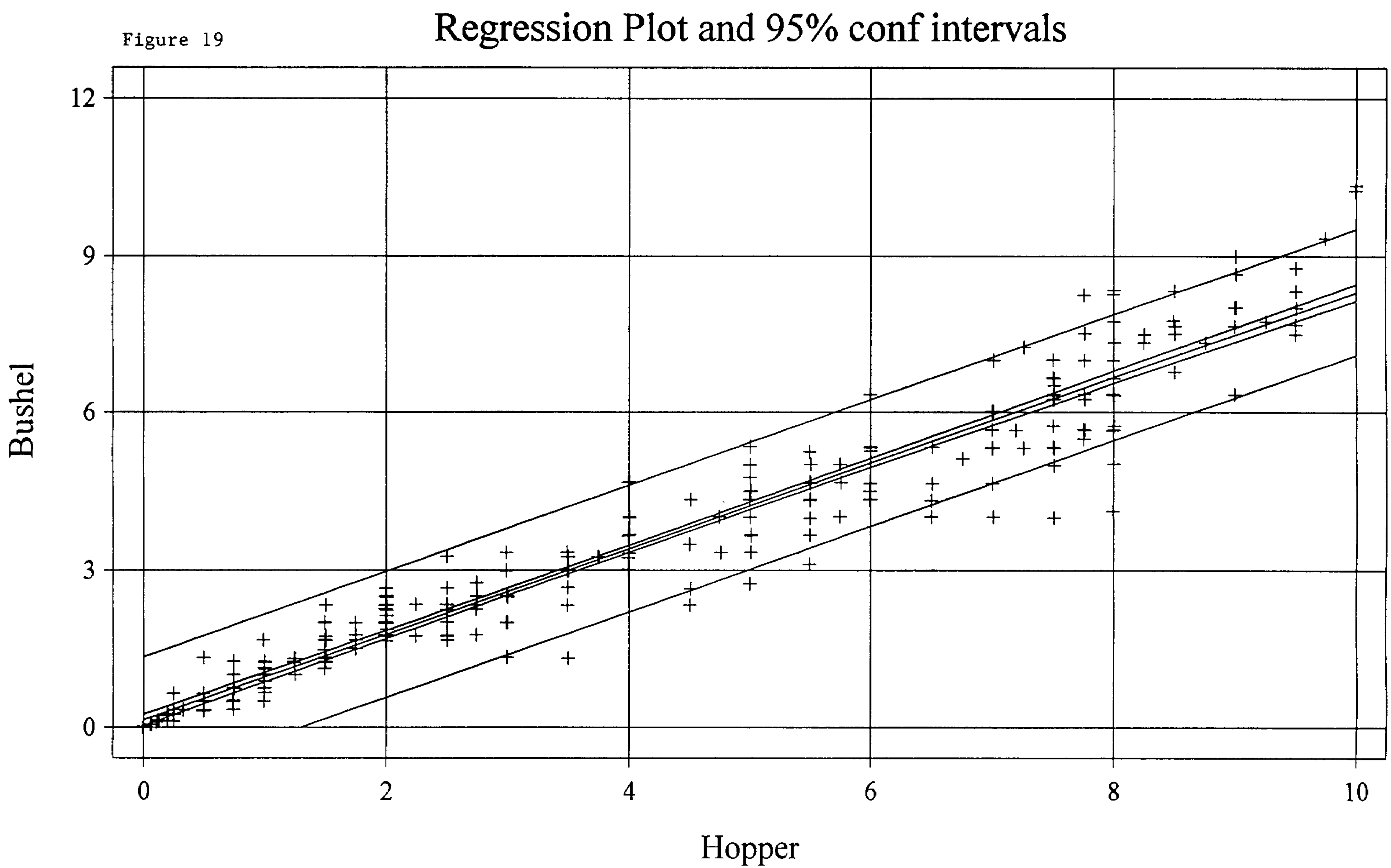
