SEASONAL CYCLE OF CONDITION INDEX OF OYSTERS IN THE YORK AND RAPPAHANNOCK RIVERS[1]

By

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ABSTRACT

Five series of studies were made to test for differences in condition index of oysters grown in the York and Rappahannock Rivers. Oysters were cultured in elevated trays and on the bottom from 1956 through 1961. All groups came from a single source and were selected for uniformity in size. Rappahannock oysters showed high indices in late spring and fall with a low in late summer; the level of condition of bottom groups was below that of trays. York River oysters showed a peak of condition in late spring; in most years there was no increase in quality in late fall; bottom oysters were generally of lower quality than those in trays, but differences were not as large as in the Rappahannock. In general, the level of quality in the York was almost always lower than in the Rappahannock. Differences in level of index between tray and bottom oysters were not associated with presence of *Dermocystidium* or *Pinnotheres ostreum* or with age or crowding, but were probably the result of factors associated with the bottom.

INTRODUCTION

Quality of oyster meats is of considerable interest to commercial growers, for it often determines the margin of profit. High quality meats are usually plump with a creamy white color, and they generally fill the shell cavity. In contrast meats of low quality are shrunken with a high water content and a translucent appearance.

It has long been known that oyster meats vary greatly in quality, but reasons for the variation are not well understood. Many complex factors associated with the environment are involved as indicated in a review by Korringa (1952).

In the present study "Condition Index" was selected as an acceptable measure of quality and yield. It is defined as:

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1 Contribution: Virginia Institute of Marine Science, Virginia Fisheries Laboratory, Gloucester Point, Virginia. Contribution No. 104.

$$\text{Condition Index} = \frac{100 \times \text{dry weight (g) oyster meats}}{\text{size of the shell cavity (cc)}}$$

In effect, condition index (C. I.) compares meats with their theoretical maximum size, that is, the volume of the shell cavity. The higher the numerical value for "C. I." the greater will be the amount and quality of meats from any given bushel. In addition, C. I. may serve as a measure of the recent physiological history of the animal, as low indices have been shown to be associated with disease or unfavorable environmental conditions.

Among factors that appear to lower C. I. are certain organisms associated with oysters: the mud worm, *Polydora websteri*, according to Lunz (1941); the parasitic fungus, *Dermocystidium marinum*, according to Ray *et al*. (1953), and unpublished data of Virginia Institute of Marine Science; attached mussels according to Engle and Chapman (1953); and the oyster crab, *Pinnotheres ostreum*, according to Haven (1959).

Storage of reserve food, principally in the form of glycogen, and the condition index of oysters are both related to the sexual cycle (Medcof and Needler, 1941; Engle, 1958). Generally, along the Atlantic coast, high condition indices occur in late spring and are associated with an accumulation of food reserves and with developing gonads. Indices are low in summer after spawning, but improve again during a period of food shortage in late fall. Age apparently has some effect on condition (unpublished data, Virginia Institute of Marine Science). Examples of environmental conditions that may influence meat quality are: crowding and available food (Korringa, 1952), water depth (Nelson, 1950, and Loosanoff and Engle, 1942), low salinity (Engle, 1946, and Beaven, 1946), and character of the bottom (Ito and Imai, 1955).

In many previous studies it is difficult to attribute observed differences in index to known causes. Frequently the past history of oysters was unknown, and consequently indices were subject to unknown sources of variation. The present study, begun in 1956, was designed to eliminate or compensate for several known sources of variation.

DESIGN OF EXPERIMENT

Comparative studies were made of condition index of oysters cultured in trays and on the bottom at four selected areas: the upper York River at Purtan Bay, lower York at Tillage's Gloucester Point oyster planting, upper Rappahannock at Garrett's Bowler Wharf oyster planting, and in the lower Rappahannock at Urbanna (Fig. 1 and Table 1). Tray and bottom stations were occupied in the lower York and Rappahannock Rivers during the entire study, with the exception of the 1957-58 season, when bottom oysters were not placed in the lower Rappahannock. Tray and bottom oysters were cultured in the upper York and Rappahannock Rivers during the 1958-59 season only.

Table 1. Location of stations in York and Rappahannock Rivers

Station	Miles above mouth	Mean* salinity, ppt.	Depth	Bottom type
York				
Tillage's	6	20	14	Firm shelly mud
Purtan Bay	18	12	6	Soft sandy mud
Rappahannock				
Urbanna	14	15	7	Hard sandy clay
Garrett's	29	10	7	Shells over mud

* Data from Andrews and Hewatt (1957)

In March of each year several thousand Dermocystidium-free oysters were obtained from Wreck Shoals in the James River. Oysters selected to range from 55 to 65 mm were cleaned of fouling organisms, and randomly divided into several groups. At each station some of these oysters were held in trays elevated six inches from the bottom while another group of similar size was scattered on natural oyster bottom beside the trays. Trays were lifted each month and attached fouling organisms were scraped off the oysters. After a period for acclimatization, 25 oysters were removed each month for C. I. determinations. The same number of oysters were taken from the bottom groups, using diving gear during the warmer months and tongs in winter. After about 14 months, when sampling and natural mortality had removed nearly all oysters, new additional groups were placed at the stations. In all, five series of oysters have been studied according to the following schedule:

