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EXPERIMENTAL FARMING OF THE SOFT-SHELL CLAM, MYA ARENARIA, IN MASSACHUSETTS, 1949-1953

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BACKGROUND

The clam-farming experiments which this paper describes were carried out over the years 1949-1953 on the tidal flats of Plum Island Sound, Essex County, Mass., and where noted, in the Hampton River, N. H. The commercially-important clam, Mya arenaria, had been becoming progressively scarcer along the coasts

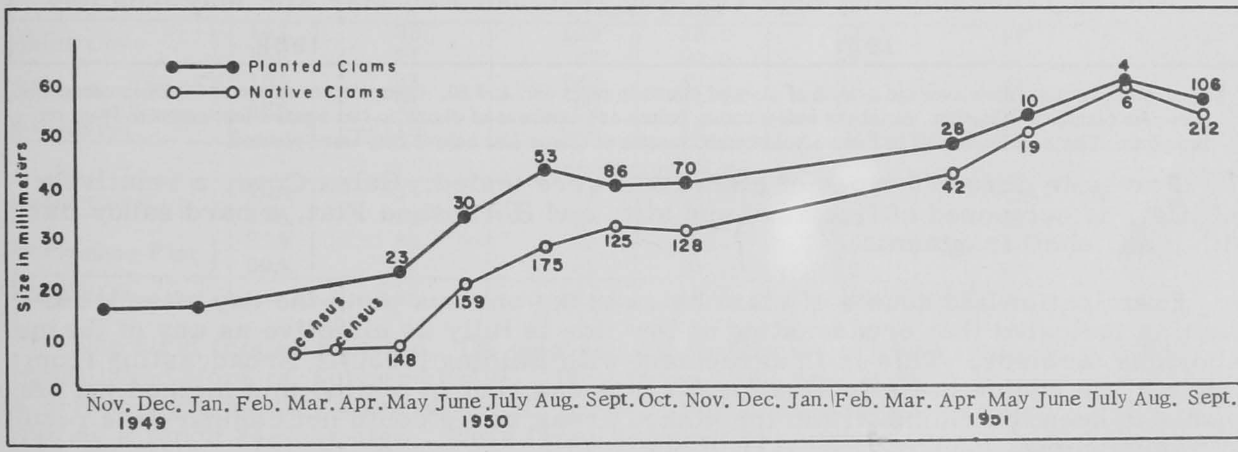

Fig. 1 - Growth of planted and native clams under chicken wire in plot 24B, based on average length from square-foot samples. Numbers of clams per square-foot sample are beside most datum points. Numbers beside points for September 1951 give numbers of clams in eight square feet. Datum point for planted clams in January is from plot 25. Points for native clams in March and April are from "open" flats around plot 24.

of Massachusetts, New Hampshire, and western Maine since about 1940, and it was generally believed that the scarcity was caused by overdigging. If overdigging was the principal cause, it was logical to assume from the work of Mead (1900-1904), Kellogg (1905), and Belding (1930) that clam farming would help to alleviate the shortage. Small clams could be taken from areas closed due to pollution and grown to market size in clean areas. Kellogg and Belding (op. cit.) had demonstrated that clams could be transplanted and that they would survive and grow well enough to produce an increase in volume, so our experiments were designed to learn more about methods and to find out if farming, either by towns or by individuals, would be feasible under present conditions.

TRANSPLANTING METHODS

On May 26 and June 2, 1949, 16 bushels of clams averaging 39 mm. in length[1/] were transplanted in Plum Island Sound at low tide (1) by broadcasting, (2) by plant-

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1/ Shell lengths were measured with vernier calipers to the nearest millimeter, and tabulated in two-millimeter groups, the odd number being combined with the next highest even number (Felin and Phillips 1948).

ing them in plowed furrows, (3) by broadcasting them on roughened ground at high tide, (4) by broadcasting from a boat. All these methods were commonly used by Massachusetts towns in 1949. The clams were planted in concentrations of about 20 and 38 per square foot.

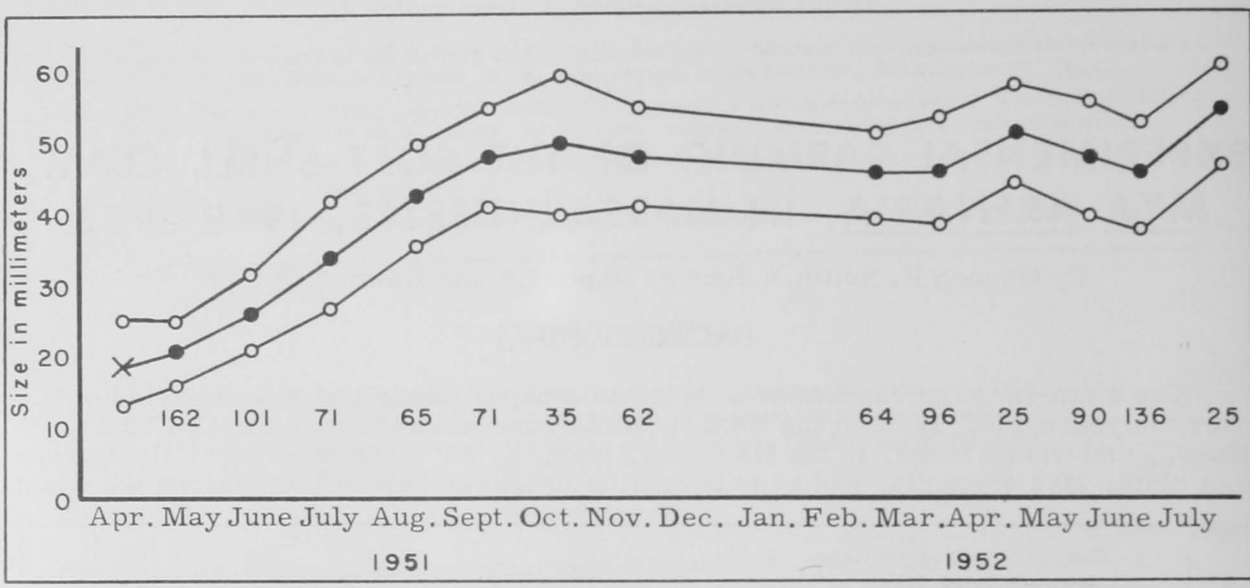

Fig. 2 - Solid points show average growth of planted clams in plots 45B and 60. Open circles above and below averages show one standard deviation. Numbers below datum points are numbers of clams in two square-foot samples from the two plots. The X at lower left is from a volumetric sample of clams just before they were planted.

Two quite different types of clam flats were tested: Hales Cove, a relatively soft flat, is composed of fine sand and silt, and Horseshoe Flat, a hard sandy flat with many shell fragments.

Examination and counts of clam holes in the various plots the day after transplanting indicated that broadcasting at low tide is fully as effective as any of the more laborious methods. This is in agreement with Belding (1930). Broadcasting from a boat may be even more effective for large areas, but in testing this method we were unable to keep the clams within the staked areas so we could not compare the results with other plots.

Within a week after the above plots had been set out, the horseshoe crab (*Limulus polyphemus*) had concentrated on them and dug up most of the clams. On June 7, 31 horseshoe crabs were found in three 10 x 20-foot plots on Horseshoe Flat, and the entire planted area was covered with depressions. On the softer soil of Hales Cove, the entire surface of the plots had been lowered enough to form square pools

Table 1 - Recoveries of Medium-Size Clams Transplanted August 17,1949, at Average Size of 33 mm. from Fenced Plot (#13)

Date Sampled	Area Sampled	Clams Recovered	Clams Per Sq. Ft.	Avg. Size	Avg. Growth
	Sq. Ft.	No.	No.	mm.	mm.
Aug. 22, 1949	2	52	26.0	-	0
Sept. 19, 1949	2	75	37.5	-	0
July 5, 1950	1	1	1.0	61	27
July 10, 1950	16	62	3.9	58	26
Aug. 30, 1950	16	92	5.8	63	32
Sept. 7, 1950	32	97	3.0	-	-
Oct. 20, 1950	3	19	6.3	62	26
Summary of all 1950 samples:	68	271	4.0	(Survival--about 12.5%)	

of water at low tide. When the Hales Cove plots were dug in November 1949, 92 percent of the clams had disappeared. Field observations and occasional trial digs indicated that most of the loss was caused by horseshoe crabs within a week after the clams were transplanted.

