THE MUSSEL RESOURCES OF THE NORTH ATLANTIC REGIONS

PART II - OBSERVATIONS ON THE BIOLOGY AND THE METHODS OF COLLECTING AND PROCESSING THE MUSSEL

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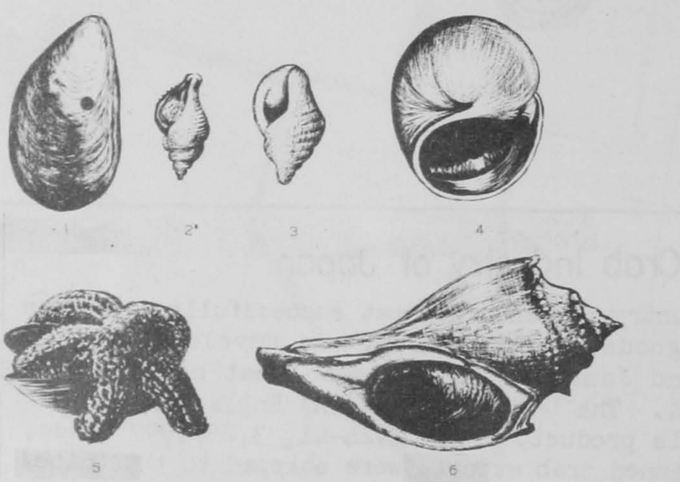
INTRODUCTION

This is the second of three papers concerning the World War II efforts to develop a mussel fishery in the North Atlantic region. The first article dealt with the survey to discover whether supplies of mussels were great enough to support a large fishery. The present paper is concerned with biological and technological observations made during the mussel survey.

SIZES OF MUSSELS

Table 3 reveals some interesting characteristics of the size distribution of the mussels on the beds. An examination of the table shows that there are many localities in which there is no well defined and distinct mode indicative of the young from the summer's set. Only Pleasant River, Narraguagus River, Winter Harbor, and Duxbury Bay have such modes. The absence of distinct year-size groups is even more apparent in the areas below low tide at Ingall's Island, Jim's Island, Moon Ledge, Skillings River, Sheep Island, Mackerel Cove, Maddaket Harbor, and off Brewster. In these eight localities, between 92.7 and 100 percent of the mussels were over two inches in length. There is little information available concerning the growth of mussels under natural conditions in the North Atlantic region. Mossop (1921, 1922) states that mussels grew 10.8 mm (.43 inches) per year at St. Andrews, New Brunswick, in the intertidal zone, while on a submerged reef the growth was 14.8 mm (.58 inches). At Sorrento, Maine, in October 1946 the mussel spat averaged .13 inches in length and ranged from .01 to .34 inches.



SOME OF THE MUSSEL'S ENEMIES:
1. A SEA MUSSEL WHICH HAS BEEN PERFORATED BY ONE OF THE WINKLES.
2. THE OYSTER DRILL (UROSALPINX CINEREA).
3. THE DOG WHELK (PURPURA LAPILLUS).
4. THE WINKLE (LUNATIA HEROS).
5. THE STARFISH (ASTERIAS FORBESII) ATTACKING A MUSSEL.
6. THE CONCH (BUSYCON CARICA).

It does not seem possible that lack of small mussels in many of the localities during September, October, and November, can be attributed to rapid growth of the year's spat to the three-or four-inch size. It would seem more likely that the survival of the spat is variable from year to year. Lambert (1935) reported that

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Note: Part I (The Survey to Discover the Locations and Areas of the North Atlantic Mussel Producing Beds) of this series appeared in the September 1949 issue of Commercial Fisheries Review, pp. 1-10.

the production of spat from the Zeland mussel beds was very irregular from year to year. Mossop (1921) stated that some years are poor spat producers in New Brunswick, and Storrow (1940) cited the disappearance of 1936 spat and the failure of any successful spat formation in 1937 and 1938 at Whitby, England. Hobson, Storrow, Leach, and Wright (1935) reported that the fall of spat at Blyth, England, was unimportant during two or three years prior to 1935, and that this condition was also true at Budle Bay and Holy Island. Observations at Sorrento and Sullivan, Maine, during 1946 revealed that, although no spat had set on the natural beds, a heavy set of spat had occurred on brush which had been put on the flats in hope of encouraging the successful settling of clams. This spat failed to survive the winter except for a negligible portion which set close to the mud. While mussels are reared in the Baltic on harwood branches thrust into the mud, such a method of culture might not be economically feasible in the United States because of labor costs. Possible methods for cultivation of this species are given by Loosanoff (1942, 1943a).

On all ten beds from which mussels were taken both from below and above the low-tide mark, the mussels from below were larger than those from above. (Figure 5 shows this difference in size.) The larger size of the submerged mussels is characteristic of most North Atlantic mussel beds. Studies on the St. Andrews, New Brunswick, mussels by Mossop (1921, 1922), Coulthard (1929), Newcombe (1935), and Warren (1936) demonstrated that the rate of growth varied inversely with the exposure between tides. Another factor, not yet clearly evaluated, is the possibility that there is a decreased mortality among the submerged mussels and they are able to grow to a larger size. No attempt was made during the survey to analyze the growth rate of the mussel populations.

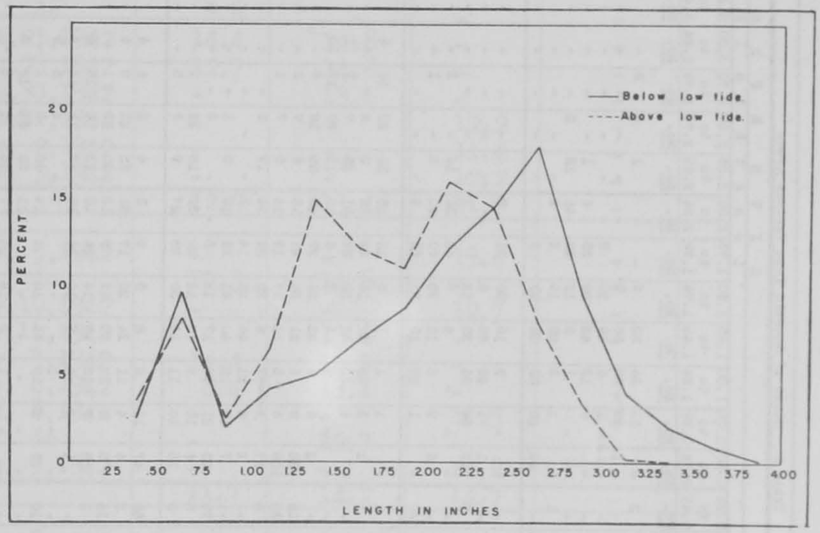


FIGURE 5 - SIZE OF MUSSELS FROM ABOVE AND BELOW LOW TIDE ON TEN MAINE MUSSEL BEDS.

