Report of the
2000 Stock Assessment Workshop
for the
New Jersey Oyster Seed Beds

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2000 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 (the seed beds), 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 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 last year, 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, over the past two years, two new projects were undertaken: dredge tow lengths were measured by GPS navigation and dredge calibration surveys were made. These new data were integrated into the regular sampling results to caculate the numbers of oysters per square meter and to estimate 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 1956 to 1989, the bay-wide mean number of oysters per bushel was about 100, with an 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 (1990 to 1999), the overall mean has generally been between 150 and 175, but has fallen to 100-125 over the past two years (Figure 1). The 1956-89 bay-wide mean spat per bushel was about 50, with an average maximum of 2100 (Table 1). In the last decade the overall average was 114, about twice the earlier figure. The maximum seed taken by the industry during this period was in the 1970's and early 1980's, when 300,000 to 450,000 bushels per year were transplanted to the lower bay leased grounds (Figure 2).

The result of the presentations and discussions by the Rutgers personnel, and the subsequent discussion by the combined the stock assessment committee and Rutgers personnel is presented below.

Status of stock and fishery:

With the exception of an increase in the submarket (2.5-3") oysters in 1997, both market (>3") and submarket oysters have been declining on the major beds used for marketing (Shell Rock, Bennies Sand, Bennies, and New Beds) since 1996, immediately after direct marketing began (Figure 3). This decline continued through 1999 (Table 2). In the past two years, the number of submarket oysters on the major market beds has changed by -44,-14, -35 and +4 oysters per bushel, respectively. Bennies bed, a large bed in the major harvest area, has suffered a large drop in total oysters, from 75 to 17 per bushel (Table 3). Average-to-low spat set and heavy mortality due mostly to Dermo disease, with some attributable to fishing, are the principal reasons for the decline. In a healthy population, the number of submarket oysters should be considerable larger than the number of market oysters. This year, however, the ratio is approaching 1:1 (Figure 3), an indication that there are not many oysters available to recruit to the fishery.

Overall declines in abundance were not restricted to the heavily fished beds (Figure 4). Proportional declines on the Upper Central Beds (Middle, Cohansey, and Ship John) mirror those of the market beds in both size classes (Figure 5). Between 1998 and 1999, losses on Middle and Ship John beds ranged from 10 to 30 oysters per bushel, respectively, but no change was detected on Cohansey. Between 1997 and 1999, about 114,000 bushels of oysters were moved from these beds to lower beds (Table 4). It should be noted that transplants of this type involve oysters of all sizes.

Average baywide spat recruitment was the second highest of the past decade (Figure 6). Most recruitment was concentrated in the Upper Central portion of the seed beds. Spat numbers this past year were > 200 per bu on Middle, Cohansey, Ship John, Shell Rock and Nantuxent Point beds. Spat numbers were very low farther down bay (<35 per bu. on Bennies, New Beds and Egg Island) (Table 3).

Dermo disease levels continue to be very high, particularly on beds that are heavily fished (Table 3, Figure 7). This trend has continued from the 1997 low point. Infection intensity was lower on beds farther upbay, and mortality due to disease was less; however, some mortality certainly occurred as far upbay as Cohansey. MSX disease continued to be insignificant in 1999 (<10% prevalence in the fall survey).

Condition index improved from the extremely poor condition last year (Figure 8). This improvement came in all areas of the bay, but the index showed most improvement in the central and lower portions of the seed beds.

A dredge calibration study was undertaken in December 1998, but the number of samples was relatively small, which resulted in unacceptably high variances. Additional dredge efficiency estimates were obtained in June 1999 using the same methods: comparison of a one-minute standard survey tow by the survey vessel with simultaneously collected diver quadrat samples along a transect parallel to the tow. Eleven experiments were conducted on four beds. In this second study, the quadrat size was increased to 0.5 m^2 from 0.25 m^2, and the number of samples per experiment increased from seven to twelve. Comparison of these collections by the survey dredge with those from December 1998 revealed no significant difference in the quantity collected in a one minute tow. Dredge efficiencies for the June study for oysters > 3"calculated from these tows were similar to the December values: approximately 2.5% for boxes and 4.5% for live oysters.

The total number of bushels estimated from the Fall 1999 survey quantification indicated that the highest number of market sized oysters were on New Beds and Ship John (Table 5). Numbers of submarket oysters present were somewhat higher than the market oysters, with greatest abundances on Shell Rock and Ship John. Overall, the abundance of market sized oysters was relatively low on beds receiving the most fishing effort in 1999 (Bennies, Bennies Sand, and Shell Rock). In contrast, beds farther up bay, such as Middle, Cohansey and Ship John, contain relatively large numbers of oysters, but receive little fishing effort because they do not have market-quality oysters.

The Industry marketed just under 60,000 bushels in 1999 (Figure 2). The number of weeks of fishing was 26.5 this year, compared to 30 last year, 17 in 1996, and 25 in 1997. Not all boats in the industry used all their allocation this past year. The spring season (15.5 weeks) harvest was 27,668 bushels and the fall season (11 weeks) yielded 32,271 bushels. The harvest was about equally apportioned between spring and fall, and CPUE based on vessel days was about the same at 64.3 and 65.5 bu/day for spring and fall, respectively. The CPUE has dropped markedly from 1997 (average = 91 bu/day) and 1998 (average = 81 bu/day). The bulk (>66%) of the 1999 harvest came from Shell Rock and Bennies beds. Including Bennies Sand and New Beds increases the harvest to >87% of the total. Low catch on New Beds was partially explained by its being closed during the fall season. Given the low dredge efficiencies and the relatively high exploitation rates, the productive areas of these beds must have been dredged multiple times; however, fishing mortality was never greater than 30% of natural mortality on any bed (Table 6).

Management Advice:

It is emphasized that the data collected during the fall survey are obtained from a relatively few samples on any given bed and the variability of the estimates is large. Thus, individual numbers must be viewed with caution. In spite of these difficulties, historical trends in the data are sound. Consequently, the is little doubt that the steady decline in oyster abundance on the four beds supporting the bulk of the 1999 landings indicates that these beds are showing the accumulative strain of harvest and disease mortality. The numbers of submarket oysters continues to decline and there is little resilience, in the form of 2.5-3" oysters, in the system to provide continuing harvests at the current levels. Dermo levels remain high and may be expected to continue to produce heavy mortality. In the absence of the ability to estimate biomass at maximum sustainable yield, the goal of management of the heavily fished beds should be to retain a constant abundance of market sized oysters. A constant-abundance model using fall 1999 standing stock estimates shows that insufficient numbers of market and submarket sized oysters are present on the heavily fished beds to support a spring harvest in 2000 if mortalities continue as they have for the past decade and a fall season would be possible only if natural mortality rates are well below average.

In view of the low numbers of oysters presently on the major market beds, a management approach oriented toward preservation of the existing fishery and its participants is suggested. Current levels of Dermo disease mortality, uncertainty of future mortality rates, and belief in the resiliency of the resource point to a management plan with an perceived acceptable level of risk. This management plan allows utilization of reserves on the upper seed beds, with potential long-term reduction of stocks, in zones not currently fished. This is an unusual approach because under the current declining conditions of the beds, a typical management approach would be to maintain or increase the standing stock. It is emphasized that the status of the resource should be evaluated annually, and, if the goal of maintaining a stable stock on the beds from Shell Rock downbay is not achieved, further reductions in harvest will likely be required.

The conclusion, based on the constant abundance model approach, that stocks on the market beds will have to be supplemented by oysters transplanted from the upper beds is based on an assumption that the natural mortality rate on the lower beds will approximate the average for the past decade of about 0.5 per year (Figure 9). To determine whether a fall season can occur on the market beds without a supplemental transplant from the upper bay, a late summer stock evaluation on the market beds should be made. The data collected will be from the same test and bed grids collected in November. The data collected will be the same as in the standard sampling except information on spat and associated fauna will be excluded. This assessment, along with regular sampling on the beds during spring and fall, will provide disease intensity information, and more up-to-date mortality figures that may be lower than the long-term average of 0.5. A below-average mortality (<0.35) would allow a fall season. The fall season, should one be possible, should begin after the August reassessment.

