AN EVALUATION OF THE MARYLAND OYSTER SANCTUARIES MONITORED BY THE MDNR SHELLFISH PROGRAM'S FALL OYSTER SURVEY

Prepared by Mitchell Tarnowski
Maryland Department of Natural Resources
Shellfish Program

March, 2005

FOR MORE INFORMATION PLEASE CONTACT

Maryland Department of Natural Resources
Fisheries Service
Tawes State Office Building
580 Taylor Avenue
Annapolis, MD 21401

1-800-688-FINS   410-260-8258

DNR GENERAL INFORMATION

1-877-620-8DNR

www.dnr.state.md.us

Fisheries Service Ext. - 8258

Robert L. Ehrlich, Jr., Governor
Michael S. Steele, Lt. Governor
C. Ronald Franks, Secretary, DNR

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

Mr. Christopher Judy and Dr. Mark Homer of the MDNR Shellfish Program offered many constructive comments that have been incorporated into this report. Eric Campbell of the Shellfish Program constructed Appendix A and Figure 1, Robert Bussell of the Shellfish Program developed Appendix B, and Paul Genovese of the MDNR Fisheries Service produced Figure 2. Their assistance is greatly appreciated.

EXECUTIVE SUMMARY

The Maryland Department of Natural Resources currently monitors thirteen oyster sanctuaries as part of its annual Fall Oyster Survey, representing a cross section of sanctuaries in different salinity regimes and with varying rehabilitation efforts. The dredge-based surveys provide information to assess the status and trends of oyster populations in these sanctuaries, including relative abundance, general age/size structure, recruitment, and observed mortality. Disease levels are extrapolated from proximal disease sentinel bars or rarely are derived directly from the sanctuaries.

All of the surveyed sanctuaries have received restoration improvements, including combinations of habitat enhancement through shell plantings, population augmentation with seed plantings, and buy-backs. The timing of the shell plantings was often serendipitous, especially given the amount of activity in 2001 and 2002, when the newly deposited shell attracted significant spat sets on several sanctuaries. Even sanctuaries in lower salinity areas experienced modest recruitment in 2002 when spatfall was widespread throughout the bay. The shells often continued to catch spat in succeeding years, though usually with lower counts. In one extraordinary case, Mill Hill sanctuary received a near record spat set on a nine-year old shell planting. Natural spat sets, though unpredictable, are crucial for establishing and maintaining oyster populations on the sanctuaries.

Seed planting counts tended to decline sharply early on, and then stabilized at much lower levels, often supplemented by natural recruitment. Four years of drought (1999-2002) allowed disease levels to reach record high levels, devastating oyster populations, including those in the sanctuaries. Mortalities of 1+ year class oysters, even in typically lower salinity areas, sometimes exceeded 50%. The population structure on the sanctuaries came to resemble that on open-harvest bars, where the oyster biomass is largely concentrated in sublegal sizes. On the open-harvest bars the market-sized oysters were exploited by watermen, whereas in the sanctuaries the markets were cropped by disease as evidenced by box counts.

Disease levels, and consequently mortalities, plummeted in 2003 and 2004 with the increase in freshwater flows, permitting some of the recently established sanctuary populations to grow. This is especially true on Pt. Lookout, where the 2001 year class is thriving.

Conditional analyses are evaluated within constructs specified by the Oyster Management Plan, in particular the expansion of oyster biomass, broodstock development and protection, field effects from larvae produced from protected brood oysters, and the manipulation of gene pools via natural selection to produce disease-resistant oysters. As to the efficacy of developing naturally selected, disease tolerant oysters on the sanctuaries, this is a long-term process on the scale of many decades or longer; only time will tell as to whether it will succeed. The premise behind the buy-back project was that larger oysters harvested from disease-infected waters were survivors that had greater disease tolerance than their neighbors that had succumbed to the blights. Unfortunately, when planted in denser concentrations, buy-backs died at similar or even higher rates than nearby bars.

Despite the recent establishment and/or enhancement of numerous sanctuaries and the subsequent maturation of their oyster populations, there has been no evidence of far-field recruitment effects, that is, that the sanctuaries serve as larval sources for other bars. Spat indices during the past two years rank near the bottom of the 20-year record. However, these years were characterized by high freshwater flows, which could have dampened recruitment. Given the vagaries of spatfall in Maryland, it would be extremely difficult to evaluate the performance of broodstock sanctuaries and ascribe far-field effects to them without the use of sophisticated genetic techniques.

In summary, environmental conditions are the overwhelming determinants of sanctuary success. In particular, freshwater flow into the bay is the foremost controlling factor in oyster recruitment, disease, and mortality. The impact of this was even more exaggerated in recent years, first with a four-year drought, followed by abnormally high freshwater input. In the face of such extraordinary conditions, the results have been decidedly mixed. Biomass has increased on many of the sanctuaries, but at much lower levels than anticipated, especially in the lower salinity zones. Despite the numerous rehabilitation projects within the sanctuaries, many of the sanctuary populations tend to resemble natural populations in relatively short periods of time. Although Point Lookout demonstrates the potential of sanctuaries to increase biomass, its location in a normally high disease area does not bode well for its long-term prospects. Overall, it appears that the sanctuary program to date has fallen far short of its stated goal of contributing to the ten-fold increase in oyster biomass in Chesapeake Bay.

INTRODUCTION

The Chesapeake Bay Program Oyster Management Plan (OMP) envisions the oyster sanctuary program as an important management tool in oyster restoration. The potential benefits to be accrued from a sanctuary program include an expansion in oyster biomass, ecological improvements such as protecting biological interactions of the oyster bar community, an increase in broodstock and larval production producing a far-field effect of enhanced recruitment, and the selection for more vigorous, disease-tolerant stocks in enzootic areas (CBP, 2004).

The Maryland sanctuary program currently consists of 31 sites of varying sizes totaling 27,549 acres distributed throughout the Chesapeake Bay and tributaries (Appendix A). There are currently 17 restoration partners involved with the Sanctuary Program. In addition, the Potomac River Fisheries Commission (PRFC) has established five sanctuaries in the mainstem of the Potomac River. Most of the Maryland sanctuaries have had restoration activities associated with them, including habitat improvements and/or oyster plantings when appropriate. Planting records of shell and oyster seed quantities and expenses are on file at MDNR.

The MDNR Shellfish Program presently monitors 13 individual oyster bars in the Maryland Sanctuary Program during the annual Fall Oyster Survey (Fig. 1). In addition, several bars within larger multiple-bar sanctuaries such as Zone A of various Oyster Recovery Areas (ORA) are also surveyed. Another two sanctuary bars that had been monitored for several years subsequently became impractical to sample during the Fall Survey.

Many of the remaining sanctuaries have sampling or logistical constraints which exclude them from the Fall Survey. For example, some have been planted with alternative cultch material such as reef balls and concrete rubble that cannot be sampled with the oyster dredge used on the Fall Survey. The University of Maryland monitors several of these sanctuaries with a diver-based survey that is more appropriate for these types of substrate (Paynter, 2005).

For a detailed description of the Fall Survey sampling method see Tarnowski (2003). Briefly, a known volume of material (both shell cultch and oysters) is taken from the dredge sample and sorted through. Both live and dead oysters are enumerated according to broad age/size categories (spat, smalls, markets) and the counts are standardized to one bushel of dredged material. The percent observed oyster mortality is calculated as: [(# dead)/(#live + #dead)] * 100. Disease status is extrapolated from nearby disease sentinel sites.

Because some sanctuaries have had multiple enhancement actions, each treatment area within a sanctuary is sampled separately. Three open-harvest areas with several years of survey data also have been included for comparison with nearby sanctuaries.

Relative biomass estimates (grams dry weight/bushel of dredged material) on the oyster bars were calculated for each general size/age category (markets, smalls, spat) based on height/ dry weight relationships obtained from a previous study by the Sarbanes Cooperative Oxford Laboratory, the average heights of each size category recorded during the Fall Survey, and the number of oysters/bushel in each size category (Table 1):

Biomass (gdw/bu) = $w_{hm}*n_m + w_{hs}*n_s + w_{h0}*n_0$, where

w_h = grams dry weight for the average height of each size/age-category

n = number of oysters/bushel material in each size/age-category

m = market size/age-category oysters (≥ 76 mm shell height)

s = small size/age-category oysters (≥ 1 year old < 76 mm shell height)

0 = spat size/age-category oysters (< 1 year old)

To calculate the sanctuary biomass index (B.I.), the combined biomass of smalls and markets was divided by the 1994 baseline biomass (84.4 gdw/bu.).

Biomass Index (B.I.) = $(b_m + b_s)/(b_{1994})$, where

b_m = market oyster biomass

b_s = small oyster biomass

b_{1994} = 84.4 gdw/bu. (avg. biomass of small and market oysters in 1994).

The 1994 B.I. of 1.0 is the metric used to measure progress toward the goal of a ten-fold increase in oyster biomass (i.e. B.I. 10.0).

The layout of this report follows the OMP convention of categorizing sanctuaries functionally according to their salinity regimes (Fig. 2) (CBP, 2004). As defined in the OMP, these are as follows:

Zone 1 (5 ppt to < 12 ppt) – increase biomass, enhance reef habitat through stocking and long-term survival.

Zone 2 (12 ppt to 14 ppt) – transition area with elements of Zones 1 and 3.

Zone 3 (>14 ppt) – develop disease resistance by concentrating and protecting large numbers of individuals with potential for disease resistance, enhance reproduction and spat settlement.

This report presents the results of a representative sampling of sanctuaries in these three categories. Only individual bar sanctuaries that have been assessed during the MDNR Fall Oyster Survey are treated in this report (Appendix B). Because of their complexity, multiple bar sanctuaries such as the ORA's are not included in this report.

RESULTS

Zone 1 (18 sanctuaries/20,167 acres)

Chinks Point Sanctuary

This sanctuary, originally established as an individual bar in the mouth of the Severn River, has since been incorporated into the larger Severn River Sanctuary. Because of the four-year drought (1999 – 2002) followed by high freshwater runoff years (2002 – 2004), the recent salinity regime of this bar has categorically fluctuated between Zone 1 and Zone 2. The substrate was rehabilitated with a dredge shell planting in 1998; that year the Fall Survey found no oysters on the bar. This was followed up with two seed oyster plantings in 1999 using natural seed and hatchery-reared seed.

The seed oysters appear to have suffered considerable losses in the first year after planting (Fig. 3). Although the observed mortality was low in 2000 (Fig. 4), the number of live oysters/bushel dropped substantially. This suggests that in this case the observed mortality underestimated the true mortality. The fragile boxes of the small seed oysters probably did not remain articulated until the 2000 Fall Survey, skewing the observed mortality downward.

Observed mortality climbed sharply in 2001 and 2002, coinciding with high dermo disease levels on nearby Hacketts bar, a disease sentinel site (Tarnowski, 2003). Hacketts bar also had 13% prevalence of MSX disease in 2002, the first time it had been reported from that bar in 10 years.

While the elevated salinities of 2002 resulted in high disease levels, they also fostered a widespread spatfall in Maryland, including in the upper bay. Chinks Point experienced a very light set that year (App. B). Population levels have stabilized since then, resulting in a modest population of market-size oysters.

Alms House Sanctuary

Alms House bar, in the South River, received a fresh-shell planting in 1997. Oyster counts per bushel on the natural portion of the bar showed some decline between 1999 and 2001, when observed mortalities shot up from 12% to 60% (App. B). This bar was incorporated into the larger South River Sanctuary and was subsequently dropped from the Fall Survey.

Strong Bay Sanctuary/ Wickes Beach open-harvest bar

Strong Bay, located in the lower Chester River, was planted with dredge shell in 2002. It received a light set that year, an unusual occurrence in that river (Fig. 5). This was augmented with a hatchery-reared seed planting in 2003. Although the observed mortality was low in 2004, the oyster count dropped substantially, similar to what occurred after the first year on Chinks Point (App. B).

Wickes Beach is an open-harvest bar in the lower Chester River near Strong Bay. The bar was planted with natural seed in 1998, which experienced considerable mortalities in 2001 and 2002 at the height of the dermo disease epizootics (Fig. 5; App. B). This bar will be used as a comparison site to evaluate the Strong Bay Sanctuary after it matures.

Ringgold Sanctuary

Ringgold was a natural, unimproved bar when it was monitored by the Fall Survey. Located upriver from Strong Bay in the middle portion of the Chester River, it nevertheless suffered heavy observed mortalities approaching 60% in 2002, leaving the bar severely depleted of oysters (Fig. 6; App. B) . This bar has had restoration activities including two plantings with stones as alternative cultch in 2003. Consequently, this sanctuary was dropped from the Fall Survey that year.

Cambridge Sanctuary

This sanctuary consists of two bars – Green Marsh and Shoal Creek. These have been long-time closures by Maryland Department of the Environment (MDE) for public health reasons due to the proximity of the Cambridge sewer outfall. In the past there have been occasional state-sponsored programs to move “pollutes” from these bars and relay them on bars in approved clean waters, where the oysters could depurate bacteria before harvesting for human consumption. This practice has since been dropped with the establishment of the sanctuary.

Oyster populations on Green Marsh, a natural, previously unimproved bar located just downriver of the Rt. 50 bridge, remained relatively low but stable between 1997 and

2001 (Fig. 7), then crashed in 2002 when the observed mortality peaked at 73% (Fig. 8). In 2002, MSX disease had infected 53% of examined oysters on the nearby Sandy Hill disease sentinel bar and was found as far as Oyster Shell Point, several miles upriver from Green Marsh. Dermo disease levels were extremely high at these sentinel sites in both 2001 and 2002 (Tarnowski, 2003).

A dredge shell planting on Green Marsh in 2002 caught a light spat set (Fig. 7). This cohort was supplemented in 2003 with a hatchery-reared seed planting. Survivorship appears to have been good over the year following the planting, without the sharp post-planting drop in counts seen on Chinks Point and Strong Bay.

Shoal Creek, on the upriver side of the Rt. 50 bridge, has also received both habitat and population enhancements. A 1998 dredge shell planting was followed by a 1999 natural seed planting. A second seed planting, this time from the Horn Point hatchery, was made in 2001 (Fig. 9).

Shoal Creek oysters began to experience elevated observed mortalities in 2000 (Fig. 10). An apparent dip in observed mortality in 2002 (the highest mortality year on record in Maryland) was probably due to the 2001 hatchery seed, which contributed enough live oysters to the counts in 2002 to lower the mortality rate. Nevertheless, actual counts/bushel in 2002 were considerably lower than the previous year - another example of the post-planting decline of seed oysters observed on other bars. Despite these mortalities, the oyster counts on the planted areas have remained consistently higher than on a natural, unimproved section of the sanctuary (Fig. 9).

Senator Paul J. Bailey Sanctuary

This sanctuary, situated off Trent Hall near the upper oyster-growing reaches of the Patuxent River, was planted with hatchery-reared seed in 2002. These oysters appear to be surviving, with good oyster counts per bushel of material (including a few market-sized individuals) and no observed mortality in 2004 (App. B). A sample of oysters taken during the 2004 Fall Survey found no disease on this sanctuary.

Heron Island Sanctuary

Heron Island Sanctuary, in the middle oyster-growing portion of the Potomac River near the Maryland shoreline, was established in January, 1996 under the auspices of the Potomac River Fisheries Commission. It was reopened in December, 2001 to hand tonging with an 18 ft. restriction on the length of the tong shafts. Therefore, the area within the bar that cannot be reached by hand tongs is still an oyster sanctuary. Since the re-opening of the sanctuary, when the first day's catch was less than ten *oysters* per boat, fishing mortality has been non-existent (A.C. Carpenter, PRFC, pers. comm.). The MDNR Fall Survey has been sampling two areas within the sanctuary. One section that is too deep for hand tonging was planted with fresh shell in 1996, while the other, shallower area is unimproved.

This sanctuary is in the worst condition of any monitored during the Fall Survey. Although no spat have been found on this bar since at least 1996, the occasional presence of a few small oysters indicates that a very light spat set occurs sporadically (Fig. 11). However, there has not been enough recruitment to boost or even maintain the population. The population on the 1996 planting, which had always been sparse, is now essentially extirpated. The unimproved area, which had a larger oyster population, experienced high observed mortalities culminating at 85% in 2002 (Fig. 12); no live oysters were found in 2004.