The mussel beds of New Brunswick, Maine, and New Hampshire are situated near the low-tide mark. Very few mussels are found more than three feet below the low-tide level. Huntsman (1918), Mossop (1921), Newcombe (1935), and Warren (1936) remarked on the absence of New Brunswick mussels in depths of over a fathom, and believed that predators, such as, starfish (*Asterias vulgaris* and *A. forbesii*), sea urchins (*Strongylocentrotus drobachiensis*), whelks (*Buccinum undatum*), cockles (*Polinices heros*), and drills (*Thais lapillus*) were responsible. These predators, in general, do not occur in less than a fathom.

In contrast, many beds in Cape Cod Bay, Buzzard's Bay, and other southern New England localities are located in depths of over 40 feet. During dredging operations in Cape Cod Bay, starfish, sea urchins, and whelks (Table 2)[1] were collected with mussels. This would indicate that either these predators were in such small numbers as not to prevent the establishment of beds in subtidal depths, or perhaps factors other than predators influence the depth at which mussels grow.

1/Appeared in Part I published in September 1949 issue of *Commercial Fisheries Review*.

Table 3 - Sizes of Mussels from Various Areas

Locality	Date	Depth in Relation to Mean Low Water	Dead Mussels by Volume	Live Mussels	LIVE MUSSELS — Length in Inches: 0.00 to 0.24	0.25 to 0.49	0.50 to 0.74	0.75 to 0.99	1.00 to 1.24	1.25 to 1.49	1.50 to 1.74	1.75 to 1.99	2.00 to 2.24	2.25 to 2.49	2.50 to 2.74	2.75 to 2.99	3.00 to 3.24	3.25 to 3.49	3.50 to 3.74	3.75 to 3.99	4.00 to 4.24	Average size (total) 1/	Average size (above 2") 1/	Above 2" By Number	Above 2" By Volume
		Feet	Percent	Number	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	Inches	Inches	Percent	Percent
New Brunswick:																									
Lepreau Point	Nov.17,1943	2 to 0	2/	74	-	3	-	11	24	23	7	-	-	1	2	2	-	1	-	-	-	1.31	2.78	8.1	2/
Lepreau Harbor	do	2 to 0	2/	101	-	-	1	22	38	35	5	-	-	-	-	-	-	-	-	-	-	1.16	-	0.0	0.0
Letite Harbor, Mill Cove	Nov.16,1943	2 to -1	2/	114	-	-	-	1	6	49	50	8	-	-	-	-	-	-	-	-	-	1.48	-	0.0	0.0
Little Letite Passage	do	2 to -1	2/	166	-	-	-	5	19	42	58	35	6	1	-	-	-	-	-	-	-	1.56	2.11	4.2	2/
Midjik Bluff	Nov.19,1943	2 to 0	50.0	134	-	-	-	-	1	9	15	48	46	12	3	-	-	-	-	-	-	1.95	2.17	45.5	62.5
do	do	4 to 2	2/	62	-	1	-	1	9	28	19	2	2	-	-	-	-	-	-	-	-	1.43	2.06	3.2	2/
Digdequash Inlet	Nov.18,1943	2 to 0	2/	120	-	-	14	28	35	28	13	2	-	-	-	-	-	-	-	-	-	1.14	-	0.0	0.0
Maine, Eastport-Lubec Section:																									
Spectacle Island	Oct.12,1943	2 to 0	2/	91	-	-	-	-	3	15	50	21	2	-	-	-	-	-	-	-	-	1.63	2.09	2.2	2/
Jim Island	do	2 to 0	2/	60	-	-	1	1	28	26	4	-	-	-	-	-	-	-	-	-	-	1.24	-	0.0	0.0
Leadurny Point	Nov.20,1943	1 to 0	2/	125	1	7	13	34	24	33	12		1	-	-	-	-	-	-	-	-	1.07	2.02	.8	2/
Long Island	Oct.11,1943	2 to 0	2/	124	-	-	-	-	-	4	7	61	36	14	-	2	-	-	-	-	-	1.99	2.20	41.9	2/
Scrub Island	Oct.14,1943	2 to 0	2/	199	-	-	6	9	5	13	73	70	20	2	-	1	-	-	-	-	-	1.69	2.15	11.6	2/
Pennamaquan River	Oct.15,1943	2 to 0	2/	164	-	-	-	1	10	15	71	63	4	-	-	-	-	-	-	-	-	1.68	2.14	2.4	2/
Maine, Jonesport Section:																									
Indian River	Oct.20,1942	0 to -2	2/	127	-	1	-	1	1	1	5	18	25	32	22	10	8	3	-	-	-	2.33	2.53	78.7	2/
do	do	2 to 0	35.0	122	-	1	1	3	18	30	14	29	22	2	2	-	-	-	-	-	-	1.63	2.16	21.3	2/
West River	do	0 to -2	18.5	198	-	-	-	4	15	33	18	32	61	25	7	2	1	-	-	-	-	1.88	2.24	48.5	77.0
Cape Split Harbor	Oct.21,1942	0 to -2	18.5	87	-	-	-	-	1	2	2	8	10	15	20	17	10	2	-	-	-	2.50	2.66	85.1	93.6
do	do	2 to 0	18.5	191	-	-	2	6	4	22	26	27	43	36	18	7	-	-	-	-	-	1.97	2.36	54.5	75.9
Pleasant River, Reef Point	Oct.23,1942	0 to -2	33.1	227	-	16	88	8	6	21	28	27	18	6	7	2	-	-	-	-	-	1.27	2.30	14.5	45.7
