2005 Shell-Planting Program in Delaware Bay

Report to the U.S. Army Corps of Engineers

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This report provides information specific to the 2005 shell-planting program. The importance of the program, for New Jersey, is reviewed in the report of the 8^{th} SAW that is attached to this document as an addendum. This is possible because New Jersey carries out a quantitative stock assessment and, as a consequence, can place the recruitment obtained for New Jersey in the context of the quantitative estimates for the native shell on these oyster beds. However, trends in population dynamics are very similar on both sides of the bay, so that generalities concerning the shell-planting program evinced through quantitative methods in New Jersey are very likely to be applicable to the Delaware case.

The attached report of the 8^{th} SAW summarizes the status of the stock in 2005. Comparison to trends in the Delaware stock survey suggests that the similar trends occurred on both sides of the Bay. The 8^{th} SAW found that oyster abundance declined slightly in 2005 to the lowest level since the onset of Dermo disease circa 1989 and to one of the lowest levels in the 1953 to 2005 record. Declines were concentrated on the medium-mortality beds upbay of Shell Rock. Elsewhere, abundance increased over 2004 levels. 2005 was the sixth consecutive year of low recruitment. The number of spat per >20-mm oyster was 0.340; insufficient to sustain the present population. Population dynamics modeling indicates that the market-size component of the population is no longer in a period of negative surplus production, however. Abundance of $\geq 3''$ oysters is expected to increase in 2006, unless fishery exploitation or natural mortality rates are unusually high. Natural mortality, bay-wide, was 12% of the stock in 2005, a relatively typical non-epizootic mortality rate. An increasing trend in Dermo disease suggests that an increase in natural mortality rate can be expected in 2006.

The 2005 shell-planting program was designed specifically to address the issue of low recruitment and occurred in a timely fashion, as 2005 recruitment on the natural oyster beds was insignificant to sustain population abundance over the long term. The monitoring program was composed of five components: (1) a small monitoring program for a downbay shell plant pursuant to the decision to transplant the spatted shell upbay; (2) a monitoring program to measure spat settlement potential carried out through late September; (3) a monthly monitoring program to track trends in growth and disease exposure; (4) a quantitative evaluation in

October to determine the overall success of the project as of season's end in 2005; (5) a dredge calibration component to determine the applicability of remote sampling by oyster dredge of shell plants.

Summary of Shell-planting Program

The 2005 program consisted of six shell plants in New Jersey and two shell plants in Delaware. The New Jersey program was larger due to the additional support from funds provided by the State of New Jersey; however, as these plants contributed to the program as a whole, they are included in this report. Three types of shell were planted: surf clam shell obtained from New Jersey shucking houses, ocean quahog shell obtained from New Jersey shucking houses, and Maryland oyster shell obtained from shell mining operations in Chesapeake Bay.

Shell-planting was carried out in July, 2005. Three 25-acre grids received direct plants in New Jersey: Shell Rock 4, 12, and 43. A fourth plant off Reed's Beach was moved upbay in September to Bennies Sand 11. All three types of shell were planted in New Jersey. Two 25-acre areas were planted in Delaware, on Jigger Hill and Lower Middle beds. Maryland oyster shell was planted in both areas. Ocean quahog shell was also planted on Lower Middle. Specifics of the distribution of shell are provided in the following table. Locations are provided in Figure 1.

The Maryland oyster shell proved hard to track as time went on and its original unique appearance disappeared. Final numbers for the Maryland shell plants are less precise and likely underestimated in comparison to the clam-shell plants.

Recruitment estimates were obtained from three sampling sources. In October, samples were taken by oyster dredge in survey mode as a component of the oyster stock assessment program. In October, diver samples were obtained as a component of the dredge calibration program. In early November, samples were obtained by scientific dredge as part of the growth and mortality monitoring program. In Delaware, ocean quahog shell was planted as a base for a cover of Maryland oyster shell and, as a consequence, did not and was not expected to obtain the recruitment success of other plants. The lower recruitment rate on Upper Middle is likely also explained by the fact that oyster shell was planted more thickly here than elsewhere to build up bed integrity. This was a purposeful component of the 2005 program in Delaware.