An estimated 400,000 bushels of oysters >2.5" remains on Middle, Ship John, and Cohansey. Oysters on these beds, which are not fished for market, can serve as a source of oysters for transplantation to the market beds, and subsequent harvesting from these beds. A planning horizon model can be used to estimate the number of bushels that can be moved to the heavily fished beds, based on an estimated 10-year replacement rate for the oyster population. This would permit the transplant of 40,000 bushels down bay during 2000. Under the constant abundance scenario, the same number of oysters could be harvested from the beds on which these oysters are placed. Approximately one half of this total should be transplanted in the spring and an equivalent quantity harvested (Figure 10). Another 20,000 bushels can be transplanted in the fall to support a fall harvest of the same amount. This transplant program should be conducted under the following criteria: 1) the oysters must be moved according to the "rough-cull law" (no more than 15% cultch), 2) Cultch Fund monies should be allocated to buying and planting shell, **not** to intermediate transplanting, and 3) the transplanted oysters should be placed in an area that will be closed during spring harvest.

Cultch planting is essential to enhance production and serves two functions: 1) it replenishes material removed from beds by harvest and thus maintains the physical integrity of the beds and 2) it serves as a substrate for spat set. Cultch placed in locations where the best setting is known to occur, and if needed, moved to more appropriate nursery areas, can greatly enhance seed production. Because of a scarcity of available and anticipated funds, Cultch Fund revenues should be used in 2000 for cultch replacement, on a 1 to 1 basis, on the upper beds from which seed is projected to be removed. Any remaining revenues should be directed to placing shell in high setting areas and then moving spatted shell upbay to upper seed beds (Ship John, Cohansey, Middle). This means allocating sufficient funds to both shell planting and subsequent movement of spat to replenish areas from which oysters have been transplanted.

The importance of resource enhancement cannot be overemphasized. To effect this, a five-year business plan should be developed by the Delaware Bay Shellfisheries Council. Key components of this plan should include

Financing

Resource utilization

Enhancement strategies

Implementation mechanisms

Risk evaluation to the resource and the industry

Science Advice

1) The late summer stock assessment and the disease monitoring programs should be continued in 2000.

2) The survey data for the 1990's should be reassessed to allow for a evaluation of the basic random sampling program.

3) A production model, which includes an explicit growth parameter, should be developed for stock assessment. Model improvement will require obtaining growth and mortality data by bed or at a minimum bay segment. This will include a yield per recruit model for the seed beds.

4) The planning horizon model should be further developed and used to design an improved transplant program for the upper seed beds.

5) A study to determine the ability of oysters to repair shell damage at various temperatures below 10° C should be conducted.

6) A study designed to evaluate the effects of repeated dredging on oyster population and the effect of bed closure is on going and should be continued through the next year. This will require the continued closure of the experimental portion of New Beds until the termination of this research program.

7) A seed bed survey should be conducted to delineate the resource more precisely. Options include acoustic and side-scan sonar methods, and an update of the strata utilizing the historical data set, including volumes collected during the 1954-1988 surveys.

8) Harvest-area rotation should be considered. A test should be conducted to determine the degree to which area closures of six months to one year are efficacious in improving long-term production.

9) The density that can be economically harvested should be determined and this density used in future stock assessments to refine the number of bushels available for harvest.

10) An environmental monitoring program should be implemented to provide temperature, salinity, food supply, and seston data for model development.

11) A study should be undertaken to evaluate the value of shell plantings relative to spat settlement, survival and growth.

Table 1. Long term (1956-1989) average and average maximum numbers of oysters and spat per bushel for the New Jersey sectio Delaware Bay. Bay = Bay wide, Upper = Round Island, Arnolds, Upper Arnolds. Upper Central = Upper Middle, Middle, Cohansey. and Ship John Lower = Egg Island and Ledge. All other beds included in the Central Region.

	Oyster		Spat	
	Average	**Avg Max.**	**Average**	**Avg Max.**
Bay	102	613	51	2101
Upper	345	1068	100	2258
Upper Cental	151	735	75	2223
Central	66	569	35	1217
Lower	30	242	20	875

Table 2. Seed Bed Oyster Size-Frequency 1999

Size (mm)	Round Is	Up Arn	Arnolds	Middle	Cohansey	Ship Jn	Seabrz	Shell Rk	Ben Snd	Bennies	Nantux	Hog Shl	New Beds	Beadons	Vexton	Egg Is
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	2.4	0.5	1.3	0.8	0.3	0.4	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.1	0.0	0.0
20	4.8	3.3	5.5	3.9	2.4	4.1	1.6	1.2	3.5	0.2	3.4	2.3	0.0	5.2	1.7	0.0
25	10.8	6.2	19.1	7.2	6.8	3.3	5.9	6.0	11.3	0.2	10.7	4.4	0.0	8.3	2.0	0.0
30	19.0	17.0	25.0	12.0	13.0	6.0	2.8	9.9	8.2	0.3	14.8	3.9	0.1	6.1	3.1	0.4
35	22.8	22.7	25.6	17.3	26.8	13.0	3.1	9.4	7.8	0.8	23.9	9.5	0.1	4.3	3.6	0.4
40	22.1	19.4	20.8	14.9	27.1	15.0	9.1	10.2	8.5	0.3	32.2	15.1	0.4	5.7	5.1	0.8
45	20.4	21.3	23.7	17.1	21.2	15.8	11.8	15.0	9.9	1.0	29.1	12.1	0.8	6.0	6.7	0.4
50	23.1	18.9	29.2	17.8	24.2	13.8	8.3	12.1	11.7	1.1	21.2	10.3	1.0	6.6	4.7	2.3
55	22.6	20.8	16.5	12.4	22.4	11.6	4.7	8.4	12.2	1.1	15.7	6.5	2.9	5.9	4.8	3.0
60	17.1	21.3	17.5	11.6	16.2	9.0	5.9	9.6	10.3	1.8	9.6	5.3	3.3	4.7	3.7	2.6
65	17.1	16.1	8.1	8.7	15.6	6.0	5.9	6.9	8.7	1.3	7.2	4.0	3.9	3.3	3.6	1.1
70	7.9	10.4	6.8	5.2	12.4	5.0	4.3	6.8	4.3	1.4	4.2	4.4	4.8	2.7	2.0	5.3
75	3.6	5.2	3.2	5.2	5.3	4.3	5.5	6.3	3.7	2.0	3.1	2.3	3.5	1.3	2.5	1.5
80	3.6	2.4	1.6	2.3	7.4	1.9	3.9	4.1	3.3	1.5	2.7	3.2	5.3	1.4	2.0	1.9
85	1.0	4.3	1.0	1.0	1.8	1.2	4.7	3.2	3.7	1.8	0.4	2.5	3.3	1.0	2.3	1.9
90	0.2	0.5	0.3	0.8	2.1	0.8	3.5	1.8	1.0	1.1	1.6	2.1	2.5	0.5	1.5	1.1
95	0.0	0.5	0.0	0.2	1.8	1.1	2.4	0.9	1.0	0.7	0.4	1.4	1.0	0.3	1.1	1.9
100	0.0	0.9	0.0	0.2	0.6	0.3	1.6	0.0	0.0	0.6	0.2	0.7	0.7	0.2	0.7	0.8
105	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.4	0.2	0.0	0.4	0.3	0.3	0.5	1.1
110	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.2	0.1	0.2	0.2	0.4	0.0	0.3	0.8
115	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
120	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2
Total/bu	199	192	205	139	208	113	85	113	110	17	181	90	34	64	52	28
Number Measured	826	405	633	671	704	842	217	764	564	208	809	515	312	748	389	75
Greater than 3"	8	14	6	10	19	10	22	17	13	8	9	13	17	5	11	12
Greater than 2.5 "	33	40	21	24	47	21	32	31	26	11	20	21	26	11	17	19
Average Size	45	47	42	45	48	46	54	49	48	65	43	48	70	43	52	71

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

Attached is a summary of the 1999 seed bed sampling data with similar data for 1997 and 1998. All data were collected between November 8, 1999 and November 10, 1999 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. 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 1999 indicates the **average** number of bushels brought up by the 3 dredge hauls from each grid. The dredge was estimated to hold 7 bushels so if 7 is in the column all dredges were full.

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.

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.

Table 3. Delaware Bay Seed Bed data for 1999.

