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THE EFFECTS OF SEED SIZE, SHELL BAGS, CRAB TRAPS, AND NETTING ON THE SURVIVAL OF THE NORTHERN HARD CLAM *MERCENARIA MERCENARIA* (LINNÉ)[3]

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ABSTRACT Seed size at planting is the dominant factor affecting hard clam survival to marketable size when field grow-out techniques are used. The use of plastic mesh nets, crab traps, and wire mesh bags (filled with oyster shells) alone or in combination can be used to increase survival of hard clams of ≥6 to 8-mm shell height. These techniques do not provide sufficient protection for 2-mm seed. The combination of net + crab trap + shell bag was nearly twice as effective as the net alone when 10 to 14-mm seed was used and over five times as effective as the net alone when 6 to 8-mm seed were planted. Survival in excess of 50% slows the growth rate and yields higher percentages of submarketable, <25-mm thick (New York legal limit) clams. Local markets and dealers would accept all clams >22 mm.

KEY WORDS: Hard clam, *Mercenaria mercenaia*, survival, predator exclusion.

INTRODUCTION

Commercial planting of seed clams for field growth to marketable size requires a series of decisions based on: size and cost of clam seed, cost of providing protection, the specific environment, and the predators that are present. When small seed clams are first planted, smaller predators may destroy a significant portion of the seed (Castagna and Kraeuter 1977, 1981; Eldridge et al. 1979). Experiments have shown that survival of clams in field plots is dependent on the presence of adequate protection throughout the warmer months (April-October) until clams are harvested (Kraeuter and Castagna 1980). The present series of tests were designed to examine the effects of predator protection provided by nets, shell bags, and crab traps to a size series of hard clam seed. Nets were considered to be useful in preventing clam seed predation by the blue crab *Callinectes sapidus* Rathbun and as the clams neared harvest size, predation by the cow-nosed rays *Rhinoptera bonasus* (Mitchill) (Kraeuter and Castagna 1980). Crab traps were used in an attempt to reduce predation by blue crabs, and shell bags were used in an attempt to trap xanthid crabs, chiefly *Panopeus herbstii* H. Milne-Edwards and *Neopanope texana* (Smith). These latter species are not attracted to baits, but are cryptic by nature and are found hiding in shell debris or among clumps of oysters. The bag of oyster shells provided a habitat which could readily be removed along with the crabs. The tested hypothesis was that combinations of these protective devices should increase survival of the hard clam *Mercenaria mercenaria* if these predator species significantly affected clam survival. This is the first in a series of experiments designed to test the effectiveness of various protection methods and the interactions between clam size and those techniques.

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MATERIALS AND METHODS

All experiments were conducted in Bradfords Bay near the town of Wachapreague, VA. Bradfords Bay is typical of the circular or nearly circular lagoonal bays of the ocean side of Virginia's Eastern Shore. This marsh-lagoon complex consists of shallow bays with extensive mudflats and oyster reefs surrounded by a salt marsh that is dominated by *Spartina alterniflora* Loisel. A minimum of freshwater flows into the system and salinities remain high throughout most of the year. Substrates are typically sandy behind barrier islands and near ocean inlets, and become progressively muddier toward the mainland. The experimental site was on muddy substrate, in the intertidal zone, and outside a fringe of oyster reefs. Water temperatures at the site ranged from -1 to 30°C and salinities ranged from 14 to 33 $^{0}/_{00}$.

Seed clams that were used during the experiments were reared in the culture facility of Virginia Institute of Marine Science from spawns conducted the preceding year. These clams were over wintered in flowing seawater tables and graded by size in the spring. The rearing and grading techniques have been described (Castagna and Kraeuter 1981). Replicate plots were prepared by spreading gravel about 3 cm thick on the mud substrate one week prior to planting the clams (Castagna and Kraeuter 1981; Kraeuter and Castagna 1977). Four gravel plots were laid out with at least 30 m between them in separate parts of the intertidal zone. Plots 1 and 4 contained five experimental treatment sites 1.5 x 1.5 m (5 x 5 ft) in size and Plots 2 and 3 were similar except only four treatment areas were constructed. The size of the experimental treatment area was chosen to make these experiments directly comparable to our previous studies (Kraeuter and Castagna 1977, 1980). The treatment areas were designed to test survival of three sizes of clam seed with various combinations of shell bags, crab traps, and nets (Table 1).

Clams were graded into three size categories 2 mm, 6 to 8 mm, and 10 to 14 mm, and groups of 8,000 2-mm, 6,000 6 to 8-mm, and 5,475 10 to 14-mm clams were placed in mesh bags for transport to the field and planted in the appropriate plots (Table 1). These replicate lots of seed clams were randomly assigned to a particular plot and planted at low tide when the plots were exposed. All clams were planted in May 1979.