Green crabs (Carcinides maenas) probably dug some of the clams also, but we did not suspect their importance at that time. The principal result of this first series of transplanting experiments was to prove that natural predation was a major problem which would have to be met if clam farming was to be successful.

EXPERIMENTS ON METHODS OF COMBATTING NATURAL PREDATION

After the first transplanting experiments had been eliminated by predators, more plots were set out to test methods of keeping predators away from the clams by the use of fences and screens.

Table 2 - Recoveries of Large Clams Transplanted November 16, 1949, at Average Size of 46 mm. from Fenced and Unprotected Plots

Location	Plot No.	Estimated No. Planted Per Sq. Ft.	Recoveries				Date Sampled (1950)
			No. from 4-Sq.-Ft.	No. Per Sq. Ft.	Avg. Size in mm.	Avg. Size of "Planting Ann."	
Fenced Plots							
Hales Cove	14A	38	100	25.0	57	48	July 18
	15A	21	82	20.5	52	40	July 25
Horseshoe Flat	18A	38	182	45.5	57	44	July 21
	19A	21	85	21.3	55	43	
Summary:		118	449	28.1	(Survival 95%)		
Unprotected Plots							
Hales Cove	16A	38	94	27.0	58	50	July 18
	17A	21	36	9.0	56	41	July 25
Horseshoe Flat	21A	38	60	15.0	58	49	July 21
	20A	21	57	14.3	59	46	
Summary:		118	247	15.4	(Survival 52%)		

The first fenced plot (no. 13) was set out in August of 1949, following the then unpublished work of Turner (1949). This fence, and others built later, was made of 3-foot-wide poultry wire of 2-inch mesh. The lower edge was buried 6 inches, making a fence $2\frac{1}{2}$-feet high. This fence kept out horseshoe crabs, so in November of 1949 two more series of plantings were set out on Horseshoe Flat and Hales Cove, arranged so that fences could be built around some of them the following spring. The clams were of 2 size groups--(1) the larger, dug commercially in Quincy, Mass., averaged 46.2 mm. in length, and (2) the smaller from Scarborough, Me., averaged 16.1 mm.

When these plots were set out, the horseshoe crabs had left the flats for the winter. Most of the green crabs had left and those that remained were nearly dormant. The only predators that seemed likely to attack the clams during the winter were ducks and gulls, because both of these had been seen "puddling" the flats with their feet to wash out small clams, as described by Medcof (1949). Therefore parts of several plots of small clams were covered with one-inch mesh chicken wire staked down flat on the soil soon after the clams had dug in.

Only one small piece of wire about 6 x 6 feet on plot no. 24B remained through the winter, but this one plot, as we shall see later, showed what clams may do where they are well protected.

Examination of tables 1, 2, and 3 will show the results from fenced and unprotected plots of large and small clams, and from a plot of small clams protected by chicken wire staked down over them. The effect of covering planted clams with chicken wire is further demonstrated by table 4, which shows results of transplanting experiments in 1951 and 1952. These will be discussed in detail later.

Table 3 - Recoveries of Small Clams Transplanted November 18, 1949, at Average Size of 16.1 mm. from Protected and Unprotected Plots

Location and Plot No.	Estimated No. Planted Per Sq. Ft.	Area Sampled (Sq. Ft.)	No. Per Sample	No. Per Sq. Ft.	Average Length in mm.	Average Length of Annulus Formed at Time of Planting	Date Sampled
			Protected with Fence				
Hales Cove Plot 14B	216	1	7	7.0	54	22	Oct. 9, 1950
		1	4	4.0	54	21	
		1	7	7.0	54	21	
		5	9	1.8	57	24	Nov. 15, 1950
		7	22	3.1	58	22	
Summary:		15	49	3.3	(Survival--1.5%)		
			Protected with Fence				
Hales Cove Plot 15B	108	1	1	1.0	45	18	Oct. 9, 1950
		1	2	2.0	50	20	
		1	1	1.0	57	23	
		16	11	0.7	54	21	Nov. 15, 1950
Summary:		19	15	0.8	(Survival--9.7%)		
			Unprotected				
Hales Cove Plot 16B	216	1	0	0	-	-	Oct. 9, 1950
		1	0	0	-	-	
		1	0	0	-	-	
		6	0	0	-	-	Nov. 15, 1950
			Unprotected				
Hales Cove Plot 17B	108	1	0	0	-	-	Oct. 9, 1950
		1	0	0	-	-	
		1	0	0	-	-	
		6	0	0	-	-	Nov. 15, 1950
			Unprotected				
Hales Cove Plot 23	54	1	6	6	-	-	May 11, 1950
		1	3	3	-	-	June 22, 1950
		1	0	0	-	-	Aug. 9, 1950
		4	0	0	-	-	Nov. 1, 1950
			Unprotected				
Hales Cove Plot 24A		1	10	10	-	-	May 11, 1950
		1	0	0	-	-	June 22, 1950
		1	0	0	-	-	Aug. 9, 1950
		1	0	0	-	-	Sept. 20, 1950
		1	0	0	-	-	Nov. 1, 1950
			Protected with Chicken Wire for 2 Years				
Hales Cove Plot 24B	108	1	23	23	23.5	-	May 11, 1950
		1	30	30	34.2	-	June 22, 1950
		1	53	53	44.0	-	Aug. 9, 1950
		1	86	86	40.0	-	Sept. 20, 1950
		1	70	70	41.0	-	Nov. 1, 1950
		1	28	28	48.0	-	Apr. 12, 1951
		1	10	10	54.0	-	May 28, 1951
		1	4	4	61.0	-	July 26, 1951
		8	106	13	57.0	-	Sept. 11, 1951
Survival 12%--Sept. 11, 1951							
			Protected by Wire Part of Winter, Clammers Dug in Plot				
Hales Cove Plot 25	108	1	20	20.0	16.7	-	Jan. 11, 1950
		1	5	5.0	14.2	-	
		1	30	30.0	24.8	-	May 19, 1950
		½	0	0	-	-	
		4	9	4.5	52.2	-	Sept. 18, 1950
		3	5	1.7	50.4	-	
			Protected by Wire Part of Winter				
Horseshoe Flat Plot 26B	108	1	20	20.0	24.7	16.4	May 19, 1950
		1	1	1.0	37.0	19.0	July 5, 1950
			Unprotected				
Horseshoe Flat Plot 26A	108	1	2	2.0	28.1	17.8	May 19, 1950
		1	0	0	-	-	July 5, 1950
			Unprotected				
Horseshoe Flat Plot 27	108	1	15	15.0	24.9	16.2	May 19, 1950
		1	0	0	-	-	July 5, 1950

It should be explained that the fences kept out horseshoe crabs but not green crabs. By the summer of 1950 we had learned that green crabs, not birds, were