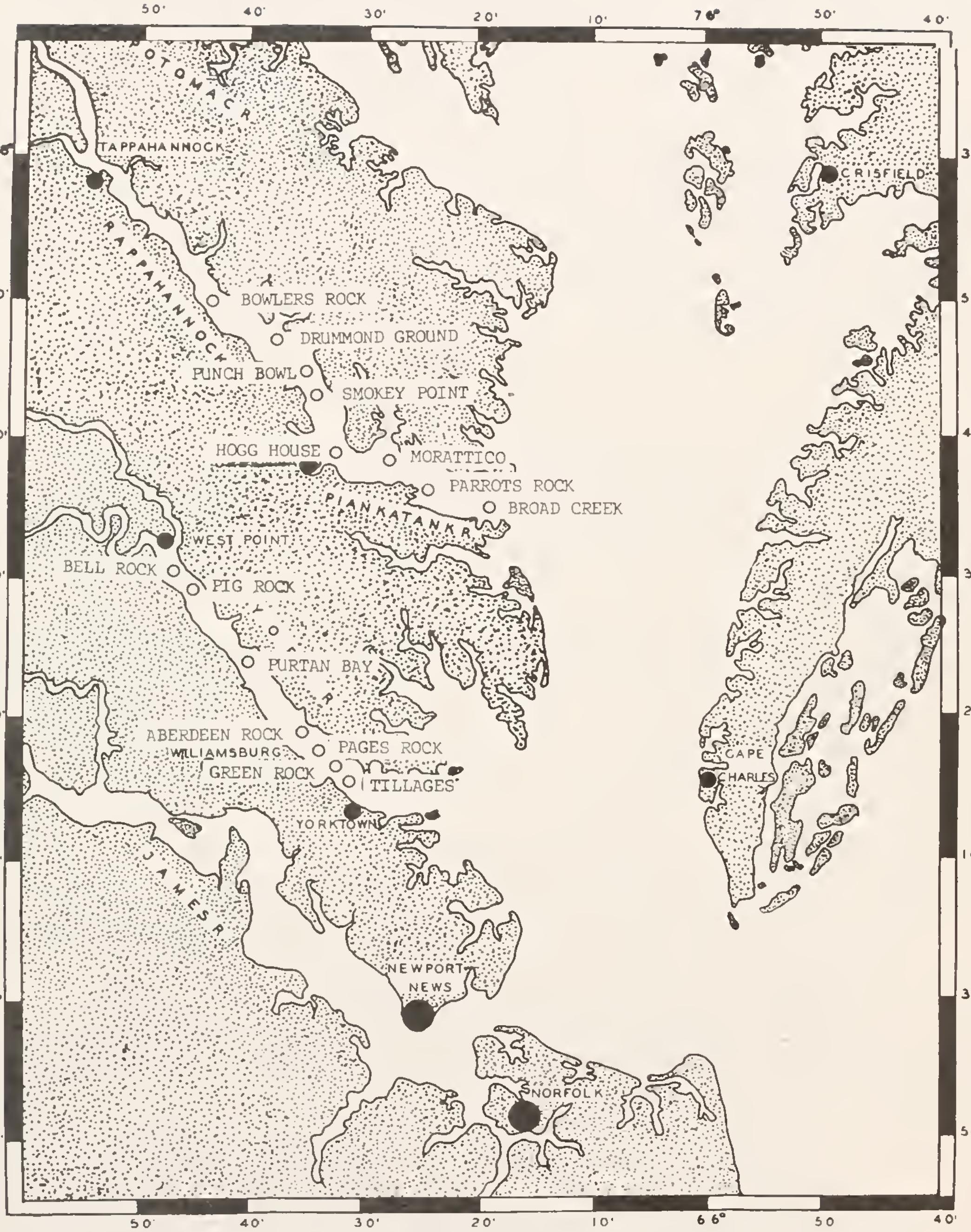

Fig. 1. Location of all stations occupied during study in York and Rappahannock Rivers.

I. Transplanted June 1956, sampled September 1956 through June 1957

II. Transplanted March 1957, sampled June 1957 through June 1958

III. Transplanted March 1958, sampled April 1958 through August 1959

IV. Transplanted March 1959, sampled April 1959 through September 1960

V. Transplanted March 1960, sampling in process

In the 1957-58 studies (Series II), on the lower York River, triplicate trays 150 feet apart were maintained, instead of the usual single tray. Seasonal data for this station are represented by mean values from the three trays. Data from these trays were also used to study possible variation of C. I. over relatively short distances.

During each season, control studies were carried out at various commercial oyster grounds in both rivers. Twenty-five market-sized oysters were dredged from 16 public grounds in the York and Rappahannock Rivers during the winter and condition indices were determined (Table 7).

In review, the attributes of this experimental design are:

1. Culturing oysters in trays minimizes variability due to bottom types or deposits, to the local effects of bottom topography, and other benthic factors. Tray oysters might reasonably show the potential C. I. of any region. Experimental oysters on the bottom serve to relate tray to bottom conditions.

2. Experimental lots for any single series were made up by random selection from a group of uniform size taken from a point source. This technique gave the best assurance that initially the variation and mean C. I. of each lot would not be significantly different. Thus mean differences in C. I. of the processed oysters in the following period of experimentation are more likely to be due to local environmental conditions than to possible initial variation and mean differences.

3. Each group of oysters is followed for only about 14 months. This restricted time period helps prevent large differences in such factors as size and rate of infection with parasites, which might develop if the oysters were held for longer periods.

4. The transfer of experimental groups from the James to the stations by March of each year avoided movement during periods of shell and meat growth. However, it must be stated that in March, indices of Wreck Shoal oysters may range from 4.0 to 5.5, and there was generally an initial rapid increase in condition indices after transplanting.

LABORATORY PROCEDURE

Techniques for determination of C.I. reviewed by Galtsoff *et al.* (1947) were somewhat modified. In the regular monthly sampling, 25 oysters were processed as a unit. Each oyster was drained exactly one minute after shucking. After draining, all 25 meats were placed in a single aluminum foil dish and dried at 87C to a constant weight. Shell cavity volume was determined in the usual manner, by calculating the differences in displacement between the entire group of oysters and their empty valves.

At times of expected maximum and minimum fatness, 25 to 55 oysters were processed individually. The shell cavity volume for each oyster was determined, and the meat dried individually in a small glass petri dish. The mean condition indices of individually processed oysters were tested by the t or t^1 tests to adjudge possible significant differences (Tables 2, 4, 5, and 6).

Incidence of pea crabs (*Pinnotheres ostreum*) was noted during the processing of samples. In the late fall of each year small tissue slices were obtained for study of *Dermocystidium* infections. Incidence of these two oyster parasites was observed to determine their possible influence on condition index.

RESULTS

Seasonal Cycles of Tray and Bottom Oysters

Lower York River (Tillage's): Monthly samples of tray and bottom oysters indicated a definite seasonal cycle (Fig. 2). Both groups had the highest C.I. during May, June, and early July, followed by a decline in quality during mid-summer. After the spawning season there was little increase in quality and both groups of oysters went into the winter period with about the same C.I. they had shown in late summer.