Bed		Bushels/ Haul	Percent Oyster			Oysters/Bushel			Spat/ Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence		
			1999	1998	1997	1999	1998	1997	1999	1998	1997	1999	1998	1997	1999	1998	1997	1999	1998	1997
Round Island		3.8	46.6	56.3	74.2															
Round Island		1.9	29	49.6	57.9															
Round Island	*	0.6	21.1	26.5	40.3	199	146	239	79	99	51	12	24	15	30	20	10	0.7	0.5	0.1
Round Island		1.2	19.2	20.0	27.5															
Round Island		1.3	8.5	12.7	14.7															
Round Island		0.6	5.8	1.1	14.3															
Up. Arnolds		5.7	53.3	–	28.1															
Up. Arnolds		1.1	24.6	–	5.7	192	–	109	93	–	41	17	–	12	–	–	–		–	–
Up. Arnolds	*	0.6	18.9	–	–															
Arnolds	*	6.3	64.4	47.9	60.4															
Arnolds		7.3	64.3	43.2	39.7															
Arnolds		3.2	38.3	42.5	33.6	205	168	237	99	90	40	22	17	11	66	30	40	1.3	0.5	0.3
Arnolds		0.4	34	39.5	24.8															
Arnolds		0.01	20	33.3	20.6															
Arnolds		0.3	0.76	0.0	0															
Up. Middle			–	5.2	–															
Up. Middle			–	0.0	–	–	0	–	–	7	–	–	0	–	–	–	–	–	–	–
Middle		5.2	77.5	78.8	73.9															
Middle		1.8	75.4	75.8	72.1															
Middle	*	2.2	54.8	66.7	70.5															
Middle		0.9	20.2	56.1	57.5															
Middle		0.4	17.4	41.6	48.3	139	211	262	306	165	52	19	14	8	100	90	10	2.2	3.3	0.2
Middle		1.3	6.8	33.3	44.3															
Middle		0.2	5.8	7.0	16.4															
Middle		0.1	3.5	0.0	16															
Middle		0.0	0.0	0.0	7.3															
Cohansey		2.7	72.7	72.2	78.3															
Cohansey	*	6.4	71	68.2	57.5															
Cohansey		2.7	59.3	32.8	55.2	208	161	262	561	103	72	26	17	12	100	100	80	1.8	3.2	0.8
Cohansey		1.1	52.6	12.5	34															
Cohansey		0.4	34.9	9.1	26.3															
Ship John		6.7	73	67.7	83.9															
Ship John	*	8.7	70.3	57.9	83															
Ship John		5.2	70	55.4	80	218	201	344	330	370	234	26	19	14	80	–	–	2.2	–	–
Ship John		4.4	58.2	55.2	76.5															
Ship John		1.7	3	22.2	28.3															
Seabreeze		2.8	53	–	–															
Seabreeze	*	2.1	20	–	–	85	–	–	50	–	–	33	–	–	90	–	–	2.5	–	–
Seabreeze		0.3	3.5	–	–															

Bed		Bushels/ Haul	Percent Oyster			Oysters/Bushel			Spat/ Bushel			Percent Mortality			Dermo Percent Prevalence			Dermo Weighted Prevalence		
			1999	1998	1997	1999	1998	1997	1999	1998	1997	1999	1998	1997	1999	1998	1997	1999	1998	1997
Shell Rock	*	6.1	55.7	64.0	82.9															
Shell Rock		3.2	48.1	60.0	76															
Shell Rock		4.3	47.6	54.1	75.7															
Shell Rock		2.6	46.3	52.4	57.1	113	198	190	208	198	95	36	24	19	93	100	50	2.3	2.1	0.6
Shell Rock		3.3	33.8	49.3	38.3															
Shell Rock		2.8	27.1	36.8	23.7															
Shell Rock		0.1	5.1	29.5	22.6															
Bennies Sand		3.8	52.8	46.9	57.5															
Bennies Sand	*	3.9	40.6	22.6	56.2															
Bennies Sand		3.7	26.6	19.3	17.5	110	103	94	184	264	109	36	34	23	100	100	30	2.9	2.4	0.6
Bennies Sand		0.9	11.8	0.2	4.7															
Bennies		2.1	13.8	59.1	86.1															
Bennies	*	5.1	11.6	51.3	63.3															
Bennies		3.1	10.9	42.1	36.8															
Bennies		3.8	10.7	38.3	29.6															
Bennies		2.9	9.6	23.1	28.1															
Bennies		1.2	7.9	19.7	14.5															
Bennies		3.3	4.4	14.3	11.1	17	75	77	2	105	150	57	40	22	97	100	90	3	3.1	1.3
Bennies		0.1	3.1	6.7	10.9															
Bennies		1.3	1	5.7	6.2															
Bennies		2.1	0.7	2.5	5.7															
Bennies		0.6	0.4	2.3	3.6															
Bennies		2.1	0.3	0.9	0.8															
Nantuxent Pt		8.3	66.7	--	45.9															
Nantuxent Pt	*	8.7	64.7	--	39.4															
Nantuxent Pt		7.4	62.4	--	34.1	181	--	109	440	--	99	38	--	25	100	--	100	3	--	3
Nantuxent Pt		6	48.3	--	31.4															
Nantuxent Pt		6.4	46.4	--	9.9															
Nantuxent Pt		0.2	40.7	--	2.5															
Hog Shoal		7.3	47.7	--	76.3															
Hog Shoal		7.3	39.5	--	75.2															
Hog Shoal		3	24.8	--	57.1	90	--	142	99	--	162	50	--	29	100	--	--	2.9	--	--
Hog Shoal	*	7.1	22.7	--	53.3															
Hog Shoal		8.2	21.8	--	38.6															
Hog Shoal		5.1	20.6	--	16.8															
New Beds	*	3.6	40.8	55.8	75.2															
New Beds		3.4	34.7	37.5	16.5															
New Beds		2.7	30.1	21.9	15.9															
New Beds		3.6	15.9	20.9	12.8															
New Beds		2.4	13.5	11.1	7.9	34	61	23	9	41	165	66	54	39	95	100	60	2.8	3.5	1.1
New Beds		2.5	6.1	10.7	7															
New Beds		4.1	3	8.0	4.7															
New Beds		0.4	3	6.7	4.7															
New Beds		2.9	1.4	2.6	1.1															
New Beds			--	--	1															

Bed		Bushels/ Haul	Percent Oyster 1999	Percent Oyster 1998	Percent Oyster 1997	Oysters/Bushel 1999	Oysters/Bushel 1998	Oysters/Bushel 1997	Spat/ Bushel 1999	Spat/ Bushel 1998	Spat/ Bushel 1997	Percent Mortality 1999	Percent Mortality 1998	Percent Mortality 1997	Dermo Percent Prevalence 1999	Dermo Percent Prevalence 1998	Dermo Percent Prevalence 1997	Dermo Weighted Prevalence 1999	Dermo Weighted Prevalence 1998	Dermo Weighted Prevalence 1997
Strawberry			--	43.7	--															
Strawberry			--	39.0	--															
Strawberry			--	37.5	--	--	67	--	--	123	--	--	52	--	--	--	--	--	--	--
Strawberry			--	27.1	--															
Strawberry			--	8.1	--															
Strawberry			--	5.0	--															
Hawks Nest			--	56.1	--															
Hawks Nest			--	27.3	--															
Hawks Nest			--	12.0	--															
Hawks Nest			--	8.2	--	--	36	--	--	218	--	--	60	--	--	90	--	--	4.4	--
Hawks Nest			--	5.6	--															
Hawks Nest			--	2.4	--															
Beadons		8.1	75	77.9	79.5															
Beadons		8.3	59.4	50.0	68															
Beadons	*	3.9	45.6	46.5	58															
Beadons		3.7	23.3	33.3	57.6															
Beadons		1.4	20.8	29.7	30.6	64	150	89	377	127	553	45	32	34	100	80	100	4.1	3	2.9
Beadons		4.2	17.2	28.0	18.6															
Beadons		6.7	17	14.2	14															
Beadons		5.1	6.8	9.9	12															
Beadons		0.3	4.8	9.5	5.1															
Beadons		4.7	2.4	4.2	1.5															
Vexton		4.3	46.2	--	66.7															
Vexton	*	3	40.9	--	56.9															
Vexton		4	27	--	56.1															
Vexton		5.9	25.9	--	53.9															
Vexton		4.1	8.1	--	41	52	--	100	54	--	307	54	--	28	100	--	--	3.8	--	--
Vexton		4	6.8	--	24															
Vexton		4.9	2.4	--	7.4															
Egg Island		2.9	48.7	56.5	38.2															
Egg Island		3.3	14.7	7.9	21															
Egg Island	*	3.7	8.7	4.6	12															
Egg Island		1.3	1.2	3.0	11.1															
Egg Island		1.6	0.4	2.8	3.2	28	37	8	2	13	130	35	42	41	100	--	80	3.9	--	1.4
Egg Island		2.3	0.4	2.3	2.7															
Egg Island		0.8	0.4	0.0	1.6															
Egg Island		2.1	0.3	0.0	0.6															
Egg Island		0	0	0.0	0															
Egg Island		0	0	0.0	0															
Ledge			--	10.24	--															
Ledge			--	2.68	--															
Ledge			--	1.23	--															
Ledge			--	1.03	--	--	4	--	--	3	--	--	55	--	--	85	--	--	2.2	--
Ledge			--	0.68	--															
Ledge			--	0.65	--															
Ledge			--	0	--															

Table 4. Bushels of oysters from Upper Central Delaware Bay seed beds.