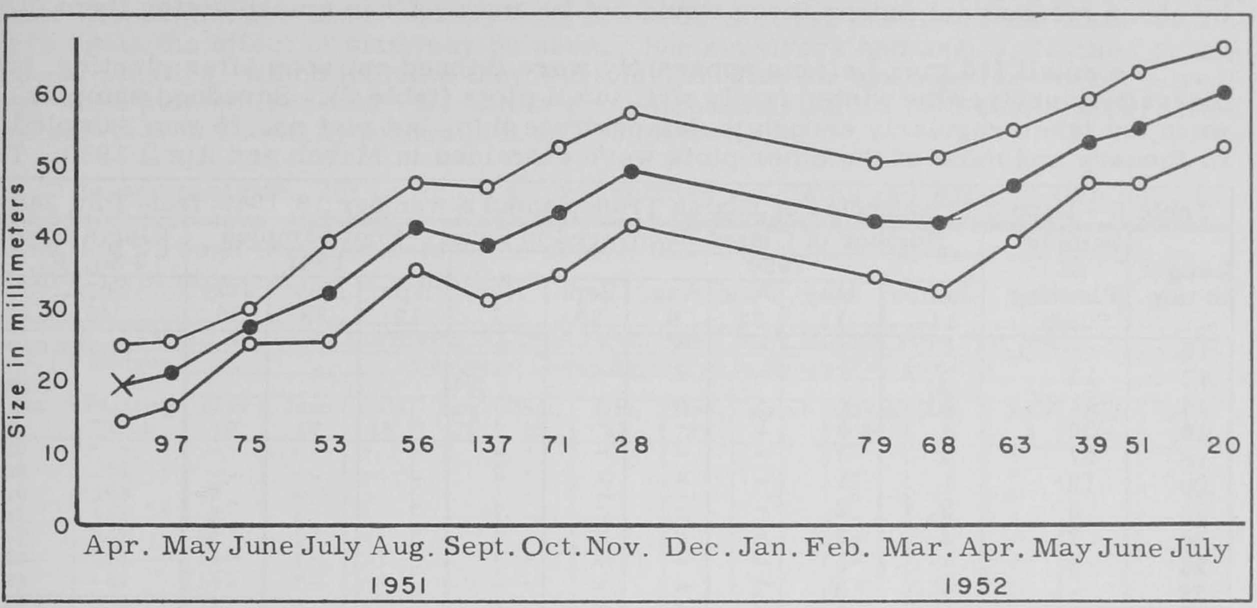

Fig. 3 - Solid points show average growth of planted clams in plot 46. Open circles above and below averages show one standard deviation. Numbers below datum points are numbers of clams in single square-foot samples. The X at lower left is from a volumetric sample of clams just before they were planted.

digging up planted clams inside the fences. During the summer months we had watched the crabs going through and over the fences at high tide, and one crab was caught in the act of devouring a 50 mm. clam.

Table 4 - Recoveries from Protected and Unprotected Plots of Clams in Various Types of Soil (Planted April 17-19, 1951, at Average Length of 19 mm.)

Plot	Est. No. Planted Per Sq. Ft.	Plot Dim. (Ft.)	Number of Planted Clams Recovered in One-Square-Foot Samples													Protection
			1951							1952						
			May 10-11	June 12-13	July 16-17	Aug. 22-27	Sept. 20	Oct. 22	Nov. 23	March 3	March 31	May 1	June 3	June 25	July 30	
Hales Cove--Mod. Soft Fine Sand and Silt																
45A	51	15x15	37	4	0	0	0	0								None
45B	51	15x15	51	50	16	48	54	33	13	51	57	38	26	40	11	Chicken wire
46	104	5x11	162	101	71	65	71	35	62	64	96	25	90	136	25	Chick. wire on frame
47	104	5x11	149	3	0	0	0	0								None
48	104	5x11	71	-	52	2	0		1	(Wire carried away in August)						Chicken wire
Ordway's--Firm Fine Sand and Silt																
60A	51	15x15	42	1	1	0	0	0								None
60B	51	15x15	46	25	37	8	83	38	15	28	11	25	13	11	9	Chicken wire
Rowley "Finger Flat"--Loose Rippled Sand, Low																
49A	51	15x15	9	0	0	0										None
49B	51	15x15	20	0	0	0	(Wire carried away early June)									Chicken wire
Thorofare--Hard Rippled Sand, High																
51A	51	15x15	11	3	1	-	-	2								None
51B	51	15x15	13	3	9	-	-	7								Chicken wire
53A	104	10x10	39	0	0	-	-	3								None
53B	104	10x10	21	21	0	-	-	1								Chicken wire
Dole's Island Bar--Rippled Sand, Low																
54	51	15x15	-	(Clams washed away when planted)												None
Dole's Island Pond--Soft Silt and Detritus, High																
55	51	15x15	-	-	0	0	0									None
Jones Grant, Hampton River, N. H.--Mod. Soft Fine Sand and Silt																
56A	25	15x30	-	-	2										-	None
56B	25	15x30	-	-	13										-	Chicken wire
57A	51	15x15	-	-	4	Wire removed and most of clams dug up by clammers.									0	None
57B	51	15x15	-	-	11										4	Chicken wire
59A	25	15x30	-	-	0										-	None
59B	25	15x30	-	-	(holes seen)										-	Chicken wire

Survival of the planted clams depended on both the size at planting and the degree of protection. Inside a fence, where green crabs could go but horseshoe crabs could not, about 95 percent of the large clams survived for 8 months. With no protection, only about 50 percent of the large clams survived for 8 months (table 2). There was little or no loss of large clams during the winter, but they became thinned out rapidly as soon as the horseshoe and green crabs became active in the spring.

No further work was done with large clams because those available were nearly market size (2 inches) when transplanted, and unless such clams were obtained by cheap mechanical means there would not be any profit in transplanting them.

The small (16 mm.) clams apparently were thinned out soon after planting, but thereafter survived the winter fairly well in all plots (table 3). Screened samples were not taken regularly enough to demonstrate this, but plot no. 25 was sampled in January and most of the other plots were examined in March and April 1950. The habit which small clams have of coming up out of the soil and moving about (Smith 1953) may account for some of the initial loss. Birds probably were responsible for some of the thinning, but the horseshoe crabs and green crabs were the predators that did the real damage. In March and April clams were still abundant enough in all sampled plots to produce good digging, but they were completely eliminated in most unprotected areas within a few weeks after the horseshoe and green crabs became active in the spring (see the May, June, and July samples in table 3). A few

Table 5 - Length Frequencies of Clams Transplanted November 18, 1949, from Plot 24B

Length in mm.	Sample of Planting Stock	Number of Clams Recovered in Square-Foot Samples									Clams from 8 Sq. Ft.
		1950						1951			
		Jan. 11 1/	May 11	June 22	Aug. 9	Sept. 20	Nov. 1	Apr. 12	May 28	July 26	Sept. 11
10	-	1	-	-	-	-	-	-	-	-	-
12	12	2	1	-	-	-	-	-	-	-	-
14	41	3	-	-	-	-	-	-	-	-	-
16	30	3	4	1	-	-	-	-	-	-	-
18	27	6	1	-	-	-	-	-	-	-	-
20	12	1	1	-	-	-	-	-	-	-	-
22	5	2	2	-	-	-	-	-	-	-	-
24	2	2	3	-	-	-	-	-	-	-	-
26	3	-	5	-	-	-	-	-	-	-	-
28	-	-	2	2	-	-	-	-	-	-	-
30	3	-	1	4	1	3	2	-	-	-	-
32	-	-	-	5	-	3	2	-	-	-	-
34	-	-	2	4	1	4	6	1	-	-	-
36	-	-	1	3	2	11	6	-	1	-	-
38	-	-	-	5	2	11	8	-	-	-	-
40	-	-	-	3	8	19	8	1	-	-	1
42	-	-	-	2	4	11	8	1	-	-	2
44	-	-	-	-	13	9	17	6	1	-	4
46	-	-	-	-	8	7	5	4	1	-	9
48	-	-	-	-	7	2	5	3	1	-	5
50	-	-	-	1	3	2	1	5	1	-	8
52	-	-	-	-	1	2	-	-	-	-	7
54	-	-	-	-	3	1	1	2	-	-	10
56	-	-	-	-	-	1	-	2	-	1	7
58	-	-	-	-	-	-	1	-	1	-	8
60	-	-	-	-	-	-	-	3	1	1	10
62	-	-	-	-	-	-	-	-	-	1	6
64	-	-	-	-	-	-	-	-	1	-	7
66	-	-	-	-	-	-	-	-	-	1	2
68	-	-	-	-	-	-	-	-	2	-	5
70	-	-	-	-	-	-	-	-	-	-	5
72	-	-	-	-	-	-	-	-	-	-	6
74	-	-	-	-	-	-	-	-	-	-	1
76	-	-	-	-	-	-	-	-	-	-	2
78	-	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-	-
82	-	-	-	-	-	-	-	-	-	-	1
N	135	20	23	30	53	86	70	28	10	4	106
$\bar{X}$	16.1	16.7	23.5	34.2	43.5	40.1	40.7	48.3	53.9	60.7	56.9
$S_{\bar{x}}$	3.65	3.12	6.08	5.99	4.78	5.19	5.37	5.63	10.25	3.59	16.79