Location	Type of Shell Planted	Bushels Planted	Spat Collected	Spat/Bu	Projected Harvest
New Jersey					
Benny Sand 11	Replant of surf clam	22,500	12,713,461	565	12,000
Shell Rock 4	Maryland oyster	36,752	8,051,590	219	11,197
Shell Rock 12	Ocean quahog	18,248	13,503,520	740	18,769
Shell Rock 12	Maryland oyster	18,737	2,678,540	143	3,723
Shell Rock 43	Surf clam	8,000	2,492,214	312	3,464
Shell Rock 43	Ocean quahog	7,600	3,116,607	410	4,332
Delaware					
Lower Middle	Maryland oyster	46,382	1,793,637	38	2,494
Lower Middle	Ocean quahog	17,778	195,037	11	271
Jigger Hill	Maryland oyster	54,651	3,122,950	57	4,343

Projections of marketable bushels assumed a 3-year time to market size and natural mortality at the juvenile rate in year 1 and at the adult rate in years 2 and 3. The mortality estimates used were the 50^{th} percentiles of the 1989-2005 New Jersey time series: for Shell Rock, 0.443, 0.182, 0.182; for Bennies Sand: 0.529, 0.267. 0.267. Bushel conversions assume 268 oysters per bushel, based on dock-side monitoring of bushels landed in New Jersey. Details are presented in the accompanying report of the 8^{th} SAW. Equivalent data are not available for Delaware. The Shell Rock mortality rates have been applied to these beds based on their approximate location in the Bay's salinity gradient.

Perusal of this table reveals that ocean quahog and surf clam did equivalently well. Maryland oyster shell tended to be lower in total spat catch; however, this may have been due to (a) the lateness of planting (see later discussion), or (b) difficulty in recognition. Likely, recruitment on Maryland oyster shell is underestimated. Recruitment was lower in Delaware. To some extent, this is due to more concentrated shell planting and to some extent this is due to the reliance on Maryland oyster shell. However, the evidence suggests an overall lower recruitment rate in Delaware waters in 2005. Expansion of the monitoring of recruitment potential in 2006 to include Delaware sites may provide instructive information for 2006.

Overall, recruitment enhancement programs were successful in 2005. In New Jersey, where a quantitative evaluation is easier, the shell plants raised the ratio of spat to oyster on Shell Rock from 0.471 to 0.991 and on the high-mortality beds[♮] from 0.808 to 0.905. This latter was accomplished even thought only one high-mortality bed, Bennies Sand, received a shell plant. Figure 20 in the accompanying

[♮] High-mortality beds include Bennies Sand, Bennies, New Beds, Ledge, Egg Island, Vexton, Nantuxent Point, Beadons, Hog Shoal, Strawberry, and Hawk's Nest.

report of the 8^{th} SAW shows the significance of these ratios. In the 53-year history of the New Jersey survey, a bay-wide set exceeding 1 spat per oyster has happened only 17 times. Values above 0.5 generally are associated with stock expansion. Consequently, the ratios achieved on these two beds are substantive.

Shell planting in New Jersey in 2005 enhanced recruitment bay-wide in New Jersey by 10%, even thought the total area planted was a mere 100 acres. On Shell Rock, shell plants accounted for 52.4% of total recruitment. On the high-mortality beds, the single shell plant on Bennies Sand 11 accounted for 10.7% of total recruitment.

Comparisons in Delaware can only be made on a per-bushel basis. Nevertheless, data from the Delaware survey indicates that shell planting successfully enhanced recruitment. The average spat/bushel, based on 15 samples, for the Ridge/Jigger Hill area was 8.1. The average spat/bushel, based on 6 samples, for the Lower Middle bed was 23.3. The average spat/bushel for all Delaware beds was 14.5, ($\pm$3.53)[‡]. In contrast, the shell plants yielded an average of 43 spat/bu, minimally three times the bay average, and a likely underestimate given the recognition difficulty for Maryland oyster shell.

Reed's Beach Shell Plant

Shell was planted off Reed's Beach in an area of high setting potential and then monitored carefully for recruitment. The goal was to transplant this shell back upbay (to Bennies Sand 11) when total recruitment was maximal. As the number of living spat is always a function of the rate of larval settlement and the rate of spat mortality, typically the shell would be moved when spat counts begin to decline. The Reed's Beach shell plant was monitored weekly from July 27 to August 17, 2005, at which time replanting to Bennies Sand 11 began. This decision was based on the following time series of spat counts.

Sampling Day	Spat per Bushel
July 27	1,036
August 1	1,480
August 8	2,109
August 17	1,909
October replant	565

In 2005, this plant/re-plant program netted no more spat per bushel than

‡ The average for the same region in New Jersey was about double, 31, lending substance to the conclusion that the lower spat counts on Delaware beds was due to an approximately factor of two lower recruitment rate on the Delaware side of the bay, rather than any inherent differences in the shell-planting program.

a direct plant on Shell Rock. However, evidence exists that the replant may have occurred a few weeks late as the last sampling prior to initiation of field activities in late August showed a per-bushel spat count about three times the final spat count on the replant. Further review of this plant and replant approach to determine economic benefit is desirable in 2006 as a 2003 pilot program was more successful.