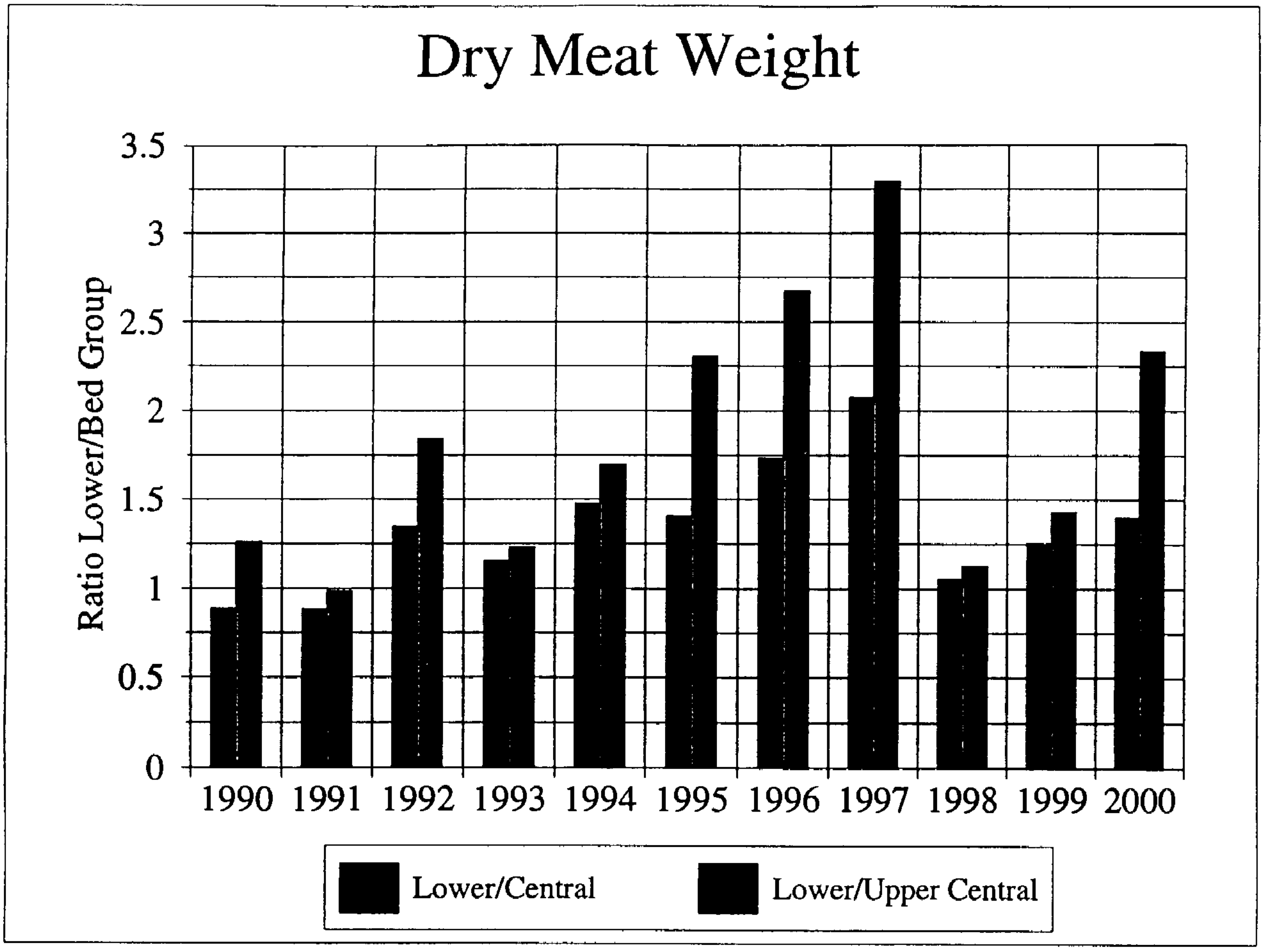