Zone 2 (9 sanctuaries/6,317 acres)

Neal Addition Sanctuary

Located in the middle portion of the Patuxent River estuary, this sanctuary was improved with dredge shell and hatchery-reared seed in 1999. Counts remained high in the following year and there was no observed mortality (Fig. 13). In 2001, these oysters suffered nearly 50% observed mortality consistent with a sharp decline in live counts (Fig. 14). By 2002, their third year, the population was decimated, with the observed mortality reaching 94%. The Broomes Island disease sentinel bar slightly upriver from the sanctuary had been heavily infected with dermo disease since 1999 and had MSX disease in three of those four years; the observed mortality in 2002 was 72%.

The Neal Addition Sanctuary received some light natural spat sets in three successive years from 2001 to 2003, which, combined with recent lower mortalities, has resulted in modestly higher oyster counts in 2003 and 2004 (Fig. 13).

Mill Hill Sanctuary

Mill Hill in Eastern Bay was established as a sanctuary to protect the abundant 1997 year class on that bar. More recently, a number of experimental plots within the sanctuary were developed to test alternative cultch materials and planting techniques. Because of the experimental nature of these plantings and the problems associated with dredging on them, the Fall Survey effort focused on an old 1988 dredge shell planting in the sanctuary. This bar received a tremendous spat set in 1997, despite the fact that the cultch planting was nine years old (Fig. 15). Again, total counts dropped sharply after one year despite a low observed mortality (Fig. 16). Unfortunately, observed mortalities began to climb in 1999, peaking at 58% in 2002. These mortalities coincided with high dermo disease levels at the nearby Parsons Island disease sentinel bar, which also had some MSX disease in 2001 and 2002.

Oyster counts steadily dropped to a low in 2002. Since then the counts have climbed slightly and appear to have stabilized due to disease abatement and some light spatfalls (Fig. 15). Only a relatively low percentage of the oysters have survived to market size over the years. Despite the huge broodstock potential of the 1997 year class and higher salinities thought to be favorable to recruitment, spat sets have been disappointing since then. The otherwise widespread spatfall of 2002 failed to produce any spat on Mill Hill.

Cook Point Sanctuary

This is the site of an artificial reef constructed in 1997. Four large mounds of dredge shells were planted with hatchery-reared seed that same year. Few oysters were found during the 2004 survey. The adjacent Cook Point disease sentinel site had100% observed mortality in 2002 (App. B).

Poplar Island Sanctuary

This recently established sanctuary received a dredge shell planting in 2003. Few oysters were found during the 2004 survey (App. B).

Point Lookout Sanctuary

Although in Zone 2, this sanctuary is treated with two other legislated power-dredge sanctuaries in Zone 3 below.

Zone 3 (4 sanctuaries/1,273 acres)

The Legislated Power-Dredge Sanctuaries –

Piney Island East Addition, Northwest Middle Ground, Point Lookout

Power dredging was expanded by the Legislative Acts of 1999 into three counties: Calvert (Ch. 407), St. Mary's (Ch. 478) and Dorchester (Ch. 633) and was renewed in Somerset County (Ch. 580). In addition to creating the power-dredge zones, the laws provided for the establishment of oyster sanctuaries within the power-dredge zones and required the institution of an oyster buy-back program.

Three of the power-dredge sanctuaries are monitored by the Fall Survey - Piney Island East Addition (PI) in Tangier Sound (Somerset County), Northwest Middle Ground (NW) in the bay mainstem east of the shipping channel (Dorchester County), and Point Lookout (PtL) on the lower western shore (St. Mary's County). Bottom habitat was improved with dredge shell plantings on all three sanctuaries: PI in 2000 and 2002, PtL in 2001, and NW in 2002. The timing of these plantings was serendipitous – three of the four plantings received spat sets in the same year they were made. Spat counts ranged from fair on PtL (198/bu.) (Fig. 17) to very good on NW (948/bu.) (Fig. 18). The benefit of planting shell in good recruitment years is readily apparent at PI, where spat counts on the newly shelled area in 2000 was 492/bu., whereas counts on an adjacent unimproved plot were 18/bu (Fig. 19). However, the unimproved plot outperformed the 2002 shell planting, which suffered a recruitment failure despite the generally fair spatfall around the bay that year. The shell plantings on PI continued to attract light spat sets in subsequent years, although the sets on the plantings were comparable to the unimproved area in intensity. An adjacent open-harvest bar also received good spat sets on coincident shell plantings (1999, 2000) and later (Fig. 20). The other two sanctuaries followed the more general baywide pattern of little or no spatfall in 2003 and 2004

The oyster populations that resulted from the good spat sets on PtL and NW have benefited from low disease pressure in 2003 and 2004. Oyster samples taken from these sanctuaries during the 2004 Fall Survey had very low levels of Dermo disease and no MSX disease. Observed mortalities have been running under 10% (Fig. 21; App. B). Consequently, these sanctuaries have thriving populations of oysters.

The situation on PI is quite different. The oyster population in this sanctuary follows the classic pattern of dynamics in high disease areas. A good spat set develops into a large population of small, one to three year old oysters. Disease inflicts heavy mortalities so that few attain market size (Fig. 19). As a result, there is little increase in biomass as the older oysters are constantly cropped off by Dermo disease and all ages of oysters are periodically decimated by MSX disease. This pattern continues on PI even though other bars around the bay have had low disease levels and low mortalities over the last two years (MDNR, unpub. data). Oyster samples taken from PI during the 2004 Fall Survey found high levels of Dermo disease, which would help account for the nearly 60% observed mortality that year (Fig. 22). Thus, live oyster counts and population structure within the sanctuary on the 2000 shell planting, the 2002 shell planting, and the unimproved plot were approximately the same in 2004 (Fig. 19) and only marginally better than a nearby open-harvest area (Fig. 20).

At Point Lookout, the 2004 live oyster counts in an open-harvest area adjacent to PtL were comparable to counts in that sanctuary (Fig. 17). The open area received a shell planting and spat set in 2002 and since these oysters had not reached market size, there had not yet been any harvesting activity on that plot. Ignoring new recruitment, the difference in counts between the open and closed areas would be expected to start diverging next year as the open area oysters reach market size and are harvested, unless disease and/or illegal harvesting were to remove oysters from the sanctuary.

The Legislated Power-Dredge Sanctuaries –

Buy-backs

The legislation creating the power-dredge zones required that some oysters harvested in these zones be purchased back from the watermen and planted in the newly established sanctuaries. The underlying concept behind the buy-back program was that because these oysters had reached market size in the high-disease regions of southern Maryland, they had been selected for some measure of disease tolerance. Placing these larger survivors in a sanctuary would allow them to serve as broodstock to produce disease tolerant offspring. By concentrating the buy-back oysters within the sanctuary, the fertilization efficiency among the disease tolerant individuals would be improved, while reducing the chances of fertilization by less disease tolerant individuals.

A total of 495 bushels were purchased during the 1999-2000 season. The cost, totaling $12,368, was almost evenly divided between the MDNR Shellfish Program and the Chesapeake Bay Foundation. The Northwest Middle Ground, Point Lookout, and Piney Island East Addition Sanctuaries each received 165 bushels, with counts varying between 45,000 and 50,000 oysters per sanctuary. The average shell heights of the six groups of plantings were between 89.3 mm and 92.5 mm.

The high disease pressure during this period severely tested the buy-back project. Dermo disease, which is highly contagious between oysters, could readily spread among the concentrated buy-backs and MSX disease was at elevated levels at nearby disease sentinel bars. Consequently, mortalities were generally very high (Fig. 23). In 2000, the first year of the buy-back program, observed mortalities ranged from 48% on NW, an isolated bar in the middle of the bay, to almost 60% on PI and PtL. By 2001, the observed mortality had climbed to 63% on NW and a devastating 81% on PI; PtL remained about the same as the previous year. These mortality estimates were similar or even higher than nearby bars. For example, the Piney Island East disease sentinel bar had observed mortalities of 27% in 2000 and 12% in 2001, while Butlers, a disease sentinel bar not far from PtL had 67% and 32% mortalities in those years, respectively (Tarnowski, 2003). Combining all the surveyed bars within a region (MDNR, unpub. data), observed mortality estimates are compared with buy-backs from within its region in the table below:

Market Oysters Observed Mortality		
Sanctuary and Associated Region	**2000**	**2001**
NW Middle Ground Buy-backs	48%	63%
Lower Bay East	48%	51%
Point Lookout Buy-backs	58%	62%
Lower Bay West	64%	42%
Piney Island East Add. Buy-backs	58%	81%
Lower Tangier Sound	46%	37%

Buy-back monitoring was dropped after 2001.

Kitts Creek East Sanctuary

Located in Pocomoke Sound, Kitts Creek East is another higher salinity sanctuary. This bar received seed plantings in three successive years from 1998 to 2000. Live oyster counts dropped sharply in 2001 and bottomed out in 2002 (Fig. 24), when the observed mortality peaked at 60% (Fig. 25). Dermo disease at the nearby Marumsco disease sentinel bar was extremely high during this period (reaching an intensity of 5.0 on a scale of 0 – 7.0 at 100% prevalence in 2001) and MSX disease was also active (Tarnowski, 2003).

Light spat sets in most years, especially in 2002, and lower mortalities in 2003 and 2004 have brought the oyster counts up to where they were in 1999 and 2001 (Fig. 24). Over the past six years only a relatively small percentage of oysters attained market size on this bar, with the market counts remaining fairly consistent among years.

DISCUSSION

Environmental conditions are the overwhelming determinants of whether sanctuaries are successful. In particular, freshwater flow into the bay is the foremost controlling factor in oyster recruitment, disease, and mortality. The impact of this was even more exaggerated in recent years, first with a four-year drought followed by an extended period of abnormally high freshwater input. In the face of such extraordinary conditions, the results from the sanctuaries have been decidedly mixed. The following discussion is based on the objectives for oyster sanctuaries set in the OMP that are tracked by the Fall Survey.

Increase Biomass

Increasing oyster biomass is the primary objective of the sanctuary program and is a component of the larger goal to achieve a ten-fold increase in oyster biomass in Maryland. This can be accomplished by protecting an existing population from harvesting and supplementing it with young oysters or by establishing a new population, in both cases either through shell plantings to encourage natural recruitment or seed plantings. Not surprisingly, shell plantings on the sanctuaries proved their value in attracting spat sets, performing well when the plantings were made in good recruitment years and even in succeeding years beyond the planting. This natural recruitment has established, supplemented, and/or maintained oyster populations on several sanctuaries. In areas of low recruitment, the general strategy on sanctuaries has been to establish or augment a population by planting seed oysters. This action was taken on a number of sites. Unfortunately, both natural seed and hatchery-reared seed often had significant declines in counts after one year. The result was that oyster numbers increased in the sanctuaries, but not as high as perhaps expected.

Many of these sanctuary activities took place during the four-year drought when disease levels reached record highs. Even normally low salinity/low disease areas such as the Chester River suffered as much as 60% mortalities. Conversely, certain sanctuaries in high disease/mortality areas - notably Point Lookout, NW Middleground, and Piney Island East Addition - have benefited from the high freshwater runoff of the last couple of years and have thriving oyster populations, but this seems to be a short-term exception. The more common scenario is the one at Mill Hill, where over the past eight years the sanctuary received a near record spatfall, only to see this population gain rapidly erode. By 2002 the number of oysters greater than one year old on Mill Hill was actually lower than in 1997, with a slight increase observed in subsequent years.

Table 1 lists the sanctuaries covered in this report that are generally (but not always, as noted in the table) more than two years old, along with their 2004 status regarding biomass trends. The baseline reference used to determine these trends is either: 1. the initial biomass on the sanctuary bar when it was established or improved with plantings, or 2. a nearby open-harvest bar at the time the sanctuary was established. The exception was Strong Bay, which was compared with 2004 data from an open-harvest bar. Also, 2004 biomass estimates are provided for open-harvest areas at Point Lookout and Piney Island East.

Seven of the eighteen sanctuary treatment plots showed an increase in biomass (ranging between 22% and 544%), two had no difference, and nine were actually lower when compared to either earlier levels on the sanctuary or nearby open-harvest bars. The 2004 biomass estimates for the open-harvest areas at Point Lookout and Piney Island East were comparable to the nearby sanctuaries (–5% and –19% differences from the respective sanctuaries).

Biomass indices ranged between 0.0 and 3.68 (Table 1). Two sanctuaries had indices above 3.0 and eight other sanctuary plots were above the baseline index. Two sanctuaries (Ringgold and Strong Bay) showed no real difference from the baseline B.I. and six sanctuary plots were below the baseline B.I. Thus, although half of the sanctuary treatment plots had lower relative biomasses compared to the reference bars, slightly more than half of the sanctuaries showed some improvement over the baseline biomass index.

The 2004 average B.I. for all sanctuary treatment plots (excluding Ringgold, which was not sampled in 2004) was 1.68. This represents 7% progress toward the target goal of achieving a ten-fold increase in oyster biomass on the sanctuaries. Considering the absence of fishing mortality, the length of time many of these sanctuaries have existed, and that most of these sanctuaries have received some form of improvement (seed, shell, or both), this result is not encouraging with respect to long-term increases in stock biomass. Furthermore, the three open-harvest areas in this evaluation have performed just about the same as their respective sanctuaries in terms of the 2004 B.I.

Table 1. Oyster sanctuary 2004 biomass status. Total biomass includes all size/age categories; biomass index (B.I.) is based on market and small oysters only.

Year	*Reference Bar*/ Sanctuary	Tot. Biomass gdw/bu	Change from Reference	Biomass Index ('94 baseline)
1999	*Chink's Point*	*347.27*		
2004	Chink's Pt. – avg. 2 plots	193.90	-44.2%	2.30
1996	Heron Island – '96 fsh	*14.07*		
2004	Heron Island – '96 fsh	1.18	-91.6%	0.01
1996	*Heron Island – unimproved*	*162.36*		
2004	Heron Island – unimproved	0.00	-100.0%	0.00
1999	*Ringgold*	*126.84*		
2002	Ringgold	90.75	-28.5%	1.08
2004	*Wickes Beach – open harvest*	*157.11*		
2004	Strong Bay	86.66	-44.8%	1.03
1997	*Green Marsh – unimproved*	*88.02*		
2004	Green Marsh – '03 hatch. seed	213.32	+142.4%	2.53
1997	*Shoal Creek – unimproved*	*48.04*		
2004	Shoal Creek - unimproved	58.64	+22.1%	0.69
1999	*Shoal Creek – '99 seed*	*269.63*		
2004	Shoal Creek – '99,'01 seed	279.72	+3.7%	3.3
1997	Mill Hill	*456.55*		
2004	Mill Hill	136.94	-70.0%	1.62
1997	*Cook Point – open harvest*	*53.21*		
2004	Cook Pt. Sanc.–'97 hat. seed	7.72	-85.5%	0.09
2000	*Neal Add. – '99 hatch. seed*	*510.57*		
2004	Neal Add. – '99 hatch. seed	64.31	-87.4%	0.76
1999	*Pt. Lookout – open harvest*	*48.26*		
2004	Pt. Lookout – open harvest	293.43	+508.0%	3.48
2004	Pt. Lookout – sanctuary	310.77	+543.9%	3.68
2002	NW Middle Ground – '02 dsh	*75.84*		
2004	NW Middle Ground – '02 dsh	209.74	+176.6%	2.49
1999	*Piney Isl. E. – open harvest*	*33.42*		
2004	Piney Isl. E. – open harvest	106.40	+218.4%	1.26
2004	Piney I. E. Sanc.– avg. 3 plots	131.37	+293.1%	1.56
1999	*Kitt's Creek East*	*175.98*		
2004	Kitt's Creek East	166.89	-5.1%	1.98
2004	**Avg. all sanctuaries**[a]	**142.82**		**1.68**

[a] Average of all treatment plots (n=17) within sanctuaries in this table. Ringgold was not included since sampling was discontinued after 2002.

In summary, biomass has increased on many of the sanctuaries, but at much lower levels than anticipated, especially in the lower salinity zones. Furthermore, four of the top seven B.I. sanctuaries are in normally high disease areas, where the favorable conditions of the past two years can be expected to regress in the future, along with the oyster biomass. Although an area such as Point Lookout demonstrates the potential of sanctuaries to increase biomass, its location does not bode well for its long-term prospects. Overall, the sanctuary program to date has fallen far short of its stated goal of contributing to the ten-fold increase in oyster biomass in Chesapeake Bay.

Disease Resistance

One of the goals for establishing sanctuaries in high disease areas is the development of disease resistant oysters through natural selection. According to the OMP, this is to be accomplished by planting "high numbers of individuals with potential disease resistance…at high densities."

The premise behind the buy-back project was that larger oysters harvested from disease-infected waters were survivors that had greater disease tolerance than their neighbors that had succumbed to the blights. Unfortunately, when planted in denser concentrations, buy-backs died at similar or even higher rates than oysters on nearby bars.