Monitoring of Recruitment Potential

New Jersey carries out a program designed to monitor recruitment potential. This program records the number of spat settling on 20 oyster valves in deployed bags at selected sites throughout the New Jersey part of Delaware Bay. Data for 2005 can be found in Figure 21 of the accompanying report of the 8^{th} SAW. The 2005 program showed the anticipated trend of greater spat availability downbay, though the differential was not as high as in some years, and a much higher setting potential bay-wide in 2005 than in 2004. The spat monitoring program suggested two recruitment waves occurred in 2005, one early, in July, and another later, in August/September. This two-wave hypothesis was confirmed from size-frequency distributions of spat on shell plants that typically showed bimodal distributions. The following table shows end-of-year size-frequency distributions of spat expressed in terms of the percent of the total for each shell plant in each 2-mm size class.

Size (mm)	Surf clam Benny Sand 11	Surf clam Shell Rock 43	Ocean quahog Lower Middle	Ocean quahog Shell Rock 43	Maryland oyster Jigger Hill	Maryland oyster Lower Middle	Maryland oyster Shell Rock 4	Maryland oyster Shell Rock 12
0-2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2-4	0.5	1.2	0.0	0.9	2.7	0.0	0.0	0.0
4-6	4.6	6.3	0.0	2.1	0.0	0.0	0.0	0.0
6-8	5.5	9.7	0.0	2.4	0.0	0.0	0.0	0.0
8-10	5.9	8.1	2.2	2.9	0.0	0.0	0.0	0.0
10-12	4.6	7.9	0.0	4.7	2.7	0.0	0.0	16.7
12-14	1.7	5.6	0.0	5.6	5.4	14.3	2.1	16.7
14-16	2.7	6.1	0.0	2.9	8.1	0.0	2.1	0.0
16-18	2.0	5.0	2.2	7.9	10.8	0.0	0.0	16.7
18-20	1.7	5.9	4.3	7.9	0.0	0.0	4.2	0.0
20-22	1.7	7.5	15.2	10.3	5.4	0.0	2.1	0.0
22-24	2.1	6.5	0.0	13.8	18.9	0.0	8.3	0.0
24-26	5.0	6.6	6.5	11.4	0.0	14.3	14.6	0.0
26-28	5.8	5.9	17.4	10.6	8.1	0.0	14.6	33.3
28-30	11.0	5.5	17.4	5.3	5.4	14.3	12.5	0.0
30-32	11.7	3.7	8.7	3.8	8.1	28.6	14.6	0.0
32-34	10.8	2.9	8.7	4.7	8.1	14.3	18.8	0.0
34-36	8.2	2.1	6.5	1.8	8.1	14.3	0.0	16.7
36-38	7.9	1.5	6.5	1.2	8.1	0.0	6.3	0.0
38-40	5.9	1.3	4.3	0.0	0.0	0.0	2.1	0.0

Monitoring of Growth and Mortality

Dermo prevalences in the area of the bay used for shell planting are typically above 50%. These measurements were made on adult oysters sampled from within the area receiving shell. Prevalence were somewhat lower on the Delaware side, suggesting that disease exposure, as expected, is lower on that side of the bay at a given river-mile marker. Weighted prevalences are consistent with the more detailed information provided in the accompanying report of the 8^{th} SAW that determined that Dermo increased in intensity in 2005 over 2004. Although the impact of disease on the animals obtained from shell plants cannot yet be determined, the data suggest that an average exposure will occur – these areas were not unusually disease free – and that anticipate natural mortality rates will be lower on the Delaware side. Thus, survivorship of spat to adult size should be higher.

Location	Spat on Planted Shell Growth Rate (mm d^{-1}) Sept-to-Dec (97 days)	Native Adult Dermo Prevalence	Native Adult Dermo Weighted Prevalence
Jigger Hill – Maryland oyster			
September		50%	0.95
October		85%	1.53
December		45%	0.60
Lower Middle – Maryland oyster			
September		30%	0.40
October		40%	0.55
December	0.12	0%	0.00
Shell Rock 4 – Maryland oyster			
September		65%	1.43
October		90%	2.20
December	0.04	65%	0.90
Shell Rock 12 – ocean quahog			
September		70%	1.00
October		95%	2.33
December		70%	0.85
Shell Rock 43 – ocean quahog			
September		90%	2.28
October		100%	2.53
December	0.08	75%	1.18
Bennies Sand 11 – surf clam			
September		85%	1.80
December	0.05	85%	1.13

Growth rates of 2005 spat are also provided in the previous table. As little information exists for juvenile growth rates of oysters in Delaware Bay, the data cannot be used to infer whether 2005 spat growth rates were exceptionally high or low.

