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Seasonal Effect on Yield, Proximate Composition, and Quality of Blue Mussel, *Mytilus edulis,* Meats Obtained From Cultivated and Natural Stock

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ABSTRACT—Seasonal effect on yield, proximate composition, and sensory quality of steamed blue mussel, Mytilus edulis, *meats obtained from cultivated and natural stocks was determined. Both populations (cultivated and natural) gave the highest yield in early spring and a secondary peak was observed in late summer through fall. Minimum yield was detected in June through July after the mussels had completed spawning. The average steamed meat yield of the mussels for the year was 19.4 percent for the cultivated mussels and 13.5 percent for the natural stock. Yield maxima within a single harvest season were related to shell length, which was identical for the two populations examined in spite of age differences. Proximate composition analyses revealed no seasonal change in ash and only a slight variation in lipid content. Moisture, protein, and carbohydrate content were significantly affected by the season. Both cultivated and natural stocks of blue mussels were acceptable throughout the year.*

INTRODUCTION

Blue mussels, *Mytilus edulis,* have been enjoyed by coastal populations in Europe for many centuries. The initial supply of this seafood came from natural mussel beds found in the littoral and sublittoral zone, where mussels are attached to rocks by byssus threads. However, with time and increased demand, fishermen realized the ease with which this mollusk could be cultivated, and developed techniques best suited to their areas. One of the oldest methods of mussel cultivation, which is still practiced in France, is the "bouchot" system where mussels are grown on poles driven into the ocean floor in the intertidal zone.

A more recent method of propagating and fattening blue mussels is "bottom cultivation" practiced in Denmark, Holland, and West Germany. A third method, very effectively used in southern France, Spain, and Italy, employs ropes which are either fixed horizontally in surface layers of the ocean or suspended from floating rafts (Drinkwaard, 1972; Mason, 1972; Hurlburt and Hurlburt, 1975). Although mussel cultivation is an active industry in England, at least 10 percent of the annual harvest comes from natural mussel beds (Dare and Edwards, 1975).

Off the coast of Maine, natural mussel beds which were harvested, averaging about 9.5 million pounds per year during the period from 1943 through 1946, provided an inexpensive protein source (Scattergood and Taylor, 1949b). A subsequent decline in landings was considered to reflect competition from other protein foods as well as unavailability of good quality mussels (Dow and Wallace, 1954). Nevertheless, a relatively small market was retained supplying the demand of certain ethnic groups in metropolitan areas. As the quality of this seafood is being appreciated by a larger consumer market, increased interest in mussel cultivation has been noticed.

Significant seasonal change in meat yield, observed in cultivated mussels (Mason, 1972) and of mussels obtained from natural beds (Dare, 1976), is known to reflect gonad development and spawning. The proximate composition (protein, carbohydrate, lipid, and ash) has also been observed to show seasonal change (De Zwaan and Zandee, 1972; Dare and Edwards, 1975). The most noticeable change in composition was increased glycogen content in mussels harvested during late summer and fall. This increase was attributed to the type of food which the blue mussels ingested (Drzycimski, 1961). The mineral composition of raw mussel meats was investigated by Segar et al. (1971) and Ball et al. (1975), while the effect of processing on proximate composition and mineral content was reported by Slabyj and Carpenter (1977). Although this shellfish is still primarily marketed in the shell, little information is available on quality loss during transportation and storage (Drinkwaard, 1972; Slabyj and Hinkle, 1976).

The objective of the present study was to determine the seasonal effect on meat yield and proximate composition of freshly steamed blue mussel meats of natural and cultivated stocks, as well as their acceptability throughout the year.

MATERIALS AND METHODS

Blue mussels from natural beds, used in this investigation, were obtained from a commercial source. The mussels were harvested primarily from the intertidal zone near Cushing, Maine. The mussels were washed, graded, and packed in 1-bushel quantities (27.2 kg) in plastic mesh bags and held immersed in the ocean on a raft for 1 or 2 days, for the mussels to cleanse themselves of silt and sand. Sampling was not restricted

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to a single mussel bed or a selected age group.

The cultivated mussels were obtained from a limited commercial supply where they were grown on Spanish rafts (Lutz, 1974). Again, sampling was not restricted to a single shell length. All samples were transported and held up to 2 days in ice before being used. In the laboratory all mussels were scrubbed under cold running tap water and briefly drained.