do	do	2 to 0	26.7	224	-	33	108	6	3	12	17	18	14	5	7	1	-	-	-	-	-	1.03	2.32	12.5	58.5
Harrington River, Ripley Is.	Oct.30,1942	0 to -2	13.6	161	-	8	17	5	17	6	23	26	34	19	6	-	-	-	-	-	-	1.70	2.29	36.6	65.7
do	do	2 to 0	20.5	116	-	-	2	8	21	44	25	14	2	-	-	-	-	-	-	-	-	1.40	2.11	1.7	8.2
Narraguagus Bay, Back Bay	Oct.31,1942	0 to -2	31.8	169	-	-	7	19	15	40	41	23	18	5	1	-	-	-	-	-	-	1.51	2.17	14.2	33.0
do , Long Point	do	1 to -2	31.8	193	5	72	25	21	34	17	12	5	-	-	2	-	-	-	-	-	-	.81	2.53	1.0	12.5
Pinkham Cove	Nov. 2,1942	2 to -2	17.0	153	-	5	6	10	9	10	14	29	39	18	12	1	-	-	-	-	-	1.78	2.25	45.7	67.1
Joy Bay	Nov. 3,1942	2 to -2	25.0	162	-	3	15	15	11	12	30	28	27	9	7	5	-	-	-	-	-	1.64	2.30	29.6	59.1
Maine, Frenchman Bay Section:																									
Winter Harbor	Nov. 5,1942	2 to -2	30.9	190	17	68	47	14	8	8	5	5	3	4	2	4	4	1	-	-	-	.82	2.69	9.5	73.0
Stave Island Harbor	do	0 to -2	15.7	177	-	2	4	4	11	24	20	17	26	33	22	8	6	-	-	-	-	1.98	2.46	53.7	83.7
do	do	2 to 0	22.0	212	-	14	5	3	32	60	19	8	12	40	19	-	-	-	-	-	-	1.62	2.39	33.5	73.0
Hog Island	Nov.10,1942	2 to -2	24.1	137	-	2	5	7	12	18	14	14	13	13	14	18	6	1	-	-	-	1.95	2.60	47.4	81.8
Soward's Island	Nov.11,1942	0 to -2	22.6	109	-	-	1	2	1	2	10	16	18	29	11	12	4	2	1	-	-	2.26	2.51	70.6	87.5
Ingull's Island	Nov. 7,1942	0 to -2	26.4	47	-	-	-	-	1	-	-	-	1	-	4	5	9	17	9	1	-	3.18	3.23	97.9	99.6
do	do	2 to 0	4.6	144	-	10	13	8	19	36	18	4	14	16	5	1	-	-	-	-	-	1.47	2.33	25.0	68.0
Sullivan Harbor, Moon Ledge	Nov. 6,1942	0 to -2	9.5	72	-	-	-	-	-	-	-	-	11	20	24	13	3	1	-	-	-	2.56	2.56	100.0	100.0
do	do	2 to 0	27.4	74	-	-	-	-	1	9	18	14	7	18	5	2	-	-	-	-	-	1.98	2.42	43.2	70.0
Raccoon Cove	Nov. 8,1942	2 to -2	10.2	110	-	-	1	1	2	6	8	10	25	14	24	13	6	-	-	-	-	2.26	2.51	74.5	90.7
Skillings River	do	0 to -2	14.5	89	-	-	-	-	-	-	1	1	2	5	22	36	18	4	-	-	-	2.81	2.83	97.8	99.1
Maine, East Penobscot Bay Sec.:																									
Herrick Bay	Nov.18,1942	2 to -2	12.7	123	-	-	2	3	5	12	12	9	13	20	22	12	11	2	-	-	-	2.21	2.61	65.0	89.3
Centre Harbor	Nov.15,1942	2 to -2	12.0	122	-	-	1	1	3	2	5	28	39	23	9	4	5	2	-	-	-	2.16	2.38	67.2	81.8
Deer Isle, Fish Creek	Nov.17,1942	2 to -2	25.5	164	-	1	5	8	15	17	25	18	16	19	27	11	1	1	-	-	-	1.91	2.49	45.7	79.4
Deer Isle, Greenlaw's Cove	do	2 to -2	26.7	45	-	-	1	1	-	2	3	4	6	7	10	6	4	1	-	-	-	2.34	2.61	75.5	90.9
White Island	do	2 to -2	30.8	80	-	-	-	1	1	1	1	6	4	11	19	22	8	5	1	-	-	2.61	2.74	87.5	97.2
Jim's Island	do	2 to -2	31.4	69	-	-	-	-	-	-	-	5	5	34	19	5	1	-	-	-	-	2.44	2.47	92.7	95.5
Swan's Island, Mackerel Cove	Nov.23,1942	0 to -2	30.2	68	-	-	-	-	-	-	-	-	1	7	21	30	9	-	-	-	-	2.75	2.75	100.0	100.0
do	do	2 to 0	7.6	134	-	-	1	-	6	10	32	27	37	15	6	-	-	-	-	-	-	1.92	2.23	43.3	88.9
do , Atlantic Harbor	do	0 to -2	23.6	96	-	-	1	5	1	1	-	4	12	15	45	11	-	1	-	-	-	2.40	2.57	87.5	96.7
do	do	2 to 0	10.0	296	-	2	6	7	3	27	35	33	38	48	70	20	6	1	-	-	-	2.12	2.49	61.8	80.4
Maine, West Penobscot Bay Sec.:																									
Muscle Ridge Channel, Sheep Is.	Nov.20,1942	0 to -2	35.6	77	-	-	-	-	1	-	2	1	2	17	36	14	4	-	-	-	-	2.59	2.63	94.8	97.9
do	do	2 to 0	12.0	160	-	-	-	-	-	-	3	11	79	62	5	-	-	-	-	-	-	2.22	2.25	53.8	94.0
Massachusetts:																									
Duxbury Bay	Dec.16,1942	1 to -1	20.0	452	124	40	99	51	17	21	26	43	29	2	-	-	-	-	-	-	-	.82	2.11	6.9	34.3
Chatham Harbor	Dec.18,1942	1 to 0	2/	175	-	-	3	16	43	101	11	1	-	-	-	-	-	-	-	-	-	1.26	-	0.0	0.0
Cape Cod Bay, off Brewster	do	-25 to -40	15.3	129	-	-	-	-	-	-	-	-	1	4	13	49	36	14	10	2	-	3.04	3.04	100.0	100.0
do	Sept.5,1944	-25 to -40	18.6	53	-	-	-	-	-	-	-	-	-	-	1	2	4	22	17	7	-	3.47	3.47	100.0	100.0
Muddaket Harbor	Mar.20,1943	-5 to -10	2/	57	-	-	-	-	-	-	-	-	-	-	3	9	23	17	4	-	1	3.18	3.18	100.0	100.0

1/Calculated from original ungrouped measurements.