		Bed	
Year	**Middle**	**Ship John**	**Cohansey**
1997	30,000	0	0
1998	0	6,000*	6,000*
1999	14,650	17,350	40,200

* Records are incomplete, but indicate 12,000 bushels were moved from ShipJohn/Cohansey in 1998.

Table 5

Comparison of the number of bushels of market oysters harvested and the number of bushels of market (>3 inches) and submarket (2.5-3 inches) oysters present during the November. 1999. survey on the high quality areas and on the entire bed. Zeros in survey abundance indicate beds not surveyed in 1999.

		Survey Abundance--Markets		Survey Abundance--Submarkets	
Bed	Harvest	Total Bed	High Quality Area	Total Bed	High Quality Area
Arnolds	1219.	12541.	12541.	70992.	70992.
Beadons	20.	39129.	36536.	56758.	55985.
Bennies	17141.	47672.	45658.	26528.	26528.
Benny Sand	6284.	28612.	20210.	34060.	30167.
Cohansey	687.	46311.	41201.	84452.	79717.
Egg Island	88.	17833.	17833.	13921.	13921.
Hawk's Nest	249.	0.	0.	0.	0.
Hog Shoal	214.	30694.	24091.	24601.	21202.
Ledge	183.	0.	0.	0.	0.
Middle	0.	33238.	33238.	74935.	74935.
Nantuxent	0.	43767.	43682.	99465.	99229.
New Beds	5839.	200244.	124963.	211660.	109034.
Sea Breeze	158.	35761.	35761.	26909.	26598.
Shell Rock	24372.	63306.	63306.	123780.	123568.
Ship John	2057.	102980.	102980.	264428.	263539.
Strawberry	656.	0.	0.	0.	0.
Vexton	346.	36676.	26020.	29670.	21206.
UpperMiddle	0.	0.	0.	0.	0.

Table 6

Comparison of harvest and natural mortality expressed as the number of bushels harvested to the number of bushels of market-size boxes taken in the November, 1999 survey

Arnolds	0.24774
Beadons	0.00029
Bennies	0.31262
Benny Sand	0.13296
Cohansey	0.01186
Egg Island	0.00324
Hog Shoal	0.00226
Middle	0.00000
NantuxentP	0.00000
New Beds	0.02307
Sea Breeze	0.00800
Shell Rock	0.27003
Ship John	0.01383
Vexton	0.00341

Figure Legends

Figure 1. Decadal mean total oyster abundance from Delaware Bay seed beds. Abundance in oysters per bushel of material.

Figure 2. Historic harvest of seed oysters from Delaware Bay seed beds. Selection of market oysters rather than seed planting has been the predominant use of seed beds since 1995.

Figure 3. Decadal mean oysters per bushel on Market beds apportioned between market (>3") and submarket (2.5" to 3") categories. Market beds are considered to be Shell Rock, Bennie's, Bennie's Sand and New Beds.

Figure 4. Decadal mean oysters per bushel on Market beds (see figure 3 above) and Upper beds. Upper beds are considered to be Middle, Cohansey and Ship John.

Figure 5. Decadal mean oysters per bushel apportioned between market (>3") and submarket (2.5" to 3") categories. Comparison of Major Market beds and Upper beds (see Figure 4 above).

Figure 6. Decadal mean spat set abundance from Delaware Bay seed beds. Abundance in numbers of spat per bushel of material.

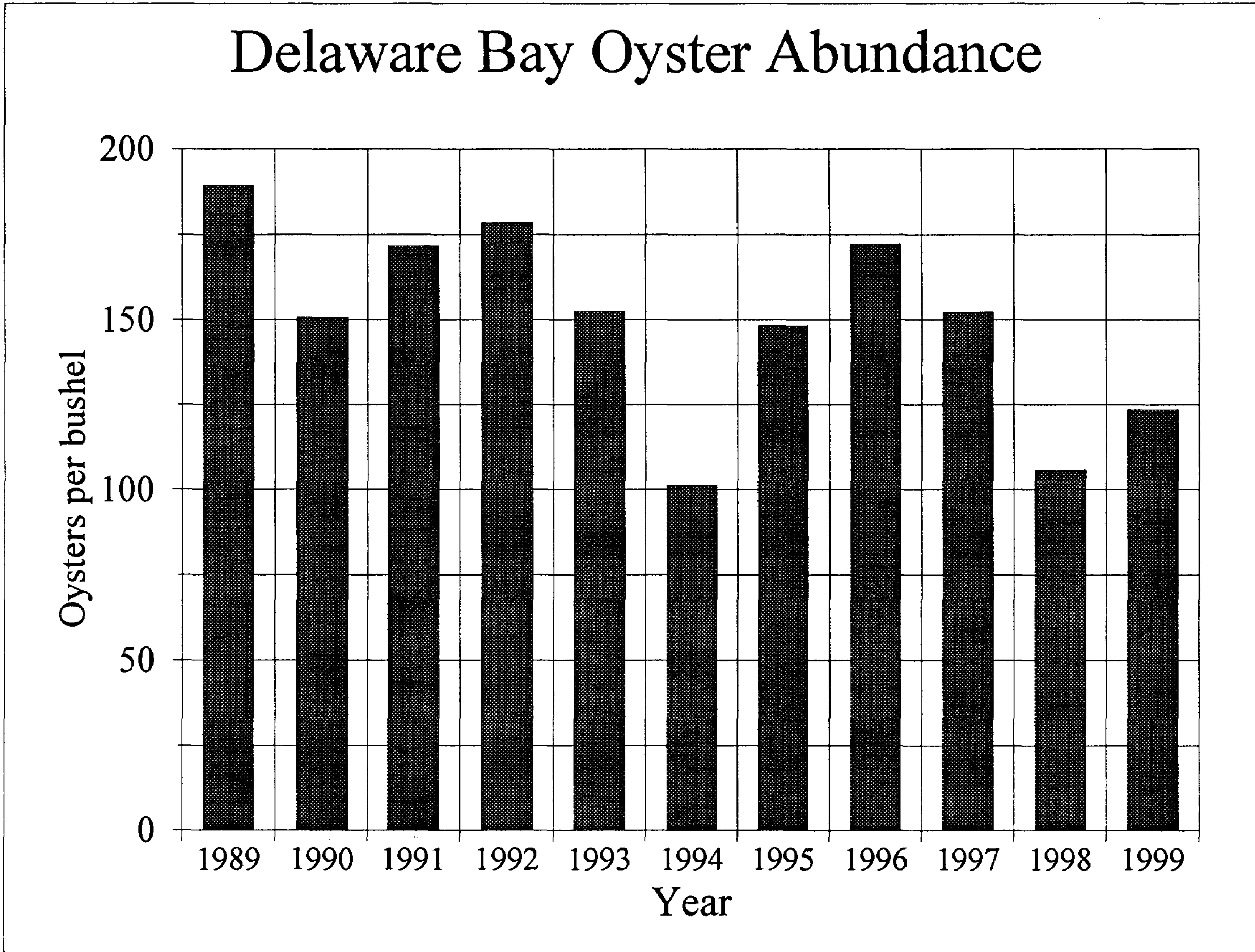
Figure 7. Decadal average Dermo (Perkinsus marinus) for 4 areas of the Delaware Bay seed beds. Upper = Round Island, Upper Arnolds and Arnolds. Upper Central = Upper Middle, Middle, Ship John, Cohansey, Seabreeze and Shell Rock. Lower = Egg Island and Ledge. All other beds form the Central region of the seed beds.

