FLORIDA STATE BOARD OF CONSERVATION

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EXPERIMENTS ON THE HOLDING OF FRESH SHRIMP IN REFRIGERATED SEAWATER

by

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April 9, 1952

ML 2738

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1. Summary

1. The longer trips made by shrimp boats fishing the new Key West, Texas and Campeche grounds have aggravated the difficulties of landing shrimp in a strictly fresh condition. Icing appears inadequate. Long periods on ice also result in increased amounts of black spot on the shrimp.

2. In the present experiment samples of Key West shrimp were held in seawater at approximately 0 °C (32 °F). The quality of these shrimp compared to samples held in crushed ice was evaluated by a taste panel, on the basis of flavor, odor and the amount of black spot.

3. Iced samples and seawater-held samples scored approximately the same up to ten days of preservation. Samples in seawater scored higher than those in ice from twelve days on. One seawater sample was edible after 24 days.

4. Headed shrimp kept better than those with heads on.

5. Shrimp in the same seawater throughout the experiment kept somewhat better than those on which part of the seawater was changed daily. This point requires further checking.

6. Black spotting can be completely avoided by holding the shrimp in refrigerated seawater.

7. There appears to be an advantage in holding the shrimp as cold as possible, the best sample being that held just above the freezing point of seawater, -1 °C.

2. Introduction

Shrimp of the Family Penaeidae support the most valuable fishery of the South Atlantic and Gulf states. Up to about 1945, the fishery was prosecuted almost entirely on the white shrimp (*Penaeus setiferus*) and in that year 143,660,000 pounds were landed (Anderson et al). The shrimp fishery underwent a rapid expansion in the following years, when new grounds were opened up in Texas and Mexican waters (Lyles, 1950), Key West (Idyll, 1950) and elsewhere. Other species soon became important in the catch. The Texas-Mexican landings include a large proportion of *P. aztecus*, the brown grooved shrimp, while the Key West fishery is supported entirely by *P. duorarum* the pink grooved shrimp. The latter species is also caught in the Campeche (Mexico) fishery which developed in 1950-1951 (Springer, 1951). As the fishery expanded and extended its range many additional boats, drawn from other fisheries, and others newly commissioned for the purpose, began shrimp fishing. Most of the new vessels were larger than the older boats, and thus able to make longer trips.

Increased lengths of time at sea have raised new problems of handling the catch. Whereas, formerly, boats were away from port only one day as a rule, they now remain at sea for from 3 to 7 days in the Key West fishery and from 10 to 15 days or more in the Campeche fishery. As a result it has become increasingly difficult to land shrimp in a fresh condition. Even the large boats have inadequate hold capacity for the quantities of ice necessary for long periods of time. Furthermore, even with large quantities of ice, shrimp do not remain in perfectly fresh condition for the length of time required to get them to market. In the Key West fishery the freshest shrimp are one day old, the stalest are about six days old. Shrimp caught at Campeche and landed in most U. S. Gulf of Mexico ports are a minimum of four days old and a maximum of about 13 days old. They must still be transported to markets after this period of time; it requires an additional 1 to 5 days or more to accomplish this.

Shrimp held in ice or frozen characteristically develop a condition called "black spot" or "black discoloration." The longer the shrimp are held the more pronounced is the discoloration. It occurs in the form of spots or bands which usually develop first on the cepholothorax (or "head") of the shrimp, and later on the tail, where it shows up first on the membranes between the abdominal segments. In severe cases almost the whole tail is blackened (Fig. 1). It has been shown (Fieger, 1950; Idyll, 1950) that this discoloration is not the result of bacterial or fungicidal action. Fieger (1950, 1952) has established that the discoloration is caused by an oxidative enzyme system. An enzyme (tyrosinase) contained in the exoskeleton of the shrimp is acted on by oxygen and changes tyrosine to a dark brown or black colored substance. Shrimp which are protected from contact with the air do not develop black spot.

Black discoloration of shrimp constitutes a serious problem to the industry. This problem increases in importance as boats go further afield for their catches, and as larger production enters the markets, thereby causing consumers to demand better quality of shrimp. Black spotted shrimp can be eaten without endangering health, but there is evidence that the quality of black spotted shrimp is lower than that of shrimp free from the condition. Certainly the discoloration causes consumer resistance. Many dealers will not accept shrimp which are markedly discolored. Fishermen and shippers are frequently obliged to discard part of their catch. The losses from Campeche catches from this cause are said to average 10% of the catch. Instances are cited where full loads have had to be discarded. The economic loss from this cause is high.

The present experiments were undertaken in behalf of the Florida State Board of Conservation to discover new methods of holding fresh shrimp to avoid the difficulties and deficiencies of packing in ice, and to study control measures for black discoloration.

The writers gratefully acknowledge the assistance of many people in planning and executing these experiments. Mr. Lawrence Strasburger, Vice-President of the Envoldsen Shrimp Company and consulting technologist gave invaluable advice in setting up the project and in establishing the techniques. Mr. Harold E. Crowther, Chief of the Technology Section, Fish and Wildlife Service, was also of great assistance in the planning of the work. Mr. James Hyndman, bacteriologist for the Pure Food and Drug Administration, New Orleans, helped to devise the bacteriological procedure. Mr. A. V. Gruber of Condenser Service and Engineering Co. provided the initial impetus for the experiments, gave a great amount of practical assistance in its early phases, and loaned the Marine Laboratory part of the equipment. Mr. Ned Turner of the Dayco Shrimp Co., Key West, went to considerable trouble to make a special trip to the Key West grounds in order to secure the raw material for the experiment. Mr. Turner also donated most of the shrimp used. Mr. Newt Barnett of Miami allowed the authors to accompany him on his shrimp vessel, and donated shrimp for one phase of the experiment. Mr. Carl B. Carlson of the Fish and Wildlife Service and Mr. Harry C. Higgins of Harry C. Higgins, Inc. gave valuable advice on the design of the refrigerating equipment which would be necessary for holding shrimp in seawater.

3. General Procedure.

Samples of pink shrimp *P. duorarum* used in this experiment were obtained on January 19, 1952, from a commercial shrimp trawler operating 35 miles northwest of Key West, Florida.

Six samples each of 450 shrimp were used. Shrimp 35 to 40 to the pound (heads-off size) were selected.