2/Not recorded.

The upper limits of the beds are determined by the effect of exposure on young mussel larvae, according to Mossop (1921). Undoubtedly, the larger mussels also suffer considerable mortality from exposure to temperature extremes and to the erosion of ice or storms. Crows, gulls, and ducks may also be important factors in some regions.

MEAT YIELDS

The seasonal variation in the yield of mussel meats is of great importance, both to those engaged in processing mussels and to the conservationists. To harvest the shellfish at the peak of their "fatness" is a sound practice, for the processor is able to obtain a greater poundage of meats from a bushel, thus reducing the cost of the meats; the cannery workers operate at greater efficiency by producing more meat weight from the effort expended to shuck out a bushel; and the harvesting of the mussel at its peak provides the maximum production from a given quantity of mussels.

Table 4 - Pounds of Raw Mussel Meats per Bushel at Various Localities

Locality	Date	Quantity of Meat per Bushel			
		Depth in Feet in Relation to Mean Low-water			
		2 to 0	0 to -2	2 to -2	-25 to -40
		Pounds	Pounds	Pounds	Pounds
Maine, Jonesport Section:					
Indian River	Oct. 20, 1942	-	10.9	-	-
West River	do	9.6	-	-	-
Cape Split Harbor	Oct. 21, 1942	14.4	14.8	-	-
Pleasant River, Reef Point..	Oct. 23, 1942	12.7	14.8	-	-
Harrington River, Ripley Is.	Oct. 30, 1942	-	13.1	-	-
Narraguagus River, Back Bay.	Oct. 31, 1942	-	-	12.2	-
Pinkham Cove	Nov. 2, 1942	-	-	11.4	-
Joy Bay	Nov. 3, 1942	-	-	12.2	-
Average		12.2	13.4	11.9	-
Maine, East Penobscot Bay Sec.:					
Winter Harbor	Nov. 5, 1942	-		19.4	-
Stave Island Harbor	do	12.3	14.8	-	-
Hog Island	Nov. 10, 1942	-	-	12.7	-
Soward's Island	Nov. 11, 1942		13.6	-	-
Ingall's Island	Nov. 7, 1942	14.4	16.9	-	-
Sullivan Harbor, Moon Ledge.	Nov. 6, 1942	8.4	13.1	-	-
Raccoon Cove	Nov. 8, 1942	-	-	11.9	-
Skillings River	do	-	12.7	-	-
Bar Harbor	Nov. 9, 1942	-	-	14.8	-
Average		11.7	14.2	14.7	-
Maine, E. Penobscot Bay Sec.:					
Herrick Bay	Nov. 18, 1942	-	-	16.9	-
Centre Harbor	Nov. 15, 1942	-	18.6	-	-
Deer Isle, Fish Creek	Nov. 17, 1942	-	-	17.4	-
Deer Isle, Greenlaw's Cove .	do	-	-	16.1	-
White Island	do	-	-	19.7	-
Jim's Island	do	-	-	21.1	-
Swan's Island, Mackerel Cove	Nov. 23, 1942	13.1	14.4	-	-
Swan's Island, Atlantic Harbor	do	13.1	16.9	-	-
Average		13.1	16.6	18.2	-
Maine, W. Penobscot Bay Sec.:					
Muscle Ridge Channel, Sheep Island	Nov. 20, 1942	12.2	15.2	-	-
Massachusetts:					
Cape Cod Bay, off Brewster .	May 12, 1943	-	-	-	16.1

A difference in the meat yields between the Jonesport, Frenchman Bay and East Penobscot Bay regions can be noted from Table 4. It is evident that the East Penobscot Bay mussels were fatter than those of the other two regions, and the Jonesport section mussels had the poorest meats. However, to separate the effect of season and location, samples would have to be taken throughout the year in various sections of the coast. It is interesting to note that when the Maine fishery developed after 1942, the canners preferred the mussels collected from beds in Frenchman Bay and Penobscot Bay due to the heavy yield of meats in those sections as compared with the Washington County region.

In all eight areas where meat weights were obtained from mussels gathered from above and below low tide, the mussels below low tide had heavier meats. The greater meat yields of the submerged mussels and their larger size were the primary reasons why many Maine canneries insisted that the fishermen collect mussels from below the intertidal zone.

To determine the seasonal variation of mussel yields, two localities in Boothbay Harbor, Maine, were selected as sampling stations. Station A was located two feet above the mean low-water mark and Station B was at the mean low-water mark. Due to unusual ice conditions and the loss of the mussels by freezing, Station B had to be abandoned in December. Table 5 shows the yield of fresh mussel meats between October 1943 and August 1944. From these data it is apparent that Boothbay Harbor mussels reach their peak condition in June and gain relatively little weight during August through February.

Table 5 - Yield of Fresh Mussel Meats at Boothbay Harbor, Maine

Date	Quantity of Meats per Bushel	
	Station A	Station B 1/
1943:	Pounds	Pounds
Oct. 8	11.0	11.8
18	-	13.6
20	12.2	-
25	13.5	14.3
Nov. 1	11.3	-
2	-	13.2
7	11.9	-
25	12.3	12.8
Dec. 2	-	13.2
3	11.8	-
20	11.2	-
1944:		
Feb. 22	12.5	-
Apr. 4	15.4	-
May 7	17.5	-
June 4	19.3	-
July 8	11.4	-
Aug. 2	11.7	-

1/Mussels destroyed at Station B by freezing during December.

The weekly yield of steamed meats at a Maine cannery is shown in Table 6. The mussels had been steamed 12 minutes at 212 degrees Fahrenheit before being opened. The shellfish were collected during the 1943-44 season from the same region in Muscongus Bay; therefore, the yields can be considered as representative of that particular locality. During the period December 11 to January 22 the yields tended to decrease; but thereafter began to increase to the end of the season on May 6, when the cannery began experiencing difficulties in handling the meats, which have a tendency to break apart when the spawn is fully developed.