Yield studies were performed by weighing six composite samples, consisting of 30 individuals, before steaming. After steaming the mussels for 6 minutes (Waterman, 1963), the meats and shell were weighed separately and the average shell length of the batch was determined. The meat to shell weight relationship, determined from selected harvests, was obtained by weighing the steamed meats and empty shells of blue mussels of similar shell lengths (±1 mm).

Lipid content was determined on three 50-g composite samples of freshly steamed meats according to the procedure recommended by Bligh and Dyer (1959). Moisture was obtained on 200-g composite samples in triplicate by drying steamed meats to constant weight under vacuum at 70°C. The dried tissue was pulverized in a Wiley (Intermediate) Mill[1] for protein and ash determination (Slabyj and Carpenter, 1977). Carbohydrate content was obtained by difference.

Sensory evaluation was performed on coded steamed meats presented in a randomized complete block design with three replications. When only the natural mussel stock was available for examination (July and August), the steamed meats were presented two at a time, from three replicated steamings. The panelists (13 to 24), many of whom had previously participated in sensory evaluation of mussels, were asked to rate the samples for flavor (5-point scale with 5 representing the best quality) and for texture (7-point scale with 7 representing mushy and 1 representing tough, chewy meats).

The sensory data were analyzed by the variance method, using the treatment × judge interaction (Bliss, 1960) to test for a significant treatment F ratio. The least significant difference procedure was used to measure the differences between the two means.

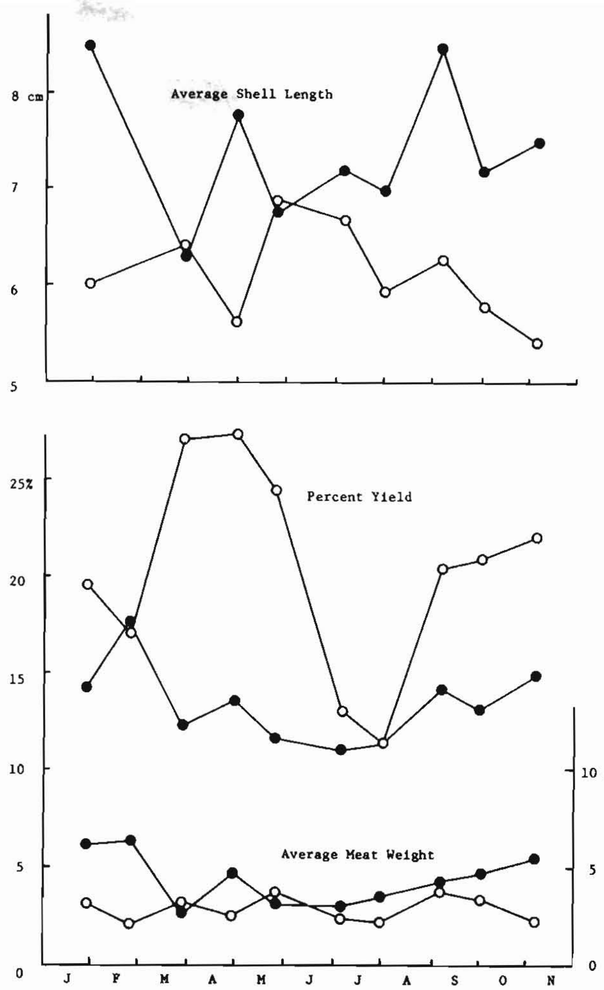

Figure 1.—Seasonal effect on steamed meat yield of cultivated (open circles) and natural stocks (closed circles) of blue mussels in 1976 as related to meat weight and shell length.

RESULTS AND DISCUSSION

Data obtained on yield determinations for cultivated and natural stocks of blue mussels, *Mytilus edulis*, for 1976 are shown in Figure 1. The cultivated mussels had a maximum steamed meat yield of about 27 percent during the months of March and April. This high yield coincided with the prespawning stage of the mussels, as observed by the grower. The yield dropped to a minimum of 11.5 percent in August, but rose to a secondary peak (22.1 percent) in the fall.