1/ Sample from plot 25, adjacent to plot 24B which was not sampled at this time.

clams (0.7-1.5 percent) survived inside fences where they could be reached by green crabs but not by horseshoe crabs. So with small clams, the two predators under discussion are about equally bad; if one doesn't eat the clams the other will. Here again the effect of size may be seen. The survivors had annuli, formed at the time of planting, which indicate they were larger than the average for the lot when they were planted (see table 3). An intermediate situation in both size and percentage survival is shown by fenced plot no. 13 (table 1).

The one plot (no. 25) in which a few unprotected clams did survive was on firmly-packed fine sand and silt, near the bank of Plum Island. Unfortunately, clammers dug through this plot sometime during the first winter so we were unable to secure a reliable series of samples from it.

Table 6 - Length Frequencies of Clams Transplanted April 17, 1951, from Plot 45B

Length in mm.	Sample of Planting Stock	Number of Clams Recovered in Square-Foot Samples												
		1951							1952					
		May 10	June 12	July 16	Aug. 22	Sept. 20	Oct. 22	Nov. 23	March 3	March 31	May 1	June 3	June 25	July 30
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	34	-	-	-	-	-	-	-	-	-	-	-	-	-
14	103	2	-	-	-	-	-	-	-	-	-	-	-	-
16	151	3	1	-	-	-	-	-	-	-	-	-	-	-
18	152	10	4	-	-	-	-	-	-	-	-	-	-	-
20	115	14	1	-	-	-	-	-	-	-	-	-	-	-
22	83	14	7	1	-	-	-	-	-	-	-	-	-	-
24	53	2	10	-	-	-	-	-	-	-	-	-	-	-
26	25	2	10	-	1	1	-	-	-	1	-	-	-	-
28	22	-	7	1	-	1	-	-	1	2	-	-	-	-
30	19	2	3	2	-	1	1	-	4	2	-	-	-	-
32	8	-	2	5	2	2	1	-	3	5	1	-	-	-
34	4	1	1	2	4	3	-	-	1	5	1	-	-	-
36	5	1	2	1	5	6	2	-	-	2	1	-	1	-
38	3	-	1	3	5	8	4	2	7	3	1	-	1	-
40	3	-	-	-	6	3	2	-	10	7	4	1	-	-
42	2	-	-	-	5	5	1	1	4	4	4	1	-	-
44	-	-	-	-	5	2	3	-	2	1	3	-	2	-
46	1	-	-	-	9	3	2	-	3	8	4	4	2	2
48	2	-	1	1	3	5	2	3	4	6	4	2	3	-
50	-	-	-	-	-	4	3	-	4	5	2	4	3	1
52	-	-	-	-	1	5	3	1	2	2	2	2	5	-
54	-	-	-	-	-	1	5	1	2	-	2	1	2	2
56	-	-	-	-	2	2	-	1	2	2	2	2	6	-
58	-	-	-	-	-	2	1	1	-	-	2	2	5	2
60	-	-	-	-	-	-	2	2	-	2	1	1	4	-
62	-	-	-	-	-	-	-	-	1	-	-	2	2	1
64	-	-	-	-	-	-	-	-	1	-	2	3	3	-
66	-	-	-	-	-	-	1	1	-	-	2	-	1	1
68	-	-	-	-	-	-	-	-	-	-	-	1	-	2
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N	785	51	50	16	48	54	33	13	51	57	38	26	40	11
$\bar{X}$	19.45	21	26	33.5	41.4	42.7	46.9	51.4	42.7	42.1	48.3	53.5	54.1	57.3
Sx	5.37	4.27	5.33	5.45	6.09	7.88	8.57	8.4	8.28	7.94	8.71	7.49	6.89	7.75

Expense seems to be the major obstacle to raising clams by protecting them with wire over the flats. These experiments were not on a large enough scale to give adequate production cost figures, but if we assume 1,200 legal clams per bushel (Turner 1950) and 20 clams per square foot, then 60 square feet of flat could produce a bushel. Wire to cover that area would cost around \$1.60, and it probably would have to be replaced once, bringing the cost for wire alone to around \$3 to \$4 a bushel.

Experiments in progress indicate that a small vertical fence with a flange on top may be a satisfactory means of protecting clams from horseshoe crabs and green crabs. According to Dr. P. Korringa of Holland,2/ the French oyster growers use a fence only 10 inches high (25 to 30 cm.) with a flange on top to protect oyster spat from green crabs. A barrier similar to this was tried in Plum Island Sound in the summer of 1952. This fence acted as a partial barrier, but it was too small and

2/ Unpublished letter from Dr. P. Korringa of the Ruksinstituut voor Visscherijonderzoek Bergen op Zoom, Holland, to John Glude, Chief, Clam Investigations, U. S. Fish and Wildlife Service, Boothbay Harbor, Me.

was eroded badly, so results were not conclusive. A much larger and stronger fence was built in 1953. This fence was built in the shape of a circle, to enclose the largest possible area per unit length and avoid eddy-producing corners. It was 300 feet in circumference, 18 inches high, and the flange was made of 1- by 6-inch boards, each 10 feet long. The boards were lapped instead of butted to simplify construction. The stakes were 2 by 2 inches; a 4-foot stake was driven in the mud at each overlap of the boards and a 3-foot stake driven in between. One-inch mesh chicken wire, 2 feet wide, was stapled on the inside of this wooden structure, and the bottom edge buried about 6 inches. The actual construction took about 15 man-hours, or 3 men one tide and 2 men the next. The fence proved to be very rigid, and probably stronger than necessary.