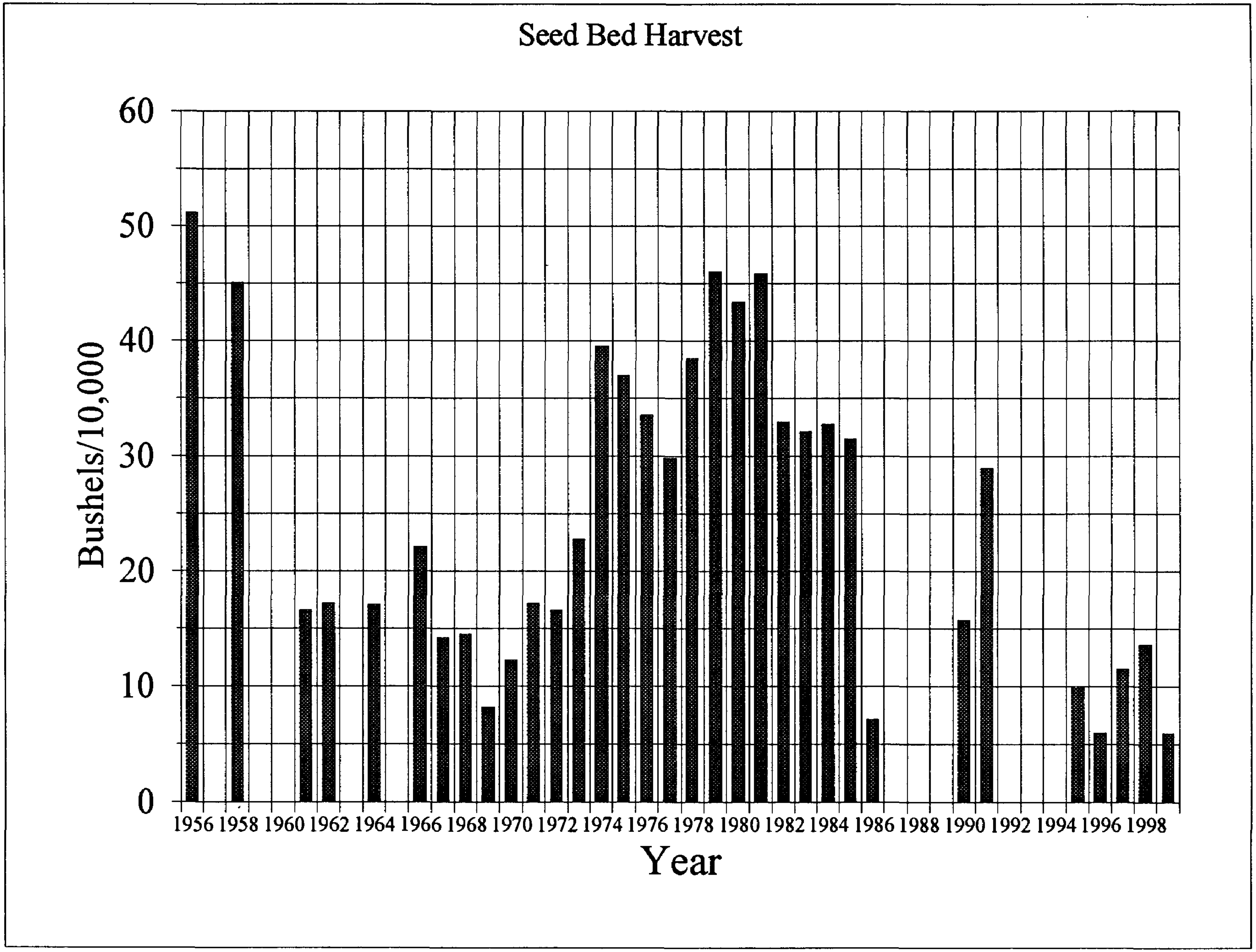
Figure 8. Decadal average condition index (meat dry weight/hinge to lip oyster measurement) for 4 areas of the Delaware Bay seed beds. Upper = Round Island, Upper Arnolds and Arnolds. Upper Central = Upper Middle, Middle, Ship John, Cohansey, Seabreeze and Shell Rock. Lower = Egg Island and Ledge. All other beds form the Central region of the seed beds.

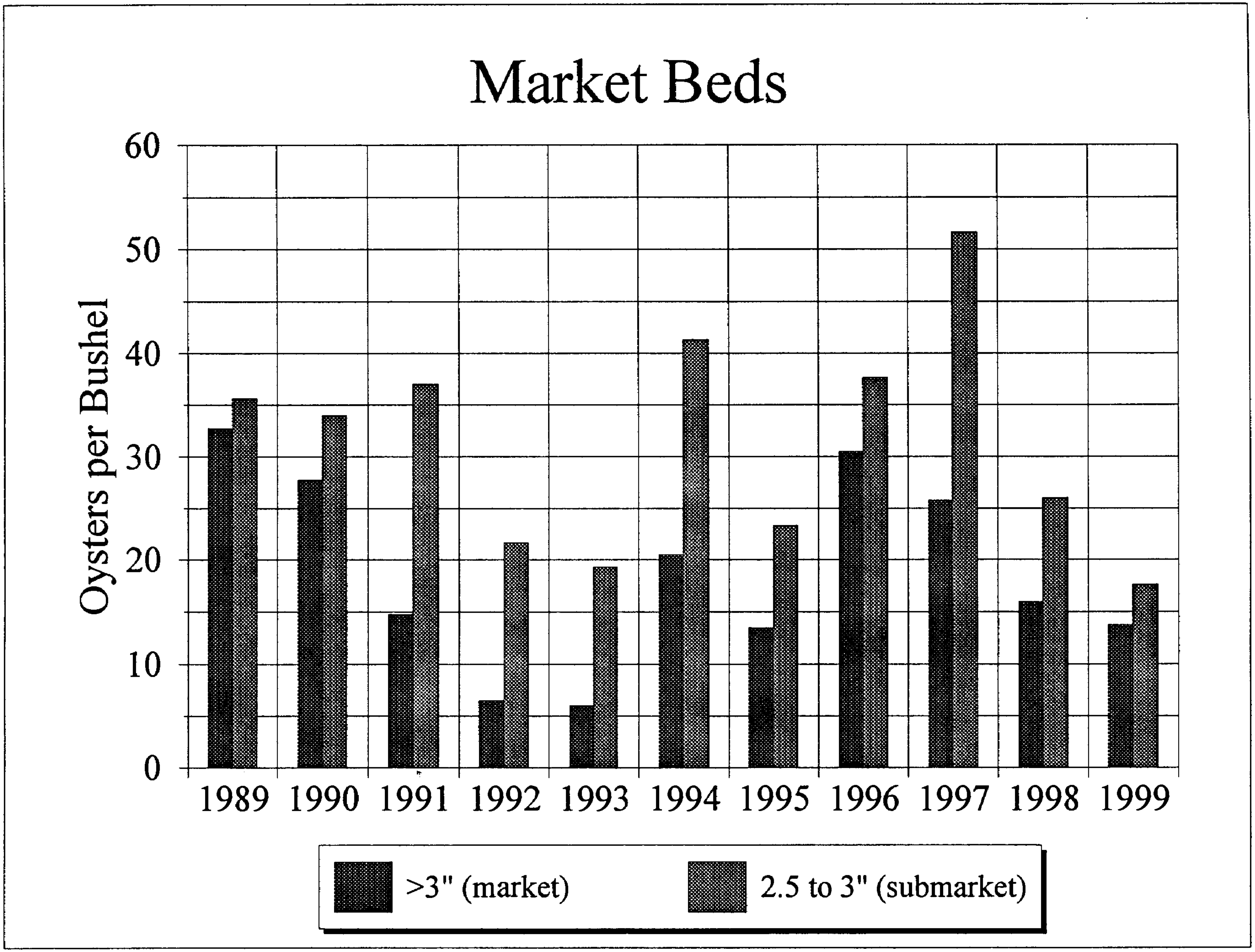
Figure 9. Plot of the results of the oyster fisheries model designed to maintain stock abundance on the Major Market beds. The variable q is the reciprocal of dredge efficiency (1/efficiency). Contour lines are plots of estimated allocations, in bushels, for the spring (left plot) and fall (right plot) fishing seasons. The spring season was defined as beginning April 1 and ending May 31. The fall season was defined as September 1 to November 30. The zero line marks the line of zero allocation. Any combination of natural mortality rate and q falling below this line would result in a season closure. The decadal long-term average natural mortality rate for these beds is estimated to be around 0.5 per year.