Mussels obtained from natural beds revealed a relatively small peak in yield during the month of February (17.8 percent). This yield dropped to a minimum of about 11 percent in July and August, and subsequently had a secondary peak (14.8 percent) in the fall. Since these mussels were obtained from different mussel beds located primarily in the littoral zone, it is not

[1]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

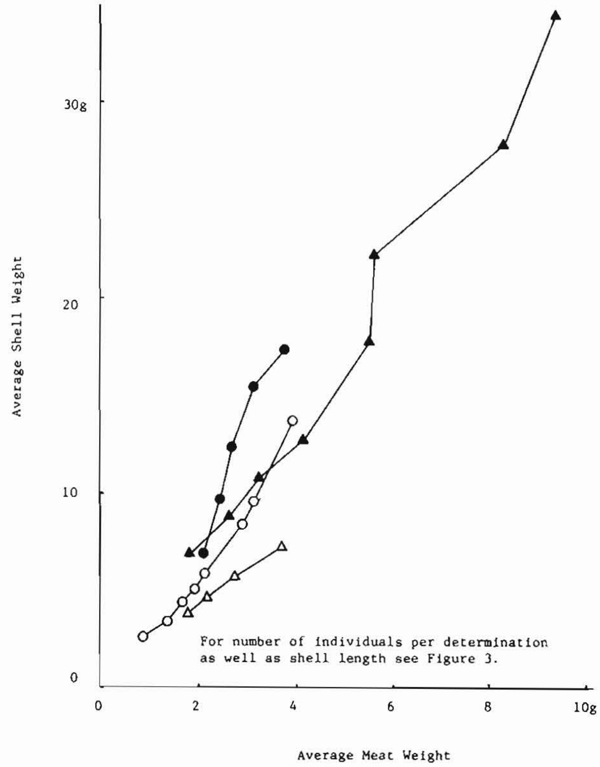

Figure 2.—Relationship between steamed meat and shell weight of cultivated (open circles and triangles) and natural stocks (closed circles and triangles) of blue mussels harvested in July 1976 (circles) and March 1977 (triangles).

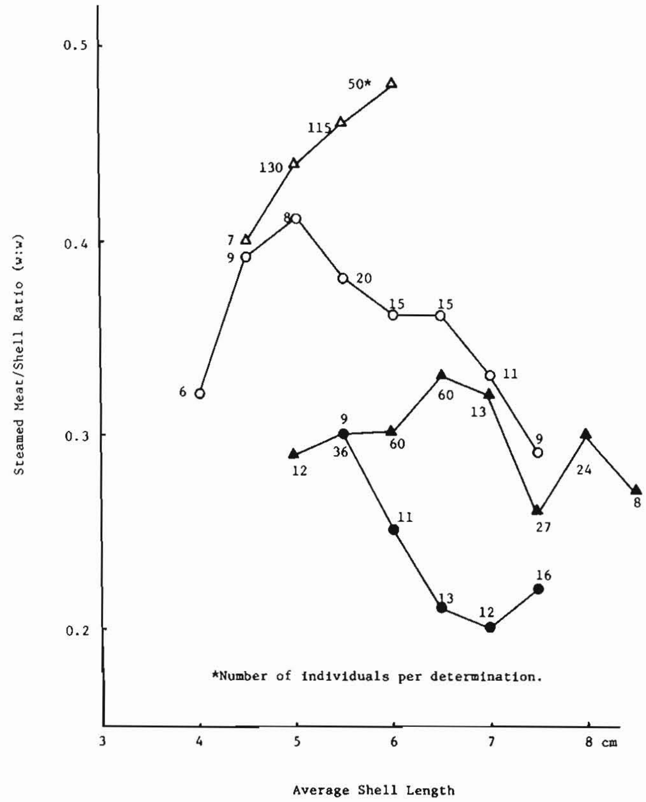

Figure 3.—Shell length VS steamed meat/shell ratio of cultivated (open circles and triangles) and natural stocks (closed circles and triangles) of blue mussels harvested in July 1976 (circles) and March 1977 (triangles).

surprising to observe a relatively small peak in yield during the spring season. Meat yields from different mussel beds are known to vary noticeably (Scattergood and Taylor, 1949a). In fact, from the data presented in Figures 2 and 3, it can be estimated that blue mussels of the natural stock harvested in March of 1977 exhibited an overall yield of about 20 percent. Factors such as food availability, light intensity, wave action, exposure to air, and population density will adversely influence meat yield (Baird and Drinnan, 1957; Mason, 1972; Dare and Edwards, 1975). Furthermore, the fisherman, from whom the mussels were obtained, avoided harvesting mussels that could spawn in transit. According to his experience, such mussels are sensitive to handling and may die.