Table 7 - Length Frequencies of Clams Transplanted April 17, 1951, from Plot 46

Length in mm.	Sample of Planting Stock	Number of Clams Recovered in Square-Foot Samples												
		1951							1952					
		May 10	June 13	July 16	Aug. 22	Sept. 20	Oct. 22	Nov. 23	March 3	March 31	May 1	June 3	June 25	July 30
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	34	-	-	-	-	-	-	-	-	-	-	-	-	-
14	103	7	-	-	-	-	-	-	-	-	-	-	-	-
16	151	25	1	-	-	-	-	-	-	-	-	-	-	-
18	152	43	7	-	-	-	-	-	-	-	-	-	-	-
20	115	27	4	1	-	-	-	-	-	-	-	-	-	-
22	83	28	20	1	-	-	-	-	-	-	-	-	-	-
24	53	9	26	2	-	-	-	-	-	-	-	-	-	-
26	25	6	9	8	-	-	-	-	-	-	-	-	1	-
28	22	5	9	9	1	-	1	-	-	-	-	1	-	-
30	19	5	6	11	-	-	-	-	-	2	-	-	-	-
32	8	4	7	4	2	1	-	-	-	4	-	-	1	-
34	4	1	4	11	5	-	-	1	3	1	-	4	-	-
36	5	1	3	3	6	2	2	1	4	5	-	6	7	-
38	3	-	3	3	6	1	1	2	2	8	1	2	12	-
40	3	1	1	1	7	6	4	1	7	6	-	4	12	-
42	2	-	-	6	8	5	1	4	5	5	2	9	16	-
44	-	-	1	4	9	9	2	5	8	6	3	8	19	1
46	1	-	-	1	5	13	-	10	7	16	2	5	11	2
48	2	-	-	1	3	9	1	11	9	10	-	9	11	3
50	-	-	-	3	7	8	5	8	7	10	2	11	13	5
52	-	-	-	2	-	-	5	8	4	5	3	5	10	1
54	-	-	-	-	2	5	3	2	3	9	4	9	9	2
56	-	-	-	-	3	5	2	2	3	1	2	6	4	4
58	-	-	-	-	1	-	2	4	2	5	2	2	2	2
60	-	-	-	-	-	3	2	1	-	1	2	2	2	-
62	-	-	-	-	-	1	1	2	-	1	1	5	4	3
64	-	-	-	-	-	3	-	-	-	-	-	-	-	-
66	-	-	-	-	-	-	1	-	-	-	1	1	-	1
68	-	-	-	-	-	-	1	-	-	1	-	1	1	-
70	-	-	-	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	1	-	-	-	-	-	1	-
74	-	-	-	-	-	-	-	-	-	-	-	-	-	1
76	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N	785	162	101	71	65	71	35	62	64	96	25	90	136	25
$\overline{X}$	19.45	20.5	25.9	34.1	42.7	47.9	50.4	48.3	45.6	46.0	51.7	48.0	46.3	54.2
Sx	5.37	4.65	5.46	7.71	7.02	6.88	9.60	7.14	6.15	7.56	6.96	8.16	7.34	6.90

During the summer of 1953 this fence effectively protected clams from the horseshoe and green crabs, their two worst enemies. Figure 5 shows the flat outside the fence has been completely dug up while the surface inside is still smooth. A baited green-crab trap set inside the fence caught 24 crabs in 24 hours, but only 3 of these were too large to have gone through the meshes of the chicken wire fence. A similar trap outside the fence caught 111 green crabs, and, as is usual in trap samples, very few of the crabs were small. The effectiveness of the fence was also observed by swimming around it with an "Aqualung" at high tide, when the water was about 7 feet deep. Large and medium green crabs were clustered against the fence all around its circumference, averaging about 1 every 2 feet of fence. Some were at the base, some were clinging to the wire, but fully half were clinging to the wire up under the flange. Several small crabs and one large one were found inside. The small ones could have gone through the meshes, or they might have swum over the fence because one was seen in the act of swimming over it. While observing these crabs, it became quite obvious that little ones swim much more than big ones.

No horseshoe crabs were ever found inside the fence. Those seen around the fence usually went off in some other direction after bumping into the wire, apparently no effort being made to get over or under the fence.

Apparently the small crabs that went through and over the fence were not numerous or large enough to do serious damage to the clam crop.

Table 8 - Length Frequencies of Clams Transplanted April 19, 1951, from Plot 60B

Length in mm.	Sample of Planting Stock	Number of Clams Recovered in Square-Foot Samples												
		1951							1952					
		May 11	June 12	July 17	Aug. 27	Sept. 20	Oct. 23	Nov. 26	March 3	March 31	May 1	June 3	June 25	July 30
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	34	-	-	-	-	-	-	-	-	-	-	-	-	-
14	103	3	-	-	-	-	-	-	-	-	-	-	-	-
16	151	5	-	-	-	-	-	-	-	-	-	-	-	-
18	152	10	-	-	-	-	-	-	-	-	-	-	-	-
20	115	6	2	3	-	-	-	-	-	-	-	-	-	-
22	83	7	4	2	-	-	-	-	-	-	-	-	-	-
24	53	8	6	1	-	4	-	-	-	-	-	-	-	-
26	25	2	1	4	-	3	1	-	-	-	-	-	-	-
28	22	1	6	5	-	2	2	-	1	-	-	-	-	-
30	19	4	2	1	-	12	2	-	2	1	-	-	-	-
32	8	-	1	7	-	8	4	-	-	1	-	-	-	-
34	4	-	-	3	1	11	4	1	3	-	1	-	-	-
36	5	-	-	4	-	8	3	1	2	-	1	-	-	-
38	3	-	1	1	1	7	4	1	2	1	2	-	-	-
40	3	-	1	2	2	6	4	-	3	1	3	-	-	-
42	2	-	-	2	1	8	2	1	2	-	-	-	-	-
44	-	-	1	-	1	3	1	-	3	1	3	1	1	-
46	1	-	-	1	-	4	4	2	2	3	4	2	-	-
48	1	-	-	1	-	2	4	1	2	2	5	3	-	-
50	-	-	-	-	2	1	3	3	2	1	3	3	-	-
52	-	-	-	-	-	1	-	-	3	-	-	-	1	1
54	-	-	-	-	-	2	-	2	-	-	2	2	-	-
56	-	-	-	-	-	1	-	2	1	-	-	-	1	-
58	-	-	-	-	-	-	-	-	-	-	1	-	2	1
60	-	-	-	-	-	-	-	-	-	-	-	2	-	-
62	-	-	-	-	-	-	-	1	-	-	-	-	2	2
64	-	-	-	-	-	-	-	-	-	-	-	-	1	1
66	-	-	-	-	-	-	-	-	-	-	-	-	-	2
68	-	-	-	-	-	-	-	-	-	-	-	-	2	-
70	-	-	-	-	-	-	-	-	-	-	-	-	-	1
72	-	-	-	-	-	-	-	-	-	-	-	-	1	1
74	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N	785	46	25	37	8	83	38	15	28	11	25	13	11	9
$\bar{X}$	19.45	21.0	27.2	32.2	42.3	36.5	38.9	48.1	41.9	42.5	45.5	50.6	60.5	63.7
Sx	5.37	4.36	5.93	5.04	5.24	7.27	6.99	7.73	7.39	6.42	5.75	4.91	7.95	6.15

The fence was not standing long enough to tell just what effect it would have on the native clams, but it protected a small plot of transplanted clams. On July 28, 1953, about a bushel of clams averaging 17 mm. in length were planted, some inside and some outside the fence. Those outside never had a chance. With a face plate we could see green crabs grabbing many of them, and apparently none of them survived more than a few days. Inside the fence the clams dug in well, and a small plot within the fence was well peppered with their holes all summer. A square-foot sample on October 14 had 53 per square feet averaging 24 mm.

We planned to maintain this fence at least one more summer, to learn more about what could be produced by protecting a natural set, but clam diggers dug over the area early in 1954 so that particular fenced plot was abandoned.

Instead of rebuilding the fence, we worked with the towns of Ipswich, Mass., and Hampton, N. H., in helping them build fences similar to ours. Both towns purchased materials and supplied much of the labor. Unfortunately, neither of these fences was successful. The one at Ipswich clogged badly with seaweeds and colonial hydroids and could not be maintained. The one at Hampton stayed up well but it did not save either native or transplanted clams inside. Crab traps set inside and outside the Hampton fence indicated the damage was done by large numbers of crabs just small enough to go through the one-inch mesh. Crab traps fished 24 hours inside the fence on July 29, 30, and August 12, took 203, 89, and 93 crabs, respectively. The average widths were 40, 40, and 41 mm. Ninety-one percent of these were under 45 mm. wide, and therefore small enough to get through the meshes of the chicken wire. Control samples outside collected 266, 128, and 176, and the average widths were 47, 48, and 49 mm.