As to the efficacy of developing naturally selected, disease tolerant oysters, the OMP recognizes that this is a long-term process on the scale of many decades or longer. An evaluation is well beyond the scope of this or any future reports the author might submit. Suffice it to say that this is a complex issue with many theoretical pros and cons. Only time will tell as to whether it will succeed.

Broodstock Sanctuaries

Another stated objective of the sanctuary program is to protect broodstock for larval production. In addition to having more reproducing individuals, the higher densities in the sanctuaries should improve fertilization efficiencies, further enhancing the reproductive effort.

Whether the oyster population is broodstock limited has been argued over for the past two decades. Historically, oyster recruitment in Maryland tends to be episodic, with no discernable pattern related to the abundance of broodstock. Even after the late 1980's severe decline in oyster populations, as punctuated by the harvest record, substantial spat sets have continued to occur from time to time, such as in 1991 and 1997 (the second highest index on record). Even the high disease year of 2002 produced a decent spatfall, ranking fifth over the last 20 years. Yet the record high disease levels have devastated the oyster populations to an unprecedented degree. The question could be posed that, given the elevated salinities supposedly conducive to good recruitment that prevailed for four years, why weren't spat sets better (the spat indices for 2000 and 2001 were below the 20-year median)? Of course, oyster recruitment is controlled by a complex of factors that has defied prediction to date, and to single out any one factor as a causal agent runs the risk of hubris.

Despite the recent establishment and/or enhancement of numerous sanctuaries and the subsequent maturation of their oyster populations, there has been no evidence of far-field recruitment effects, that is, that the sanctuaries serve as larval sources for other bars. Spat indices during the past two years rank near the bottom of the 20-year record. However, these years were characterized by high freshwater flows, which could have dampened recruitment. Given the vagaries of spatfall in Maryland, it would be extremely difficult to evaluate the performance of broodstock sanctuaries and ascribe far-field effects to them without the use of sophisticated genetic techniques.

Overall Sanctuary Performance

To date, the sanctuaries established in Maryland have not manifested any of the anticipated benefits in significant ways. Instead, many of the sanctuary populations tend to look like natural populations in relatively short periods of time, regardless of the degree of habitat rehabilitation or population enhancement through additions of seed oysters. Perhaps this is a problem of scale, that is, if sanctuaries were a more substantial percentage of the total oyster habitat and more shell and seed oysters were available, goal progress would be more evident. Based on the Fall Survey data, however, the more likely reason is that those factors causing the severe decline in oyster populations are simply not addressed by eliminating fishing mortality. Oyster diseases don't recognize sanctuary boundaries.

REFERENCES

CBP 2004. Oyster Management Plan. Fisheries Management Planning and Coordination Workgroup, Chesapeake Bay Program. In draft.

Paynter, K. 2005. Monitoring report for Gales Lump, Strong Bay, Mill Hill, Dorchester, Somerset and St. Mary's Oyster Sanctuaries. Univ. Md., College Park. 13 pp.

Tarnowski, M. 2003. Maryland Oyster Population Status Report – 2002 Fall Survey. Annapolis, Md. 32 pp.

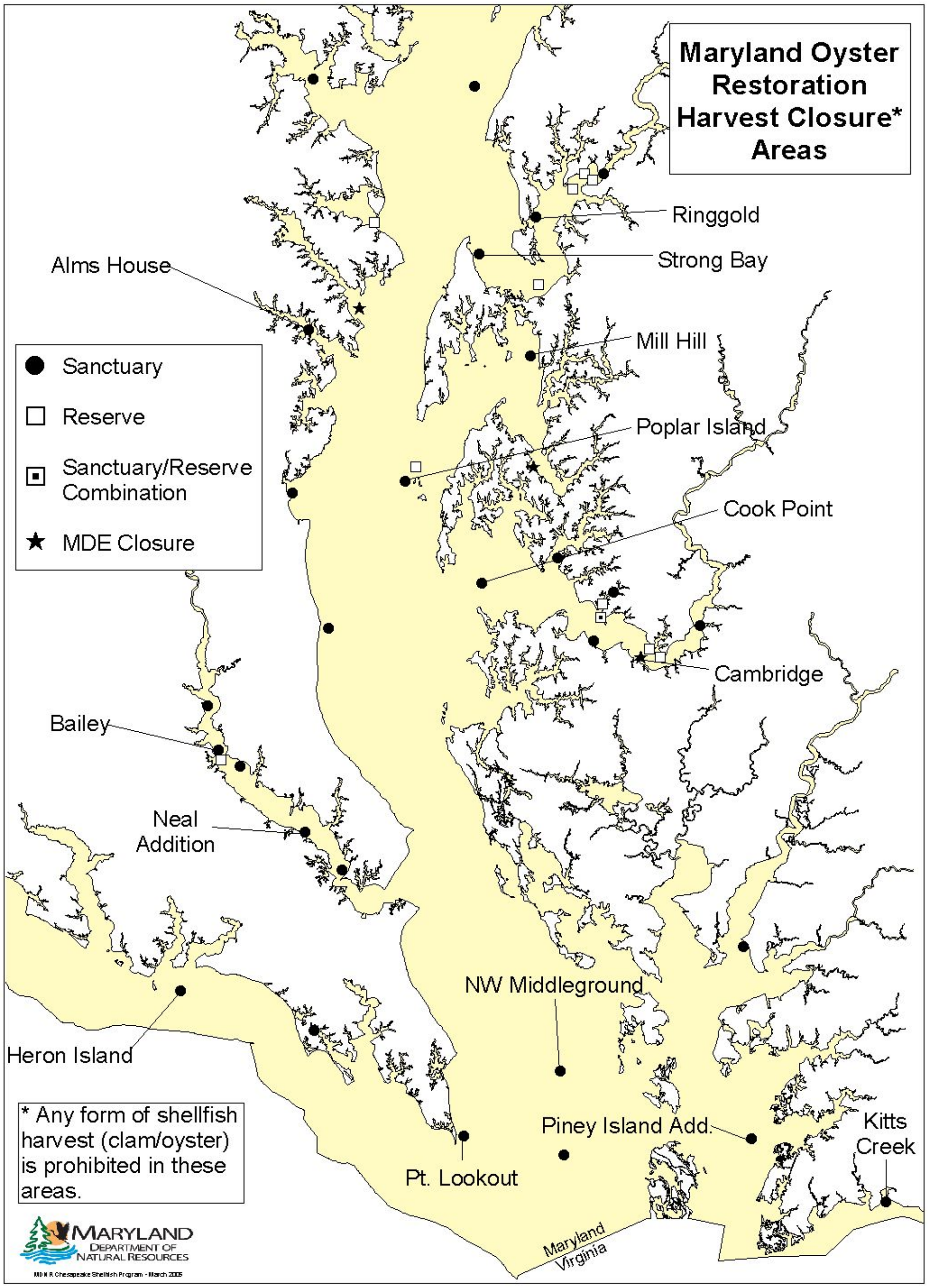

Figure 1. Location of sanctuaries in this report sampled during the MDNR Fall Oyster Survey.

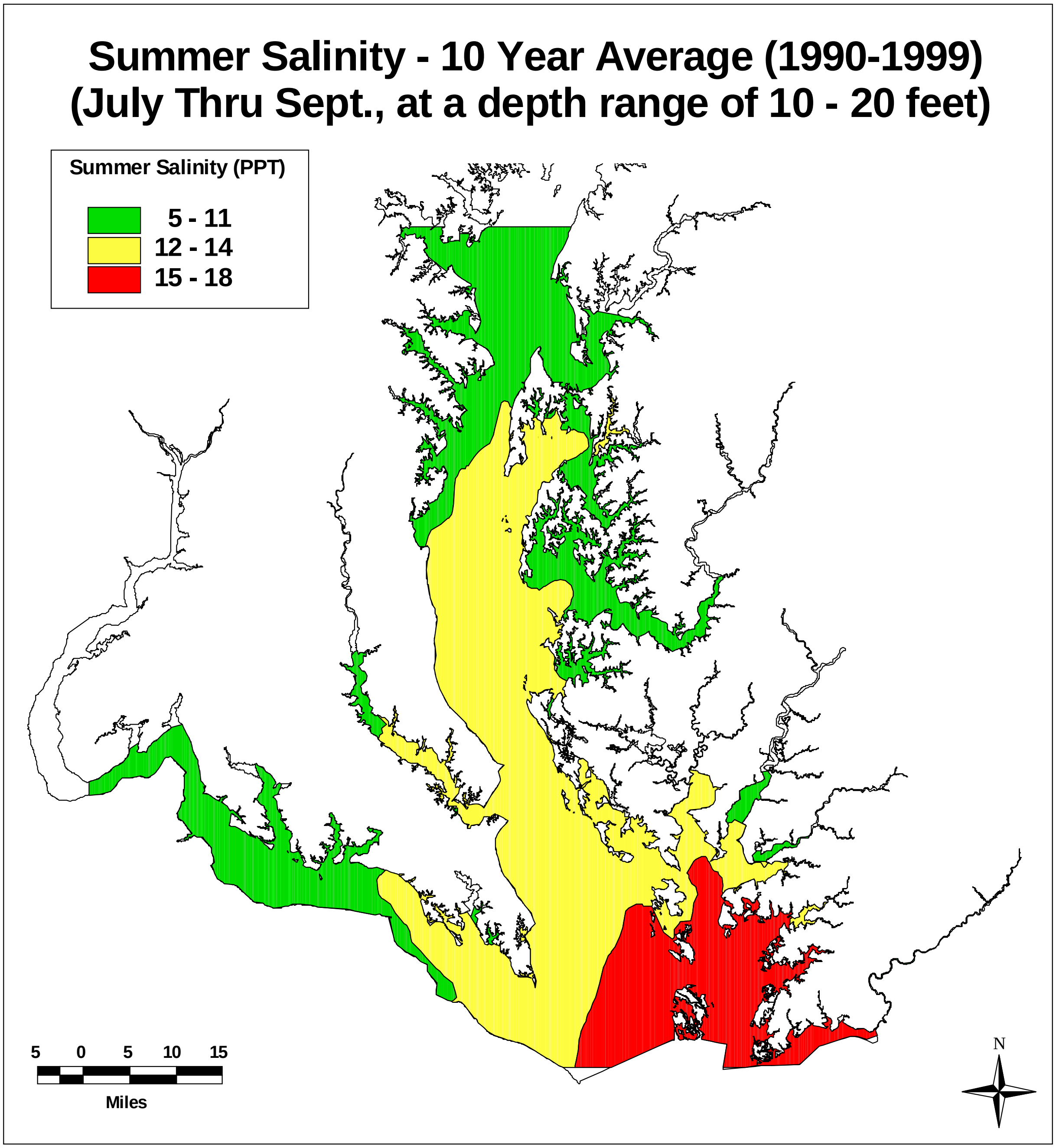

Figure 2. Salinity zones used to determine sanctuary management actions.

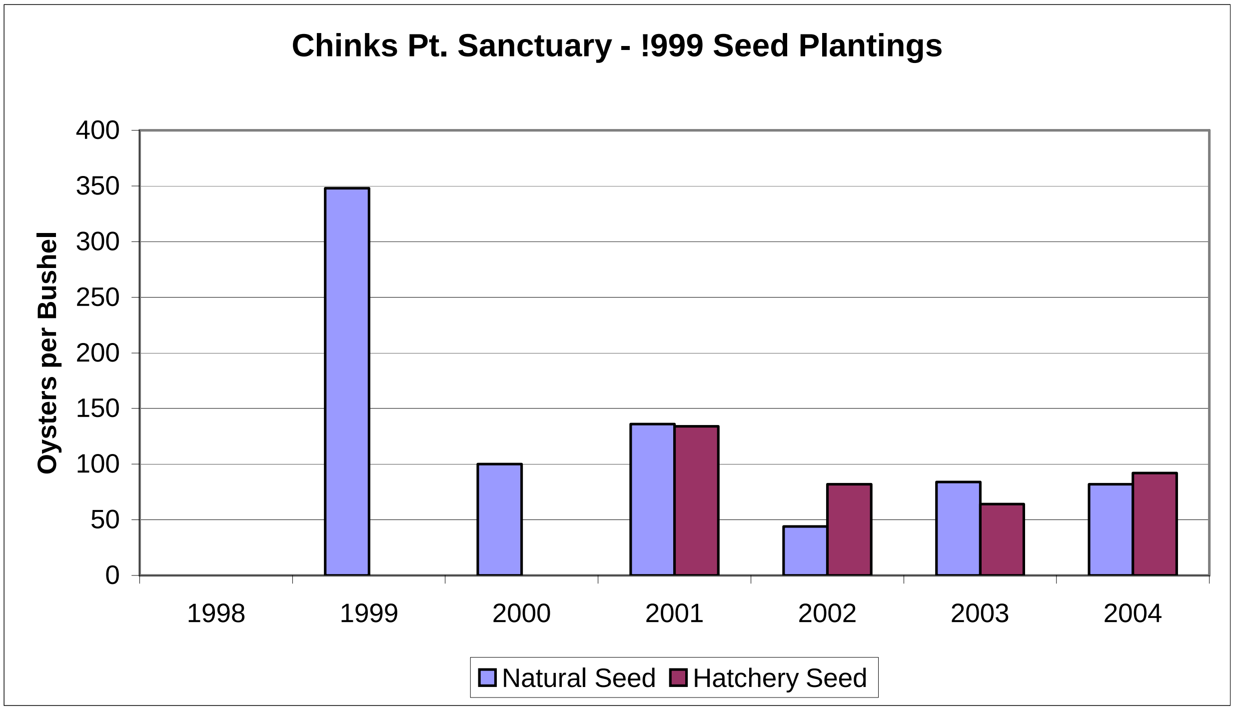

Figure 3. Chinks Pt. Sanctuary seed plantings. Hatchery seed were sampled during the Fall Survey beginning in 2001.

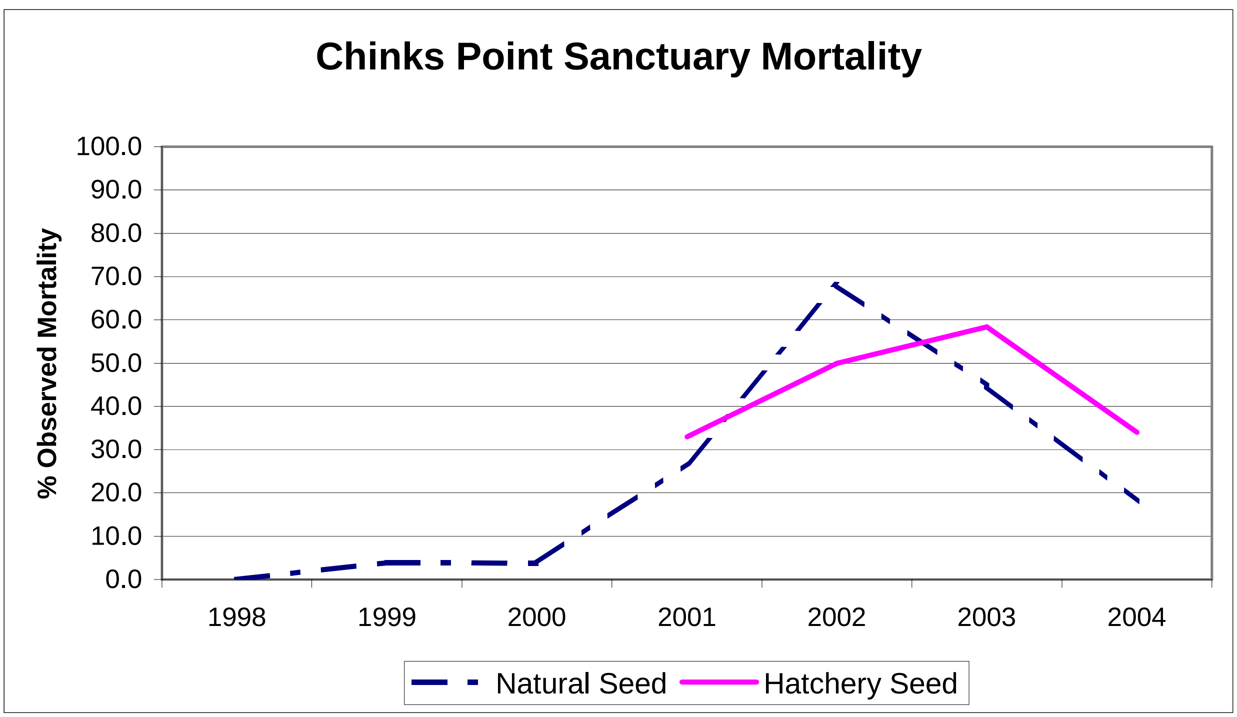

Figure 4. Chinks Pt. Sanctuary observed mortality estimates for smalls and markets.