Four of the six samples were placed in seawater pumped from the Gulf at the same place where the shrimp were caught. The remaining two samples were placed in crushed ice in regulation shrimp boxes. The samples held in seawater were placed in a plywood box with four equal-sized compartments.

The shrimp were not washed after being caught. After they had been selected for size half of them were headed. Two samples of headed shrimp and two samples with the heads left on were put in the seawater. A headed sample and one with heads on were put in separate new shrimp boxes. These were placed inside larger boxes and the intervening three inch space filled with cork and glass wool insulation.

The shrimp were brought back to Key West the night they were caught and were transported to the Marine Laboratory at Coral Gables the next day. At the laboratory the box containing the seawater samples was placed in a home-type Frigidaire freezer of 6.69 cu. ft. capacity. The box containing the shrimp was constructed so that it just fitted into one side of the freezer unit. Two of the four compartments were fitted with false bottoms of parafin- covered wood, perforated with several holes. Rubber and glass tubing was inserted into these compartments so that water could be siphoned from beneath the false bottom. Each day of the experiment (with one exception) 1000 cc of water was siphoned from these two samples (one heads off and one heads on) and replaced by an equal quantity of fresh seawater at 0°C. This seawater was obtained at the same time and place as the water in which the shrimp were originally placed, and was kept cold in the same freezer as the shrimp. The original volume of water on all samples was approximately 6500 cc so that about 15% of the water was changed each day on these two samples.

The control samples were re-iced at the dock at Key West and again upon arrival at the Marine Laboratory. Thereafter they were re-iced daily by the addition of 25 pounds of ice to each box. About every third day the shrimp ware removed from the box and completely re-iced, so that the same shrimp were not in one position in the pile for longer than this period. The six samples were thus hold as outlined in Table 1.

The temperatures of the various seawater samples throughout the experiment are shown in Table 2. The iced samples were at 0 °C throughout.

Bacteriological and organoleptic tests were run to assess the quality of the shrimp. Taste and odor were used as the criteria of quality. Accordingly five values were assigned to each of the qualities being tested. These values and the descriptive terms applied to each are shown in Table 3. From a preliminary experiment eleven Marine Laboratory staff members were selected as having the most consistent testing scores. On each testing day six people were chosen from these eleven as a panel to test the shrimp samples.

Organoleptic tests were usually conducted every two days starting on the second day after the capture of the shrimp. This pattern was broken when the regular testing day fell on a Sunday. The number of shrimp tested each day was 17; twelve boiled for the taste test and five raw shrimp for the odor and black spot tests. The testers' ability to rate the samples consistently was checked by duplicating one cooked and one raw sample. These duplicates were taken from different samples each day. Samples of iced shrimp were removed from the top of the pile. Since these shrimp were turned and re-iced approximately every third day, selectivity was avoided.

In preparation for cooking, the heads-on samples were headed and all samples were thoroughly rinsed in fresh water. Five raw shrimp, taken randomly, were placed on coded plates for odor and black spot tests. For all samples a standard cooking procedure was followed. The cooking time was five minutes, and the quantity of water was the same in each case. When identical amounts of salt were used the iced samples were rated as flat. To remedy this two heaping tablespoons of salt were added to the iced samples and a heaping 1/2 teaspoon was added to each sea water sample. When the measured amount of cooking water had come to a rolling boil the salt was added. When the water boiled again the shrimp were put in the water. The five-minute cooking period was timed from the moment the water boiled a third time. At the end of the five minutes, the cooking water was poured off and the shrimp were rinsed in cold water and placed on coded plates.

Testers were requested to eat two shrimp of each sample, and to smell and inspect all raw samples. Their scores were recorded on a mimeographed sheet.

Bacteriological tests were run on each day that organoleptic tests were made. The procedure followed was the dilution extinction method described by Zobell (1946). Comparison readings were made by eye and by electrophotometer to determine the tube with the first turbidity. The reciprocal of the dilution number gave the number of bacteria per cc.

<u>Results</u>

Results of these experiments indicate that shrimp can be held successfully in refrigerated seawater, and that this method has several advantages over present methods of handling fresh shrimp aboard fishing vessels. One sample of shrimp (headed and kept in the same seawater at -1°C) were of high quality after 15 days of holding; they were edible after 24 days. Certain samples of shrimp held in seawater were judged by the taste panel to be at least as good as ice-held shrimp up to 10 days after capture; they were judged to be better than ice-held shrimp between 12 and 24 days after capture. Shrimp held in seawater exhibited no measurable black spot throughout the period of the experiment, whereas ice-held shrimp developed moderate amounts of black spot despite careful icing procedures.

TABLE 1

Description of the method of handling of the shrimp samples

1 Held in seawater; heads off; average temperature +1 °C; approximately 15% of the water removed daily and replaced by clean seawater at 0 °C.

2 Held in seawater; heads on; average temperature +1 °C; approximately 15% of the water removed daily and replaced by clean seawater at 0 °C.

3 Held in seawater; heads on; average temperature 0 °C; held in the same seawater throughout the experiment.

4 Held in seawater; heads off; average temperature -1 °C; held in the same water throughout the experiment.

5 Held in crushed ice; heads off; 25# of ice added daily; removed from box and re-iced about every three days.

6 Held in crushed ice; heads on; 25# of ice added daily; removed from box and re-iced about every three days.

TABLE 2

Temperature of the various samples throughout the experiment

Sample No.	1	2	3	4
Day		Temperature (°C)		
1 (original)	7	11	12	11
1 (at lab)	6	6	6	6
2	-0.5	0.5	0.5	0
4	2	0.5	0	-0.5
5	1	1	0	-0.5
6	2	0.5	0	-0.5
7	1	1	0	0.5
8	1	1	0	-1
10	1	1	0	-1
11	1.5	0.75	0	-1
12	1	0.5	0	-1.5
13	1	1	0	-1
14	1	0.75	0	-0.75
15	1.5	1	0	-0.5
16	1	1	0	-0.5
17	0.8	0.8	0	-1
18	0.8	0.8	0	-1
19	1	0.8	-1	-1
20	1	0.8	-1	-1
22	1			-1.8