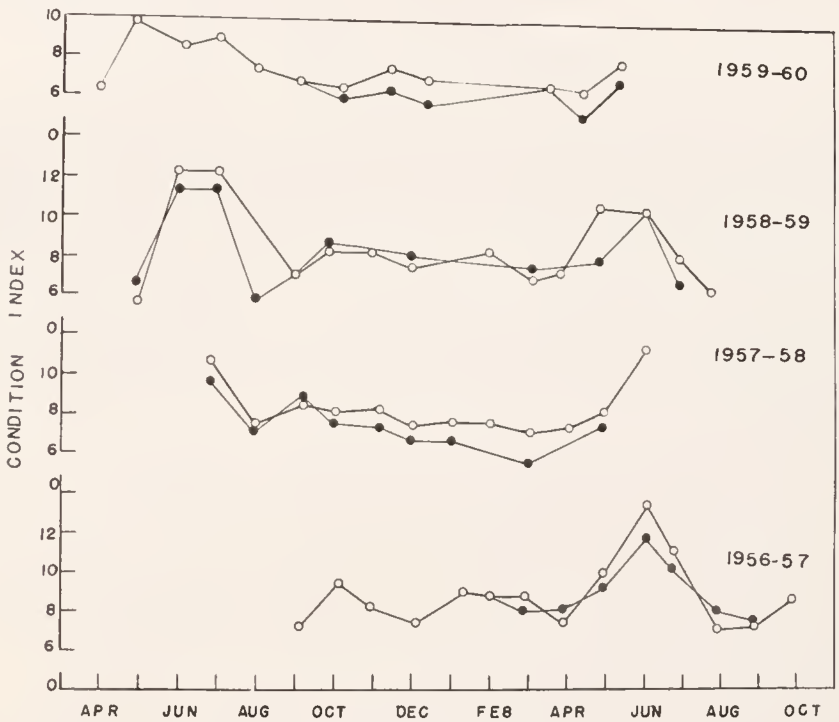

Fig. 2. Seasonal condition index cycles for four series of tray (open circles) and bottom (solid circles) oysters grown at Tillage's oyster ground in the lower York River.

The seasonal curves suggest that during the 1957-58 and 1959-60 seasons, tray oysters were of better quality than those from the bottom. However, the series for 1956-57 and 1958-59 indicated little difference between the two groups.

Composite curves based on mean values for the four series (Fig. 3) illustrate the points previously outlined: maximum indices in May and June and the apparent absence of comparable fattening during

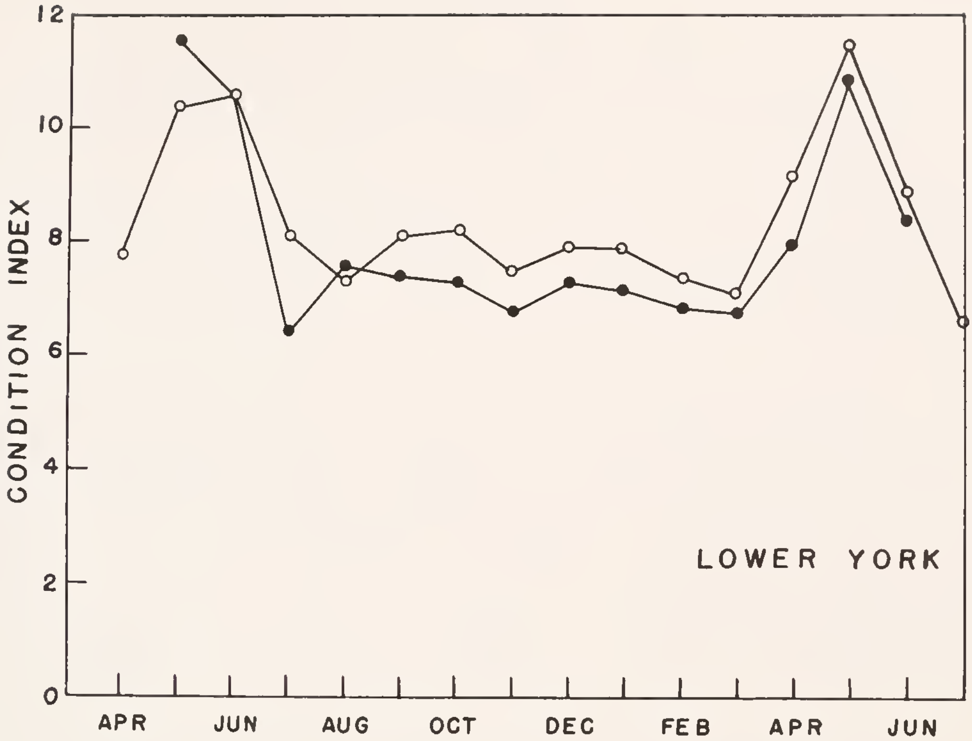

Fig. 3. Composite curve showing mean seasonal condition index cycles for the four series of tray (open circles) and bottom (solid circles) oysters at Tillage's oyster ground in the lower York from 1956 through 1960.

fall and winter. They also show an apparent superiority of tray-cultured oysters over those grown on the bottom. However, statistical analysis on individual oysters indicates that bottom oysters were significantly lower in quality in only two out of seven comparisons (Table 2).

The three trays placed 150 feet apart in the lower York in 1957 were sampled regularly as groups from March through November, and individually on December 30, 1957 (Table 3). Mean values showed small differences. In the statistical analysis of individual oysters made in December, mean differences between the three trays were not significant (Table 2).