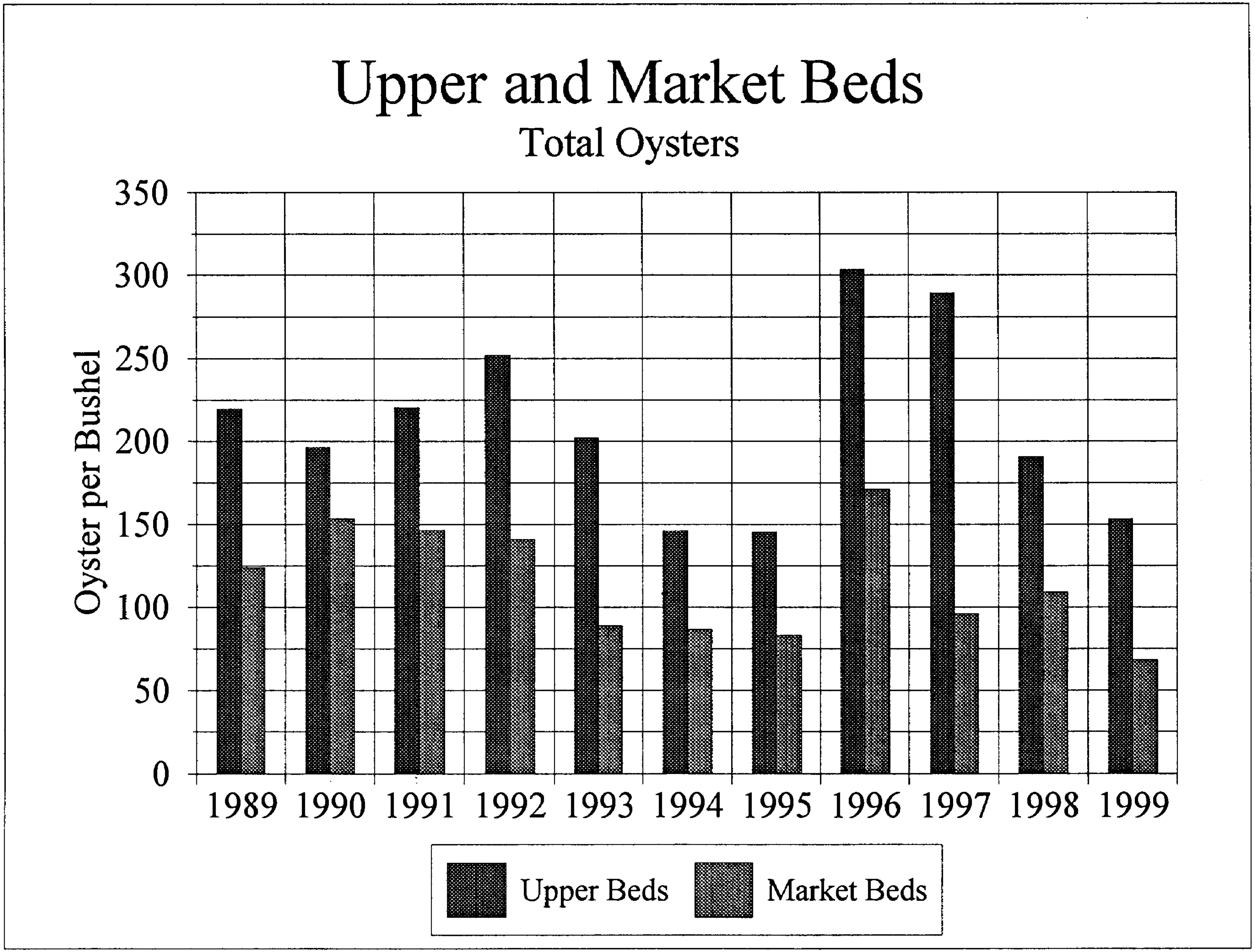
Figure 10. Diagrammatic representation of the recommended spring transplant - spring harvest. For ease of illustration the initial number of market sized oysters on both the Upper and Market beds (see figure 4 for definitions) was set at 1000,000. Harvest was set to balance the transplant. Any mortality is assumed to take place after the transplant.