TABLE 3

Examination of shrimp

	Sample 1	2	3	4	5	6	7
TASTE							
Good - 5							
Less desirable but acceptable - 4							
Mediocre - 3							
Unpleasant - 2							
Repulsive -1							
ODOR							
Fresh - 5							
Less desirable but acceptable - 4							
Stale - 3							
Unpleasant - 2							
Repulsive - 1							
BLACK SPOT							
None - 5							
Slight amount-4							
Moderate amount -3							
Large amount- 2							
Excessive amount -1							

Results

Results of these experiments indicate that shrimp can be held successfully in refrigerated seawater, and that this method has several advantages over present methods of handling fresh shrimp aboard fishing vessels. One sample of shrimp (headed and kept in the same seawater at -1 °C) were, of high quality after 15 days of holding; they were edible after 24 days. Certain samples of shrimp held in seawater were judged by the taste panel to be at least as good as ice-held shrimp up to 10 days after capture; they were judged to be better than ice-held shrimp between 12 and 24 days after capture. Shrimp held in seawater exhibited no measurable black spot throughout the period of the experiment, whereas ice-held shrimp developed moderate amounts of black spot despite careful icing procedures.

The experiments indicate that headed shrimp will keep better in refrigerated seawater than those left with the heads on. Shrimp held in the same seawater throughout the experiment kept bettor than those on which part of the water was drawn off daily and replaced by an equal amount of fresh cold seawater. This latter result is unexpected and may be due to experimental complications, as will be discussed below.

Quality of Shrimp Held in Refrigerated Seawater

"Quality" was measured by a test panel as outlined above in the section on Procedure. Judgment was made on a five-point scale of "taste" and "odor" (Table 3).

Taste - Figure 1 and Table 4 show the results of the tests for taste on the six samples throughout the experiment. Up to the 6th day of the experiment there were no appreciable differences in the scores for the various samples. On the 8th and 10th days the iced shrimp scored somewhat lower than those hold in seawater but the difference between those scores is not statistically significant. The significance of the difference between scores of various samples was determined by application of the t-test (Fisher, 1944). Although there was some variation, resulting from the magnitude of the total variance, in general scores differing by 1.0 units were on the borderline of significance at the 95% level. Similarly the difference between scores of samples #1 and #2 are significant, between #1 and #6 on the borderline, and the difference between #1 and #5 is not significant. An arbitrary score of 3.5 is established as the limit for "good" quality shrimp, those that would be eaten with pleasure. On the scale of values a score of 4 was assigned to shrimp which, while not of outstanding quality (score of 5), were fully acceptable. Shrimp scored as 3 were termed "mediocre". These were presumed to be perfectly edible, but were not of top quality. After 12 days the iced samples were approaching the score of 3.5 - the limit of "good" shrimp. After 15 days the iced shrimp were below or only slightly above this score. In all likelihood shrimp iced by present commercial methods would not retain this standard of quality for an equal length of time, because of the fishermen's and shipper's inability to handle the shrimp with the same care and with the same amount of ice as the experimental samples were handled. Shrimp below this standard of quality are frequently landed and sold, however, and are accepted by the public. By contrast all but one of the samples held in seawater were well above the 3.5 level after 13 days. Further, the samples held in seawater were subjected to treatment, in the conducting of the experiment, which may have lowered their quality. This treatment would not be necessary under commercial conditions, since it was associated with the drawing of the samples for testing. At each withdrawal of samples, the shrimp were agitated and stirred 15 times to avoid stratified sampling. This inevitably resulted in some crushing and breaking of the shrimp. Hence all the experimental procedure was in favor of the iced controls. Despite this a decided advantage appears to be shown after 10 days in favor of some of the shrimp hold in refrigerated seawater, possibly a moderate advantage after 8 and 10 days; up to 10 days both methods are satisfactory from a point of view of quality.