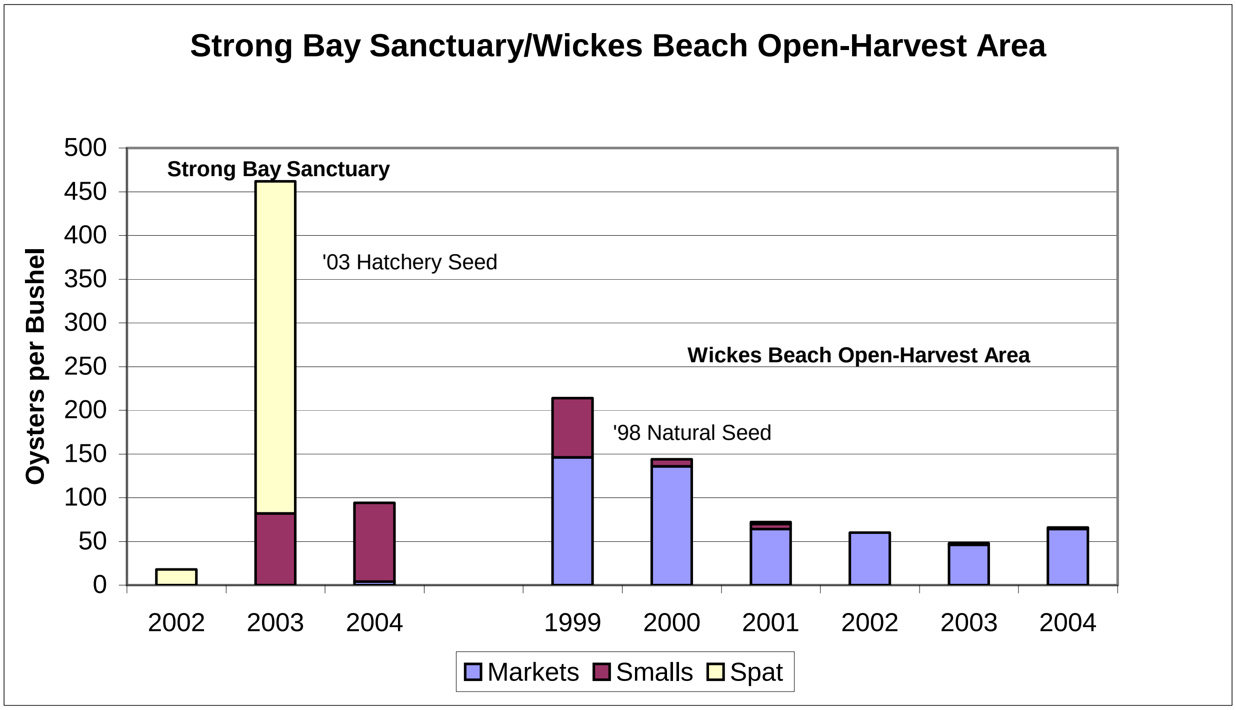

Figure 5. Fall Survey oysters per bushel counts on Strong Bay Sanctuary and Wickes Beach open-harvest area in the Chester River.

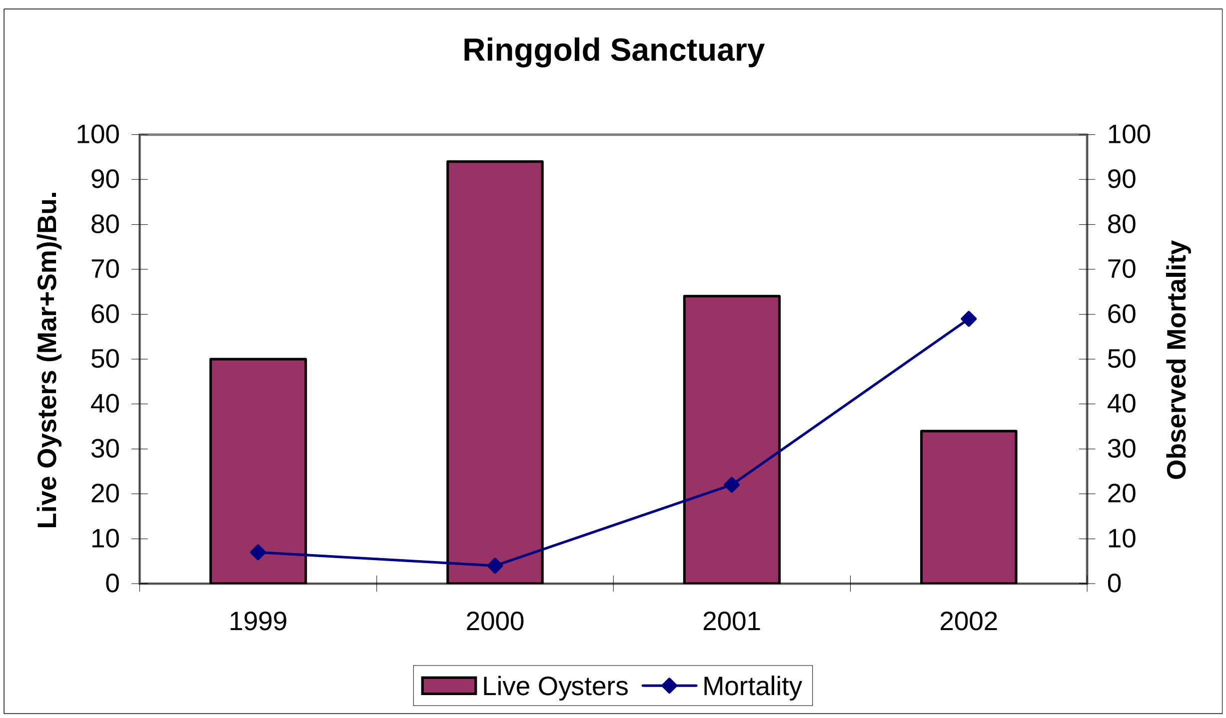

Figure 6. Ringgold Sanctuary combined live market and small oysters/bu. and observed mortality.

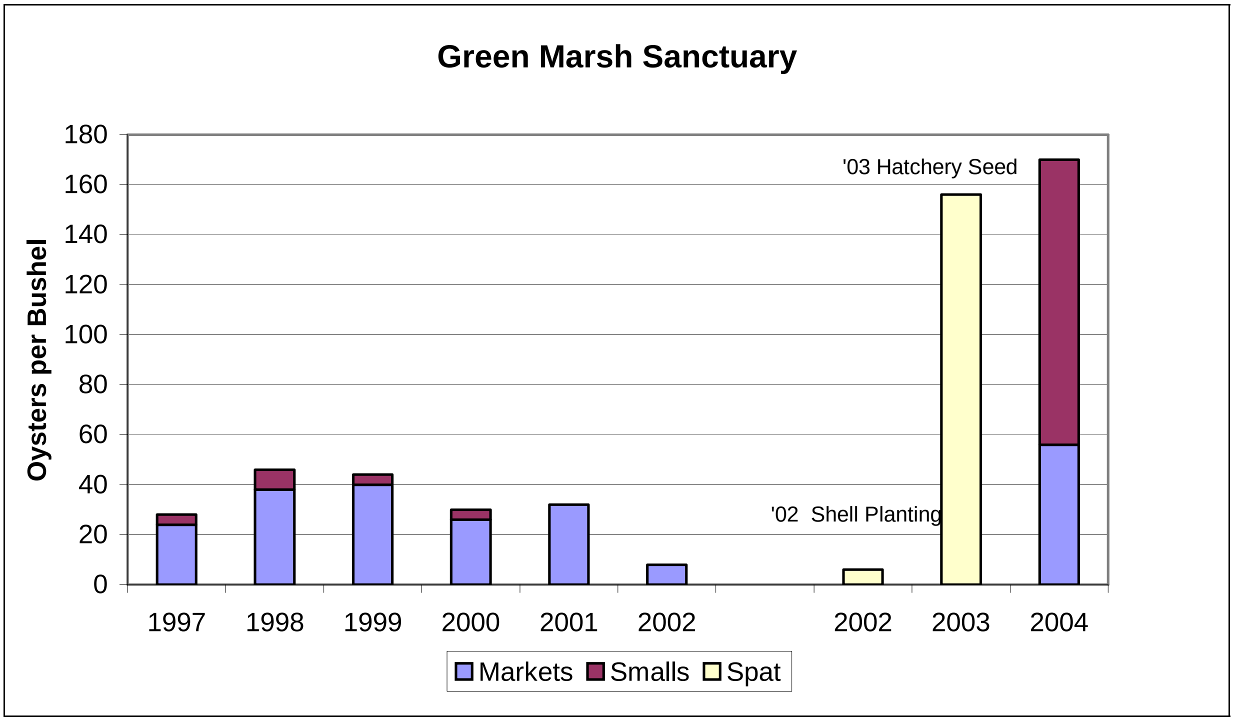

Figure 7. Oyster counts on Green Marsh bar (Cambridge Sanctuary) unimproved plot and subsequent shell/seed plantings.

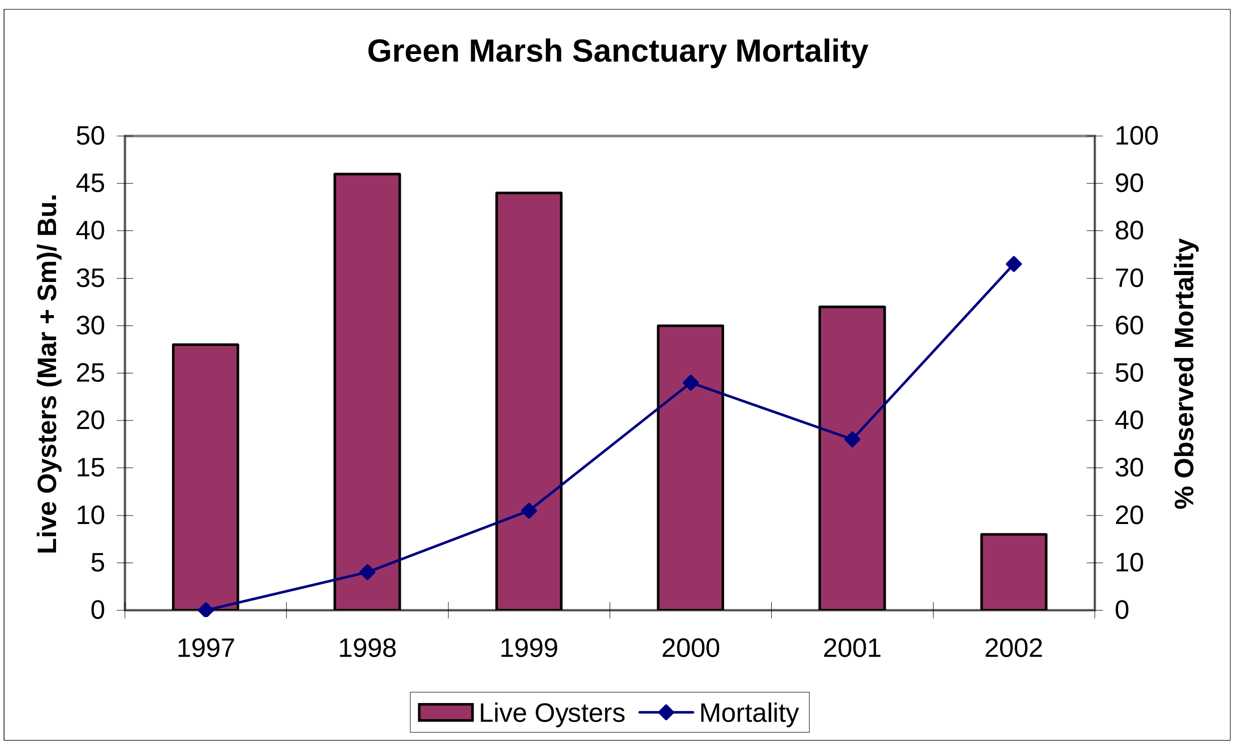

Figure 8. Observed mortality on Green Marsh bar for smalls and markets.

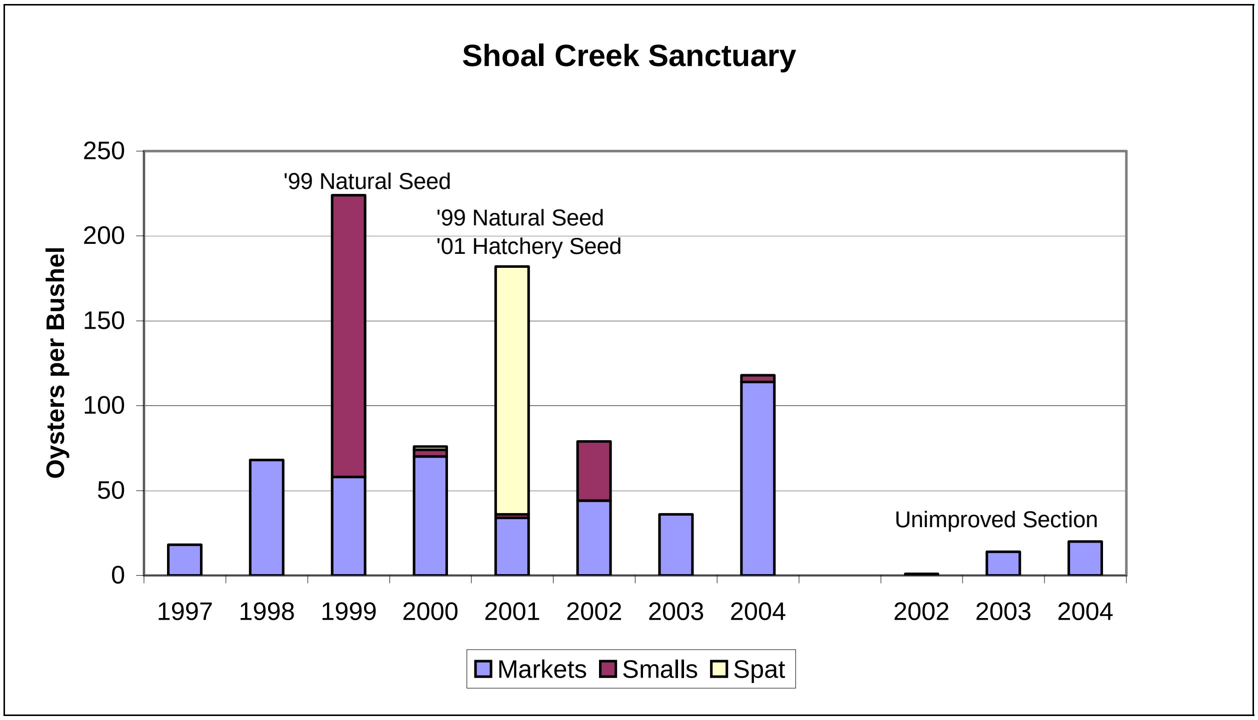

Figure 9. Oyster counts on Shoal Creek bar (Cambridge Sanctuary) enhanced vs. unimproved plots.