In view of these experiences, further fencing experiments will be done with finer-mesh wire. This should be effective if it can be maintained without clogging or washing too badly.

ATTEMPTS TO PLANT CLAMS SO AS TO AVOID PREDATORS

In April of 1951 another series of plots was set out in Plum Island Sound and in the Hampton River, N. H., to test survival on various types of flats and to get more reliable growth and survival data.

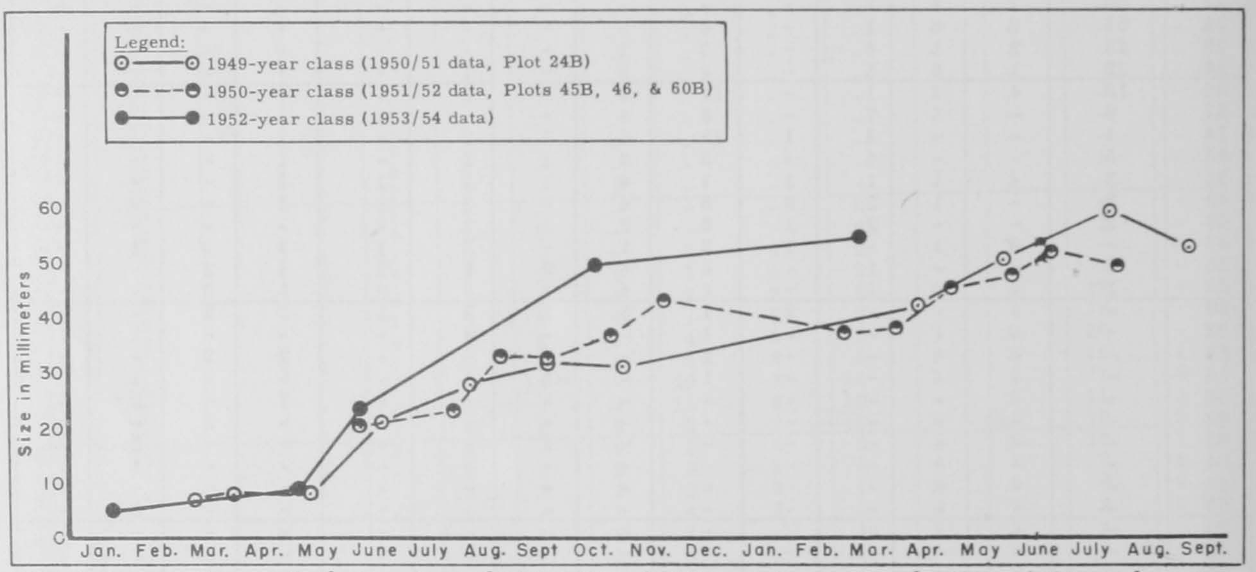

Fig. 4 - Comparative growth of native clams of 1949, 1950, and 1952 year-classes. Data for 1949 and 1950 are from protected plots, there being almost no survival elsewhere. Data for 1952 year-class are from unprotected areas, where clams survived and produced commercial digging, possibly because of more rapid growth.

This plan was adopted because the uneven distribution of native clams in Plum Island Sound, and the results from plot no. 25 mentioned above led us to believe that some areas might be more free of predators than others. Catches of green crabs in traps also indicated that high sandy flats had fewer crabs on them than muddy flats.

The results from these plots of transplanted clams are summarized in Table 4. It may be seen that the results at Hales Cove and Ordways confirmed the results of plot no. 24B (table 3) in showing that clams in those flats survived only where protected.

On the more sandy flats results were confused by the fact that the covering wire was carried away, undermined at the edges, or buried by 3 to 6 inches of shifting sand. Judging by the May samples, many of the clams washed away before they could establish themselves. On one high sandy bar, "Thorofare," the clams that did get established survived longer than in the muddy flats, but survival was not high enough in any unprotected plot to give profitable results.

SURVIVAL OF PROTECTED PLANTED CLAMS

In protected plot 24B, we established the planting density at 108 clams per square foot, and the recovery 2 years later, on a basis of 8 square feet, was 13 clams per square foot or about 12 percent.

In the protected plots 45B, 46, and 60B, survival was estimated from the average of the last four samples and the known concentration when planted. Plots 45B and 60B were each planted with 50 clams per square foot, and the average survival for the two plots combined (i.e., 8 square-foot samples) was 43 percent. Plot 46 planted with 100 per square foot apparently had a 69-percent survival, but the samples from that plot were quite variable. In any case, the clams were extremely crowded over the entire plot, probably too crowded for good growth, so we know survival was relatively high. Plot 46 not only was planted more densely than the others but it also was much better protected. It was covered by chicken wire on a frame, supported 1 inch above the surface of the soil by boards set edgewise in the mud. A few Polinices heros were found under this wire, but it kept green crabs and horseshoe crabs out better than wire that was just staked down. Crabs were sometimes found under the edges of the wire that was staked down.

Table 9 - Length Frequencies of Native Clams from Plot 24B, Chicken Wire-Protected from November 18, 1949 (History of 1949 Year-Class Shown by Figures below the Heavy Lines)

Length in mm.	Number of Clams Recovered in Square-Foot Samples									Clams from 8 Sq. Ft. Sept. 11, 1951 [4/]
	1950					1951				
	May 11	June 22	Aug. 9	Sept. 20 [1/]	Nov. 1	April 12	May 28	July 26 [2/]	Sept. 11 [3/]	
2	-	-	1	105	149	77	5	6	11	-
4	26	3	30	74	275	457	226	17	89	-
6	31	11	33	48	35	215	164	1	7	-
8	34	26	20	39	16	94	67	1	5	-
10	26	24	32	12	4	30	20	1	-	-
12	17	7	13	18	3	23	7	-	-	-
14	6	9	1	10	1	7	2	-	-	-
16	3	14	1	6	1	5	3	-	-	-
18	4	29	1	1	-	-	7	-	-	-
20	-	23	2	-	3	-	1	-	-	-
22	-	34	3	3	6	-	4	-	-	-
24	-	17	16	7	4	-	-	-	-	-
26	1	12	21	12	20	-	-	-	-	-
28	-	5	31	13	23	1	1	-	-	-
30	-	5	27	19	12	5	-	-	-	-
32	-	3	31	10	18	-	-	-	-	6
34	-	1	14	19	11	6	1	-	-	1
36	-	-	13	28	8	2	1	-	-	1
38	-	-	7	6	11	3	-	-	-	6
40	-	-	5	6	6	2	1	-	-	6
42	-	-	2	-	3	4	1	1	-	8
44	-	-	-	1	1	7	2	-	-	16
46	-	-	-	1	-	2	1	-	-	7
48	-	-	-	-	1	-	1	1	-	18
50	-	-	-	-	-	1	1	-	4	19
52	-	-	-	-	-	1	-	-	1	13
54	-	-	-	-	-	4	-	-	1	15
56	-	-	-	-	-	1	2	-	3	19
58	-	-	-	-	-	2	3	-	1	14
60	-	-	-	-	-	1	-	-	3	16
62	-	-	-	-	-	-	1	-	2	12
64	-	-	-	-	-	-	-	1	1	12
68	-	-	-	-	-	-	1	1	2	7
70	-	-	-	-	-	-	-	-	-	2
72	-	-	-	-	-	-	-	-	-	1
74	-	-	-	-	-	-	-	-	-	3
76	-	-	-	-	-	-	-	-	-	2
78	-	-	-	-	-	-	-	-	-	-
80	-	-	-	-	-	-	-	-	-	-
82	-	-	-	-	-	-	-	-	-	1
N	148	223	304	438	611	950	525	32	130	212
	Following data from clams below solid line only (growing part of 1949 year-class):									
N	148	159	175	126	127	42	19	6	-	212
$\bar{X}$	8.48	20.77	28.08	31.98	31.04	42.04	50.6	59.33	-	53.51
Sx	3.70	4.60	9.26	4.95	4.80	8.48	11.47	10.39	-	9.64

1/Thirty-two mesh sampler used.
2/Sample probably partly in area previously dug.
3/This is only one of eight square-foot samples taken with fine-mesh screen.
4/Large clams only, including those in previous column.