Cultch Availability

The quantity of cultch or surficial shell available to the dredge can be calculated for the New Jersey beds is: Shell Rock, 2.7235 qt L^{-1}; Bennies Sand, 4.6039 qt L^{-1}. For the beds as a whole, this yields, for Shell Rock, 391,352 bushels, and for Bennies Sand, 210,089 bushels. The shell-planting program added to Bennies Sand an amount of cultch equal to 10.7% of the amount originally present on the bed. The shell-planting program added to Bennies Sand an amount of cultch equal to 22.8% of the amount originally present on the bed. This is a significant increase in cultch volume on both beds.

Dredge Efficiency

A total of 16 dredge efficiency experiments were carried out on the Jigger Hill, Upper Middle, Shell Rock, and Bennies Sand shell plants. Details of the methodology have been published[†]. The focus of this program was to evaluate the efficiency of capture of planted shell particles versus native cultch. Efficiency of capture of native cultch is routinely in the range of 10%. Comparison of dredge efficiencies for native shell to past estimates showed that 2005 efficiencies were very similar to 2003 estimates. Additional information is provided in Table 3 of the accompanying report of the 8^{th} SAW. Thus, values obtained from 2005 for the shell plants are likely also to be representative.

The two survey vessels were also intercalibrated. Values for live oysters are shown in the following table. Note that the two values for Delaware beds came from simultaneous parallel tows of the two vessels and are, therefore, directly comparable.

For surf clam and ocean quahog planted shell, dredge efficiencies e for spat were low and cultch even lower than observed for native material. The following tables are catchability coefficients q computed as $q = \frac{1}{e}$. The higher the value, the more inefficient the particle capture. These numbers represent the value that a swept area measurement would need to be multiplied by in order to obtain the true number of individuals per m^2. The higher the number, the greater the error in the correction of bushel data from dredge hauls to quantitative estimates. Values of q exceeding about 15 should be considered too large to be routinely used; that is, values above $q \geq 15$ suggest that alternative sampling gear is needed for accurate quantitative estimates.

The numbers presented are those for the two survey vessels, the *F/V Howard W. Sockwell* in New Jersey and the *R/V First State* in Delaware. Note the higher

[†] Powell, E.N., K.A. Ashton-Alcox, J.A. Dobarro, M. Cummings, and S.E. Banta. 2002. The inherent efficiency of oyster dredges in survey mode. *J. Shellfish Res.* 21:691-695.

dredge efficiency (lower q) for spatted cultch in most cases versus spatless cultch suggesting spat preferentially settle on the larger particles caught more efficiently by the dredge. The dredge efficiencies for native cultch are consistent with previous measurements, for both sampling vessels, and the two sampling vessels demonstrate very similar catchabilities. The much lower efficiencies for planted cultch likely reflect the smaller average particle size versus native cultch. Overall, the indication is that spat counts are estimated poorly on planted shell using dredge samples and that 2006 estimates would better be derived from diver sampling exclusively, funds permitting.

Type of Shell Planted	Live Oysters	Spat	Cultch
New Jersey – *F/V Howard W. Sockwell*			
Average of Bennies Sand and Shell Rock			
Native (unplanted) oyster	4.87	8.97	9.70
Ocean quahog		98.30	197.59
Surf clam		150.25	123.73
Maryland oyster		None Conducted	
Delaware – *R/V First State*			
Average of Upper Middle and Jigger Hill			
Native (unplanted) oyster	7.32	1.06	11.83
Maryland oyster		1.82	178.89
Delaware – *F/V Howard W. Sockwell*			
Average of Upper Middle and Jigger Hill			
Native (unplanted) oyster	5.06	9.42	10.55
Maryland oyster		40.71	872.55

Figure 1. Map of Delaware Bay showing the New Jersey and Delaware oyster beds and the locations of 2005 shell plants, indicated by stars. Note that the Delaware beds are not completely shown, nor is the bed footprint equivalently defined in comparison to New Jersey. The grids on the New Jersey beds represent the $0.2''$ latitude $\times$ $0.2''$ longitude squares used as the template for the New Jersey stock survey. The same areal scale was used on both sides of the bay for shell planting, namely approximately 25 acres or $0.2''$ latitude $\times$ $0.2''$ longitude.