Figure 19



Bushel = 0.1472 + 0.8159 * Hopper   Hopper = 0.0492 + 1.1532*Bushel

Figure 20


Dry Meat Weight
Ratio Lower/Bed Group
3.5
3
2.5
2
1.5
1
0.5
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Lower/Central
Lower/Upper Central

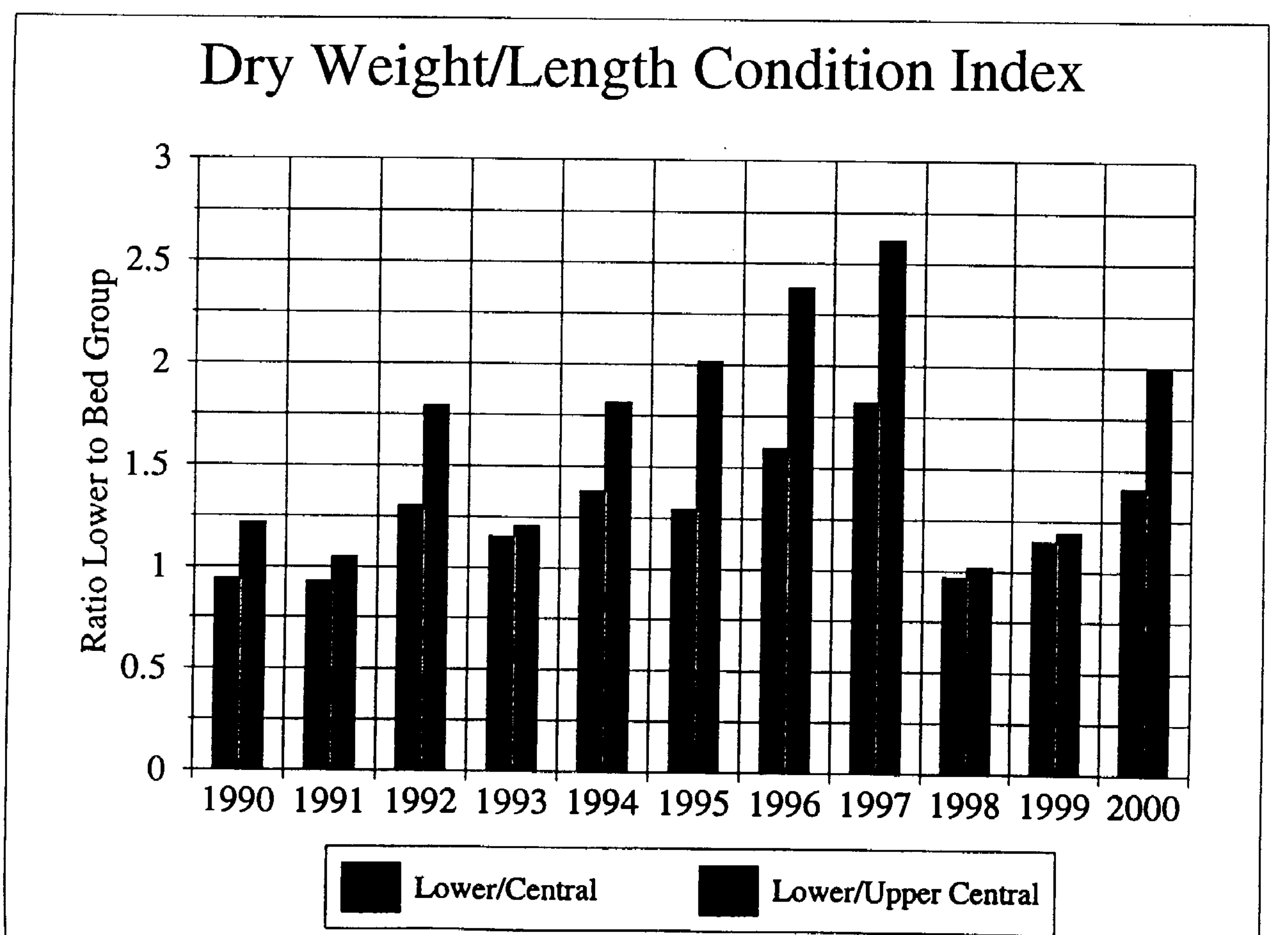
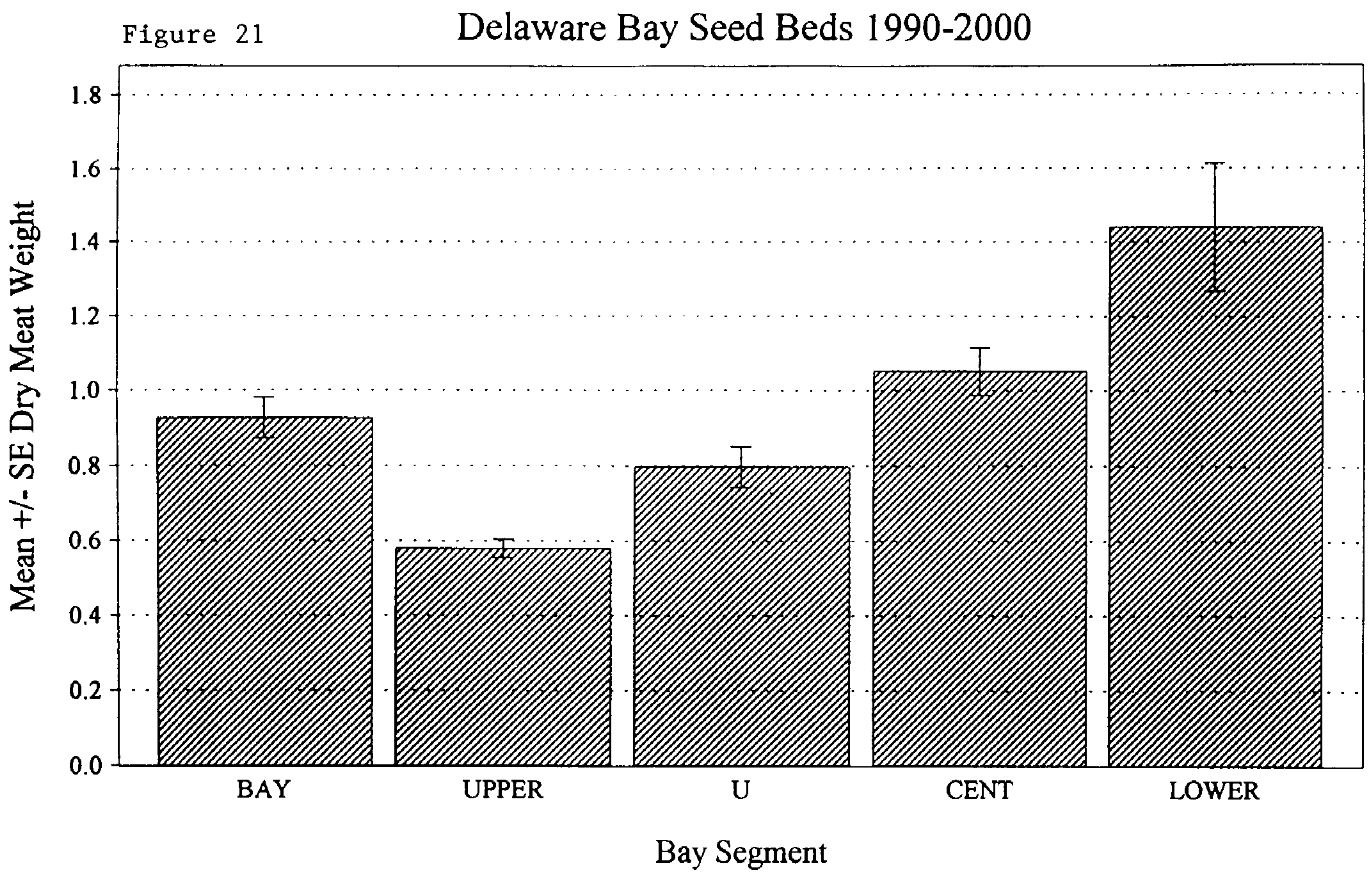