We do not know what happened to most of the clams that did not survive. Empty shells were found, but not enough to account for all the loss.

Survival was high enough in all protected plots to produce good commercial clam digging. Plot 24B produced about 25 legal clams per square foot, including natives; plot 45B produced about 16; plot 46, 23; plot 60B, about 9. Legal-size native clams were practically absent from the last 3 plots. These figures include only clams over 50 mm., and it may be seen by tables 5 to 10 that many smaller clams were "coming along," so final production would be somewhat greater.

GROWTH OF PLANTED AND NATIVE CLAMS

Transplanted clams usually were distinguishable from natives because their shells were characteristic of the region from which they had come. The clams from Scarborough, Maine, had rather chalky-appearing shells and they tended to be more round than Plum Island Sound clams. The ones from Quincy, Mass., usually had thick and deformed shells. The shells of native Plum Island Sound clams were generally smooth, slightly glossy, and more pointed posteriorly than either Scarborough or Quincy shells. The new shell, put on as the clams grew after transplanting, was typical of Plum Island Sound shells, and therefore the size at planting or the "planting annulus" could be identified and measured. A few individual clams were difficult to identify, but with these we consulted each other and arrived at a consensus. Annular rings, which form on clam shells much as they do on fish scales,

Table 10 - Combined Length Frequencies of Native Clams from Three Plots (45B, 46, and 60B), Protected (History of 1950 Year-Class is Shown by Figures Below the Solid Lines)

	Number of Clams Recovered in Three Square-Foot Samples												
	1951							1952					
Length in mm.	May 10-11	June 12	July 16-17	Aug. 22-27	Sept. 20	Oct. 22-23	Nov. 23-26	March 3	March 31	May 1	June 3-5	June 25-26	July 30 Aug. 1
2	13	4	5	100	251	146	100	19	28	43	21	-	26
4	295	181	94	339	841	935	435	64	70	524	170	4	122
6	249	93	54	53	27	78	98	33	17	327	74	6	11
8	88	40	15	13	10	7	19	29	27	128	39	8	2
10	48	11	9	4	4	1	-	28	29	58	12	5	1
12	32	-	2	-	3	-	-	16	36	20	8	1	-
14	17	2	1	-	-	1	1	2	10	11	4	3	-
16	8	5	2	-	1	-	-	1	1	20	9	2	-
18	1	8	3	1	1	-	-	2	1	9	3	3	-
20	2	5	6	-	-	-	-	1	-	7	4	2	1
22	3	2	5	2	1	-	-	-	-	-	10	5	-
24	-	-	2	1	2	1	-	-	1	1	6	4	-
26	-	5	1	1	3	2	-	-	-	-	2	6	1
28	-	2	2	-	4	-	1	2	2	-	-	4	1
30	-	1	1	1	2	-	-	1	3	-	1	11	2
32	-	-	1	3	4	2	1	2	3	-	-	4	1
34	-	-	1	-	2	1	-	4	4	-	1	1	1
36	-	-	1	-	6	1	1	2	6	1	1	-	1
38	-	-	1	2	4	2	1	5	3	-	-	1	-
40	-	-	-	4	-	1	1	3	1	-	2	-	2
42	-	-	-	2	2	1	1	5	6	2	1	1	1
44	-	-	-	1	-	-	2	-	2	-	-	1	1
46	-	-	-	-	-	-	2	-	3	1	-	2	-
48	-	-	-	-	-	-	3	-	2	-	2	1	-
50	-	-	-	-	-	1	-	-	2	3	-	-	2
52	-	-	-	-	1	-	1	-	-	-	1	2	2
54	-	-	-	-	-	-	1	-	-	-	-	-	1
56	-	-	-	-	1	-	-	1	-	-	2	2	-
58	-	-	-	-	-	-	-	-	-	-	1	1	-
60	-	-	-	-	-	1	-	-	-	-	-	1	-
62	-	-	-	-	-	-	-	-	-	-	1	1	-
64	-	-	-	-	-	-	-	-	-	-	-	-	-
66	-	-	-	-	-	-	-	-	-	-	-	-	1
68	-	-	-	-	-	-	-	-	-	-	-	-	-
70	-	-	-	-	-	-	-	-	-	-	-	1	-
	Following data from clams below solid line[1] only (growing part of 1950 year-class):												
N	-	30	27	18	34	13	15	25	38	7	12	14	10
$\overline{X}$	-	20.4	23.3	33.4	32.6	36.8	43.1	37.4	38.1	45.1	47.7	52.1	49.0
Sx	-	3.24	6.14	7.95	8.20	9.66	7.00	5.70	6.57	5.02	8.89	6.23	7.54

1/The sample taken in May was not used for average size of the growing group because of the rather extreme dominance of 4 and 6 mm. clams which do not appear to grow.

were not as distinct as the rings formed when the clams were transplanted. Growth was determined from average sizes (lengths) of clams sampled at various times.

In plot 24B clams planted at 16 mm. in November 1949 reached an average size of 57 mm. at the end of the two following summers (fig. 1).

In plots 45B, 46, and 60B clams planted in April 1951 at 19 mm. grew to averages of 54, 57, and 63 mm., respectively, in two summers. Data from plots 45B and 60B have been combined to lessen variability because both were planted at a density of about 50 per square foot and subsequent treatment was the same. Plot 46 was planted with 100 clams per square foot and, as mentioned above, it was better protected (figs. 2 and 3).

Table 11 - Length Frequencies of Native Clams from Hales Cove (History of the 1952 Year-Class is Shown by Figures Below the Solid Lines)

	Number of Clams Recovered from Samples												
	1952								1953				1954
	July 12	July 30	Aug. 15	Aug. 28	Sept. 16	Sept. 29	Oct. 13	Oct. 28	Jan. 26	May 8	June 9	Oct. 14-20	March 11
No. Sq. Ft.	1	1	1	1	1	1	1	1	3	2	4	5-6 1/	2-20 2/
Length in mm.													
2	1	4	5	180	63	86	154	38	6	2	3	297	-
4	3	26	24	305	275	306	444	124	30	34	14	706	17
6	-	1	3	10	10	2	10	-	17	28	3	94	16
8	-	-	-	-	1	-	-	-	7	33	-	18	7
10	-	-	-	-	-	-	-	-	1	18	-	6	4
12	-	-	-	-	-	-	-	-	1	11	1	3	4
14	-	-	-	-	-	-	-	-	1	13	1	5	4
16	-	-	-	-	-	-	-	-	-	5	2	1	-
18	-	-	-	-	-	-	-	-	-	15	3	-	-
20	-	-	-	-	-	-	-	-	-	3	4	2	-
22	-	-	-	-	-	-	-	-	-	1	3	-	-
24	-	-	-	-	-	-	-	-	-	-	4	-	2
26	-	-	-	-	-	-	-	-	-	-	6	-	-
28	-	-	-	-	-	-	-	-	-	-	9	-	-
30	-	-	-	-	-	-	-	-	-	-	1	-	-
32	-	-	-	-	-	-	-	-	-	-	1	-	-
34	-	-	-	-	-	-	-	-	-	-	1	1	-
36	-	-	-	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-	-	-	-	-	2	4
42	-	-	-	-	-	-	-	-	-	-	-	7	3
44	-	-	-	-	-	-	-	-	-	-	-	5	8
46	-	-	-	-	-	-	-	-	-	-	-	16	16
48	-	-	-	-	-	-	-	-	-	-	-	6	15
50	-	-	-	-	-	-	-	-	-	-	-	13	22
52	-	-	-	-	-	-	-	-	-	-	-	10	28
54	-	-	-	-	-	-	-	-	-	-	-	6	28
56	-	-	-	-	-	-	-	-	-	-	-	3	20
58	-	-	-	-	-	-	-	-	-	-	-	5	22
60	-	-	-	-	-	-	-	-	-	-	-	1	14
62	-	-	-	-	-	-	-	-	-	-	-	1	5
64	-	-	-	-	-	-	-	-	-	-	-	1	6
66	-	-	-	-	-	-	-	-	-	-	-	1	3
68	-	-	-	-	-	-	-	-	-	-	-	-	1
70	-	-	-	-	-	-	-	-	-	-	-	-	-
72	-	-	-	-	-	-	-	-	-	-	-	-	2
74	-	-	-	-	-	-	-	-	-	-	-	-	-
76	-	-	-	-	-	-	-	-	-	-	-	-	2
78	-	-	-	-	-	-	-	-	-	-	-	-	1
80	-	-	-	-	-	-	-	-	-	-	-	-	1
Following data from clams below solid line only (growing part of 1952 year-class):													
N	4	31	32	495	349	394	608	162	63	163	36	78	201
$\bar{X}$	3.5	3.8	3.87	3.31	3.7	3.57	3.85	3.53	5.1	9.3	23.8	49.4	53.8
Sx	4.99	1.39	1.01	1.04	0.9	0.8	0.93	0.8	7.38	4.74	3.99	6.38	7.15