Upper York (Purtan Bay): Studies were made through one season, from April 1958 through July 1959, in this area. The seasonal cycle (Fig. 4) appeared similar to that found in the lower river. There was a single peak of quality in the spring, followed by a decrease in summer and little change during fall and winter. The bottom oysters showed a peak of very short duration, while those in the tray remained in good

Table 2. Statistical summary of the groups of tray and bottom oysters processed individually for condition index in the York River

Date tested	Station location	Sample size	How cultured	Time in river-months	Mean condition index	Value t or t'[1]	df
			I. First Series				
9/4/56	Tillage's	41	Tray	3	7.2	1.63	80
		41	Bottom		7.7		
1/8/57	Tillage's	50	Tray	7	9.0	0.00	98
		50	Bottom		9.0		
6/3/57	Tillage's	50	Tray	12	13.3	2.46*	49
		50	Bottom		11.8		
			II. Second Series				
9/13/57	Tillage's	55	Tray	6	8.3		
12/30/57	Tillage's	55 (a)	Tray	10	7.6	0.64 a vs. c	108
		55 (b)	Tray		7.4	0.68 a vs. b	108
		55 (c)	Tray		7.8	1.34 b vs. c	108
			III. Third Series				
6/3/58	Tillage's	50	Tray	3	12.3	1.21	98
		50	Bottom		11.6		
6/3/58	Purtan Bay	50	Tray		11.2	0.41	49
		50	Bottom		11.4		
8/27/58	Tillage's	25	Tray	6	7.0	0.16	47
		24	Bottom		7.1		
8/27/58	Purtan Bay	25	Tray		10.3	3.47**	48
		25	Bottom		8.8		
11/28/58	Tillage's	25	Tray	9	7.6	0.57	48
		25	Bottom		8.0		
11/28/58	Purtan Bay	25	Tray		9.6	0.43	47
		24	Bottom		8.5		
			IV. Fourth Series				
11/9/59	Tillage's	49	Tray	8	7.9	3.48**	48
		49	Bottom	4	6.3		

* $P < 0.05$

** $P < 0.01$

Table 3. Condition indices for three trays 150 feet apart, York River

Date (1957)	No. of oysters in sample	Tray 84	Tray 87	Tray 88	Mean
March 11	25	4.9	4.9	4.9	4.9
June 27	25	10.3	10.4	10.4	10.4
July 30	25	7.7	7.4	7.3	7.5
Sept. 6	25	8.2	8.1	8.2	8.2
Sept. 30	25	7.8	8.4	7.5	7.6
Nov. 4	25	8.6	7.4	8.2	8.1
Nov. 27	25	8.0	6.8	7.2	7.3
Dec. 30	55*	7.61	7.35	7.84	7.6

* Individual oysters tested for statistical analysis (see Table 2).

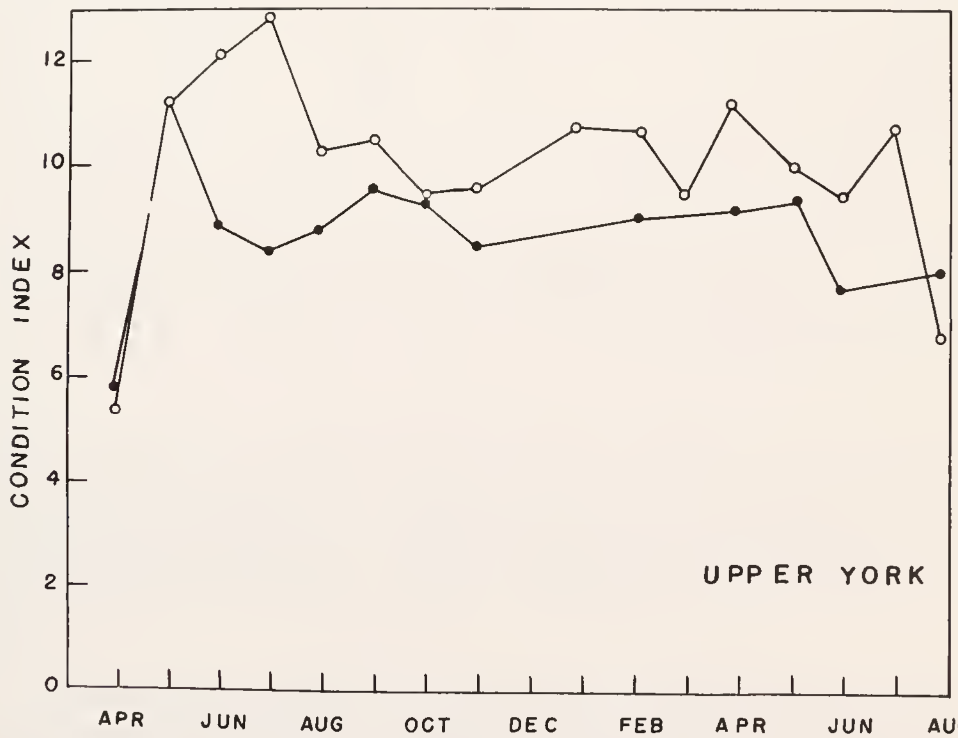

Fig. 4. Seasonal condition index cycle for tray (open circles) and bottom (solid circles) oysters grown at Purtan Bay in the upper York River from April 1958 through July 1959.

condition through July. Again, as in the lower river, tray oysters seemed to be of better quality than bottom oysters, but only the August 1958 values were significantly different (Table 2).

Lower Rappahannock (Urbanna): In contrast to values obtained in the York, condition indices of Rappahannock tray oysters indicated a definite bimodal seasonal curve (Fig. 5). There was a high during May, June, and early July, and a decrease during late summer.

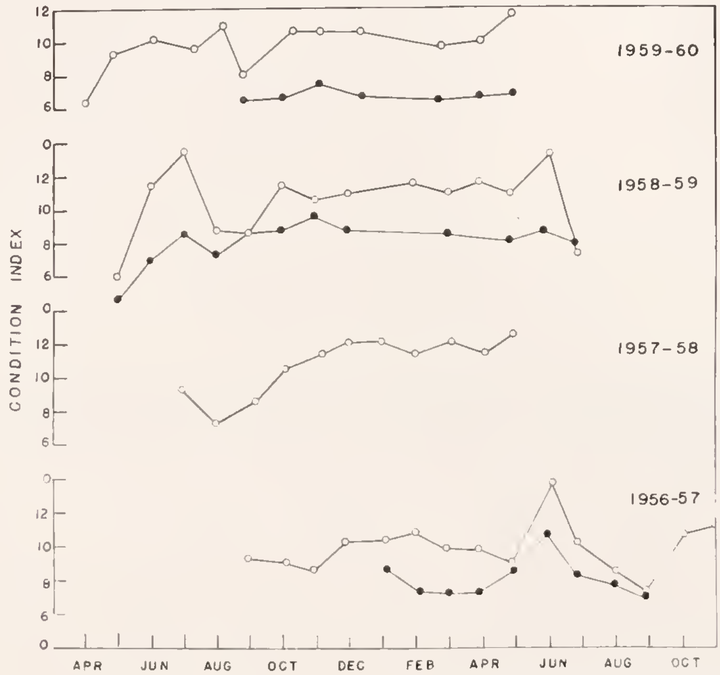

Fig. 5. Seasonal condition index cycle for four series of tray (open circles) and bottom (solid circles) oysters grown at Urbanna in the lower Rappahannock.