Variability in yield at each sampling was relatively low for each population (standard deviation of 0.3 to 2.0 percent), with an average standard deviation for the year of 0.8 and 0.9 percent for natural and cultivated stocks, respectively.

The average meat weight of individual mussel meats of the natural stock at each sampling appeared to be heavier than the meats from the cultivated stock (47.6 percent) (Fig. 1). Such a difference was anticipated in view of the fact that the shells of the natural stock were, on the average, 19.6 percent longer (Fig. 1). The overall yield of the cultivated stock examined was observed to be 19.4 percent, while that of the natural stock was 13.5 percent. This difference represents a 43.7 percent higher yield by the cultivated stock. The primary reason for this difference is that the cultivated mussels in this investigation had a shell which was about 30.4 percent lighter than that of the natural stock. It is also known that mussels grown on Spanish rafts have slimmer shells than those from the intertidal zone. The mussels from the latter source would tend to trap more water when harvested, reducing the overall meat yield.

Scattergood and Taylor (1949a) reported similar fluctuation in raw meat yield of mussels harvested at Boothbay Harbor, Maine. They observed a maximum yield of 32.2 percent in June and a minimum of 19.0 percent in July. It may be of interest to compare this raw meat maximum of 32.2 percent yield for mussels obtained 2 feet above the low-water mark in Maine waters, with the 27.3 percent maximum yield of steamed meats for cultivated mussels in the present investigation, knowing that syneresis accounts for 6.6 percent of shrinkage (Slabyj and Carpenter, 1977). Meat yields observed in a commercial plant for January (10.0 percent) and April (14.6 percent), as reported by Scattergood and Taylor (1949a), resemble data reported in the present study for mussels harvested from natural beds.

Other investigators have also observed seasonal changes in the meat content of blue mussels, attributing the loss in meat weight to spawning (Dare and Edwards, 1975; Dare, 1976). The timing of this change in yield was somewhat different and the peaks were reversed when compared with the present investigation.

In order to determine the meat to shell weight relationship at a single harvest, these parameters were plotted for mussels of similar size (Fig. 2). This graph indicates a linear relationship between the meat and shell weight. It is important to note that this relationship is not fixed, but changes with the season in both populations (cultivated and natural stocks). Such a change was anticipated, since mussels harvested in the spring have well-developed gonads, at which time the meats almost entirely fill the shell cavity, while mussels harvested in the summer have gonads which are reduced to a minimum. Baird and Drinnan (1957) observed a similar relationship when plotting raw meat weight against shell weight of mussels of similar size. Regression lines fitted to their data appear to have slopes of 3.0 and 4.2 for mussels obtained from sublittoral and littoral zones, respectively.

Since the slope of the regression line is indicative of yield (the shallower the slope the higher the yield), it is possible to compare yields of different populations. Although Baird and Drinnan (1957) did not indicate the season when their study was conducted, the slope of their regression line for the littoral mussels falls within the values obtained for mussels harvested from natural beds in March and July as presented here (3.7 and 6.3, respectively). Similarly, the slope of the regression line for the sublittoral mussels (3.0) is comparable with that of cultivated mussels in the present study harvested in March and July (1.6 and 3.7, respectively) (Fig. 2).

When using meat and shell weight data and plotting shell length against a ratio of meat/shell weight (Fig. 3), it is possible to detect not only a difference in "apparent" yield between the two populations (cultivated and natural stocks) and between the two seasons of harvest (July and March), but also a difference in maximum yield associated with shell size within a single harvest. The apparent yield cannot readily be converted to actual yield, as given in Figure 1, since it is not known what weight "mussel liquor" (seawater trapped by closed shells) constituted. For this reason, the use of steamed meats to shell weight ratio, instead of the actual yield, has been preferred in order to avoid problems associated with liquor loss in harvested mussels (Drinkwaard, 1972; Coleman, 1973; Slabyj and Hinkle, 1976).

From the limited number of samples examined, it appears that the 6.5-cm mussels gave maximum yield in early spring, while in the fall the maximum yield was obtained from the 5.0-cm long mussels, regardless of whether they were of the cultivated or of natural stock. This perhaps indicates that the 6.5-cm mussels have the greatest capacity to recruit all resources for reproduction, while the 5.0-cm mussels have the highest tissue to shell ratio in a non-spawning population. The similarity in the yield pattern, as related to shell length of the two populations, is noteworthy in that these mussels came from different areas of the Maine coast, were of different age groups, and grew in a different environment.