To compare the fresh-shucked yields with those of steamed mussels, it is necessary to apply a conversion factor of 0.5 to the fresh weights. This factor is a rough approximation, for the yield of steamed mussels is inversely affected by the temperature and duration of the steaming process, both of which shrink the fresh meats.

MUSSEL PEARLS

White or bluish white pearls are commonly found in mussel meats. These pearls are valueless, for their small sizes, lack of lustre, and irregular shapes preclude their use in jewelry. As these pearls are usually very small, they are not generally noticed by the consumer to any greater extent than he would notice occasional grains of sand in clams or oysters. However, if the pearls are over one millimeter in diameter and very numerous, they are not only annoying, but may cause damage to the consumer's teeth. On rare occasions, pearls have been found which measure more than six millimeters in diameter; fortunately, most pearls are less than one millimeter in diameter. The presence of large and numerous pearls might prove to be a deterrent to the sale of mussels; consequently, a method of eliminating this nuisance was sought.

Table 6 - Yield of Meats per Bushel of Steamed Mussels at a Maine Cannery during 1943-44 Season

Week Ending	Operating Days	Bushels Processed	Total Meat Yield	Meat Yield per Bushel
1943:	Number	Number	Pounds	Pounds
Dec. 4	4	460.0	2,700.3	5.87
11	6	764.5	4,800.7	6.28
18	5	456.0	2,802.2	6.15
25	4	480.0	2,828.4	5.89
1944:				
Jan. 1	4	464.0	2,830.6	6.10
8	3	403.0	2,321.8	5.76
15	5	540.0	3,213.9	5.95
22	5	551.0	3,221.3	5.85
29	5	549.0	3,497.8	6.37
Feb. 5	4	588.0	3,883.7	6.60
12	5	614.5	4,136.1	6.73
19	3	374.0	2,468.8	6.60
26	6	893.0	6,433.0	7.20
Mar. 4	6	766.0	5,552.3	7.25
11	6	800.0	6,022.2	7.53
18	5	809.0	6,176.6	7.63
25	5	690.0	5,211.5	7.55
Apr. 1	6	826.0	6,566.9	7.95
8	5	865.0	7,395.9	8.55
15	5	684.0	5,970.6	8.73
22	5	712.0	6,425.6	9.02
29	5	704.0	6,279.0	8.92
May 6	1	120.0	1,122.6	9.36
Total	108	14,113.0	101,861.8	7.22

The pearls are embedded in the flesh of the mantle and cannot be seen easily when the gonads are approaching maturity in the winter and spring. No practical method has been developed to detect all the pearls in the meats or to separate mechanically the pearls from the mantle without tearing the latter to shreds. Often it is possible to discover excessively pearly mussels as they are being removed from the shells, or while they are being weighed into the cans, and such meats should be discarded. Several of the canneries have workers detailed to remove all conspicuously pearly meats. The rejection of such meats is only a partial solution to the problem because many of the embedded pearls would not be seen.

During the survey, the quantities of pearls present in mussels collected from various beds were determined by a simple laboratory method of maceration. Three ounces of fresh meats were placed in a quart of boiling water and one ounce of potassium hydroxide was added. The solution was then boiled for five minutes. When the meats became thoroughly macerated, the pearls dropped to the bottom of the container from which they could be easily removed. With one exception, no attempt was made in the field to remove the tiny pearls of less than about .25 millimeters from the mixture of sand and debris, for such pearls were so small that their presence would hardly be detected by the consumer. In a later experiment, to evaluate the effect of acetic acid on pearls, all pearls visible under a low power microscope were measured.

Table 7 shows the numbers and sizes of pearls from each three-ounce sample of meats taken from the various beds. Although all areas contained pearls to a greater or lesser extent, the occurrence of the larger and most objectionable ones was limited. At the end of the Maine survey in 1942, it was felt that, until further study was made, mussels should not be taken from those beds whose samples showed the greatest numbers of large pearls. It was decided to consider as beds to be temporarily avoided those areas whose samples had either more than nine pearls with a diameter of one millimeter and greater, or more than three pearls with a 1.5 millimeter diameter and greater in a three-ounce sample of fresh drained meats. By use of such standards, about one-fifth of the total estimated mussel production would be eliminated, but this quantity would not seriously interfere with the potential fishery. The areas which would thus be banned temporarily from the mussel supply were: Back Bay, Skillings River, Ripley Islands, Long Point, State Island, and Joy Bay, which had a total estimated supply of 60,000 bushels. Canners were advised in January 1943 to avoid these areas until a further study was made.

Table 7 - Number of Pearls from Commercially Important Mussel Beds[1]

Location of Bed	Diameter of Pearls in Millimeters Along Longest Axis: Quantity 0.25 to 0.99	1.00 to 1.24	1.25 to 1.49	1.50 to 1.74	1.75 to 1.99	2.00 to 2.24	2.25 to 2.49	2.50 to 2.74	Summary: 1 mm and over	1.50 mm and over	1.75 mm and over
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
Maine:											
Mackerel Cove	17	-	-	-	-	-	-	-	-	-	-
Pemaquid River	7	1	-	-	-	-	-	-	1	-	-
Centre Harbor	18	1	-	-	-	-	-	-	1	-	-
Hog Island	3	-	1	-	-	-	-	-	1	-	-
Herrick Bay	4	-	-	1	-	-	-	-	1	1	-
Winter Harbor	6	-	-	1	-	-	-	-	1	1	-
White Island	13	2	-	-	-	-	-	-	2	-	-
Pinkham Bay[2]	10	1	-	1	-	-	-	-	2	1	-
Cape Split Harbor	1	-	1	-	1	-	-	-	2	1	1
Fish Creek	10	-	1	-	1	-	-	-	2	1	1
Jim's Island	3	1	1	-	1	-	-	-	3	1	1
Moon Ledge	13	1	-	2	-	-	-	-	3	2	-
Raccoon Cove	4	3	1	-	-	-	-	-	4	-	-
Goose Islands	5	3	1	-	-	-	-	-	4	-	-
Indian River	5	4	-	1	-	-	-	-	5	1	-
Ingall's Island	4	4	-	-	-	1	-	-	5	1	1
Greenlaw's Cove	5	-	2	3	-	-	-	-	5	3	-
Sheep Island	12	2	-	3	-	-	-	-	5	3	-
Reef Point	8	5	1	2	-	1	-	-	9	3	1
Soward's Island	19	4	2	1	1	-	-	1	9	3	2
Back Bay	18	1	2	4	-	2	-	-	9	6	2
Skillings River	17	5	2	4	-	1	-	-	12	5	1
Ripley Islands	49	9	6	2	-	-	-	-	17	2	1
Long Point	112	11	3	7	-	-	-	-	21	7	-
Stave Island	53	10	4	6	2	-	-	-	22	8	2
Joy Bay	78	12	4	7	1	5	-	-	29	13	6
Massachusetts:											
Cape Cod Bay off Brewster	18	3	-	-	-	-	-	-	3	-	-

1/Number of pearls from 3 ounces of mussel meats. Meats were obtained from mixed samples of mussels collected from parts of each bed.
2/Includes Dyer Harbor.