A second maximum in late fall or winter approximated the spring peak in amplitude. In June 1958 and in the winter of 1959 bottom oysters did not show a seasonal increase in condition index comparable to that shown by the tray oysters. Composite curves based on all available data (Fig. 6) illustrate the seasonal bimodal curve for both sets of oysters.

Bottom oysters appeared to have a consistently lower index than tray oysters. Comparison of mean values for condition indices of individually processed tray and bottom oysters at expected periods of maximum and minimum fatness showed that, with one exception, tray oysters in the lower river stations were significantly of better quality than bottom oysters (Table 4).

Table 4. Statistical summary of the groups of tray and bottom oysters processed individually for condition index in the Rappahannock River

Date	Station location	Sample size	How cultured	Time in river-months	Mean condition index	Value t or t[1]	df
			I. First Series				
1/3/57	Urbanna	50	Tray	7	10.4	4.45**	49
		50	Bottom		8.5		
5/28/57	Urbanna	50	Tray	12	13.8	5.48**	98
		50	Bottom		10.8		
			II. Second Series				
8/27/57	Urbanna	50	Tray	6	8.4		
12/30/57	Urbanna	55	Tray	10	12.2		
			III. Third Series				
5/27/58	Urbanna	49	Tray	3	11.5	7.44**	97
		50	Bottom		7.1		
5/27/58	Garrett's	48	Tray	3	10.0	3.40**	96
		50	Bottom		7.9		
8/28/58	Urbanna	25	Tray	6	8.5	.07	48
		25	Bottom		8.6		
8/28/58	Garrett's	23	Tray	6	9.7	1.44	46
		25	Bottom		8.8		
12/3/58	Urbanna	50	Tray	9	11.1	4.94**	97
		49	Bottom		8.8		
12/3/58	Garrett's	50	Tray	9	14.6	2.29*	98
		50	Bottom		13.5		
			IV. Fourth Series				
11/2/59	Urbanna	50	Tray	8	11.8	9.31**	97
		49	Bottom	4	7.5		

* $P < 0.05$
** $P < 0.01$

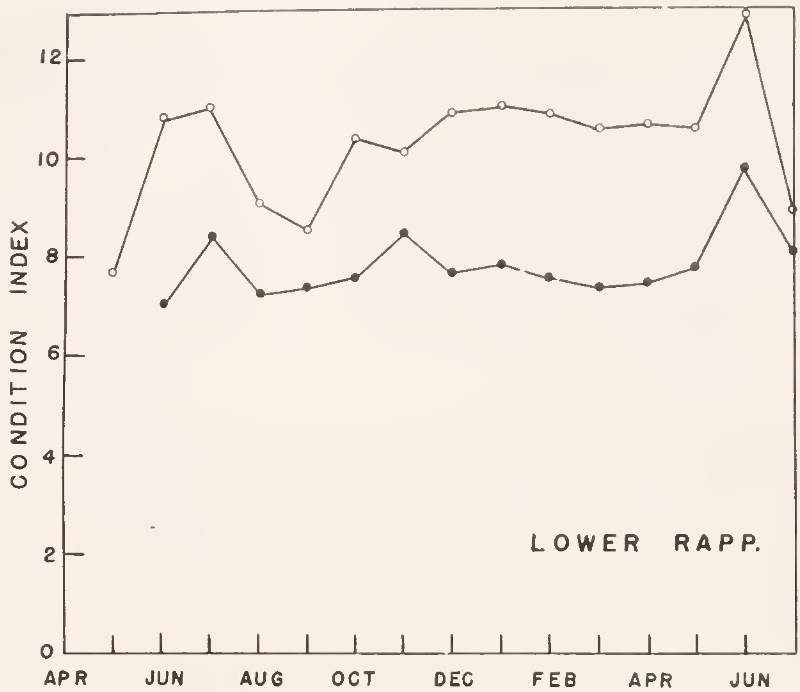

Fig. 6. Composite curve showing mean seasonal condition index cycles for the four series of tray (open circles) and three series of bottom (solid circles) oysters at Urbanna in the lower Rappahannock from 1956 to 1960.

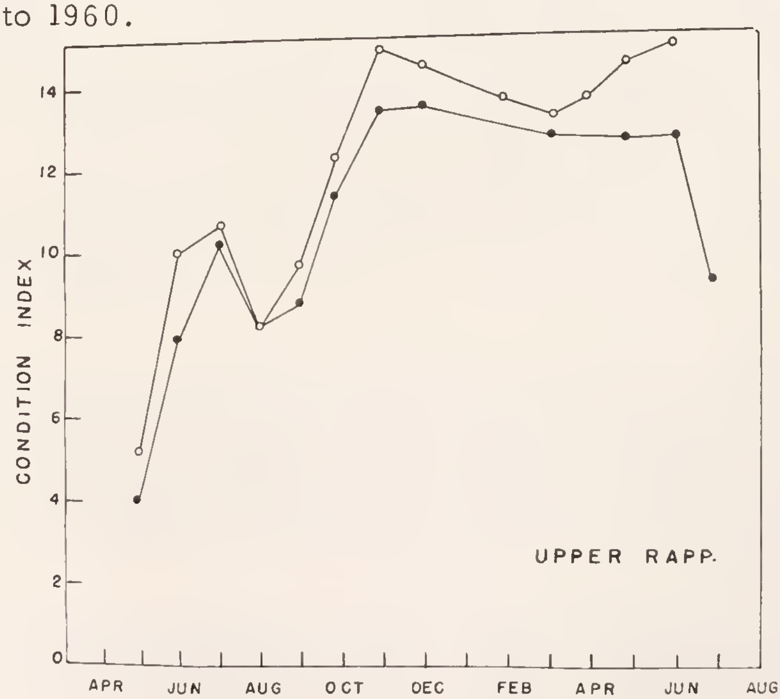

Fig. 7. Seasonal condition index cycle for tray (open circles) and bottom (solid circles) oysters grown at Garrett's oyster ground in the upper Rappahannock from March 1958 through July 1959.