Meat yield of blue mussels harvested from natural beds with a shell length greater than 7.0 cm did not follow a general pattern (Fig. 3). One can notice a dip in yield for the March population and a slight increase for the population harvested in July. An explanation for this phenomenon cannot be derived from the present study.

It may be of interest to point out that from 27,240 kg (1,000 bushels) of blue mussels harvested in March (Figs. 2 and 3), the anticipated steamed meat yield for the 6.5- and 7.5-cm mussels would be 6,292 kg (23.1 percent) and 5,285 kg (19.4 percent), respectively, assuming that liquid which these mussels can trap may represent 70 percent of the raw meat content (Slabyj and Hinkle, 1976) and syneresis may account for 6.6 percent shrinkage (Slabyj and Carpenter, 1977). Although the yield difference is only 3.7 percent, it is obvious that the difference in amount of meat obtained is 19.1 percent. Similarly, the 5.5- and 7.0-cm mussels harvested from natural beds in July would result in 5,067 kg (18.6 percent) and 4,004 kg (14.7 percent), respectively, per 27,240 kg of blue mussel shell stock, when correcting for syneresis and assuming that liquor associated with these mussels was about 1.2-fold higher than their meats. Again, the yield difference is only 3.9 percent, but the difference in amount of meat obtained from these two different size mussels is 26.5 percent.

Proximate composition of steamed blue mussel meats for the natural stock is shown in Figure 4. The minimum moisture content was 70. 8 percent and the maximum 75.8 percent. It appears that increased moisture retention of steamed meats is related to the post-spawning stage of the mussels.

Maximum protein content was observed to be 20.2 percent and the minimum 14.7 percent. During most of the year the carbohydrate content was low (about 2.2 percent), except in late summer and fall when the peak reached 6.1 percent. It appears that the drop in carbohydrate content reflects increases in moisture and protein concentrations. Lipid content was relatively low, about 3 percent, and revealed only a minor drop in concentration during the months of May through August. Little change was observed in ash content throughout the year with an average of 2.3 percent. Proximate composition of the steamed meats of cultivated stock (Table 1) is essentially the same as that obtained for mussels harvested from natural mussel beds.

Protein and carbohydrate content of both the natural and the cultivated stock is comparable with that reported by other investigators (Drzycimski, 1961; De Zwaan and Zandee, 1972; Dare and

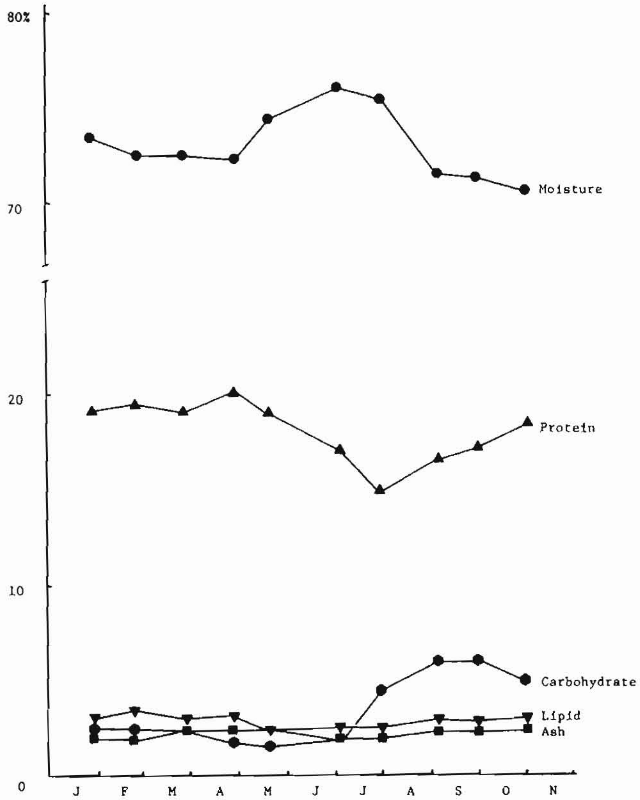

Figure 4.—Seasonal effect on proximate composition of steamed blue mussel meats of natural stock harvested in 1976.