It was realized that the problem of eliminating the pearls from the meats would be more easily solved if it were possible to dissolve the pearls in the meats without seriously altering the flavor or texture of the meats. Examination of canned vinegar-preserved mussels had revealed that pearls were absent from the meats, although the mussels had been taken from the Narraguagus River area where pearls are common and often large. It appeared that acetic acid might be a pearl-dissolving agent.

In 1943, shortly after the Maine survey was completed, we performed an experiment to determine the effect of acetic acid on pearls. A similar experiment was effected by the U. S. Food and Drug Administration shortly thereafter. Eight No. 1 picnic cans were each filled with six ounces of meats from steamed Cape Cod Bay mussels. Four different 3-percent salt solutions were prepared--with 1 percent, $\frac{1}{2}$ percent, $\frac{1}{4}$ percent, and 0 percent acetic acid concentrations. Two cans of meats were filled with each of these solutions, sealed, processed for 30 minutes at 240° F., and opened 10 days later. The flavor of the meats from those cans containing 1-percent and $\frac{1}{2}$-percent acetic acid was slightly sour, but not unpleasantly so. The pearls were then removed from the mussels in each can by the potassium hydroxide maceration method and measured with a stage micrometer on a low-power microscope.

Table 8 shows the results of this experiment. Each can contained six ounces of steamed meats and, as the shrinkage of fresh meats under the steaming process

Table 8 - Effect of Acetic Acid on Mussel Pearls

Number of Cans	Solution	Diameter of Pearls Measured in Millimeters Along Longest Axis								
		Below .50	.50 to .99	1.00 to 1.49	1.50 to 1.99	2.00 to 2.49	2.50 to 2.99	3.00 to 3.49	3.50 to 3.99	Total
		No.	No.	No.	No.	No.	No.	No.	No.	No.
1	3% salt and 1% acetic acid	4	1	-	-	-	-	-	-	5
1	do	5	3							8
Total 2		9	4	-	-	-	-	-	-	13
1	3% salt and $\frac{1}{2}$% acetic acid	23	22	5	1	-	-	-	-	51
1	do	13	6	-	1	1	-	-	-	21
Total 2		36	28	5	2	1	-	-	-	72
1	3% salt and $\frac{1}{4}$% acetic acid	158	31	2	3	-	-	-	-	194
1	do	85	29	9	-	2	-	-	-	125
Total 2		243	60	11	3	2	-	-	-	319
1	3% salt and no acetic acid	507	55	9	-	1	1	-	-	573
1	do	775	37	4	1	2	-	-	1	820
Total 2		1,282	92	13	1	3	1		1	1,393

in this instance was about 50 percent, each can had the equivalent of 12 ounces of fresh meats, or four times as much as the samples shown in Table 7. The dissolving effect of the acid on pearls is clearly indicated. While the acid-treated pearls were being measured, it was noticed that the acid had completely softened the small pearls, which would crumble when touched, and had dissolved the outer layers of the large pearls so that they were considerably reduced in size. The effect of time on the dissolving action of the acetic acid was not shown by this single experiment. It is probable that a longer storage period would have reduced further the number of pearls.

After further investigation of this problem, the U. S. Pure Food and Drug Administration advised the canners that a certain concentration of acetic acid should be added to the canned mussels. Some canneries began using vinegar and continue to do so, while others depend upon the ability of their help to see and reject pearly meats.

Although there are a number of possible explanations for the presence of pearls in mussels, they are believed generally to be the result of a parasite. Jameson (1902) believed that most mussel pearls result from the encystment of an immature trematode worm and the subsequent deposition of pearly matter around the worm. Herdman (1904), also studying the pearls of English _Mytilus edulis_, found pearls very common at Piel and likewise believed that the distomid trematode larva, Distomum somaterias, is largely responsible for the pearls. Stafford (1912) stated that pearls in considerable numbers can be found in Mytilus edulis on the Gaspe coast of Canada, and larvae similar to Distomum somateriae are found in the mussel. The adult form of the worm inhabits the intestines of the eider duck and the scoter duck (Oidemia sp.) both of which are common on the New England coast. No attempt was made during this mussel survey to ascertain the origin and study the formation of pearls in the New England mussels.

GEAR

The equipment used in harvesting mussels varies with the nature of the beds. In New Brunswick and Maine most of the mussels are exposed at extreme low tides; however, the edges of the beds are usually under several feet of water at mean low water. The submerged mussels are gathered easily by use of a long-handled clam hoe or manure fork, and this gear is also used to collect the exposed mussels. In some instances mussels have been picked from the beds by hand, but this method does not permit the collecting of many mussels during the low-tide interval.

One of the most useful tools for mussel fishing is the quahog rake. This implement is about the size of an ordinary garden rake and has teeth three inches long. A wire basket with a capacity of about eight quarts is attached behind the teeth and holds the mussels which are raked from the bottom. Using this rake from a boat, it is possible to gather mussels easily from depths of one to four feet of water. If the fisherman is skillful, shellfish from depths of over ten feet can be harvested in this way. A long-handled clam hoe or manure fork can be used in a similar fashion but, as solitary mussels usually fall off the teeth, it has the disadvantage of not being efficient, except in areas where the mussels are clustered and attached to each other. As the quahog rake has a wire basket, the mussels can be washed free of mud and some shells, by vigorously agitating the basket in the water before the mussels are dumped into the boat. It is impossible to wash the mussels in such a fashion when the clam hoe or manure fork is employed. Due to wartime conditions, quahog rakes were not available to fishermen, so this gear has not been used in the Maine fishery.