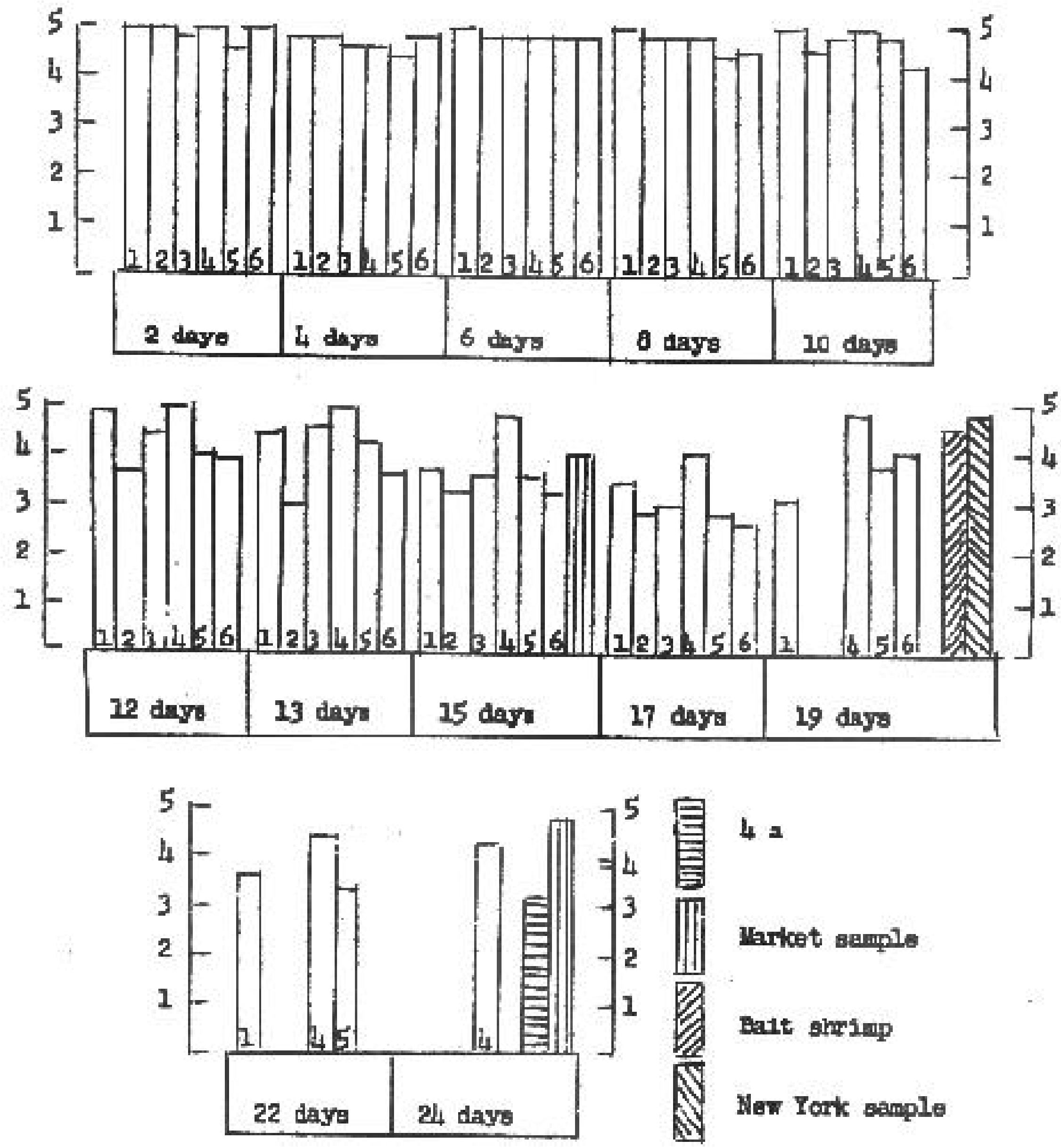

Figure 1. Taste.

TABLE 4

<u>Taste Score</u>

Days	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C	R	C
2	5.0	5.0	5.0	5.0	4.8	4.8	5.0	5.0	4.6	4.6	5.0	5.0								
4	4.8	5.5	4.8	5.5	4.6	5.3	4.6	5.3	4.4	5.1	4.8	5.5								
6	5.0	5.3	4.8	5.1	4.8	5.1	4.8	5.1	4.8	5.1	4.8	5.1								
8	5.0	4.7	4.8	4.5	4.8	4.5	4.8	4.5	4.4	5.1	4.6	4.3								
10	5.0	5.2	4.6	4.8	4.8	5.0	5.0	5.2	4.8	5.0	4.2	4.4								
12	4.8	4.8	4.6	3.6	4.4	4.4	5.0	5.0	4.0	4.0	3.9	3.9							3.9	3.9
13	4.4	4.8	3.0	3.4	4.6	5.0	5.0	5.4	4.4	4.8	3.8	4.2								
15	3.8	3.4	3.4	3.0	3.6	3.2	4.8	4.4	3.8	3.4	3.2	2.8								
17	3.8	3.8	2.8	2.8	3.0	3.0	4.0	4.0	2.8	2.8	2.6	2.6								
19	3.2	3.1					4.8	4.7	3.8	3.7	4.0	3.9	4.5	4.4	4.8	4.7				
22	3.7	3.4					4.4	4.1	3.3	3.0										
24							4.3	4.6									3.2	3.5	4.8	5.1

R Raw
C Cooked
* New York sample
+ Bait sample
4a Sample removed from #4 on 16th day and placed on ice
X Market sample

In comparing the four methods of holding the shrimp in refrigerated seawater it appears from Figure 1 and Table 4 that little differences are detectable among the methods up to 8 days. At 10 days - #2 (shrimp with heads on, with part of the water changed daily) scored somewhat lower than the others; from 12 days on the quality of this sample was noticeably lower than that of the other three samples. (Comparing samples #1 and #2 P>0.01, which is highly significant).

From the 15th day on sample #4 (shrimp with heads off, held in the same water throughout the experiment) scored higher than any other sample, including the iced controls. This superiority became more marked as the experiment progressed. Differences in scores between sample #4 and samples #1, #5 and #6 were all significant. Also the scare of sample #1 was significantly higher than that of sample #2 on the 12th day.

Shrimp held with heads on deteriorated more quickly in quality than headed shrimp. This is true of all pairs of samples, i.e., #2 scored lower than its partner #1, #3 scored lower than #4 and 6 scored lower than #5. This difference was apparent from the 10th day on.

Shrimp in which part of the seawater was changed daily deteriorated in quality more quickly than those held in the same water throughout the experiment. Here, sample #3 scored higher than its partner #2 and #4 scored higher than #1. Indications of this (for samples #3 and #2) showed up first after 10 days and the phenomenon was apparent for both pairs from the 12th day on. It was anticipated that shrimp would keep better if part of the water, containing fragments of shrimp, bacteria and dirt, were replaced by clean water. The failure of this expectation to be fulfilled may not be the result of whether or not the water was changed. It was planned to hold all seawater samples at 0 °C, and tests were made of the refrigerating machine which indicated that this could be done. However, it was found, after tile experiment was underway, that the temperature of #1 and #2 samples was 1 °C, #3 was -0 °C and #4 -1°C most of the time (Table 2). Apparently this was caused by the box being tight against the side of the refrigerator next to sample #4, with a small space (about 1/4") between the wall of the refrigerator and #1 solution. Under these conditions it is not clear whether the superior scores on #4 after 10 days, as compared with #1 was due to the water not having been changed on the former, or to the fact that the temperature of #4 averaged almost 2 °C lower than #1. Nothing conclusive can be said, then., as to the relative merit of changing the water or carrying the shrimp in the same water throughout the experiment. It is planned to conduct further experiments to separate the effects of these variables.

It would appear that headed shrimp, hold in the same seawater throughout, at temperatures between -1 °C and 0 °C will maintain their freshness longest, both as compared with shrimp held in seawater under the other conditions and compared with shrimp held in crushed ice.

In order to test the panel's reaction to shrimp available to the public, in comparison with the experimental shrimp, samples were bought in food stores in Coral Gables. These were included in the tests without the knowledge of the panel members. They replaced the usual duplicated for that day so that no hint was given that they were not experimental shrimp. Such commercial samples were included in the testing on the 15th and 24th days. The commercial sample used on the 15th day was a minimum of 5 and a maximum of 10 days "old". This was determined by tracing the shrimp from the retailer back through the wholesaler to the original buyer in Key West. The taste panel rated those shrimp as good, with a score of 3.8. The rated the best seawater-hold sample (#4) higher (score of 4.6) despite its considerably greater age compared with the commercial sample. This difference was not, however, statistically significant.