Upper Rappahannock (Garrett's): Oysters grown in trays showed a bimodal seasonal index curve (Fig. 7) similar to that for the lower river. The maximum for late fall and winter, however, was more prominent than that for the spring. In this respect the upper river differed from the lower.

Again, as in the lower river, curves for tray and bottom oysters followed similar trends, with bottom oysters apparently indicating a consistently lower index. Statistical studies of individual oysters showed that differences in the mean condition indices between tray and bottom groups were significant during spring and winter, but no difference was apparent in late summer (Table 4).

Comparison of Tray Oysters in the Two Rivers

The curves in Fig. 8, which show four year averages for tray oysters in the two rivers, suggest that those cultured in the lower York had a consistently lower condition index during the winter months than those grown in the lower Rappahannock. During spring and summer, possible differences between the two groups were not obvious. Statistical comparisons at periods of maximum and minimum fatness confirm these observations (Table 5). During each of the four winters, York River tray oysters were significantly lower in quality than those in the Rappahannock. No differences were evident during early spring and only one of the two tests in late summer showed York River oysters to have a lower index.

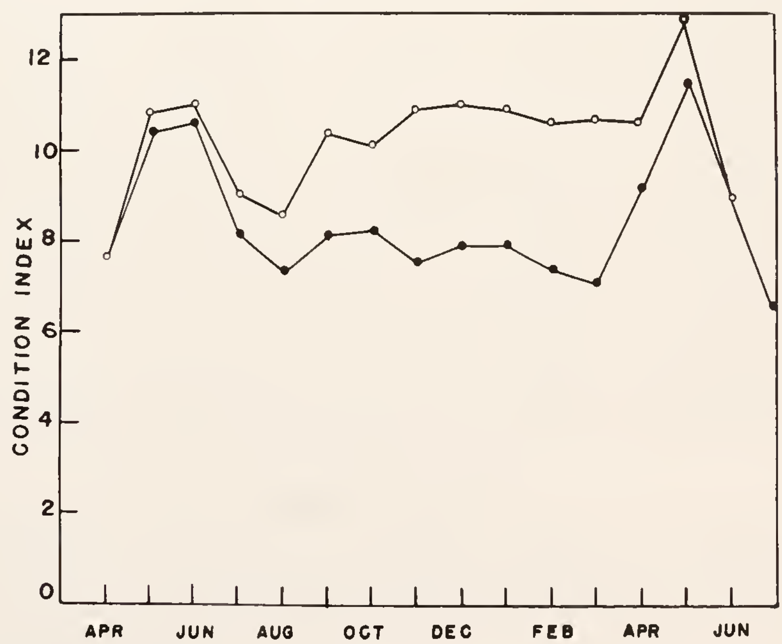

Fig. 8. Composite curve showing mean condition index curve for the four series of tray oysters at Tillage's in the lower York (closed circles) and the four series of tray oysters at Urbanna (open circles) in the lower Rappahannock from 1956 through 1960.

Table 5. Statistical summary of the groups of tray oysters processed individually for condition index in the York and Rappahannock Rivers

Date	Station location	Sample size	Time in river-months	Mean condition index	Value t or t^1	df
			I. First Series			
1/3/57	Urbanna	50	7	10.4	3.15**	49
1/8/57	Tillage's	50		9.0		
5/28/57	Urbanna	50	12	13.8	1.02	98
6/3/57	Tillage's	50		13.3		
			II. Second Series			
8/27/57	Urbanna	50	6	8.4	0.28	103
9/13/57	Tillage's	55		8.3		
12/30/57	Urbanna	55	10	12.2	12.4**	108
12/30/57	Tillage's	55c*		7.8		
			III. Third Series			
5/27/58	Urbanna	49	3	11.5	1.25	97
6/3/58	Tillage's	50		12.3		
5/27/58	Garrett's	48	3	10.0	1.83	96
6/3/58	Purtan Bay	50		11.2		
8/28/58	Urbanna	25	6	8.5	3.18**	48
8/27/58	Tillage's	25		7.0		
8/28/58	Garrett's	23	6	9.7	1.26	46
8/27/58	Purtan Bay	25		10.3		
12/3/58	Urbanna	50	9	11.1	6.22*	73
11/28/58	Tillage's	25		7.6		
12/3/58	Garrett's	50	9	14.6	8.40**	49
11/28/58	Purtan Bay	25		9.6		
			IV. Fourth Series			
11/2/59	Urbanna	50	8	11.8	7.33**	97
11/9/59	Tillage's	49		7.9		

* Tray c used, see Table 2

* $P < 0.05$

** $P < 0.01$

If curves for the upper rivers in the 1958-59 series are compared (Figs. 4 and 7) it is seen that tray oysters in the upper Rappahannock were unquestionably superior.

Comparison of Bottom Oysters in the Two Rivers

Statistical comparisons (Table 6) show that in two out of three winters, bottom oysters in the lower Rappahannock had higher indices than those grown in the lower York. Comparisons during the spring of 1958 show those in the lower York to be superior, while no difference was evident in the spring of 1957. In the summer of 1958 a single comparison showed bottom oysters in the Rappahannock to have higher indices.

Experimental and Commercial Oysters

Extensive studies on oysters from public oyster rocks were made as a basis for comparison with experimental results. Samples of 25 oysters each were taken from beds that covered the range of commercial oyster production in both rivers. Condition indices were determined in winter when oysters were being harvested for market. Results are summarized in Table 7.