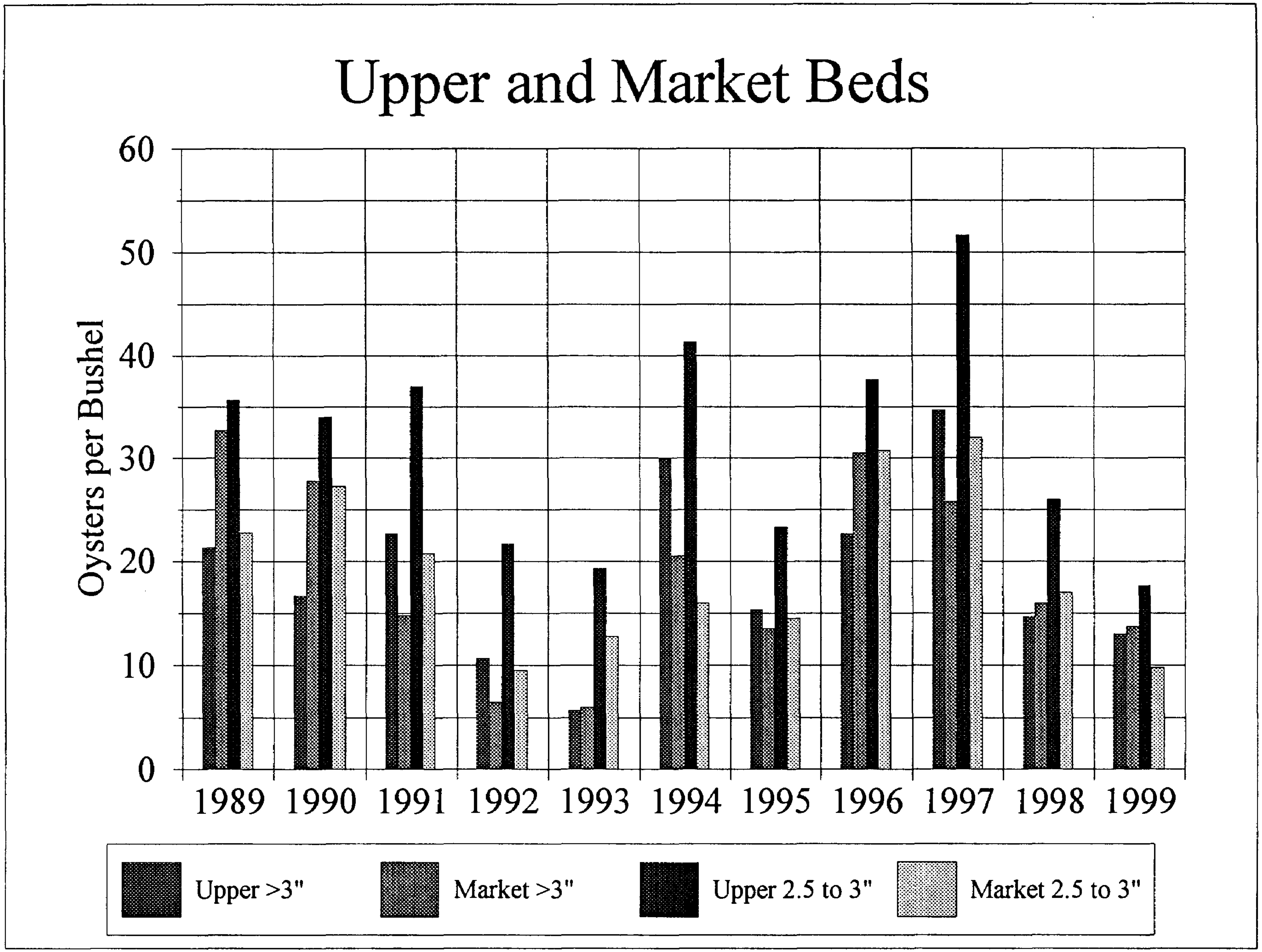
Figure 1

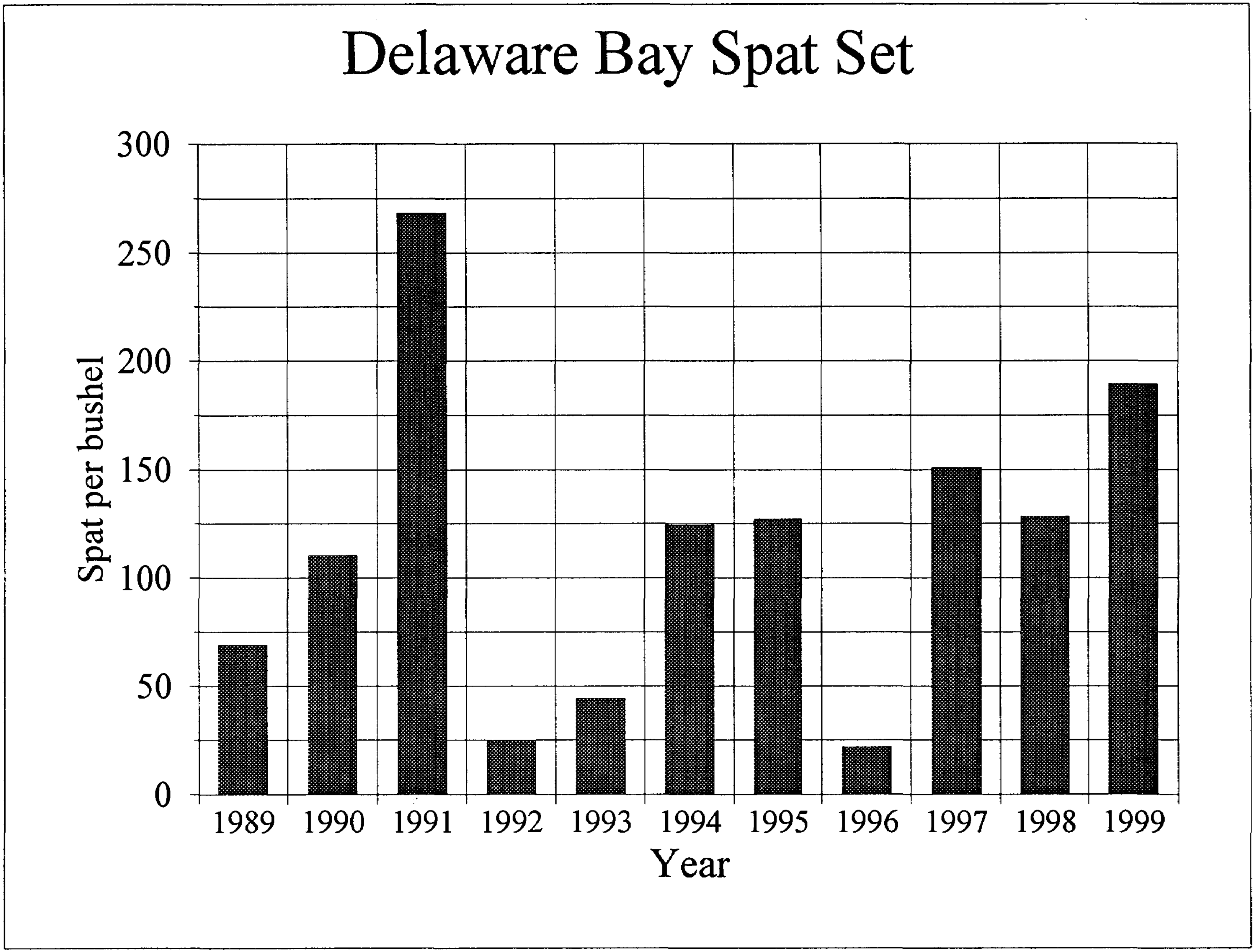

Delaware Bay Oyster Abundance
200
150
100
50
0
Oysters per bushel
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year

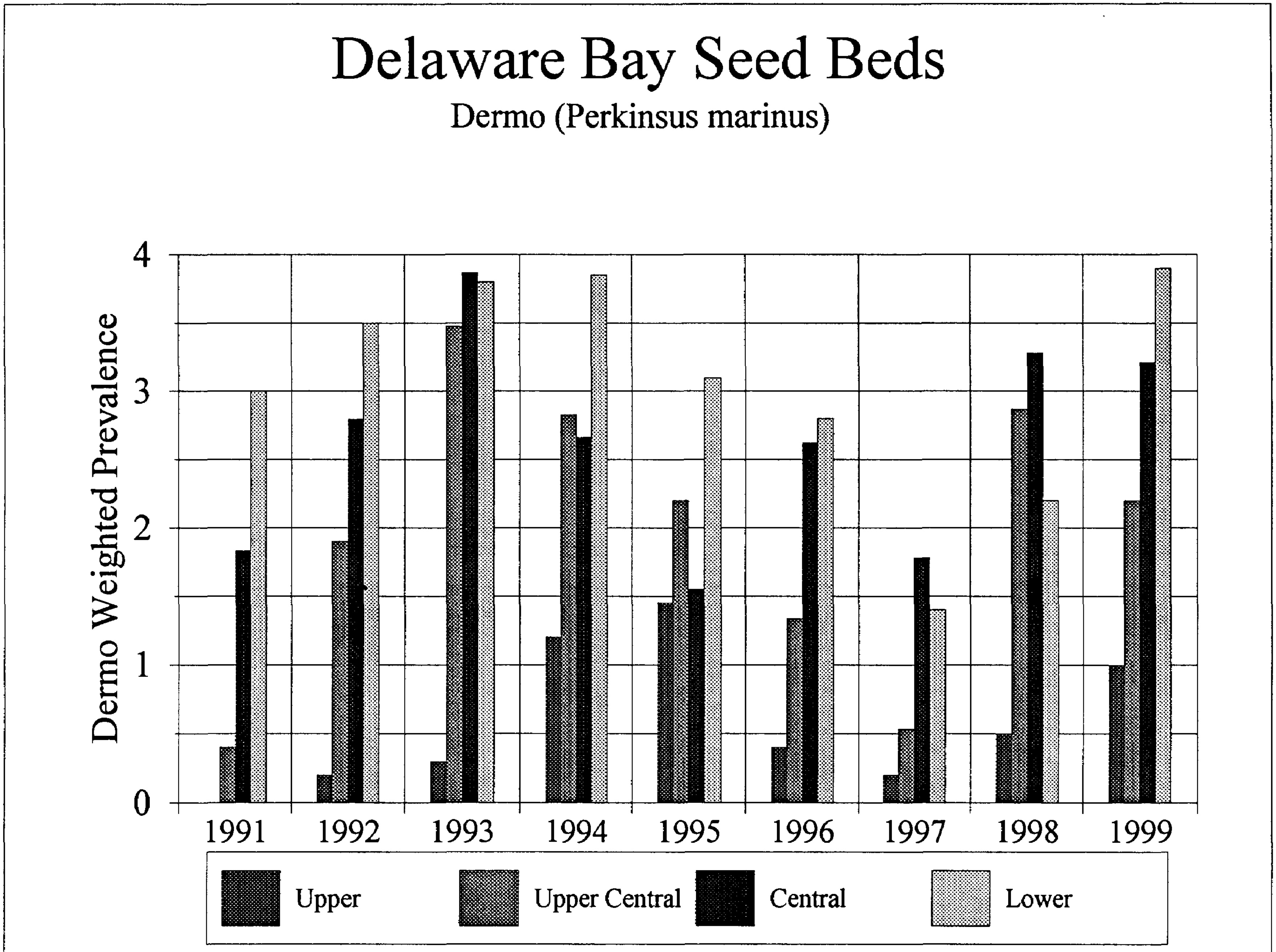

Seed Bed Harvest
60
50
40
30
20
10
0
Bushels/10,000
1956 1958 1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998
Year


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


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
Upper Beds
Market Beds


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


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


Delaware Bay Seed Beds
Dermo (Perkinsus marinus)
Dermo Weighted Prevalence
0
1
2
3
4
1991
1992
1993
1994
1995
1996
1997
1998
1999
Upper
Upper Central
Central
Lower