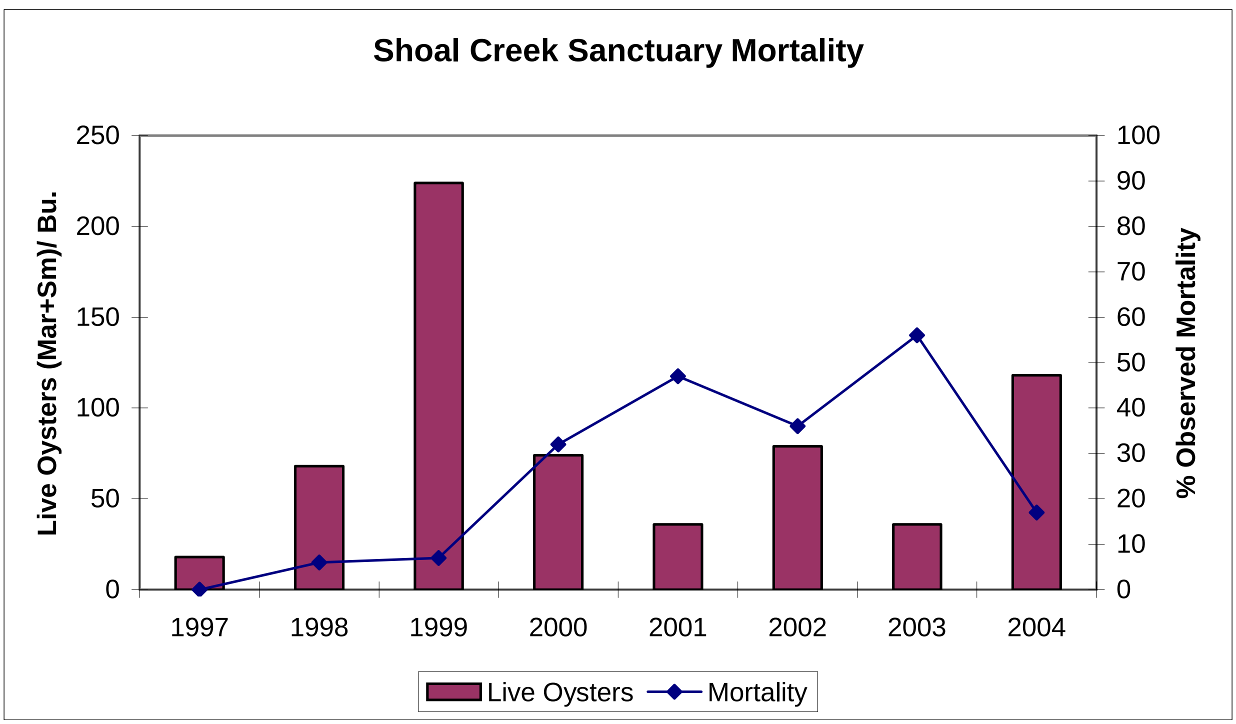

Figure 10. Observed mortalities of smalls and markets on enhanced section of Shoal Creek bar.

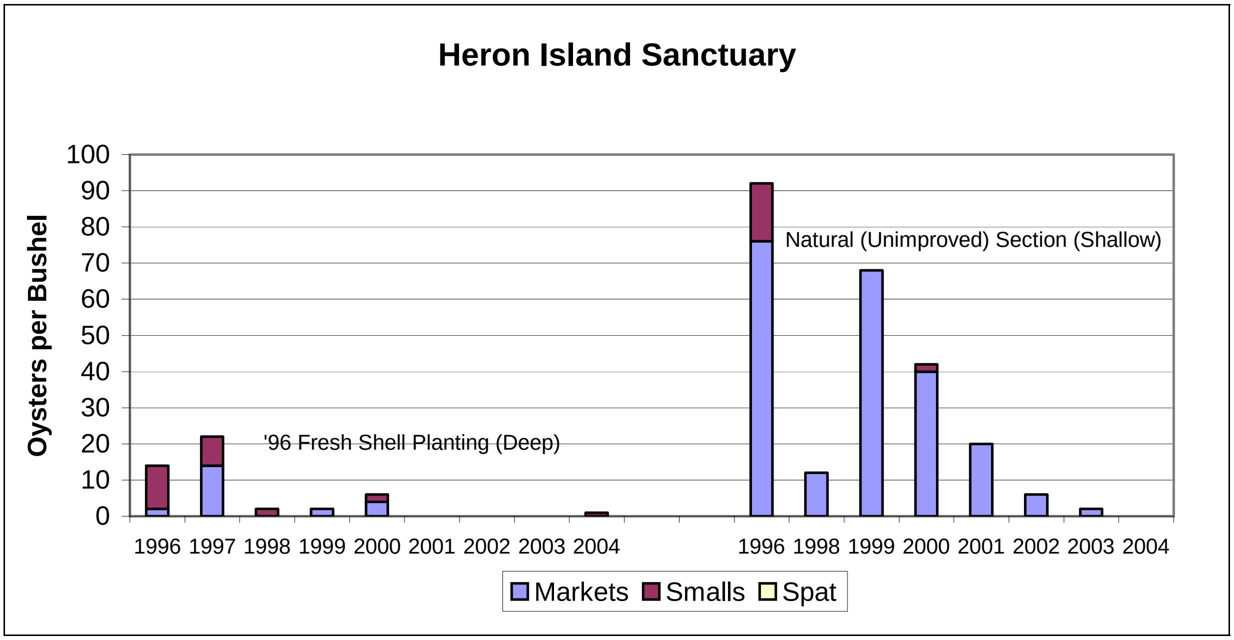

Figure 11. Oyster counts on Heron Island Sanctuary . Shell planting in deeper water remained a sanctuary; shallow area was re-opened to hand tonging in 2001.

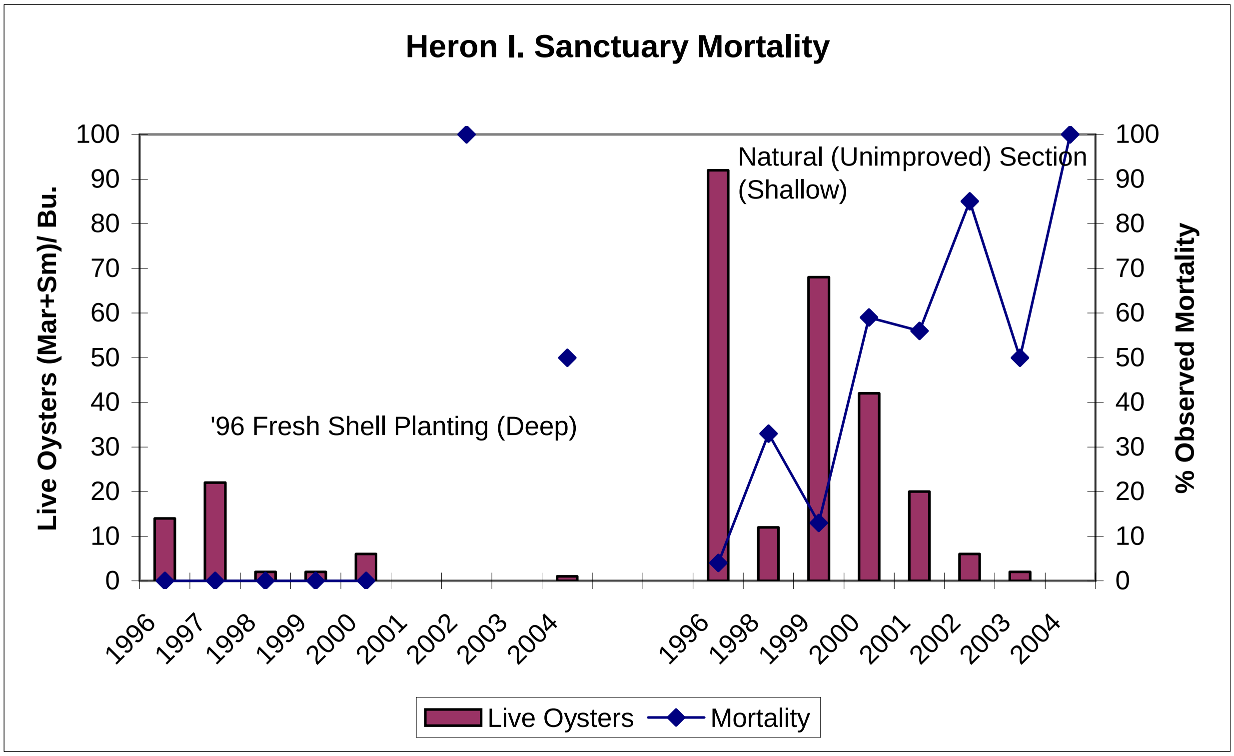

Figure 12. Observed mortality of smalls and markets on Heron Island Sanctuary. Box counts show effect of natural mortality on population in re-opened shallow section.

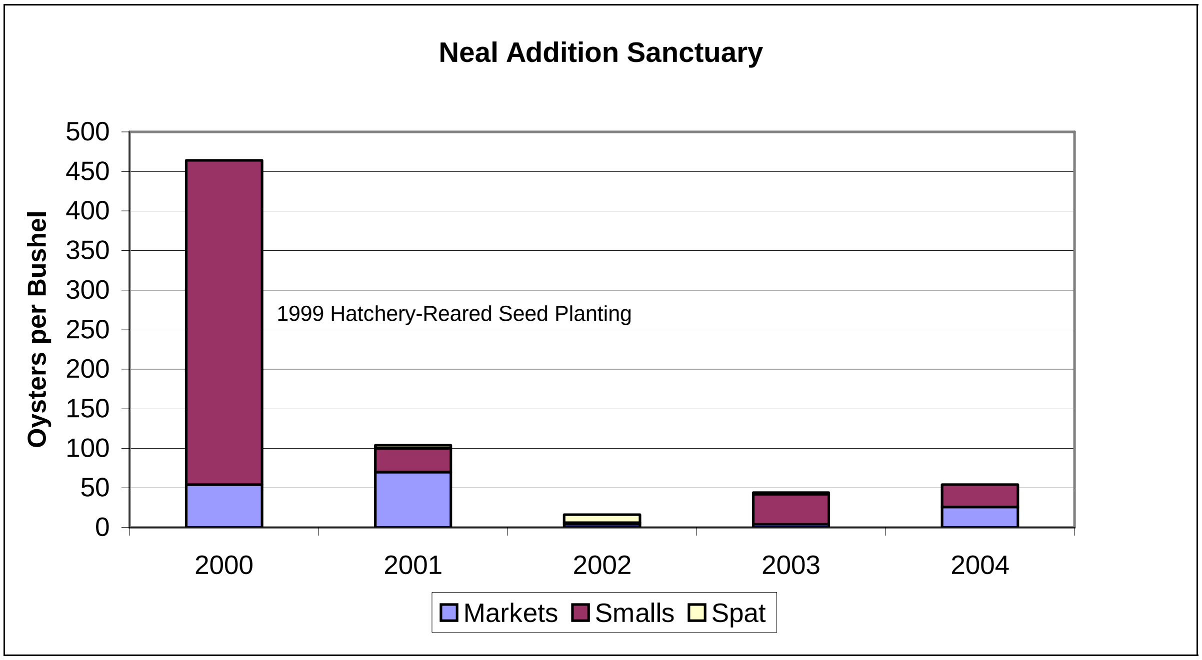

Figure 13. Neal Addition 1999 hatchery-reared seed planting counts and subsequent natural spatset.

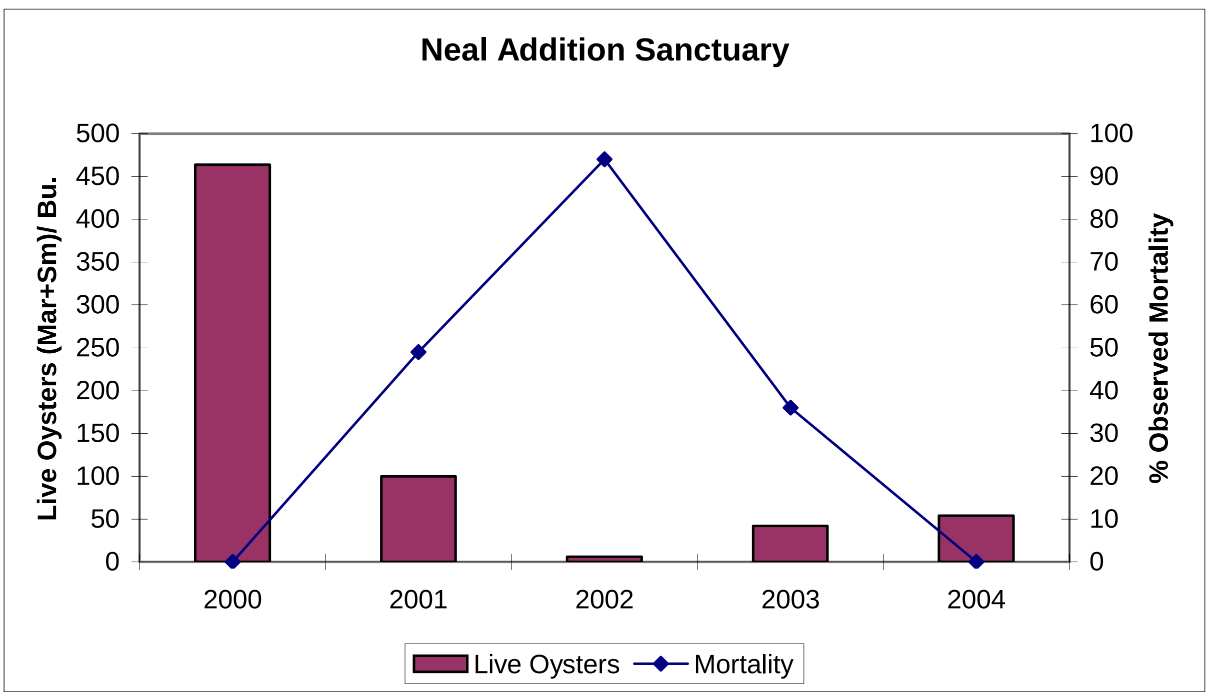

Figure 14. Observed mortality of smalls and markets on Neal Addition Sanctuary.

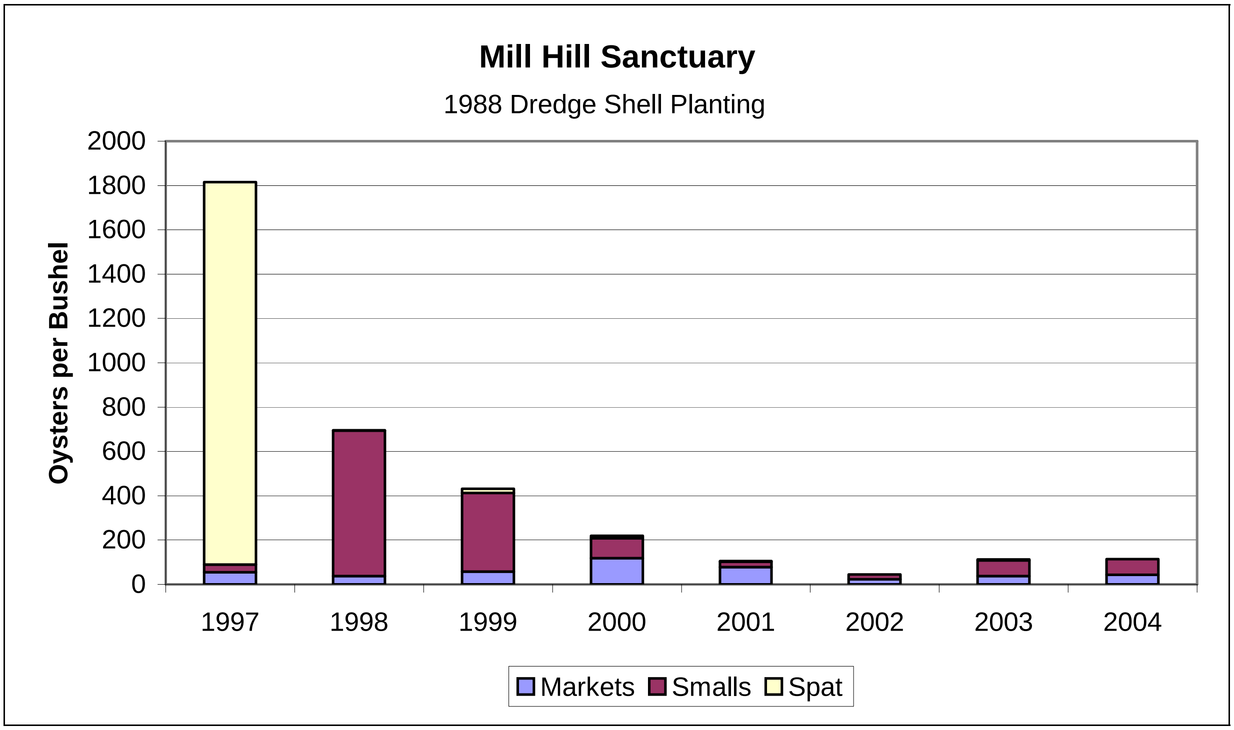

Figure 15. Mill Hill Sanctuary oyster population structure. Spat index in 1997 was second highest on record.