The shrimp bought in the store for the sampling on the 24th day were a minimum of three and a maximum of 8 days out of the water. These were given a taste rating of 4.8. The best seawater sample (#4) was rated at 4.4 on that day.

On one day a comparison was made of the quality of the test shrimp with those available in northern markets. Through the courtesy of Mr. Frank Wilkisson of Frank W. Wilkisson, Inc., a sample of Key West shrimp was obtained from the Fulton Fish Market in Now York City. These were packed in dry ice and delivered to the Marine Laboratory by air express. They were included in the panel tests on the 19th day, without prior knowledge of the testers. These shrimp scored 4.6 on the taste test. Sample #4 scored 4.8 on that day, the 19th from the time of their capture.

On this same test day (the 19th) a sample of perfectly fresh shrimp was presented to the taste panel. These shrimp were bought from a. live bait establishment and were alive five hours before they were eaten. These scored 4.8 on the taste test, the same score as sample #4. It is interesting to note that these shrimp did not score the maximum of 5, as many of the experimental samples did early in the experiment. Two tasters scored these lower than 5 and stated that they did not taste "exactly like shrimp". This would indicate that the public rarely is fortunate enough to got a really fresh product, and sometimes does not recognize it when it is encountered.

These results indicate that the test shrimp compared favorably with shrimp normally available to the public, both in Florida and northern markets, and with truly fresh shrimp.

It may be impractical at present to transport shrimp by truck in refrigerated seawater. If so this method of handling is applicable only aboard ship and on the dock. For transport to market from dockside ice would have to be used as at present. To observe the quality of shrimp held first in refrigerated seawater and then packed in ice some shrimp from sample #4 were removed from the water on the 16th day and placed in crushed ice. These were presented to the panel on the 19th day for odor and black spot judgment. On the last day of the experiment (the 24th) it was also tasted. On that occasion it scored 3.2, a little lower than the 3.5 established as the minimum for "good" shrimp.

Odor - Figure 2 and Table 5 summarize results of tests for odor. Up to 8 days all samples scored high on odor, with only slight differences being noted. Even in this early period., however, samples #2 and #3, those kept in seawater with heads on, scored slightly lower than the maximum of 5. On the 10th day samples #2 and #6 showed a decline in odor scores (4.2 and 4.4 respectively). Sample #2 was heads-on shrimp kept at 1°C with part of the water changed daily and #6 was the iced control, heads-on. From the 12th to the 17th days scores of the heads-on samples held in seawater (#2 and #3) both declined rapidly to 2.0 on the latter day. This represents a rating of "unpleasant" on the judgment scale, and these two samples were discarded at this point.

The heads-off shrimp stored at 1°C. on which part of the water was changed each day (Sample #1), scored the maximum on odor through the 10th day. Beginning on the 15th day the odor of this sample became progressively less acceptable until it went below the arbitrary value of 3.5 established as "good". Because of its higher score on taste, however., this sample was not discarded until the 22nd day. Up to the 13th day sample #1 scored at least as high as the iced control; after that time the latter scored higher, with the exception of the 22nd day.

Of all the samples, both seawater and iced, #4 (heads off, held at -1°C in the same water throughout) scored best on odor. Through the tenth day it scored the maximum of 5; on the 15th day it still scored 4.6 while the sample bought in a food store about 8 days old scored 4.0. By this time all other samples were below the 3.5 point, and remained so. Sample #4 did not go below 3.5 until the 24th day, the last of the experiment. On the 19th day #4 sample scored higher for odor than the shrimp obtained from New York, but lower than the sample which was 5 hours old.

The odor of the iced controls (heads off #5, heads on #6) compared favorably with the best seawater samples up to 8 days. On the 10th day the scores of #6 fell to 4.4. On the 13th day both iced samples scored below the "critical" 3.5, although they scored above this on the next day. From the 15th day on both iced samples remained below the 3.5 level, but did not fall in odor score as rapidly as the seawater samples, except #4.

The odor scores of the seawater-held shrimp thus declined more quickly than those for taste. Further, the odor of the water was more unpleasant than that of the shrimp themselves. In commercial practice shrimp from refrigerated seawater would require thorough rinsing before being packed in ice and frozen for shipment.

As described in the section on taste, part of sample #4 was removed from the water and placed on ice on the 16th day. This sub-sample was designated as 4a. Odor tests were made on the sub-sample beginning on the 19th day, when it scored 4.8. This is as good as the sample bought in the food store and considerably better than the odor of the same sample which had been left in the seawater, the latter scoring 4.0. The latter, in turn, scored higher than the odor of the sample obtained from New York, which scored 3.8.

On the 22nd day the odor for sub-sample 4a scored the maximum of 5.0 while the scores on sample #4 was 3.8 and on sample #5 (ice-held, heads off) was 3.2. On the final day of the experiment (the 24th) 'sub-sample #4a again scored higher than sample #4 on odor (4.0 compared to 3.2) but lower than the sample bought in the store which scored 4.2. It would appear from these results that odors which occur in seawater-hold shrimp disappear to a large degree when the sample is transferred to crushed ice.