Nets made of 12.5-mm mesh, Conwed® plastic, were stretched loosely over the gravel substrate. Edges of the nets were embedded in the mud and held in place with steel reinforcing rods placed over the mesh and pressed into the mud. Crab traps of standard commercial design were baited with fish and emptied every two days during warm months when blue crabs were active. Shell bags (45 cm wide x 60 cm long) were constructed of hexagonal wire mesh with 3.8-cm openings and filled with oyster shell and sealed. These bags were placed on the bottom near the appropriate plot and allowed to remain for 1 wk. Bags were removed from the water by pulling them quickly on board to prevent resident crabs from escaping. Each was then replaced with a new shell bag. Shell bags were removed during the colder months when crabs were no longer active. During the second year the bags were replaced every 2 wks. Four crab pots and six shell bags were located around the periphery of the appropriate plot. Experimental control areas with gravel but without nets were established for each trial. Full series of treatments were established for the two smaller seed sizes, but the 10 to 14-mm clams were not sufficiently abundant to conduct a full sequence of tests. We selected treatments that represented two ends of the spectrum for these larger clams (Table 1). More clams were planted in the 2-mm size class than in the 6 to 8-mm class because previous studies had shown that survival was seed-size dependent.

TABLE 1.

Experimental design of plots. Numbers indicate the number of clams planted in each 1.5 x 1.5-m plot. All clam sizes are based on square mesh size required to retain the clams.

Plot	Treatment	Number of Seed Clams and Sizes (mm) 2	6 to 8	10 to 14
1	Net	8,000	6,000	5,475
	Control	8,000	6,000	
2	Net + Shell Bags	8,000	6,000	
	Shell Bags	8,000	6,000	
3	Net + Crab Traps	8,000	6,000	
	Crab Traps	8,000	6,000	
4	Net + Shell Bags + Crab Traps	8,000	6,000	5,475
	Shell Bags + Crab Traps	8,000	6,000	

All plots were harvested in their entirety during October 1980. The cumulative effects of all factors are best depicted by harvest data (Kraeuter and Castagna 1980). Comparisons between treatments are analyzed by Chi-square tests following the methods outlined in Snedecor (1962).

RESULTS

Previous studies have shown that seed size at planting is a dominant factor in determining the survival to harvest, and our present data provide further confirmation, (X^2 = 59,942, df 2). Seed size was dominant, therefore, the remaining analyses were carried out within a seed-size category. Our basic assumption was that there should be no difference between treatments within a seed-size class.

Significant differences were found between treatments for 2-mm seed. These seed had significantly greater survival than expected in the Shell Bag + Trap (BP) series (Table 2). This

TABLE 2.

Numbers of hard clams harvested (by treatment). Chi-square values are based on analyses within a planted size.

Treatment*	Planted Size: 2 mm Number	2 mm X^2**	6 to 8 mm Number	6 to 8 mm X^2**	10 to 14 mm Number	10 to 14 mm X^2**
C	7	5.6 L***	15	225.7 L***		
T	21	1.0	284	6.2 G	2627	862 L
B	5	8.2 L	3	249.8 L		
TB	16	0.03	73	126.5 L		
P	5	8.2 L	1	254.0 L		
TP	10	2.7	46	169.1 L		
BP	50	66.1 G	4	247.7 L		
TBP	20	0.6	1539	7101.1 G	4676	862 G
		92.7**		8380.1**		1724**
df		7		7		1

* Treatments: C = Control, T = Net, B = Shell Bag, P = Crab Trap, and combinations thereof.
** Chi-square = 3.84 @ 95% (1 df) and 6.63 @ 99% (1 df).
Chi-square = 14.07 @ 95% (7 df) and 18.48 @ 99% (7 df).
*** G = greater survival than expected.
L = less survival than expected.

TABLE 3.

Numbers of clams harvested, percent survival (%), and mean size ($\overline{X}$) in mm of harvested experimental plots by treatment.