Between March 1956 and January 1960, York River oysters from commercial plantings showed little trend in C. I. up or down river, and no large variation from year to year. During this entire period many indices were below 6.0 and it is our experience that oysters with indices ranging around 5.5 are not desirable from an economic standpoint. Generally meats from these oysters are flaccid, semi-transparent, and with a high water content. Yields as reported by oystermen are usually about four pints of meats per "culled" bushel. During the winter of 1960-61, however, there was a distinct change in quality and yield of York River oysters indicated by an increase in indices in the December 1960 samples. Oysters reached a six-year high in quality, but as in previous years indices were below those in the Rappahannock.

Comparable studies in the Rappahannock showed indices consistently higher than in the York, oysters being of average or above average quality. Again, as in the York River, quality and yields reached a six-year high during the winter of 1960-61, as indicated by the December 1960 samples.

Table 6. Statistical summary of the groups of bottom oysters processed individually for condition index in the York and Rappahannock Rivers

Date	Station location	Sample size	Time in river-months	Mean condition index	Value t or t[1]	df
			I. First Series			
1/3/57	Urbanna	50	8	8.5		
1/8/57	Tillage's	50		9.0	1.63	98
5/28/57	Urbanna	50	13	10.8		
6/3/57	Tillage's	50		11.8	1.60	98
			III. Third Series			
5/27/58	Urbanna	50	3	7.1		
6/3/58	Tillage's	50		11.6	8.6**	98
5/27/58	Garrett's	50	3	7.9		
6/3/58	Purtan Bay	50		11.4	6.75**	49
8/28/58	Urbanna	25	6	8.6		
8/27/58	Tillage's	24		7.1	4.04**	47
8/28/58	Garrett's	25	6	8.8		
8/27/58	Purtan Bay	25		8.8		48
12/3/58	Urbanna	49	9	8.8		
11/28/58	Tillage's	25		8.0	2.04*	72
12/3/58	Garrett's	50	9	13.5		
11/28/58	Purtan Bay	24		8.5	7.79**	72
			IV. Fourth Series			
11/2/59	Urbanna	49	4	7.5		
11/9/59	Tillage's	49		6.3	2.71**	96

* $P < 0.05$
** $P < 0.01$

Table 7. Condition index of composite samples from public oyster beds

York River

	Miles above mouth	Mar. 1956	Jan. 1957	Apr. 1958	Dec. 1958	Jan. 1960	Dec. 1960
Tillage's*	6	6.2	7.4	5.7	6.6	5.6	6.7
Green Rock	8	---	---	---	7.1	5.2	---
Pages Rock	11	6.1	7.4	6.0	6.7	6.1	8.6
Aberdeen Rock	14	5.8	7.6	5.8	6.0	5.3	8.0
Purtan Bay	18	---	---	5.7	---	---	10.7
Pig Rock	22	4.4	---	5.9	---	---	7.8
Bell Rock Shallow	24	5.8	5.7	6.3	7.0	4.6	9.2
Bell Rock Deep	24	5.7	5.2	---	6.7	4.4	---
Average		5.7	6.7	5.8	6.7	5.2	8.5

Rappahannock River

	Miles above mouth	Nov. 1956	Dec. 1957	Dec. 1958	Dec. 1959	Dec. 1960
Broad Creek	1	---	9.0	10.0	---	---
Parrots Rock	6	7.6	7.6	8.1	8.1	10.3
Drummond Ground	12	8.5	7.5	8.5	8.6	6.8
Hogg House	14	7.0	9.4	8.3	7.8	12.3
Smokey Point	19	6.3	8.5	9.1	7.4	12.0
Punch Bowl	21	6.7	---	---	---	---
Morattico	24	7.7	9.3	8.6	6.2	9.8
Bowlers Rock	29	---	9.5	12.6	8.6	9.7
Average		7.3	8.7	9.3	7.7	10.1

* Private oyster ground

When oysters from the public oyster rocks (Table 7) were compared with the bottom oysters planted in the experimental study (Table 6 and Figs. 2 and 5), the latter showed higher indices in both rivers. Differences were smaller in the Rappahannock than in the York. These differences are possibly due to the greater average age of the oysters from the natural rocks.

Effects of Oyster Pests on Conditions

In the course of the laboratory work, mature stage V pea crabs (*Pinnotheres ostreum*) were removed from the oyster samples and counted. This parasite has been shown to lower condition index (Haven, 1959). Rates of infestation in experimental oysters (Table 8) show that presence or absence of the pest did not account for differences between tray and bottom oysters. For instance, in the Rappahannock, where maximum differences between the two groups were obtained, tray oysters showed more crabs but higher condition index than did the bottom oysters.

Infection with *Dermocystidium marinum* has also been associated with lower condition index (Ray *et al*., 1953). Tests for this fungus were made during fall collections. Results (Table 9) indicated that incidence in bottom oysters was only slightly higher than in the trays. Detailed study in the series of oysters processed individually indicate that, even if the few infected oysters were removed, the large differences in C. I. between tray and bottom oysters would remain. However, it is emphasized that differences in condition index between stations, between rivers, and between years are very probably subject to large variation from *Dermocystidium*. This statement is based on studies by Andrews and Hewatt (1957), who demonstrated that rates of infestation with the fungus may vary with the season and with geographic location and, as previously pointed out, incidence of the fungus has a definite influence on condition index.

Fifth Series of Tray Bottom Studies

Data for the fifth series were not completed in time for inclusion in this report, but preliminary results can be briefly summarized. In the Rappahannock at Urbanna, tray and bottom indices confirmed previous findings; however, both groups showed indices higher than in the previous five-year period.