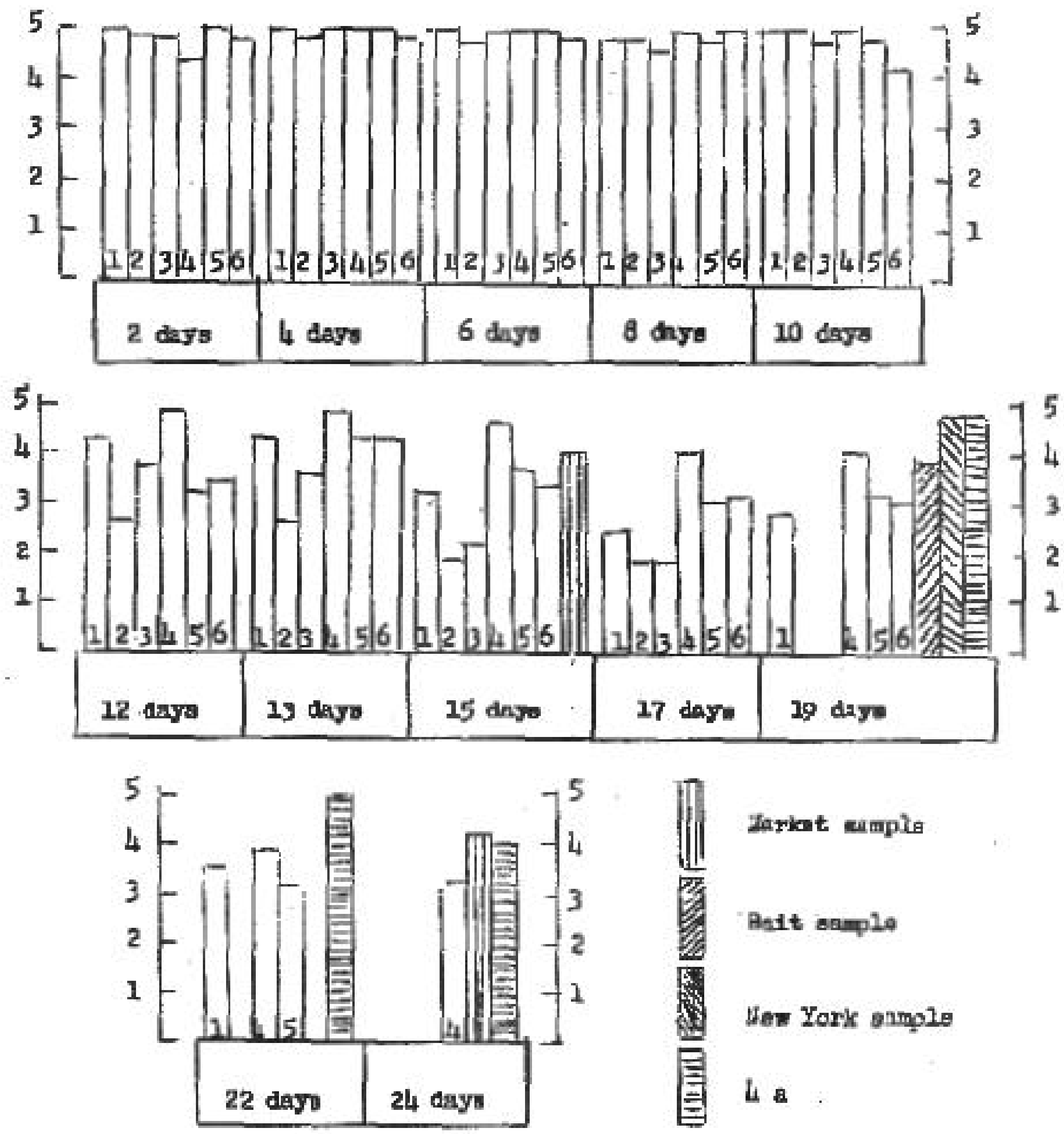

Figure 2. Odor.

TABLE 5

Odor Scores

Sample No. / Day	1	2	3	4	5	6	*	+	4a	X
2	5.0	4.8	4.8	4.7	4.6	4.8				
4	5.0	4.8	5.0	5.0	5.0	4.8				
6	5.0	4.6	4.6	5.0	5.0	4.8				
8	4.8	4.8	4.7	5.0	4.8	5.0				
10	5.0	4.2	4.8	5.0	4.8	4.4				
12	4.4	2.8	3.6	4.8	3.2	3.6				
13	4.3	2.6	3.8	4.8	4.2	4.2				
15	3.2	1.8	2.2	4.6	3.6	3.4				4.0
17	2.4	2.1	2.0	4.0	3.0	3.2				
19	2.8			4.0	3.2	3.0	3.8	4.8	4.8	
22	3.5			3.8	3.0				5.0	
24				3.3					4.0	4.3

* New York sample
\+ Bait sample
4a Sample removed from #4 on 16th day and placed on ice
X Market sample

Black Spot - In Figure 3 and Table 6 the results of the panel scores for black spot are presented. On the 2nd, 4th and 12th days some of the seawater-held samples scored lower than 5. Otherwise all the seawater-held scored the maximum 5.0, indicating complete absence of black spot. The scores lower than 5 on the 2nd and 12th days are thought to be due to hypercritical inspection of the panel. Since a score of 5 indicated no black spot, the slightest discoloration was rated 4. Inspection of the shrimp after the panel tests indicated that the discoloration being rated as black spot was not true black spot. On the 4th day sample #3 was given a score of 4 by the whole panel. This was on the basis of one shrimp (of the 5 in this sample) which showed a slight discoloration. Generally it may be said that those shrimp held in refrigerated seawater exhibited no black spot throughout the experiment.

The iced samples (#5 and #6) began to show some black spot on the 4th day, omitting the 2nd day score of 4.6 for sample #6 on the same basis as the scores for samples #1 and #3 are ignored for that day. By the 6th day both iced samples scored 4.0 and usually did not score higher than that thereafter. Some variation in score was exhibited by the iced samples which was the result of individual variations among the shrimp of the sample. Chance determined whether the sample used for black spot judgment included discolored individuals or relatively unaffected ones.

On the 15th day sample #5 (heads off, iced) scored 3.6 and #6 (heads on, iced) scored 3.8. The sample bought in the food store which was between 5 and 8 days old, also scored 3.8. On the 19th day samples #5 and #6 scored 3.8 and 4.0 respectively, while the sample from New York scored 3.8. This indicates that the iced controls developed less black spot than commercially handled shrimp, since they made scores as high or higher than the latter after longer periods of icing. This confirms the statement made previously that icing techniques used in the experiment were more acreful than those practiced (or possible) commercially. This result also strongly suggests that more thorough and careful icing can reduce black spot in shrimp hold by present methods. There is no doubt of the difference between the seawater-held samples and those hold in ice, the latter showing distinctly more black spot.