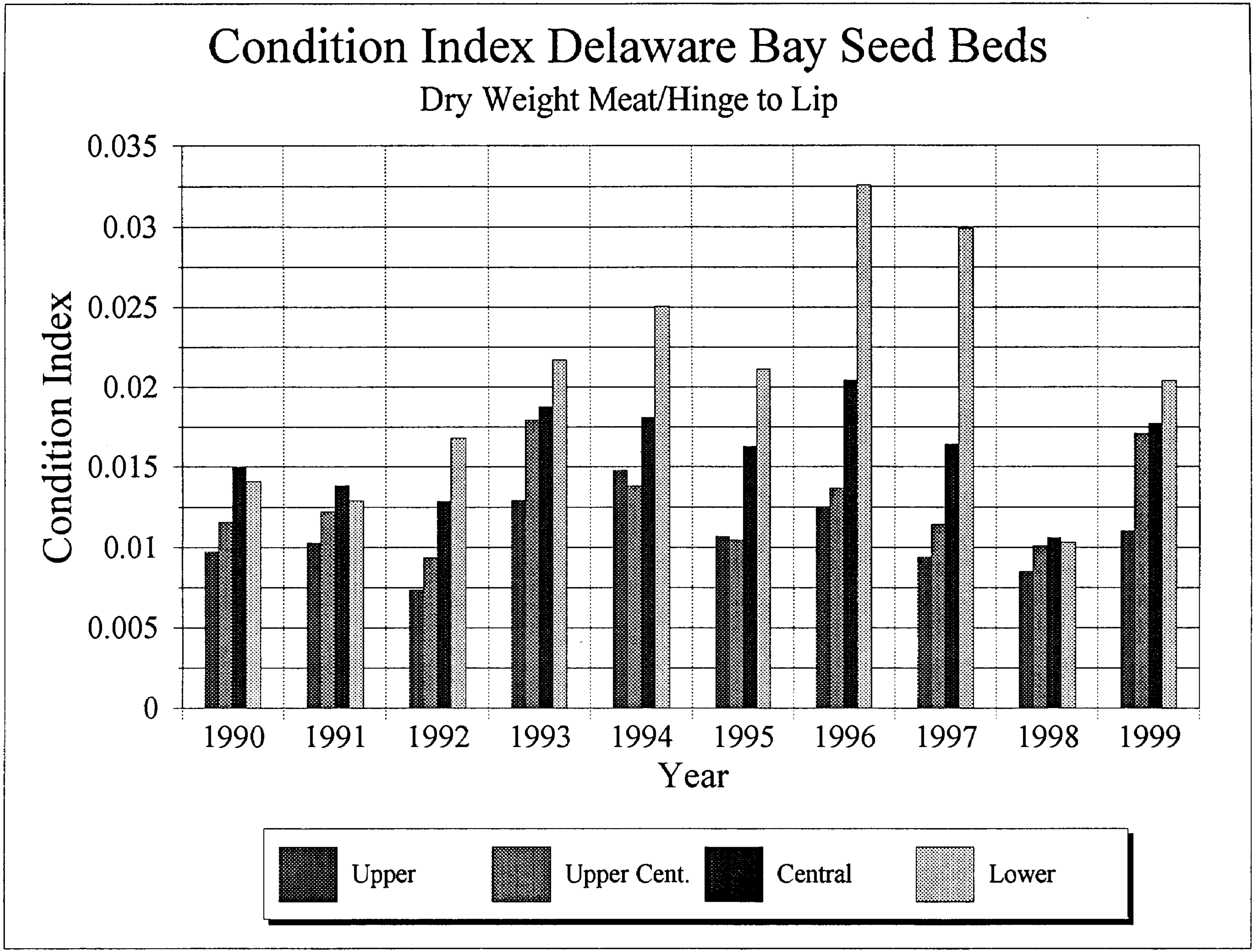
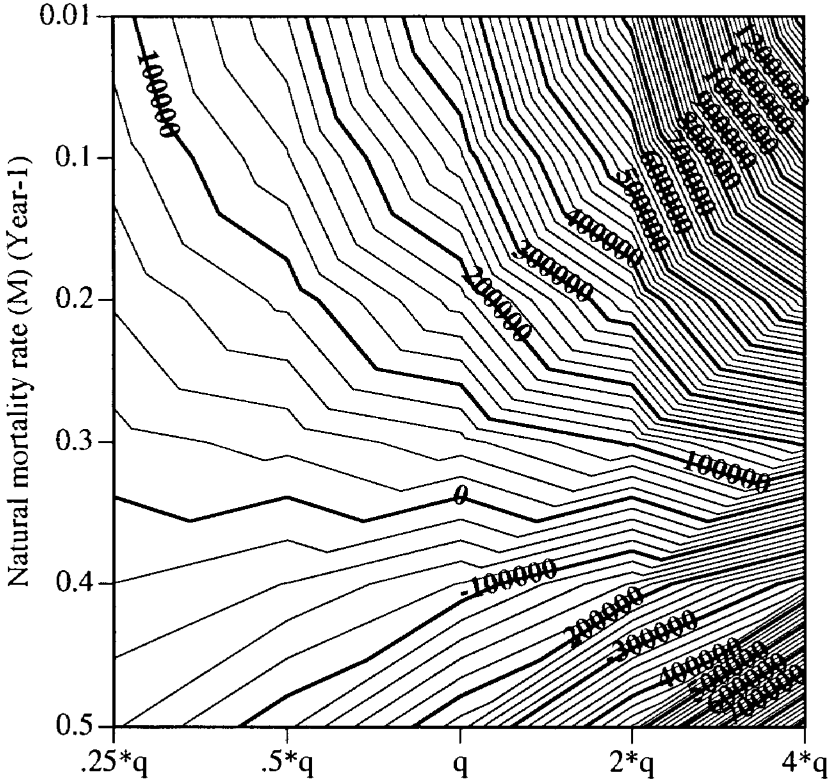
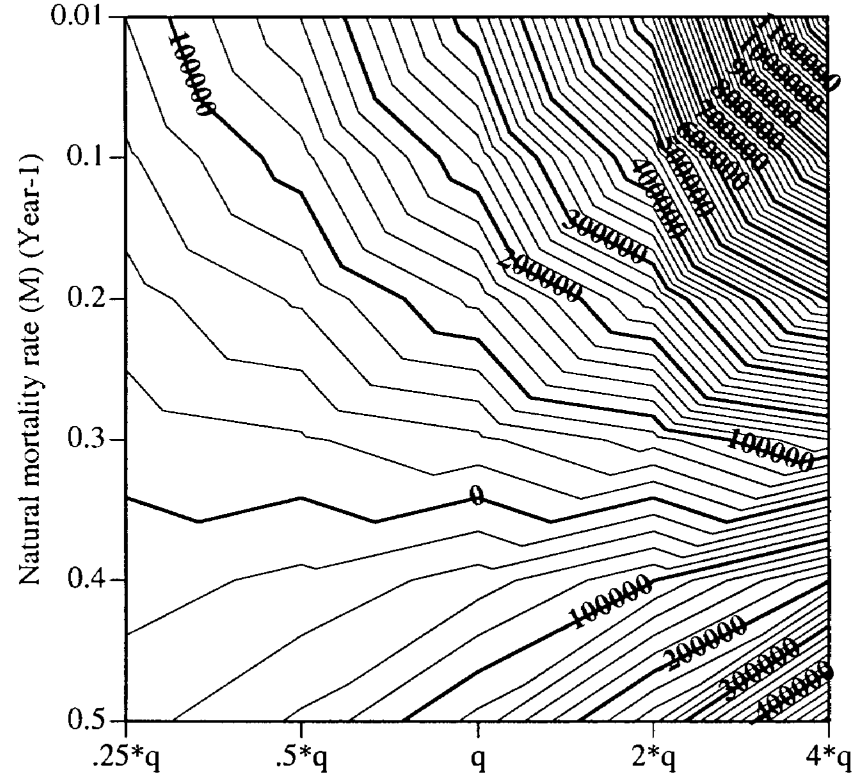

Condition Index Delaware Bay Seed Beds
Dry Weight Meat/Hinge to Lip
Condition Index
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year
Upper
Upper Cent.
Central
Lower

Figure 9

Lower Group -- FISH1 (Apr-May)



Lower Group -- FISH2 (Sept-Nov)



Spring Transplant - Spring Harvest