1/ Six square feet sampled, fine mesh (16) used on only 5 square feet.
2/ Two square feet screened with 12-mesh screens. Clams over 24 mm. dug from about 20 square feet.

It may be seen that all growth curves for planted clams show rapid growth in the spring and early summer, and little or no growth in fall and winter. There appears to be a shrinkage of the shell during the winter. This may actually occur, due to erosion or chipping of the edge of the shell, as suggested by Swan (1952). However, we have found that sizes of clams are inversely correlated with the number of clams per sample and it also happens that most of the points showing departures from a smooth growth curve are similarly associated with either unusually large or unusually small samples (see figs. 1, 2, and 3).

The effect of varying degrees of crowding within one small plot was shown by the 8 separate square-foot samples from plot 24B taken September 11, 1951, as well as by the departures from a smooth growth curve. Clams in the more crowded parts of the plot were distinctly smaller in average size. A correlation between average size and total number of native and planted clams gave a correlation coefficient of -0.8. The differences in size appear to be due to some sort of space relationship rather than lack of food; inasmuch as the square-foot samples adjoined, the entire plot was only 6 x 6 feet, and there were almost no clams in the surrounding flat to remove food from the water flowing over them. The above mentioned samples were as follows:

Number of Clams per square foot	- 18	22	23	25	26	32	72	100
Average size of Clams in mm.	- 60	55	64	58	60	59	50	51

The chicken wire put down to protect transplanted clams naturally gave some protection to natives. Small clams were sampled by screening the top 3 or 4 inches through 16 x 14 per-inch-mesh screening and the lower soil through 4-per-inch-mesh screening. The largest clams were usually picked by hand.

Fig. 5 - Fence built in Plum Island Sound, Newbury, Mass., June 3, 1953, to protect clams from horseshoe and green crabs. The photograph was taken about three weeks after the fence was built. Note that entire flat outside fence is covered with excavations of predators, while the soil inside is still smooth.

The growth of native clams was determined by comparing average lengths of the growing portion of a year class in successive samples. The small clams appearing in the May and June samples were considered to be from the previous summer's spawning because very few clams spawn earlier than May or June (Coe & Turner 1938), and also because the size frequencies of small clams sampled in late fall, winter, and early spring indicate that the May and June crop could belong to the year-class that had been spawned the previous summer. By Mav these clams are noticeably larger than they were in January, and by June most of the size frequencies are distinctly bi-modal. Of the two groups, the one containing the larger clams is what we have called the "growing portion," because its growth can be traced over at least two years, while the group of smaller clams does not seem to grow. Actually, the apparent lack of growth could be due to movement of the byssus-bearing clams, recruitment, or some change in the predator-prey relationships. Horseshoe crabs and green crabs, becoming active in the spring, might tend to concentrate on clams around 10 to 14 mm. which, if true, could cause the "trough" in the length-frequency curve.

During the summer of 1950 the natives in the only covered plot, no. 24B (table 9 and fig. 1), survived and grew so well that by September of 1951 there was an average of about 16 legal-size natives per square foot. These were clams of the 1949 year-class. Thus, the growth from plankton stage to market size took only three summers, or perhaps a little over two years.

In the three successful plots set out in the spring of 1951, small native clams were present at all times, but comparatively few survived and grew. We do not know why identical treatment produced a good crop one year and very little the next, when there were as many or more young clams. However, by adding the size-frequency data for native clams from these three plots, as in table 10, a growth curve may be derived for the protected natives of the 1950 year-class. Their growth is similar to that of the 1949 year-class (see fig. 4).

In the unprotected plots and the surrounding natural tidal flats, there was practically no survival from the 1949 or 1950 year-class. No data were secured for growth of the 1951 year-class, because no screens were down to protect it, and as with the 1949 and 1950 year-classes, there was practically no survival in the natural flats. There was practically no digging in the area, and none in our plots, so the failure of these crops was not caused by overdigging.

In marked contrast with the foregoing classes, the 1952 year-class survived well enough, even without protection, to produce some reasonably good commercial digging in upper Plum Island Sound. This year-class was not sampled as often nor as thoroughly as the others, but no sampling was needed to recognize its success during the summer of 1953. For the first time in four years the flats became pitted with clam holes, and from 8 to 15 diggers have been working on the Newbury flats almost every day from the fall of 1953 to the fall of 1954. The concentrations varied from 3 or 4 legal-size clams per square foot to about 20 from midsummer on.

The success of the 1952-class seems to have been due to rapid growth. See tables 9, 10, and 11, and figure 4 for a comparison of the 1952 year-class with the 1949 and 1950 year-classes. The larger size of this year-class of clams enabled them to dig deeper and thus be less accessible to predators. The small byssus clams, 12-15 mm. and under, were not unusually abundant during the winter of 1952/53, and as far as we could determine, predators were as abundant as ever. Therefore, we have no evidence that the success of the 1952 clams was due to any changes in the numerical relationships between predators and prey.

CONCLUSIONS

Natural predation on clams up to at least 50 mm. long is a serious problem which will have to be met if clam farming or transplanting is to be economically feasible. Horseshoe crabs and green crabs are the two most serious predators in New Hampshire and northern Massachusetts. Clams can be protected from these predators by covering flats with one-inch mesh chicken wire. In this way both native and transplanted clams can be grown from around 10 or 20 mm. to the market size of 2 inches, or about 50 mm. in two summers. Native clams under about 10 mm. long may or may not survive and grow under the chicken wire. The principal disadvantage of putting chicken wire over the clams is the expense of the wire, which might come to $3 or $4 per bushel of clams. Fences only 10-12 inches high with a flange on top may afford adequate protection and be cheaper per acre, but further experiments are required to demonstrate their successful practical application.

Growth of native clams in areas studied is rapid, from plankton stage to market size generally taking only three summers or perhaps a little over two years. One year-class (1952) grew even faster, producing a commercially-diggable crop in two summers, or a little over one year. This was the first year-class in at least 4 years to survive well enough, without protection, to produce good commercial digging. The success of this year-class and the failure of others, that were just as abundant up through the byssus stage, indicates that fluctuations in clam populations are largely natural in origin and may result from things other than fluctuations in the numbers of juvenile or byssus-stage clams.

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