Dry Weight/Length Condition Index
Ratio Lower to Bed Group
3
2.5
2
1.5
1
0.5
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
Lower/Central
Lower/Upper Central

Figure 21


Delaware Bay Seed Beds 1990-2000
Mean +/- SE Dry Meat Weight
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
BAY
UPPER
U
CENT
LOWER
Bay Segment

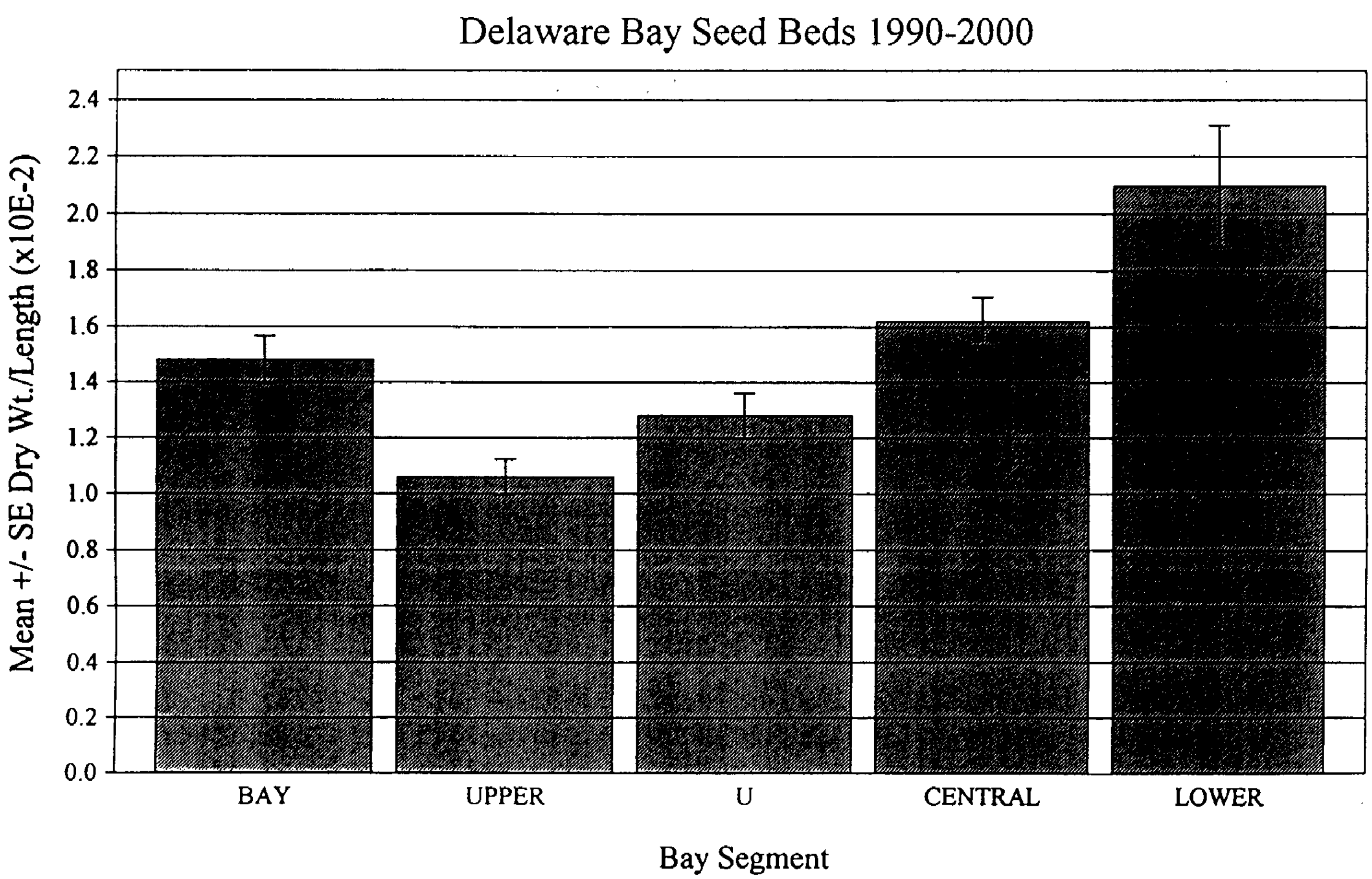

Delaware Bay Seed Beds 1990-2000
Mean +/- SE Dry Wt./Length (x10E-2)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
BAY
UPPER
U
CENTRAL
LOWER
Bay Segment

Figure 22

Examples of the time-dependent rate functions used for mortality rates. Solid line, the time-dependent fishing mortality rate, a = 0.5. Hatched line, the time-dependent natural mortality rate, a = 10.