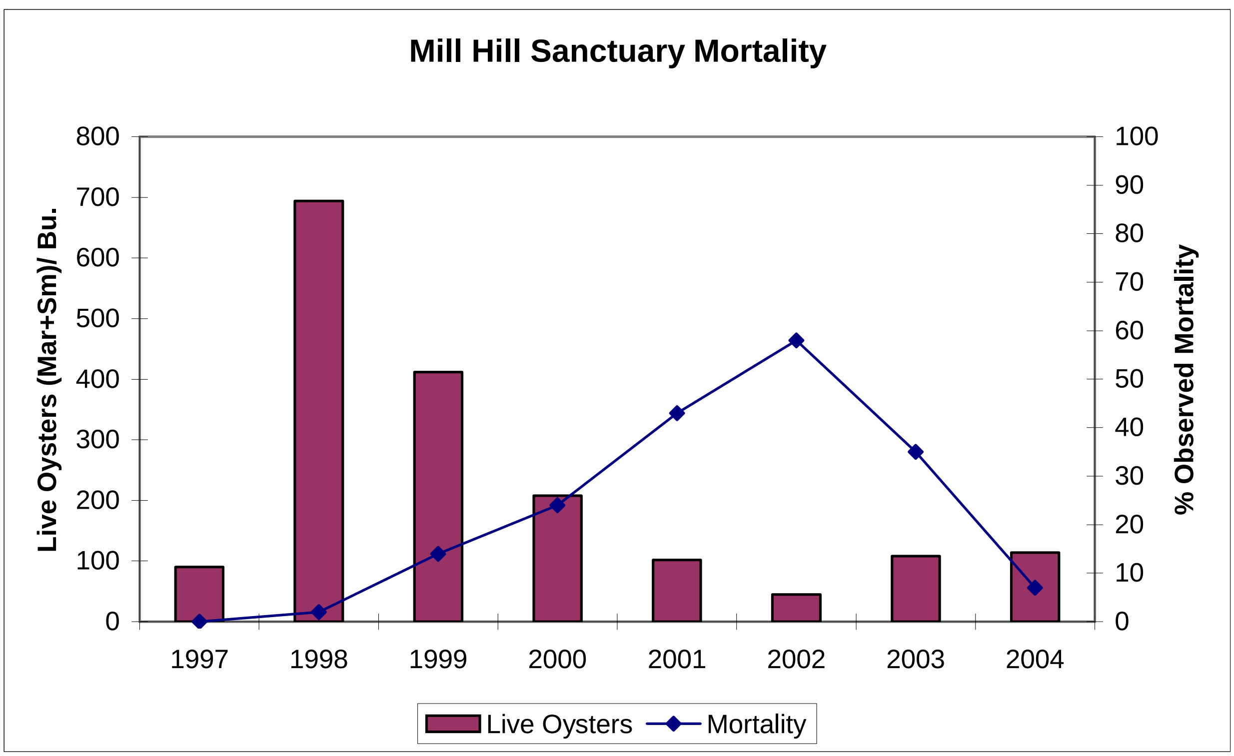

Figure 16. Observed mortality of smalls and markets on Mill Hill Sanctuary.

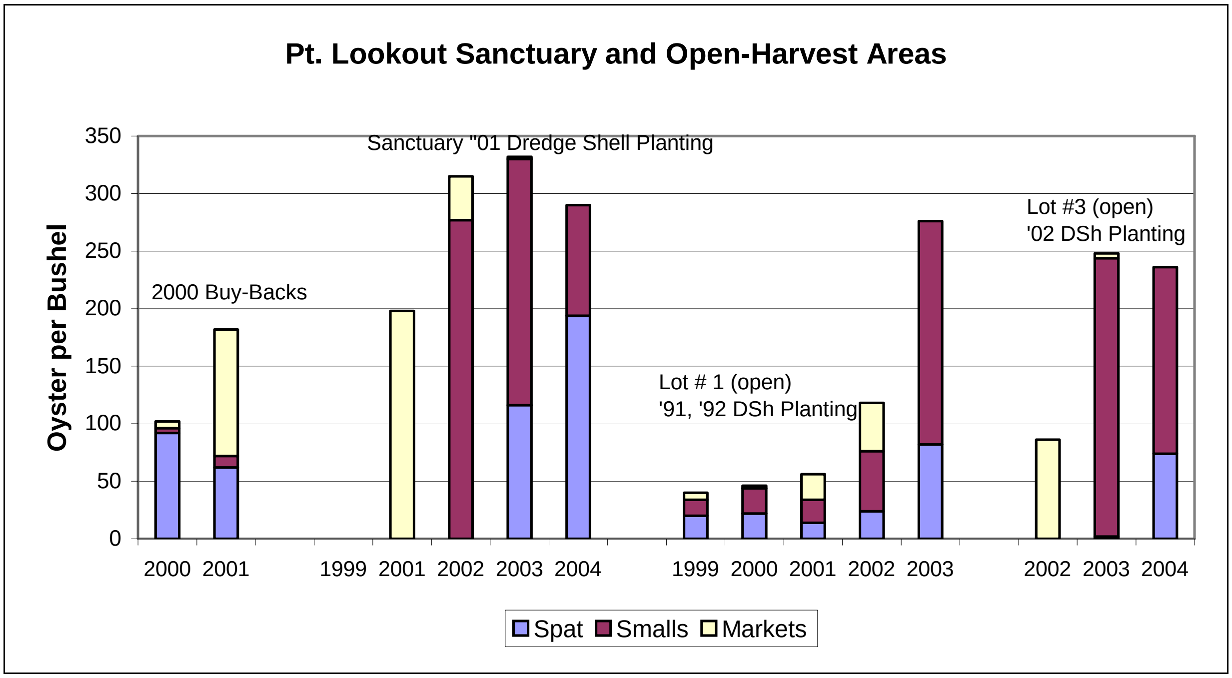

Figure 17. Oyster population structure on Pt. Lookout Sanctuary enhancements compared with open-harvest areas.

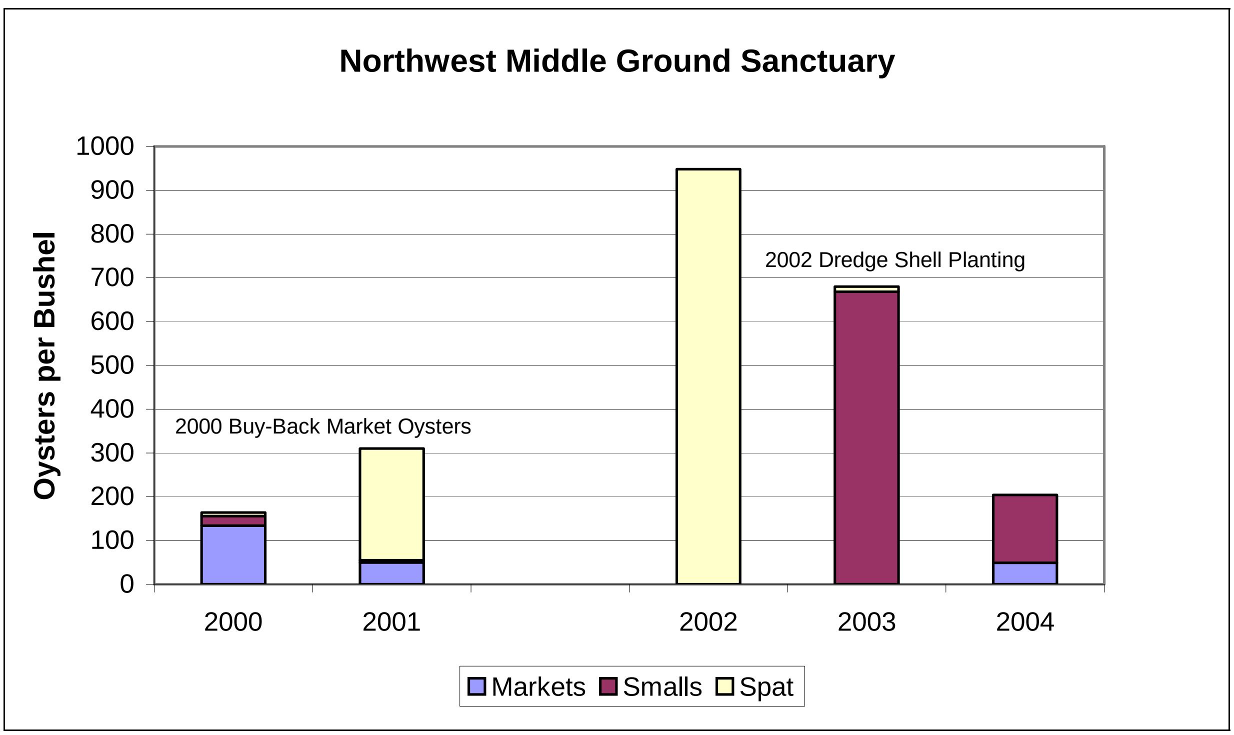

Figure 18. Oyster population structure on Northwest Middle Ground Sanctuary.

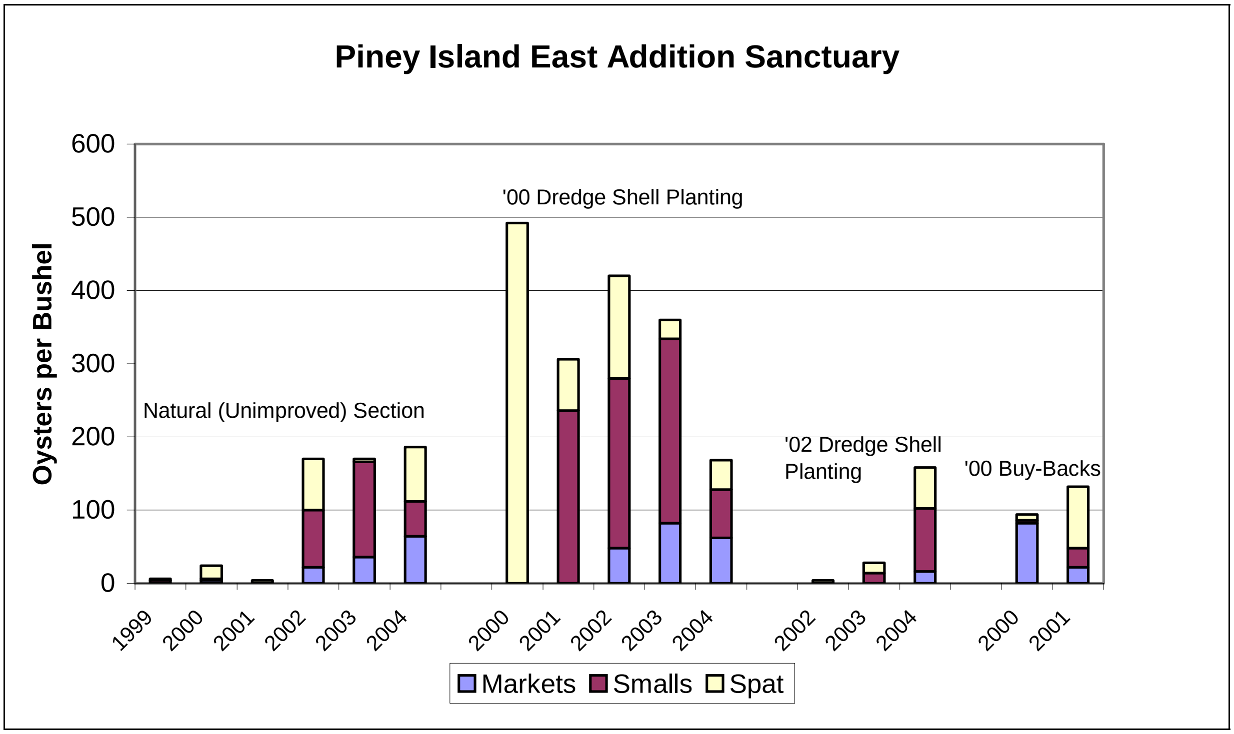

Figure 19. Oyster population structure on Piney I. East Add. Sanctuary enhancement areas compared with natural section.

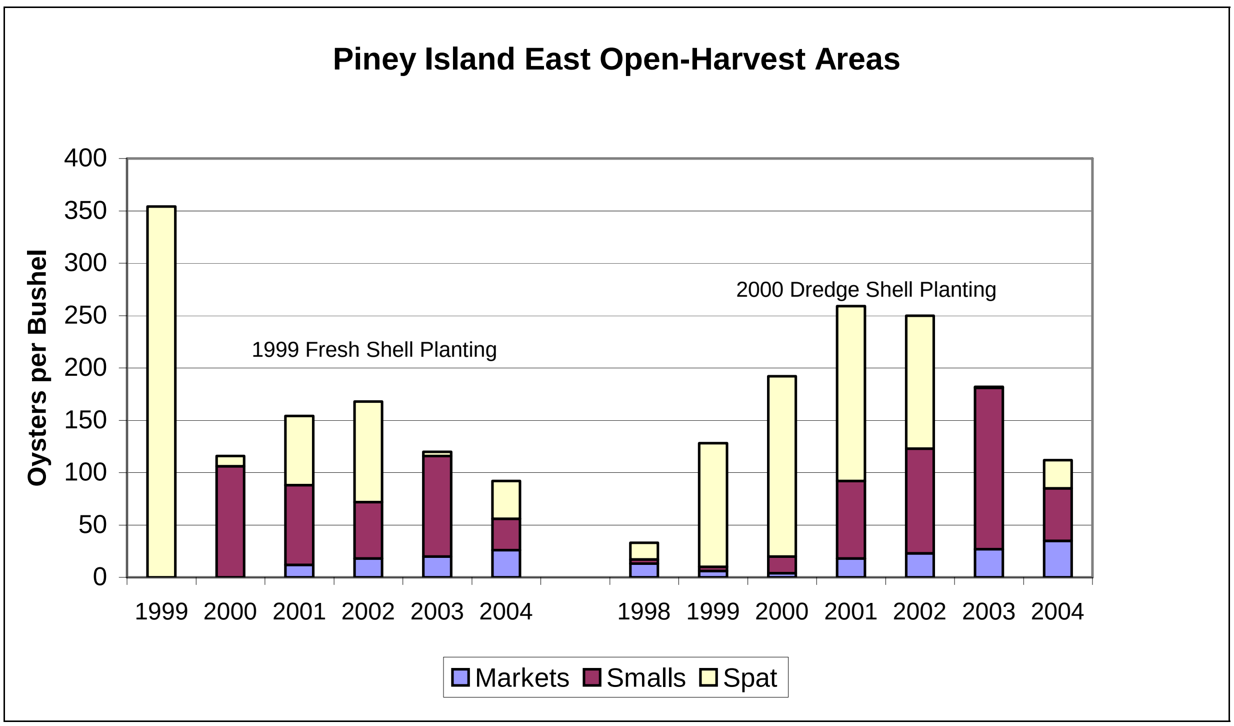

Figure 20. Oyster population structure of two enhanced plots on Piney Island East open-harvest bar.

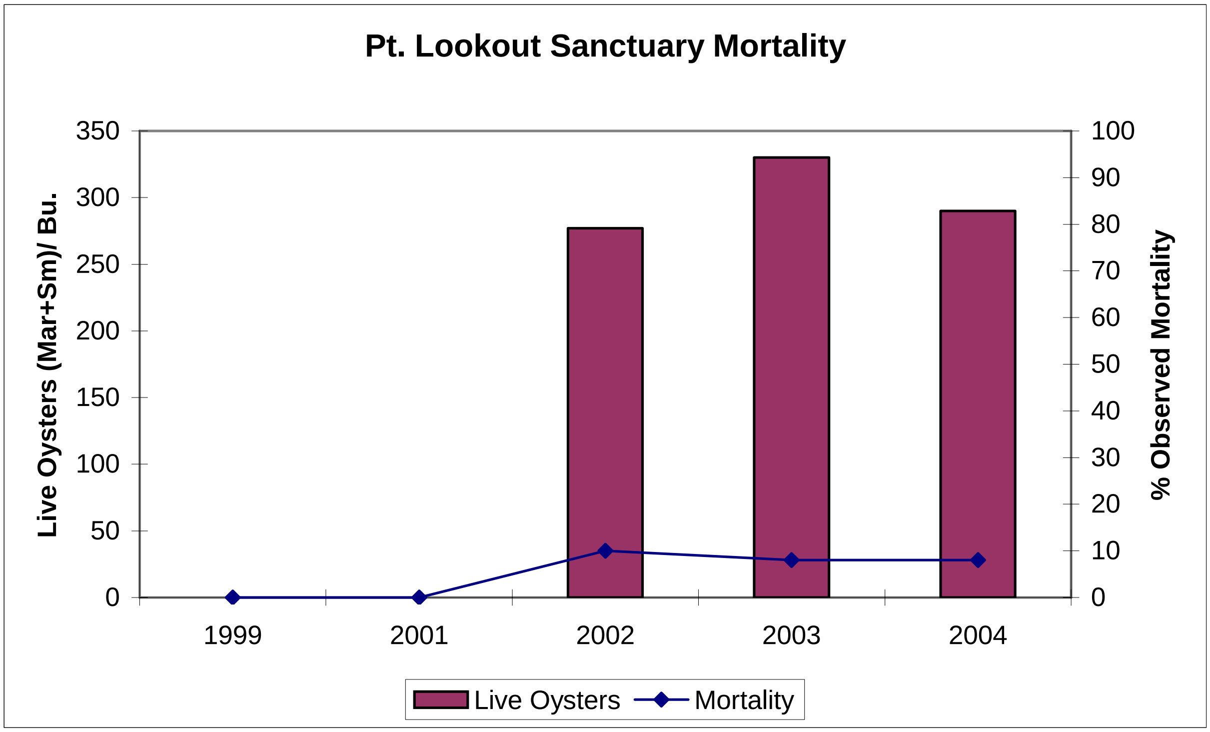

Figure 21. Observed mortality of smalls and markets on Pt. Lookout Sanctuary 2001 dredge shell planting.