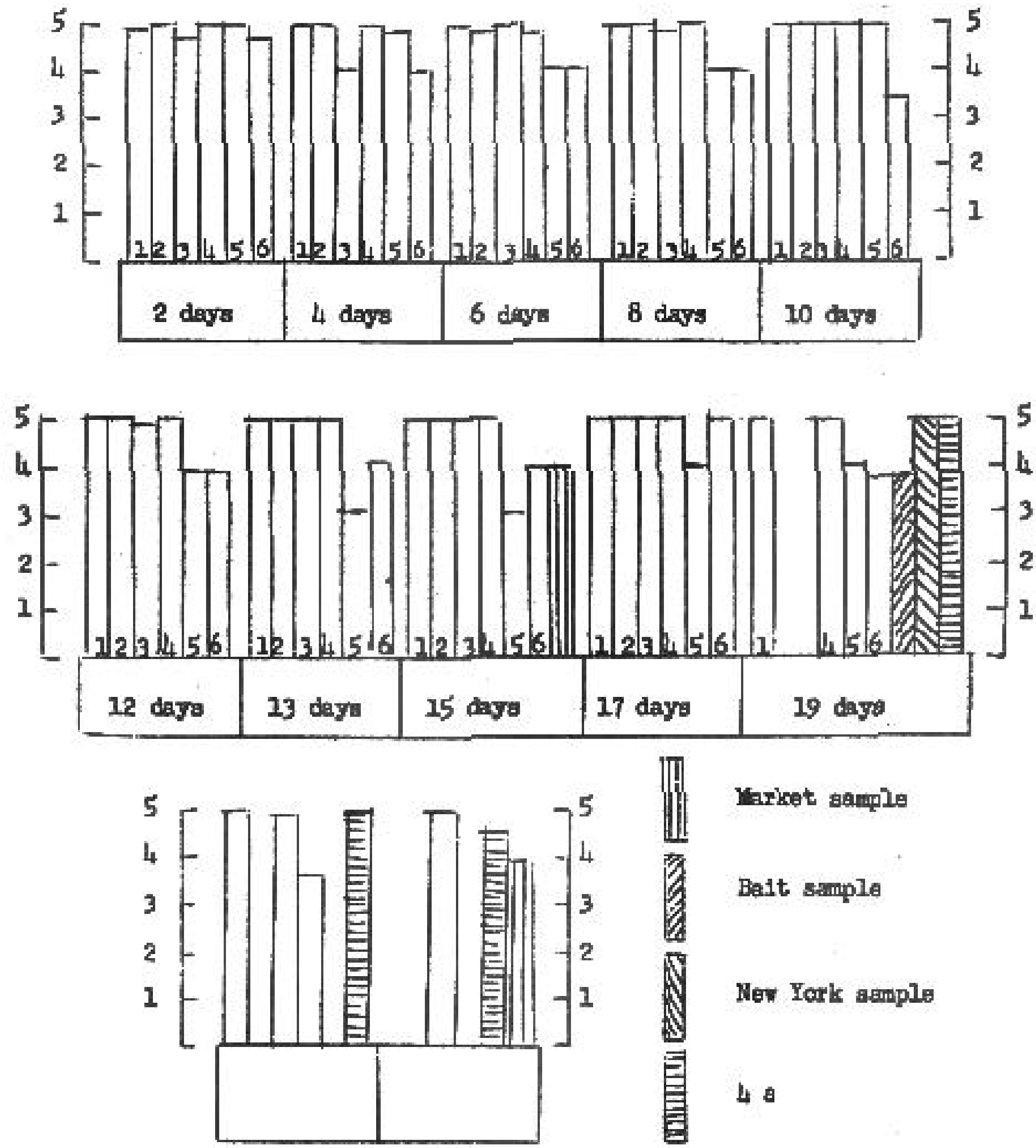

Figure 3. Black spot.

TABLE 6

Black Spot Scores

Sample No. Day	1	2	3	4	5	6	*	+	4a	X
2	4.9	5.0	4.8	4.9	5.0	4.8				
4	5.0	5.0	4.0	5.0	4.8	4.0				
6	5.0	4.8	5.0	4.8	4.0	4.0				
8	5.0	5.0	4.9	5.0	4.0	4.0				
10	5.0	5.o	5.o	5-o	5.0	3.4				
12	5.o	5.o	4.8	5.0	3-8	3.8				
13	5.0	5.0	5.0	5.0	3.4	4.2				
15	5-0	4.6	5.0	5.0	3.6	3.8				3.2
17	5.0	5.0	5.0	5.0	4.0	4.2				
19	5.0			5.0	4.0	3.8	3.8	5.0	5.0	
22	5.0			4.8	3.4				5.0	
24				5.0					4.4	3.9

* New York sample
\+ Bait sample
4a Sample removed from #4 on 16th day and placed on ice
X Market sample

Bacterial Counts - Estimates were made of the total number of bacteria in each sample of seawater and in the drip from the iced samples as described in the section on Procedure. Counts were made on each day that organoleptic tests were made. No attempt was made to identify the bacteria involved.

It was anticipated that the numbers of bacteria in the seawater samples would increase with prolonged holding and that the relative, size of the bacterial population might give some clue as to the maximum holding period.

Figure 4 is a graph of the estimated numbers of bacteria in each sample at various sampling days. Because of difficulties and errors in procedure, counts for the first test day (the second of the experiment) and the 7th test day (the 13th of the experiment) had to be discarded. On the 15th day experimental difficulties forced the rejection of counts of samples #5 and #6.

Bacterial counts on all samples showed either no increase throughout the experiment (samples #1, #4, #5 and #6) or slight increases (samples #2 and #3). In the case of samples #5 and #6, the iced controls, it is perhaps to be expected that the bacterial population would not rise greatly, since a substantial part of the ice was removed each day, and since the melting ice was continuously carrying off bacteria and foreign material from the shrimp. The lower counts of bacteria from the iced samples as compared with the seawater samples is likewise not unexpected, for the same reasons.