Table 1.—Seasonal effect on proximate composition of steamed blue mussel meats of cultivated stock in 1976.

Date	Moisture	Protein	Crude fat	Ash	Carbohydrate
1/30	[1]73.5(0.3)	19.5(0.2)	2.8(0.1)	2.0(0.1)	2.2
2/26	73.3(0.5)	20.6(0.4)	2.8(0.1)	2.1(0.1)	1.3
3/29	73.7(0.7)	19.1(0.1)	3.4(0.2)	2.2(0.1)	1.7
4/29	73.0(0.4)	20.1(0.1)	3.1(0.2)	2.7(0.1)	1.2
5/27	71.5(0.2)	21.0(0.2)	3.3(0.2)	2.2(0.1)	2.0
7/6	75.7(0.1)	16.5(0.2)	2.6(0.2)	2.4(0.1)	2.8
8/1	75.0(0.6)	14.1(0.2)	2.7(0.2)	2.3(0.1)	5.8
9/7	72.2(0.5)	16.8(0.4)	3.2(0.2)	2.0(0.1)	5.8
10/2	71.1(0.2)	18.6(0.1)	3.3(0.1)	2.6(0.1)	4.4
11/1	71.3(0.4)	18.7(0.3)	3.5(0.1)	2.5(0.1)	4.1

[1]Values in parentheses represent standard deviation on three determinations.

Table 2.—Seasonal effect on flavor and texture of cultivated and natural stock of steamed blue mussel meats harvested in 1976.

Month		Flavor means[1]		Texture means[1]	
harvested	No. of judges	Cultivated	Natural	Cultivated	Natural
Feb.	23	4.06	3.87	4.35 a	3.86 b
Apr.	23	4.17 a	3.41 b	4.67	4.30
May	21	3.98	3.89	5.13 a	4.21 b
June	16	4.00 a	3.62 b	4.60 a	4.06 b
July	13	—	3.96	—	4.08
Aug.	13	—	3.99	—	4.27
Sept.	24	3.76	4.01	4.50	4.38
Oct.	19	3.54	3.79	4.53	4.21
Nov.	22	3.68	3.73	4.59 a	4.05 b

[1]Means followed by different letters differ at $P \leq 0.05$ for that sampling period.

Edwards, 1975) for raw meats, taking into account the effect of steaming (Slabyj and Carpenter, 1977). The timing of the changes is, however, different. Drzycimski (1961) observed a more pronounced drop in lipid content as the result of spawning than was observed in the present study. Both Drzycimski (1961) and Dare and Edwards (1975) reported a significant increase in ash content which was attributed to change in protein concentration. A similar change in ash content was not observed in the present investigation.

Taste panel studies (Table 2) indicated that the cultivated mussels had slightly better flavor than the mussels obtained from natural stock. This is not surprising, since mussels growing in natural beds are in intimate contact with the ocean floor and may pick up the odor of their surroundings. This difference in flavor was only significant ($P \leq 0.05$) in April and June. No apparent change in quality was detected throughout the year in either population.

Texture means (Table 2) revealed that freshly steamed meats obtained from the cultivated stock were slightly softer than those of the natural stock, except when harvested in September and October. This observation was statistically significant ($P \leq 0.05$) in February, May, June, and November. It should be pointed out, however, that the softer texture of the cultivated mussels does not imply that this characteristic was in any way considered to be less desirable. Mussels harvested during the month of April were not considered especially soft or mushy when compared with those obtained during the remainder of the year, although the yield data indicated that these mussels were in the prespawning stage with very well-developed gonads.

Although occurence and size of pearls were not evaluated, no pearls were detected in the cultivated stock, while they were present to varying degrees in the meats of natural stocks.

In summary, it should be pointed out that the yield from both, cultivated mussels as well as mussels obtained from natural beds, was highest in the spring and slightly lower in late summer through fall. Minimum yield was obtained in June and July after the mussels had completed spawning. The overall meat yield of the cultivated mussels was considerably higher than that obtained from natural beds. Yield maxima were related to shell length within a population and both populations (cultivated and natural) exhibited the same change in yield pattern with the season. No seasonal variability in ash and only a slight change in lipid was observed. Moisture, protein, and carbohydrate content showed significant seasonal effect. It was also observed that texture and flavor of mussel meats of both populations were acceptable throughout the year, although the quality of the cultivated stock was more consistent.

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