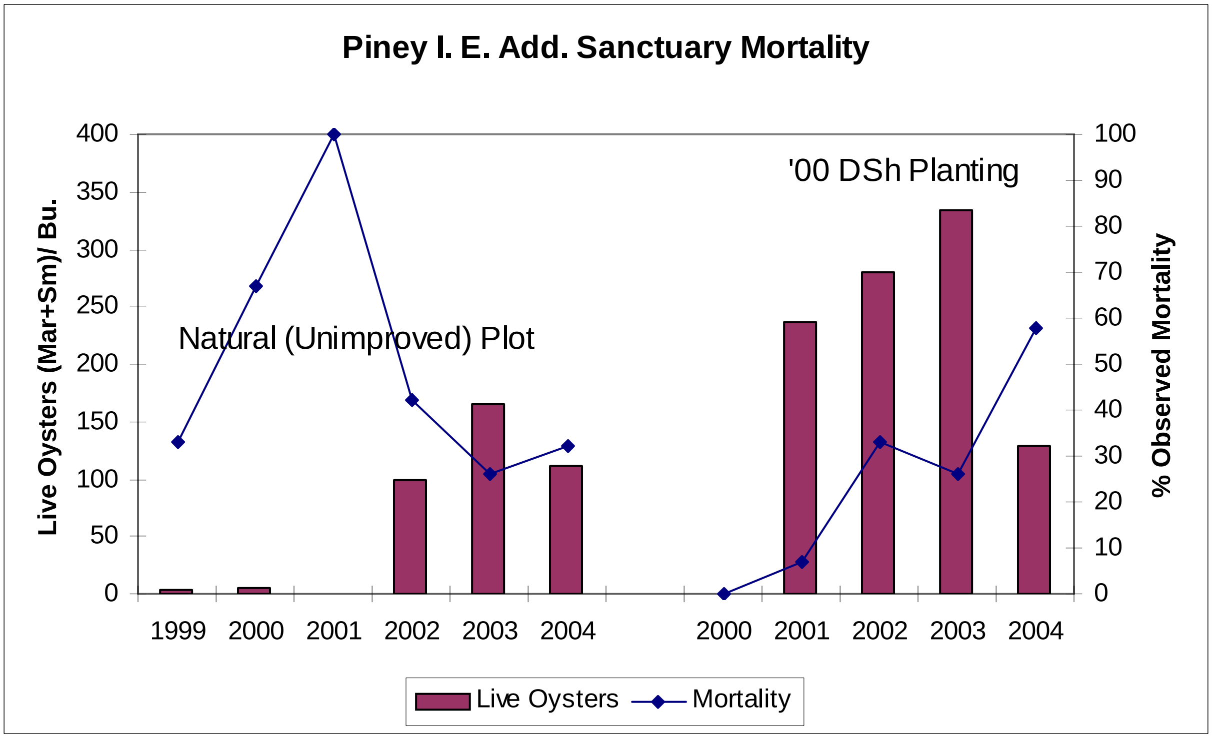

Figure 22. Observed mortality of smalls and marketson Piney Island East Add. Sanctuary, comparing natural area with enhancement area.

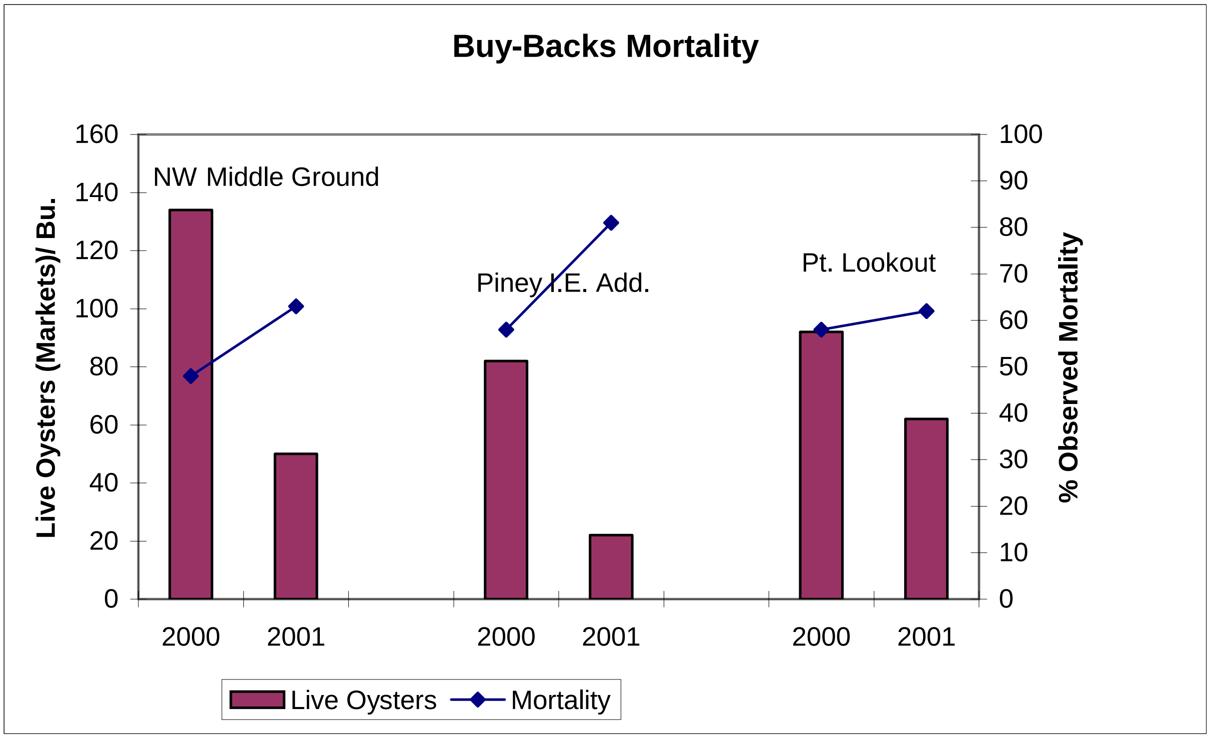

Figure 23. Observed mortality of buy-back market oysters on three power-dredge sanctuaries.

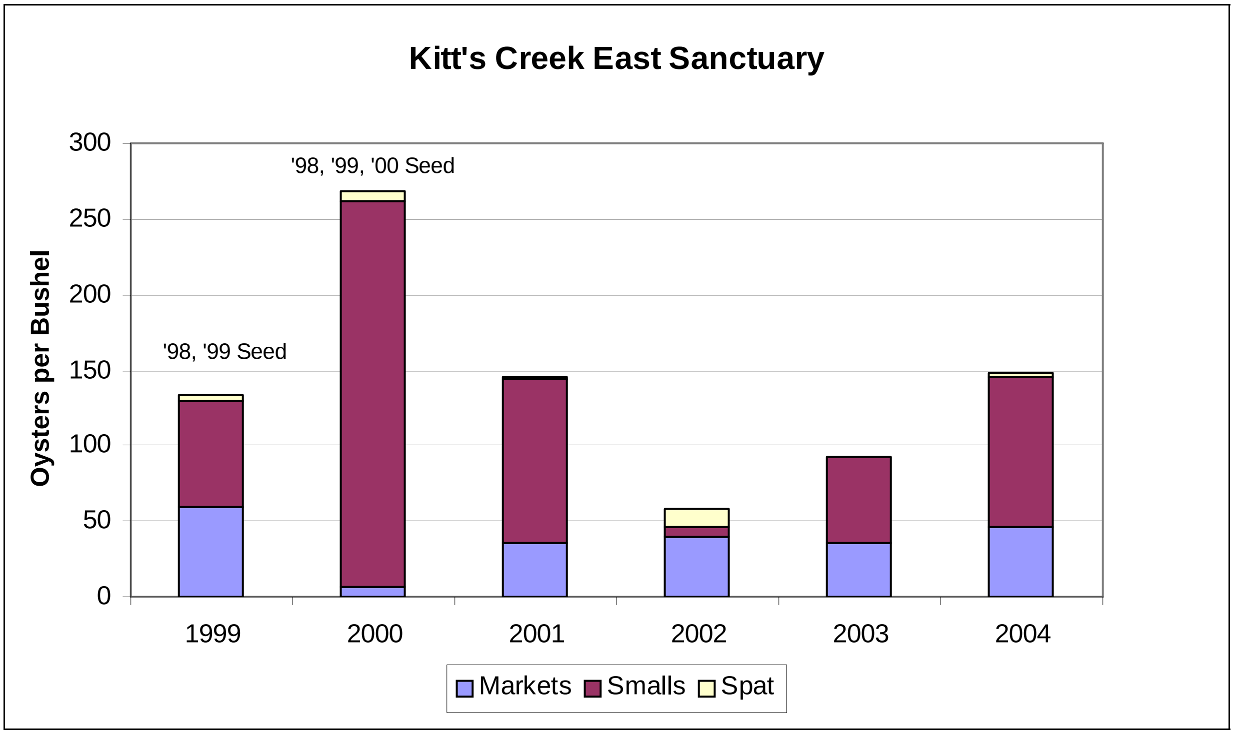

Figure 24. Population structure of oysters on Kitt's Creek East Sanctuary.

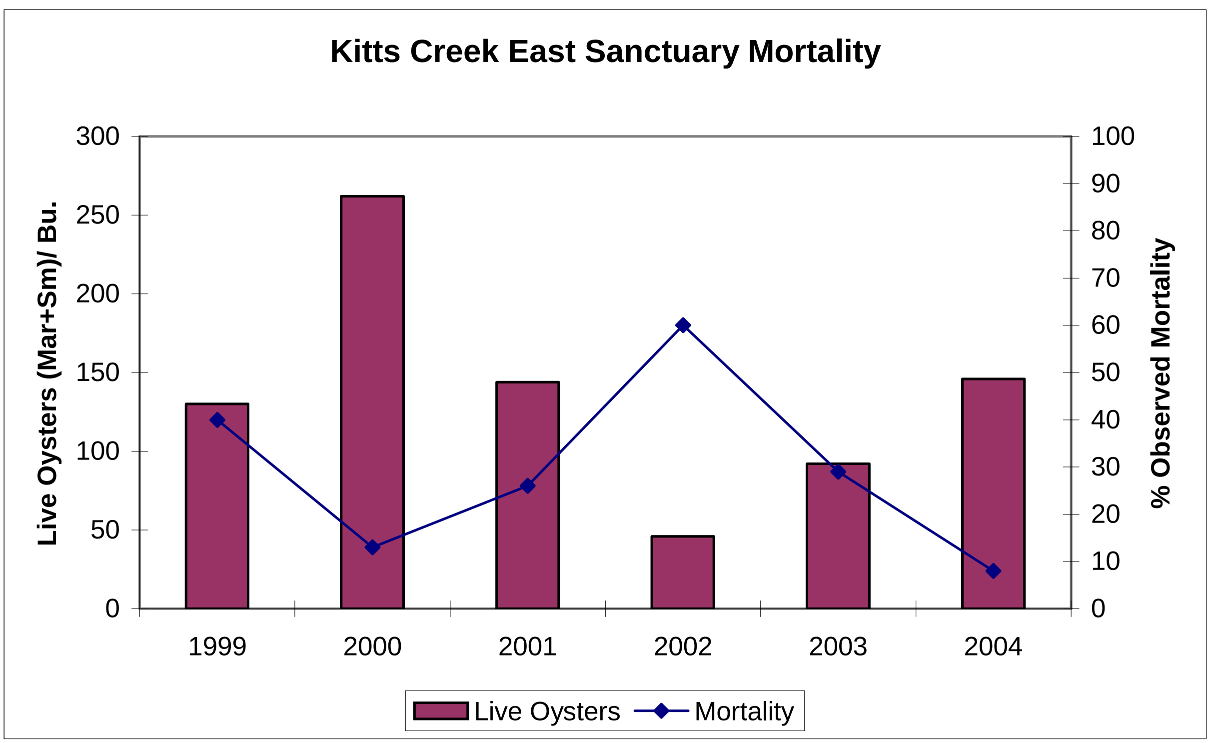

Figure 25. Observed oyster mortality of smalls and markets on Kitt's Creek East Sanctuary.

APPENDIX A. Oyster bars in the Maryland Oyster Sanctuary Program.

Location	Sanctuary Name	Total Acres	Acres Restored	Closure Method	Effective Date
Upper Western Shore	Fort Carroll	20		MDE PN	10/1/1995
	Severn River	6,719		MDE PN	10/30/1998
	South River	1,909		DNR PN	9/4/2000
	Herring Bay	5		DNR PN	7/9/2004
	Gales Lump	50		DNR PN	8/30/2002
Calvert Shore	Plum Point	5,870		DNR Reg	11/1/1999
Patuxent River	Pt. Patience			Navy	N/A
	Neal Addition	7		DNR PN	9/14/2001
	Elbow/Teague (NOB 13-2)	57		DNR PN	9/14/2001
	Kitts Marsh	28		DNR PN	6/30/2003
	Paul J. Bailey (Trent Hall)	10		DNR PN	8/20/2003
Chester River	Strong Bay	207		DNR PN	6/12/2003
	Ringgold	116		DNR PN	9/14/2001
	ORA Zone A	4,586		DNR Reg	5/20/1996
Eastern Bay Area	Mill Hill	296		DNR PN	9/30/2000
	Miles River	84		MDE PN	10/22/1979
Choptank River	Cook Point	17		DNR PN	9/14/2001
	Howell Point	6		DNR PN	9/14/2001
	Ora Zone A	4,567		DNR Reg	5/20/1996
	Horn Point Lab	10		Md Law	7/1/1986
	Cambridge	1,755		MDE PN	11/26/1937
	Oxford Lab	38		Md Law	6/1/1961
	La Trappe Creek			DNR PN	10/11/2002
Nanticoke River	Roaring Point	10		DNR PN	7/9/2004
Lower Bay	Dorchester PD	100		DNR REG	11/1/1999
	Somerset PD	100		DNR REG	11/1/1999
	St. Mary's PD	100		DNR REG	11/1/1999
	SW Middleground	17		DNR PN	9/14/2001
	Kitts Creek	1,056		DNR PN	9/14/2001
	Poplar Island	7		DNR PN	6/27/2003
	Piney Point AC	10		DNR REG	
	TOTAL ACRES	**27,757**			

PN = Public Notice
REG = Regulation

APPENDIX B

DNR Shellfish Program Fall Survey Sanctuary Monitoring Results

ZONE 1 (5ppt to <12 ppt)

											Dead Oysters per Bu.				
		Temp	Sal.	Bar	Plantings			Live Oysters per Bu			Market		Small		Total
Date	Region - Bar Name	C	ppt	Type	Seed	Dsh	Fsh	Market	Small	Spat	Old	Rec.	Old	Rec.	Mortality
	Severn River														
10/14/98	Chink's Point	19.0	14.0			98		0	0	0	0	0	0	0	0.0
10/6/99	Chink's Point	19.5	12.4	Nat+	99	98		68	280	0	4	0	8	2	3.9
10/11/00	Chink's Point	15.8	13.3	Nat+	99	98		78	22	0	4	0	0	0	3.8
11/8/01	Chink's Point	13.7	14.6	Nat+	99	98		136	0	0	48	0	2	0	26.9
11/20/02	Chink's Point	9.6	13.2	Nat+	99	98		44	0	0	80	6	8	0	68.1
11/3/03	Chink's Point	16.1	5.1	Nat+	99	98		84	0	0	68	0	0	0	44.7
11/10/04	Chink's Point	12.5	9.2		99	98		80	2	0	18	0	0	0	18.0
11/8/01	Chinks Point	13.7	14.6	Nat+	99 hat.	98		108	26	0	32	0	34	0	33.0
11/20/02	Chinks Point	9.6	13.2	Nat+	99 hat.	98		72	8	2	52	0	28	0	50.0
11/3/03	Chinks Point	16.1	5.1	Nat+	99 hat.	98		56	8	0	82	0	8	0	58.4
11/10/04	Chinks Point	12.5	9.2		99 hat.	98		84	8	0	44	0	2	2	34.0
	South River														
10/15/97	Alms House	20.0	12.0	Nat			97	0	0	0	0	0	0	0	0.0
10/6/99	Alms House	19.6	13.4	Nat			97	38	6	0	6	0	0	0	12.0
10/11/00	Alms House	16.2	12.2	Nat			97	12	4	0	2	0	0	0	11.1
11/8/01	Alms House	13.7	14.3	Nat			97	20	12	0	30	8	10	0	60.0
	Patuxent River														
10/25/04	Paul J. Baileys (Trent Pt.)	15.8	8.4		02 hat.			18	124	0	0	0	0	0	0.0

Potomac R.