Treatment*	Planted Size								
	2 mm			6 to 8 mm			10 to 14 mm		
	Number	%	$\overline{X}$	Number	%	$\overline{X}$	Number	%	$\overline{X}$
C	7	< 0.1	26	15	0.2	31			
T	21	0.2	41	284	4.7	39	2,627	47.9	36
B	5	0.1	38	3	< 0.1	35			
T B	16	0.2	36	73	1.2	40			
P	5	< 0.1	41	1	< 0.1	55			
T P	10	0.1	44	46	0.7	42			
B P	50	0.6	34	4	< 0.1	35			
T B P	20	0.2	38	1,539	25.6	38	4,676	85.4	30

* Treatments: C = Control, T = Net, B = Shell Bag, P = Crab Trap, and combinations thereof.

anomaly resulted from an experimental artifact. During the experiment, winter storms caused a rip in the net and clams from an adjacent bed of 10 to 14-mm seed were washed into the 2-mm BP plot. This small washover was enough to cause statistically significant results because survival was so poor in plots with 2-mm seed (all less than 1%). The interpretation of the usefulness of these protection methods for commercial plantings of 2-mm and other sizes was not affected because the total number of clams that moved was relatively small.

Results for the 6 to 8-mm seed were as expected with the interaction of nets with bags and crab traps providing highly significant increases in survival (Table 2). All other tests yielded less than expected survival with the somewhat surprising exception that greater than expected survival resulted when neither shell bags nor crab traps were present. It may be that the presence of either the bag or the traps alone attracted both blue crabs and xanthid crabs so that without the means of removing these alternative predators they were able to take advantage of the situation. It is also possible that the result may be a chance occurrence. A third possibility is that washover similar to that of the 10 to 14-mm seed into the 2-mm seed plot may have occurred, but we do not have direct evidence for washover in this instance.

Ten to 14-mm seed clams survived well in both the Net (T) and Net + Shell Bag + Crab Trap (TBP) treatments (Table 2), but significantly more survived when all three treatments were combined. Total survival for the combined treatments (BP = 85%) was nearly double that of the net alone (T= 48%) (Table 3).

Growth data indicated a rapid increase in size during the first summer and some individuals in the 6 to 8-mm clam plot reached nearly the same size as their counterparts in the 10 to 14-mm clam plots. When the experiment was terminated, the mean size data indicated that those plots with greatest survival had reduced growth rates because of crowding (Table 3).

DISCUSSION

Only three of the experimental treatments provided survival that was at or near commercially acceptable levels. The Net + Shell Bag + Crab Trap (TBP) combination was more effective than the net alone, and in 6 to 8-mm seed plot, survival was over five times greater with all three protective devices present. This is similar to our previous experiments (Castagna and Kraeuter 1977; Kraeuter and Castagna 1977, 1980) where interactions were not additive and all combinations were necessary for maximum survival. The importance of size at planting cannot be overlooked. This is emphasized because, although there were significant statistical differences, none of the combinations was able to produce survival in excess of 1% for the 2-mm seed clams. These survival data extend our previous findings to smaller seed sizes and emphasize the need for multiple protective devices to ensure that large numbers of clams survive. The data presented by Flagg and Malouf (1983) for hard-clam plantings in New York support our results and indicate the need

TABLE 4.

Numbers of clams in various marketable categories.

Plot*	Size at Planting in mm	Size at Harvest (in mm) >25	25 to 24	<24 to 22	<22	Total	Marketable
T B P	6 to 8	496	324	388	331	1,539	1,208
T B P	10 to 14	545	398	601	3,132	4,676	1,544
T	10 to 14	763	551**	656**	639*	2,600*	1,970*

* Plots: T = Net Cover, TBP = Net Cover + Shell Bag + Crab Trap.

** Calculated values

for multiple protective devices in other locations.

Clams from two of the three plots that yielded the greatest survival were graded (by width [thickness]) to determine marketability. All clams that were >22-mm thick were acceptable to the local market and dealers. In spite of the stunting that was evident in the bed with the greatest survival (30.5 ± 1.08-mm; mean size ± standard error t = 0.05), greater numbers of marketable clams were available in all categories than in the bed with larger mean size (37.9 ± 1.07 mm) (Table 4). The harvest from the plot that was protected by a net with initial 10 to 14-mm seed clams (2,627 survivors) was not graded except to New York market standards of 1 inch (25 mm) thickness. Twenty-nine percent of these clams were >25 mm suggesting growth similar to the 6 to 8-mm seed treatment with 1,539 survivors. The data do not indicate significant mean size differences (36.8 ± 1.04 mm *vs* 37.9 ± 1.07). Based on these data, we would expect percentage breakdown of the remaining clam size-classes to be equivalent to the data from the 6 to 8-mm TBP plot and thus a total of 1,970 individuals would be marketable. A portion (3,272) of the nonmarketable clams were replanted to be harvested within 1 year. The decision of whether to thin the beds after the first year or to wait for harvest and then to replant is based on economics and the additional growth rates. Studies of these interactions are currently underway.

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