The fact that no large increases in bacterial counts occurred in the seawater in which the shrimp were held would suggest that at the temperature involved bacterial activity is slight. Such a situation must necessarily prevail, of course, if the shrimp are to retain their quality. At the end of the experiment increases in the numbers of bacteria occurred in samples #1, #2 and #3 just before these samples were discarded as of poor quality. This may have no

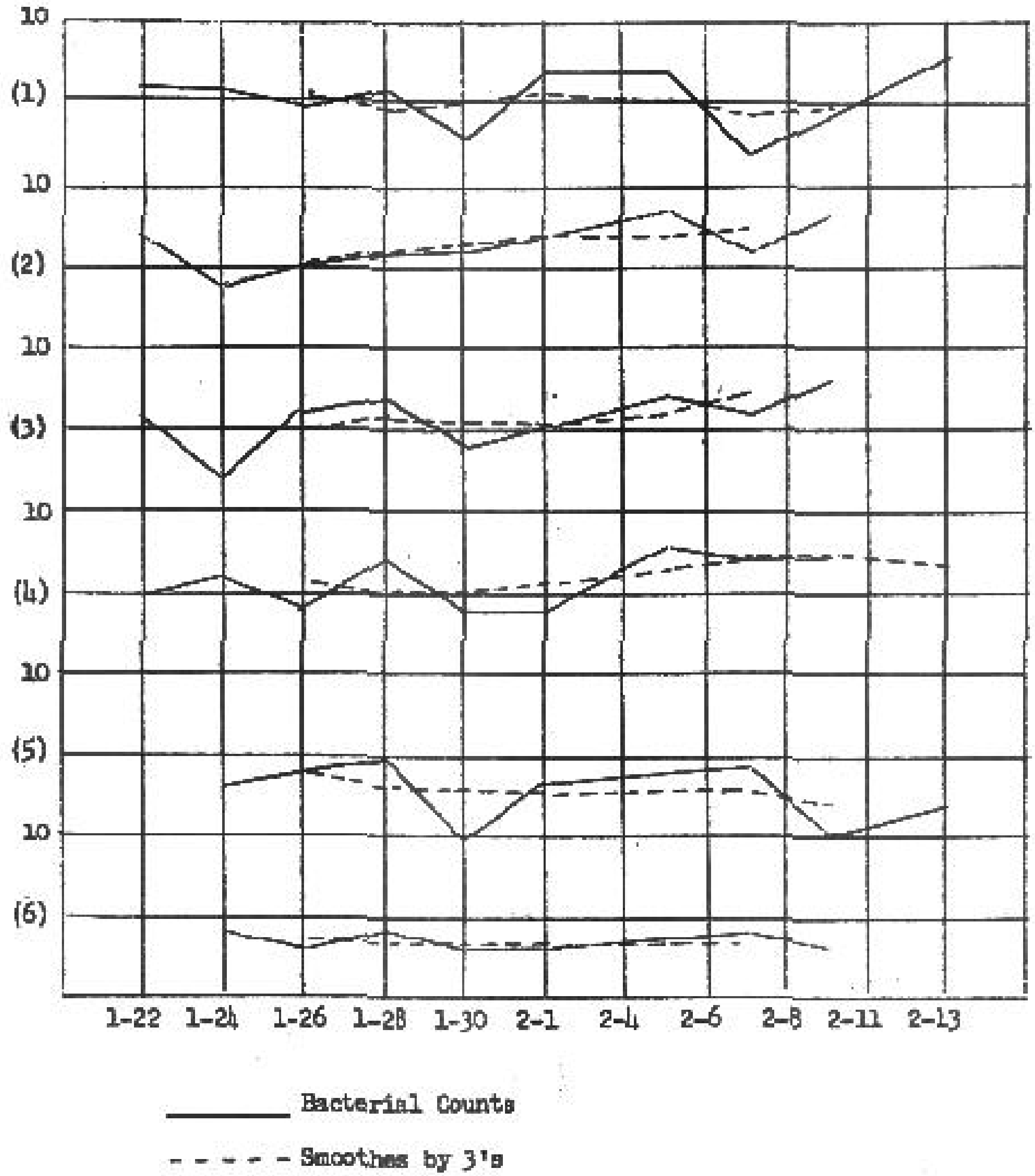

Figure 4. Bacterial counts.

significance, however, since similar increases occurred previously, to be followed by reduced counts. The two samples showing slight general rises in bacterial counts are #2 and #3, shrimp with heads left on. These were the samples which deteriorated first in quality, and were discarded earliest. The data are too few to ascribe any positive significance to this, although there may be a relationship existing.

The behavior of the bacterial populations in the samples on which part of the water was changed daily (#l and #2) is similar to that on the samples held in the same water throughout (samples #3 and #4). This suggests that the populations were being held static at the temperatures involved, and that approximately equal numbers of bacteria were added in the fresh seawater as were being withdrawn in the water siphoned off the shrimp. The bacterial results and the organoleptic test results are in agreement, and suggest no advantage to accrue from changing part of the water. If this result is confirmed by further experimentation it would simplify the procedure aboard the fishing vessels and permit a cheaper operation.

4. Discussion

It appears from these experiments that shrimp can be successfully held in refrigerated seawater. The quality of such shrimp, as judged by organoleptic tests is as good or better than shrimp held in crushed ice, particularly if long holding periods are necessary. Black spot can be completely avoided for the period during which the shrimp are in the seawater and there is evidence. that the rate of black spot formation may be reduced following the icing of shrimp hold for a period in seawater.

There are several advantages which appear to lie in the new method in addition to the important factors of higher quality, longer storage life and control of black spot. Economy is one of these. Ice costs about 16 per ton, and on long trips 30 tons or more are required. The cost of refrigeration equipment and power to operate it should be repaid in a reasonably short period, by the money saved when ice need no longer be purchased. Further savings should result from reduced losses of catch due to poor quality and black spotting of the shrimp. On long trips boats could fish until a "pay-load" was obtained, using the new system, since there would be less necessity to hurry back to port with a partial load, due to spoiling shrimp. Delays due to mechanical troubles, damaged gear and bad weather would become less serious.

Operating cost probably would be reduced, since boats could leave port without heavy loads of ice and they could take increased amounts of fuel and provisions if necessary. The weight of seawater necessary to hold the shrimp is less than the weight of ice, so that the boats could be less heavily loaded on the return trip than presently., or could carry larger loads. Further, crushing and breaking of shrimp, particularly at the bottom of the ice pile, would be eliminated, further increasing the quality.

Unloading should be easier and more rapid with the new method, since it could be done by pumping shrimp through a hose. An alternate method might be to put the headed shrimp, graded for size, in netting bags and store these in the brine. These could be unloaded quickly by hooks.

It is possible that shrimp could be transported overland as well as on the boat in refrigerated seawater or brine. Tank trucks could be employed. The weight and volume of trucking necessary by the new method would be less than by the present system, where ice and boxes constitute a great proportion of the load. Tank trucks should be able to operate more efficiently than the present trailer trucks, by reason of the decreased wind resistance and lighter weight.

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