In the York, tray and bottom oysters still maintained the same relation to each other as previously outlined, with the tray groups apparently having a slightly higher index. Indices of the York River

Table 8. Percentage of oysters containing stage V *Pinnotheres ostreum*

Station	Tray	Bottom
	First Series 1956-57	
York - Tillage's	8.4	16.7
Rappahannock - Urbanna	6.5	5.7
	Second Series 1957-58	
York - Tillage's	17.1	22.2
Rappahannock - Urbanna	7.5	X
	Third Series 1958-59	
York - Tillage's	8.1	10.9
York - Purtan Bay	9.0	3.6
Rappahannock - Urbanna	5.2	2.8
Rappahannock - Garrett's	5.3	2.8
	Fourth Series 1959-60	
York - Tillage's	8.0	5.6
Rappahannock - Urbanna	7.2	6.4

Table 9. Weighted incidence* of *Dermocystidium marinum* in oysters

Station	Tray	Bottom
	Second Series 1957-58 (tested Oct. 1957)	
York - Tillage's	0.48	---
Rappahannock - Urbanna	1.17	---
	Third Series 1958-59 (tested Sept. 1958)	
York - Tillage's	0.00	0.40
York - Purtan Bay	0.00	0.16
Rappahannock - Urbanna	0.00	0.28
Rappahannock - Garrett's	0.00	0.00
	Fourth Series 1957-60 (tested Oct. 1959)	
York - Tillage's	0.76	1.00
Rappahannock - Urbanna	1.12	0.96

* See Andrews and Hewatt (1957).

oysters remained below those in the Rappahannock, as in the previous period; however, they also reached a five-year high in quality with indices averaging about 1.5 units higher. The only departure from the general pattern was that both tray and bottom oysters in the York showed a high condition index during the fall and winter of 1961 which was almost equal to the spring peak.

DISCUSSION

An analysis of causes of variation in condition index with season or among stations was not the primary purpose of this study. The intent was to determine whether there are seasonal cycles, and if so, whether seasonal cycles vary with geographic location, with method of cultivation, or from year to year.

The seasonal condition cycles in the two rivers were not similar during most of the study. In the Rappahannock the bimodal curve demonstrated by tray and bottom oysters was the same as that typically found in Canadian waters by Medcof and Needler (1941) and in upper Chesapeake Bay by Engle (1958). The relationship of this typical curve to the sexual cycle and to food storage has been discussed by the previously cited authors.

The dominance of the spring peak of index shown by York River oysters during the 1956-1960 period did not agree with results of a previous study by Galtsoff et al. (1947) on the possible influence of sulfate pulp mill wastes on oysters in the York River. Seasonal data from that report, on per cent dry weight of oyster meats for nine locations in the York River from 1935 to 1937, indicated about equal quality during spring and fall. In contrast, during the present study, equal indices in spring and fall were indicated only during the winter of 1960-61, or in only one out of the five series of tests.

The numerical value for index varied seasonally, but perhaps the most important consideration was that, regardless of seasonal variation, York River tray and bottom oysters appeared to have a consistenly lower index than those in the Rappahannock during the winter. It is not possible now to give reasons for this variation, but certainly dissimilar environmental conditions are indicated. One of the most obvious differences is indicated by Table 1, which shows a higher mean salinity at Tillage's in the lower York, when compared to Urbanna in the lower Rappahannock. However, it is not possible to state that salinity per se is responsible for observed differences in indices between the two areas, and undoubtedly a complex of environmental factors associated with salinity are involved.

The increase in the condition indices of all experimental and commercial groups in both the Rappahannock and the York during the winter of 1960-61 to a six-year high is of great interest. It indicates that the generally lower indices noted during the four previous years are not permanently associated with the two rivers. Environmental changes may occur which influence both rivers simultaneously, but it is noted that indices in the lower York were still below those of comparable groups in the lower Rappahannock.

Various factors have been considered as responsible for the lower index of bottom oysters in comparison to those grown in trays. Higher incidence of the oyster crab (Pinnotheres ostreum) and Dermocystidium have been eliminated as possible causes. Frequent inspection of the bottom by means of diving gear demonstrated that bottom oysters were never as heavily fouled or as crowded as those in trays, so these variables probably do not account for observed differences. The method by which oysters were selected for the tray and bottom groups eliminates age, size, or variation in source as causes of differences between indices. It is concluded that variables not measured in the present study, but which are associated with the bottom environment, are responsible.

Theoretically, it appears logical that bottom oysters may be subject to higher turbidity loads than tray oysters, thus reducing feeding rate and consequently condition index. Supporting evidence is given by Loosanoff and Engle (1947), Loosanoff and Tommers (1948), and Lund (1957), who state that an increase in turbidity caused by microorganisms or by inanimate matter usually causes a decrease in pumping rate and, therefore, feeding. Harmful substances accumulated and released by bottom deposits may be detrimental to growth, as outlined by Ito and Imai (1955). Or tray and bottom oysters may be affected by differences in current velocity or available food (Lund, 1957).

An important aspect in the comparison of tray and bottom oysters is their possible utility in future studies involving condition index. It is obvious that both tray and bottom groups may show similar seasonal trends at a single station, but their level of condition index may be completely different. Therefore, in future studies the use of both groups is clearly indicated.

Bottom oysters will be of use in estimating the level of condition index in commercially grown oysters. However, because of the variable nature of the bottom, replicate groups should be placed randomly in each test area.

Tray oysters should necessarily be included in future studies as they probably show the potential of the water in an area to produce oysters of higher quality, eliminating many "bottom effects." In addition, differences in levels of indices between tray and bottom groups give an estimate of the intensity of the influence of bottom conditions.

Oysters grown in trays are frequently used by biologists to estimate growth and mortality, and present data indicate that tray oysters may have more meat per unit of shell cavity than those grown on the bottom. In addition, data to be reported in another paper indicate that tray oysters may have the more rapid growth rate. Consequently, the present study indicates that results obtained from tray studies should not be related to bottom-cultured groups without an adequate knowledge of the possible differences between the two groups.

Seasonal information obtained from both tray and bottom studies will aid commercial growers. Andrews and Hewatt (1957) state that James River seed oysters tend to reach maximum biomass on the basis of shell weight in June, about 24 to 36 months after setting. In the York River, condition index generally reaches a seasonal high during June and consequently yields and meat quality are highest during this month. Therefore, spring harvest of York River oysters is certainly indicated.

In the Rappahannock, data suggest that yields of meats per bushel and quality will be about equal during spring and fall. Therefore, oysters should be harvested in June if this season corresponds with maximum biomass. If harvest is delayed until fall, then it should not be attempted before October.

Although spring harvest of oysters is most practical for biological reasons, consumer demand may be low in the spring when oysters are in peak condition. A possible solution to this dilemma would be to freeze or process oysters harvested in June for consumption in winter when demand is high.

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