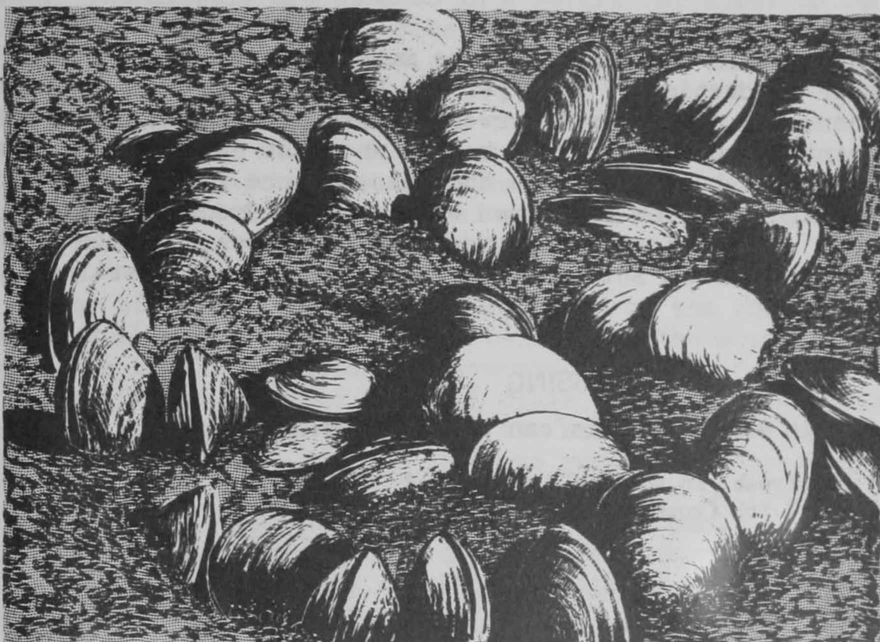
Tongs can also be employed for gathering submerged mussels, but this method is quite slow. During the survey, tongs were sometimes used, but were found to be inefficient on mud bottoms where mussels usually live. Great difficulty was experienced in trying to remove from the tongs the mud and shells which were usually mixed with the live mussels.

In Cape Cod, Buzzards and Narragansett Bays, and in Long Island Sound, mussels of marketable size are found in deep-water beds and require the use of an oyster or scallop dredge, altered to retain mussels of two inches or more in length. Such a dredge will not be an especially efficient gear for releasing small mussels after they have entered the dredge, for many mussels are found in clusters, rather than as solitary individuals. Dredges are now sometimes used in Maine in localities where this gear can be operated over the beds at high water. On those bottoms where the mussels are too thinly distributed to be profitably harvested by hoes, forks, or rakes, the dredge can be operated to good advantage; thus it permits a more thorough reduction of the marketable mussel population. What effect the dredge has on the future productivity of the bottom is not known.

Because of the simple gear by which mussels can be harvested, there was no shortage of mussel-fishing equipment. Neither was there an urgent need for new boats, as the dories, skiffs, and small power boats engaged in lobstering, clamming, and dredging were generally suitable. The only innovation was the use of small flat bottom shallow draft scows to transport mussels from the beds to the shore. In the Frenchman Bay area, where the mussel fishery was prosecuted actively, such scows were commonly employed.

CANNING FACILITIES

During the 1942 survey it was found that there were sufficient canning facilities to pack millions of pounds of mussels annually. Twenty potential Maine mussel factories were located in the region between Jonesboro and Friendship. Of ten cannery operators contacted personally, nine were very much interested in processing mussels. At five canneries it was possible to can sample packs of mussels in 1942. The large sardine factories at Eastport and Lubec were unfortunately without a convenient supply of mussels, for no large quantities were found in that region and adjacent New Brunswick by the survey. In Massachusetts, several Boston and Gloucester canneries indicated their interest in mussels and sample packs also were made there.



THE CHARACTERISTIC POSITION OF LIVE SEA MUSSELS. THE ANTERIOR END BURIED IN THE SAND OR MUD AND THE POSTERIOR OR SIPHON END PROJECTING WELL ABOVE THE LEVEL OF THE BOTTOM.

There was little or no seasonal conflict between the canning of mussels and other types of processed foods. The peak months of fish and vegetable canning are in the summer and fall seasons during which period mussel meats are relatively thin and, therefore, less valuable for canning. Clams are packed during the winter and spring months, but the supply of clams available for canning was only sufficient to enable nine out of twelve clam canneries to operate in 1942 and those nine had been at only 15 to 20 percent capacity for several years prior to 1942. The decrease in clam canning was due to the increased marketing of freshly-shucked clam meats, and to a shortage of both clams and diggers.

The equipment necessary for canning mussels differs little from that employed in clam canning. The same retorts, sealing machinery, and meat-washing devices are used. Any fish cannery having sealing machinery for "round" cans would be able to pack mussels also. All mussels should be washed in a cylindrical revolving drum, and this apparatus was soon adopted by those canneries handling mussels on a large scale. Thus, conversion to mussel canning was relatively simple.

LABOR SUPPLY

In 1942 there was a fairly adequate supply of female labor for mussel canning, especially during the winter when other fish processing was at a minimum. Male labor was not plentiful, but it was felt that the canneries would be able to secure enough men if they could operate on a larger scale during the season of relative inactivity. It was hoped that the mussel fishery would not only provide an additional supply of protein food, but also supply employment for cannery help during the slack season. This hope was realized as the fishery developed and the maintenance of experienced cannery crews was aided by providing them with more regular work.

In Maine, the clam diggers in the regions where mussels were abundant have been able to increase their production of food per man by gathering both mussels and clams. Some lobstermen were also mussel harvesters and prosecuted the mussel fishery during the late winter and early spring months when the returns from lobster fishing were low. In Massachusetts, where the mussels were found in deeper water, the scallop, quahog and sea clam fishermen were able to dredge mussels with little change in equipment. In all instances, there was an increase in the food production per man when the fishermen shifted from other shellfish harvesting to mussels.