11/6/96	Heron I. (16 ft)	14.0	6.0				96	2	12	0	0	0	0	0	0.0
11/5/97	Heron Island	14.0	13.5				96	14	8	0	0	0	0	0	0.0
11/12/98	Heron Island	18.0	12.0				96	0	2	0	0	0	0	0	0.0
11/5/99	Heron Island	13.8	14.5				96	2	0	0	0	0	0	0	0.0
11/1/00	Heron Island	15.5	14.5				96	4	2	0	0	0	0	0	0.0
10/16/01	Heron Island	19.1	15.1				96	0	0	0	0	0	0	0	na
10/23/02	Heron Island	17.7	15.9				96	0	0	0	0	0	2	0	100.0
11/12/03	Heron Island	14.1	7.7				96	0	0	0	0	0	0	0	na
10/27/04	Heron Island	16.8	10.0				96	0	1	0	0	0	1	0	50.0

11/6/96	Heron I. (11 ft)	14.0	6.0	Nat				76	16	0	2	2	0	0.0	4.2
11/12/98	Heron Island	18.0	12.0	Nat				12	0	0	0	0	6	0	33.3
11/5/99	Heron Island	13.8	14.5	Nat				68	0	0	8	2	0	0	12.8
11/1/00	Heron Island	15.5	14.5	Nat				40	2	0	54	2	4	0	58.8
10/16/01	Heron Island	19.1	15.1	Nat				20	0	0	20	0	6	0	56.5
10/23/02	Heron Island	17.7	15.9	Nat				6	0	0	30	2	2	0	85.0
11/12/03	Heron Island	14.2	6.9	Nat				2	0	0	2	0	0	0	50.0
10/27/04	Heron Island	16.8	10.0	Nat				0	0	0	3	0	0	0	100.0

Chester River

10/8/99	Ringgold (Bay Bush Pt.)	17.6	11.7	Nat				46	4	0	4	0	0	0	7.4
10/17/00	Ringgold (Bay Bush Pt.)	16.7	10.9	Nat				74	20	0	4	0	0	0	4.1
11/6/01	Ringgold (Bay Bush Pt.)	13.0	12.9	Nat				62	2	0	18	0	0	0	22.0
11/15/02	Ringgold (Bay Bush Pt.)	11.2	14.2	Nat				34	0	0	46	2	0	0	58.5

11/19/02	Strong Bay	9.2	10.3			02		0	0	18	0	0	0	0	0.0
10/31/03	Strong Bay	14.1	7.1		03 hat.	02		0	82	380	0	0	4	0	4.7
11/04/04	Strong Bay	15.2	8.6		03 hat.	02		4	90	0	0	0	0	0	0.0

Open-Harvest Area

10/07/99	Wickes Beach	17.8	12.1	Nat+	98			146	68	0	16	2	8	4	11.0
10/12/00	Wickes Beach	16.5	11.5	Nat+	98			136	8	0	20	0	18	2	21.7
11/07/01	Wickes Beach	12.3	12.9	Nat+	98			64	6	2	48	2	16	0	48.5
11/19/02	Wickes Beach	9.2	10.3	Nat+	98			60	0	0	54	4	0	0	49.2
10/31/03	Wickes Beach	14.1	7.1	Nat+	98			46	2	0	20	2	0	0	31.4
11/4/04	Wickes Beach	15.2	8.6	Nat+	98			64	2	0	8	0	0	0	11.0

Choptank River

10/23/97	Green Marsh	14.0	10.0	Nat				24	4	0	0	0	0	0	0.0
10/22/98	Green Marsh	10.0	16.5	Nat				38	8	0	4	0	0	0	8.0
10/20/99	Green Marsh	16.1	11.8	Nat				40	4	0	12	0	0	0	21.4
10/19/00	Green Marsh	16.6	11.6	Nat				26	4	0	26	0	2	0	48.3
10/29/01	Green Marsh	13.6	11.5	Nat				32	0	0	18	0	0	0	36.0
10/31/02	Green Marsh	12.4	14.8	Nat				8	0	0	22	0	0	0	73.3

10/31/02	Green Marsh	12.4	14.8			02		0	0	6	0	0	0	0	0.0
10/24/03	Green Marsh	13.7	8.9		03 hat.	02		0	0	156	0	0	0	0	0.0
10/21/04	Green Marsh	15.7	9.5		03 hat.	02		56	114	0	4	0	2	0	3.4

10/23/97	Shoal Creek	14.0	10.0	Nat				18	0	0	0	0	0	0	0.0
10/22/98	Shoal Creek	10.0	16.5	Nat		98		68	0	0	4	0	0	0	5.6
10/20/99	Shoal Creek	16.4	11.6	Nat+	99			58	166	0	6	0	6	6	7.4
10/19/00	Shoal Creek	16.6	11.1	Nat+	99	98		70	4	2	22	6	2	4	31.5
10/29/01	Shoal Creek	13.0	11.8	Nat+	99,01hat.	98		34	2	146	30	0	2	0	47.1
10/31/02	Shoal Creek	12.4	14.6	Nat+	99,01hat.	98		44	35	0	24	4	9	8	36.3
10/24/03	Shoal Creek	13.5	8.4	Nat+	99,01hat.	98		36	0	0	34	0	12	0	56.1
10/21/04	Shoal Creek	15.6	9.3	Nat+	99,01hat.	98		114	4	0	22	0	2	0	16.9

10/31/02	Shoal Creek	12.4	14.6	Nat				1	0	0	15	1	1	0	94.4
10/24/03	Shoal Creek	13.5	8.4	Nat				14	0	0	30	0	0	0	68.2
10/21/04	Shoal Creek	15.6	9.3	Nat				20	0	0	10	0	0	0	33.3

Zone 2 (12ppt to 14ppt)

											Dead Oysters per Bu.				
		Temp	Sal.	Bar	Plantings			Live Oysters per Bu.			Market		Small		Total
Date	Region - Bar Name	C	ppt	Type	Seed	Dsh	Fsh	Market	Small	Spat	Old	Rec.	Old	Rec.	Mortality
	Eastern Bay														
10/20/97	Mill Hill	16.5	14.0	Nat+		88		55	35	1725	0	0	0	0	0.0
10/19/98	Mill Hill	14.0	18.0	Nat+		88		38	656	2	2	0	7	4	1.8
10/12/99	Mill Hill	17.6	14.2	Nat+		88		58	354	20	16	2	34	16	14.2
10/16/00	Mill Hill	17.7	13.7	Nat+		88		118	90	12	20	10	28	6	23.5
11/1/01	Mill Hill	14.2	13.9	Nat+		88		78	24	4	42	8	18	8	42.7
11/18/02	Mill Hill	10.0	16.0	Nat+		88		23	22	0	37	5	16	5	58.3
10/29/03	Mill Hill	14.1	10.7	Nat+		88		38	70	4	44	0	14	0	34.9
11/03/04	Mill Hill	15.9	10.0	Nat+		88		44	70	0	6	0	2	0	6.6
	Mid-Bay East														
11/01/04	Poplar Island	16.3	9.5	Sanc.		03		0	6	0	0	0	0	0	0.0
	Choptank River														
10/21/97	Cook Pt. Nat. Bar	16.0	15.0	Nat +		90		14	18	20	2	0	2	0	11.1
10/20/04	Cook Pt. Nat. Bar	16.3	10.3	Nat+		90		1	0	4	0	0	0	0	0.0
10/20/04	Cook Pt. Art. Reef	16.3	10.3	Sanc.	97 hat.	97		5	1	1	1	0	1	0	25.0
	Patuxent River														
10/30/00	Neal Addition	16.0	14.3	Nat+	99 hat.	99		54	410	0	0	0	0	0	0.0
11/15/01	Neal Addition	13.6	16.8	Nat+	99 hat.	99		70	30	4	33	6	54	2	48.7
10/21/02	Neal Addition	17.2	17.2	Nat+	99 hat.	99		4	2	10	68	4	28	2	94.4
11/10/03	Neal Addition	14.5	9.0	Nat+	99 hat.	99		4	38	2	16	0	8	0	36.4
10/25/04	Neal Addition	15.7	9.4	Nat+	99 hat.	99		26	28	0	0	0	0	0	0.0

D_K Cook Point LCRCP0 3839.243 7616.758 15 16 Nat 90 14 18 20 2 0 2 0

	Lower Bay West														
	Sanctuary														
10/31/00	Point Lookout	14.9	17.0	Nat	buy-back			92	4	6	112	14	10	2	59.0
11/16/01	Point Lookout	13.9	18.6	Nat	buy-back			62	10	110	84	18	10	2	61.3
11/2/99	Point Lookout	16.5	17.5	Nat+				0	0	0	0	0	0	0	0.0
11/16/01	Point Lookout	13.9	18.6	Nat+		01		0	0	198	0	0	0	0	0.0
10/22/02	Point Lookout	16.6	19.6	Nat+		01		0	277	38	0	0	23	7	9.8
11/11/03	Point Lookout	14.0	11.8	Nat+		01		116	214	2	4	0	16	8	7.8
10/26/04	Point Lookout	16.3	11.7	Nat+		01		194	96	0	10	2	12	0	7.6
	Open-Harvest Areas														
11/2/99	Point Lookout Lot#1	16.5	17.5	Nat+		92,91		20	14	6	6	0	16	4	43.3
10/31/00	Point Lookout Lot#1	14.9	17	Nat+		92,91		22	22	2	52	0	30	2	65.6
11/16/01	Point Lookout Lot#1	13.9	18.6	Nat+		92,91		14	20	22	10	0	6	4	37.0
10/22/02	Point Lookout Lot#1	16.6	19.6	Nat+		92,91		24	52	42	2	0	4	0	7.3
11/11/03	Point Lookout Lot#1	14.0	11.8	Nat+		92,91		82	194	0	2	0	4	2	2.8
10/26/04	Point Lookout Lot#B	16.3	11.7	Nat+		91,92,04		4	12	0	0	0	0	0	0.0
11/2/99	Point Lookout Lot#2	16.5	17.5	Nat+		99		0	0	66	0	0	0	0	0.0
10/31/00	Point Lookout Lot#2	14.9	17.0	Nat+		99		22	42	4	36	0	38	0	53.6
11/16/01	Point Lookout Lot#2	13.9	18.6	Nat+		99		68	52	10	6	0	4	2	9.1
10/22/02	Point Lookout Lot#3	16.6	19.6	Nat+		02		0	0	86	0	0	0	0	na
11/11/03	Point Lookout Lot#3	14.0	11.8	Nat+		02		2	242	4	0	0	0	0	0.0
10/26/04	Point Lookout Lot#3	16.3	11.7	Nat+		02		74	162	0	0	0	2	0	0.8

Zone 3 (>14ppt)

Date	Region - Bar Name	Temp	Sal.	Bar	Plantings			Live Oysters per Bu.			Dead Oysters per Bu.				Total
											Market		Small		
		C	ppt	Type	Seed	Dsh	Fsh	Market	Small	Spat	Old	Rec.	Old	Rec.	Mortality
	Lower Bay East														
11/7/00	Northwest Middle Ground	14.3	18.8	Nat	buy-back	00		134	22	8	98	28	2	4	45.8
10/22/01	Northwest Middle Ground	17.4	18.5	Nat	buy-back	00		50	5	255	70	15	20	0	65.6
10/10/02	Northwest Middle Ground	22.3	20.5	Nat+		02		0	0	948	0	0	0	0	0.0
11/6/03	Northwest Middle Ground	17.7	13.0	Nat+		02		0	668	12	0	0	28	0	4.0
11/15/04	Northwest Middle Ground	12.4	13.8	Nat+		02		49	155	0	0	0	10	1	5.1
	Tangier Sound														
10/25/99	Piney Island East Add. 1	15.5	19.5	Nat				0	4	2	2	0	0	0	33.3
11/8/00	Piney Island East Add. 1	14.6	19.3	Nat				4	2	18	8	0	4	0	66.7
10/9/01	Piney Island East Add. 1	16.1	17.4	Nat				0	0	4	6	0	0	0	100.0
10/15/02	Piney Island East Add. 1	21.7	22.0	Nat				22	78	70	18	18	32	6	42.5
10/16/03	Piney Island East Add. 1	17.4	14.3	Nat				36	130	4	22	2	26	8	25.9
10/13/04	Piney Island East Add. 1	19.3	14.8	Nat				64	48	74	26	4	22	2	32.5
11/8/00	Piney Island East Add. 1	14.6	19.3	Nat+		00		0	0	492	0	0	0	0	0.0
10/9/01	Piney Island East Add. 1	16.1	17.4	Nat+		00		0	236	70	0	0	16	2	7.1
10/15/02	Piney Island East Add. 1	21.7	22.0	Nat+		00		48	232	140	4	6	72	58	33.3
10/16/03	Piney Island East Add. 1	17.4	14.3	Nat+		00		82	252	26	28	10	66	16	26.4
10/13/04	Piney Island East Add. 1	19.3	14.8	Nat+		00		62	66	40	70	20	78	10	58.2
10/15/02	Piney Island East Add. 1	21.7	22.0	Nat+		02		0	0	4	0	0	0	0	0.0
10/16/03	Piney Island East Add. 1	17.4	14.3	Nat+		02		0	14	14	0	0	0	0	0.0
10/13/04	Piney Island East Add. 1	19.3	14.8	Nat+		02		16	86	56	2	0	14	6	17.7

11/8/00	Piney Island East Add. 1	14.6	19.3	Nat+	buy-back			82	4	8	114	0	2	2	57.8
10/9/01	Piney Island East Add. 1	16.1	17.4	Nat+	buy-back			22	26	84	86	6	14	4	69.6
	Open-Harvest Areas														
11/08/99	Piney Island East	11.3	17.9	Nat+			99	0	0	354	0	0	0	0	na
11/8/00	Piney Island East	14.8	19.0	Nat+			99	0	106	10	0	0	16	8	18.5
10/09/01	Piney Island East	16.2	16.6	Nat+			99	12	76	66	2	0	14	6	20.0
10/15/02	Piney Island East	19.9	21.7	Nat+			99	18	54	96	10	4	28	10	41.9
10/16/03	Piney Island East	17.6	13.9	Nat+			99	20	96	4	14	0	42	10	36.3
10/13/04	Piney Island East	18.7	14.2	Nat+			99	26	30	36	18	0	28	4	47.2
11/04/98	Piney Island East	19.5	12.0	Nat				13	4	16	10	0	4	0	45.2
11/08/99	Piney Island East	11.3	17.9	Nat				6	4	118	4	0	2	0	37.5
11/8/00	Piney Island East	14.8	19.0	Nat+		00		4	16	172	0	0	10	0	33.3
10/09/01	Piney Island East	16.2	16.6	Nat+		00		18	74	167	1	0	8	3	11.5
10/15/02	Piney Island East	19.9	21.7	Nat+		00		23	100	127	3	2	19	7	20.1
10/16/03	Piney Island East (S&D)	17.6	13.9	Nat+		00		27	154	1	11	0	48	11	27.9
10/13/04	Piney Island East (S&D)	18.7	14.2	Nat+		00		35	50	27	18	4	51	5	47.9
	Pocomoke Sound														
10/25/99	Kitt's Creek East	13.0	11.8	Nat+	98,99			60	70	4	18	14	50	4	39.8
10/8/00	Kitt's Creek East	15.0	13.8	Nat+	98,99,00			6	256	6	4	0	26	10	13.2
10/9/01	Kitt's Creek East	15.3	14.5	Nat+	98,99,00			36	108	2	10	2	40	0	26.5
10/17/02	Kitt's Creek East	17.6	18.7	Nat+	98,99,00			40	6	12	44	2	20	4	60.3
10/17/03	Kitt's Creek East	17.2	12.0	Nat+	98,99,00			36	56	0	18	0	20	0	29.2
10/14/04	Kitt's Creek East	16.8	14.2	Nat+	98,99,00			46	100	2	2	0	8	2	7.6