PROCESSING

There are three forms in which mussels can be marketed:

1. Fresh, in the shell or shucked
2. Quick frozen
3. Canned

Mussels also can be dehydrated, but whether or not they would be acceptable to the public in this form is questionable. One disadvantage of marketing fresh mussels is apparent--it would have to be limited to population centers not far distant from the source of the shellfish, for mussels do not keep well except under special conditions. It was felt that during the period when mussels were being introduced to a greater segment of the public, it would be likely that gluts would occur, and spoilage might have resultant bad effects on future sales.

Little study has been carried on concerning the possibility of marketing quick-frozen mussels. The effect of long periods of storage on the flavor, appearance, and nutritive values of frozen mussels is not known certainly, although samples of mussels frozen for four months have been rather disappointing due to a slightly bitter taste, dark color, and toughened texture. Until further technological studies of this problem have been conducted, North Atlantic mussels probably will continue to be marketed primarily as a canned product.

The marketing of canned mussels resulted in an almost unlimited range of distribution, with little if any opportunity for spoilage. During the course of the survey, samples of mussels were shipped to a number of canners who were interested in the possibilities of mussel canning and experimental packs were prepared. The following methods were found to be most satisfactory in the experimental work, and were adopted by most of the mussel canners when the fishery later developed.

At the cannery, the mussels were washed in an apparatus similar to the cylindrical fish scaler used for redfish, herring, alewives, etc. The agitation of the mussels, together with the force of the streams of water directed upon them, caused any mud-filled shells to open and the mud to be washed out. The mud-filled shells are difficult to detect otherwise, and, if not removed, will either break apart during steaming or at the shucking table, with a resultant mixing of meats and mud. When thus smeared with mud, the meats must be washed more vigorously and consequently will often break apart and produce an inferior pack.

A live mussel is much more difficult to open than a clam, and in the process, the meat usually is torn. Steaming causes the mussels to open and makes it possible to pick the meats out rapidly. The loss in weight from steaming is an advantage since it prevents excessive shrinkage later in the cans when they are processed. The mussels are steamed in a retort for eight to ten minutes at 240° F. A shorter period of steaming does not open all the shells. A longer period tends to toughen the foot and mantle.

The bouillon from the mussels can be included in the canned or frozen product, as it adds slightly to the food content of the pack. Comparisons indicated that the addition of bouillon did not seem to increase materially the flavor of the product. This liquid from the steamed mussels, if used, should be strained and clarified, for it has a very cloudy appearance.

After steaming, the mussels were taken to the shuckers who removed the meats from the shells and the byssus, or hair, from the meats. Preliminary tests showed that the total time needed to prepare a bushel of steamed mussels for canning was one-half that required for soft clams. It is not necessary to remove a tough siphon, as with the clams, and both the mantle muscles and the foot are tender. Special care, however, must be taken to remove the byssal hairs, which have an unpleasant appearance. In regions south of Cape Cod, mussels are often hosts to the mussel crab (Pinnotheres maculatus). This small crustacean, about ½ inch long lives commensally in the mantle cavity of the mussel and should be removed from the mussel meats during the shucking operation. Although the crab is edible and esteemed by epicures, its presence in mussel meats is not appreciated by the average consumer.

The shucked meats were washed in either salt or fresh water to remove any small amount of mud which might be present. The meats then were weighed into cans. The meats should not be soaked in either fresh or salt water prior to canning. This procedure, which is sometimes used for clams, results in such a decided loss of flavor within a few hours that the soaked meats are almost tasteless. The soaking toughens the mantle and foot muscles and furthermore softens the reproductive organs to such an extent that they may crumble. Consequently, with toughened and broken meats, the product is poor in appearance and texture.

Successful packs were processed by the canners at temperatures of 240° F. for 30 minutes in a No. 1 picnic can having a drained weight content of 6½ ounces of mussel meats. Quick cooling of the cans after retorting seemed to be desirable. Further studies on the technique of mussel canning have been carried out by the technological laboratories of the Fish and Wildlife Service.

According to scallop fishermen, large beds of horse mussels (Modiolus modiolus) exist along the Maine coast. In order to explore the possibilities of developing a fishery for this species, an experimental pack was processed at a cannery in Southwest Harbor, Maine, in July 1943. The mussels were dredged from submerged beds lying in about 40 feet of water near Jonesport, Maine. Horse mussels are seldom found in any abundance in depths of less than two or three fathoms. The lengths of the mussels on the Jonesport beds ranged from four to six inches.

The horse mussels were processed in the same manner as that used for Mytilus edulis, except that a retort time of about 17 minutes was necessary to open the shells enough for easy shucking. The meats, which were reddish-orange and somewhat tough, were packed in No. 1 picnic cans. Ten to eleven meats produced a drained weight of seven ounces after processing in the can. It was felt that this product would appeal less to the consumer than Mytilus edulis and no attempt was made to promote a fishery for Modiolus modiolus.

(This article will be continued in the November 1949 issue of this periodical)

CONTRIBUTION TO THE BIOLOGY OF THE KING CRAB

If an abundant Alaska king crab population is to be maintained it is imperative that the females be protected. There is no justification for commercial utilization of the female king crab. Not only is the yield of meat small, but she is carrying developing eggs all during the year except for a short period of time just before and after moulting.

King crabs (Paralithodes camtschatica Tilesius) can be caught in much larger amounts and more easily while concentrated in shallow depths during the moulting and mating season. One of the most efficient methods of fishing is to tow trawls along the floor of the ocean and scoop up the schools of mating crabs. Observations made on board crab fishing vessels operating during the mating season in Bering Sea in 1941 clearly show that trawl fishing caused great destruction of soft shelled crabs. It was found that from twenty-five to nearly one hundred percent of all females taken in trawls at this time were either killed outright or were injured so severely they would die. Damage was extensive from the last week in April, when Bering Sea was first entered, until the latter part of May. After the first of June, the shell of the females had hardened sufficiently so that trawling caused practically no damage.

Tangle nets, being a fixed gear, cause much less damage than trawls to soft shelled crabs. This is largely due to the fact that only as crabs move about on the bottom are they caught in this gear, and since moulting and soft shelled crabs are much less active than hard shelled ones, they are much less likely to come into contact with the nets. This gear catches large quantities of male crabs as they move about in search of females during the mating season, but if of proper construction, it catches and injures very few females.

—Fishery Leaflet 340