Reprinted from PROCEEDINGS OF THE NATIONAL SHELLFISHERIES ASSOCIATION, Volume 48, 1958

STUDIES ON THE COMPARATIVE UTILIZATION OF OXYGEN BY LIVING AND DEAD OYSTERS

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Abstract

Studies were conducted using sealed mason jars and blackened paraffin-sealed battery jars. In each experiment one jar contained a live oyster, one a dead or dying oyster of the same weight and one jar contained only sea water. "Dead" oysters were killed by removing one valve and severing the heart. Disintegration of dead oysters did not require appreciably greater amounts of oxygen than that used by living oysters in respiration. Oysters survived for several days in water containing less than 1.0 ppm dissolved oxygen.

Introduction

Within the scope of responsibilities of the authors is the investigation of claims of damages by oystermen of Louisiana tidewater against various oil companies operating in the same area. In recent years there have been a number of such claims which allege that mass mortalities of oysters result from oxygen depletion caused by some operation of the industrial concern involved. These claims are all alike in that the mortalities are alleged to occur in two steps. First, there is a mechanical or chemical destruction of a few oysters on a bed. Second, these few, as they disintegrate, use oxygen from the surrounding water which results in suffocation of adjacent oysters. These, in turn, spread the area of oxygenless water until finally all oysters on the bed are dead. An example of this type of allegation was that of Mr. August Pitre (Petition, August R. Pitre vs. The Texas Company, May 3, 1954, number 32013, 24th Judicial District Court, Parish of Jefferson, State of Louisiana) which stated that "upon information and belief petitioner further avers that there was a sufficient burial (under a few drilling mud sacks) of the live oysters so as to initiate a successful oyster mortality, in that as the live oysters died it thereby caused an

Oceanography and Meteorology Series Contribution No. 112 from the Department of Oceanography and Meteorology, The A & M College of Texas.

added increase in oxygen demand, which resulted in a progressive mortality to the live oysters from one end of the lease to the other".

The authors know of no data which substantiate such claims, but there were no data which directly contradict the theory of progressive deoxygenation of a section of a bay beginning with a small nidus of dead oysters. In view of the persistency of the complaints and the prospect that it would some day be necessary to provide the court with something more substantial than opinion, it was decided to test the theory experimentally by determining whether or not the oxygen required by a dead oyster in disintegration exceeds materially that required by a live oyster for respiration.

Materials and Methods

Six experiments were conducted using mason jars or battery jars as aquaria. In each experiment groups of aquaria were set up as follows: a live oyster was placed in an aquarium containing sea water of known salinity, temperature, and oxygen content. In an adjacent aquarium an oyster, matching in weight, which had had one valve removed and the heart severed, was placed in sea water of the same content. A third aquarium contained sea water only. All three aquaria in each group were sealed, oxygen consumption was allowed to continue for a predetermined period of time after which a sample of water was siphoned from each aquarium and titrated by a modified Winkler technique for oxygen content. Each aquarium was sampled only once for oxygen content hence each figure in the tables represents the measurement of oxygen consumption of one live or dead oyster for a given period of time.

Experiments and Results

Experiment I. This experiment was set up as follows:

1. Fifteen sealed mason jars each containing 800 ml of sea water of 21.8 parts per thousand salinity taken from the running salt water system at the Texas A & M Research Foundation Marine Laboratory at Grand Isle, Louisiana were used as aquaria.

2. Water temperature was 24°C when the experiments began.

3. Five jars contained live oysters. Five jars contained oysters killed by removing one valve and destroying the heart. These oysters were designated as experimental "dead oysters", although ciliary activity continued for a considerable time. The five remaining jars contained only sea water and were designated as controls.

Table 1. Studies of utilization of oxygen by live and dead oysters. Experiment 1.

Time	O_2 content in ppm after lapse of Set 1 $\frac{1}{2}$ hr.	Set 2 $1\frac{1}{2}$ hr.	Set 3 $2\frac{1}{2}$ hr.	Set 4 5 hr.	Set 5 $22\frac{1}{2}$ hr.
Live oysters	4.72	2.81	2.02	1.33	0.00
Dead oysters	3.87	3.35	2.26	1.29	0.00
Controls	4.68	4.60	5.40	5.77	5.89

Discussion: The data from this experiment is contained in Table 1. Reduction of oxygen in the live- and dead-oyster jars in this experiment was approximately the same, and oxygen was completely exhausted in both "live" and "dead" jars within 22 hours. In Set number 5 the dead oysters, which had been killed $22\frac{1}{2}$ hours previously, had a strong odor. The oxygen in the control rose during the experiment, apparently as the result of photosynthetic activity of phytoplankton.

Experiment 2. This experiment was like Experiment 1 with the following exceptions:

1. The dead oysters were killed and held out of water for 18 hours before the experiment was begun.

2. Water temperature was 26.0°C and salinity 21.3 ppt.

3. Different periods were used.

Discussion: The data from this experiment are presented in Table 2. The dead oysters utilized oxygen at a slightly faster rate than the live oysters; the dead oyster in Set 11 exhausted the oxygen in its aquarium while 0.24 ppm remained in the live oyster jar. All dead oysters had a strong odor at the end of the experiment and were too "soupy" to retain their shapes.

Table 2. Studies of utilization of oxygen by live and dead oysters. Experiment 2.

Time	O_2 content in ppm after lapse of Set 6 1 hr.	Set 7 2 hr.	Set 8 3 hr.	Set 9 4 hr.	Set 10 5 hr.	Set 11 6 hr.
Live oysters	2.58	1.63	1.69	0.89	1.25	0.24
Dead oysters	2.38	1.41	1.41	0.97	1.13	0.00
Controls	4.04	4.06	4.04	4.68	4.35	5.24

Experiment 3. This experiment was like Experiment 1 except that:

1. Longer time intervals were used.

2. Water temperature was 23.0°C and salinity was 24.46 ppt. Discussion: There was no essential difference in the utilization of oxygen in this series of experiments (Table 3). Oxygen was exhausted in jars containing dead and live oysters between 8 and 24 hours after the experiment started.

Table 3. Studies of utilization of oxygen by live and dead oysters. Experiment 3.

Time	O_2 content in ppm after lapse of Set 12 2 hr.	Set 13 4 hr.	Set 14 6 hr.	Set 15 8 hr.	Set 16 24 hr.	Set 17 26 hr.
Live oysters	2.18	2.82	1.37	1.37	0.00	0.00
Dead oysters	2.98	2.34	2.38	0.60	0.00	0.00
Controls	3.87	3.95	4.03	4.51	3.31	3.71

Experiment 4. The following changes were made in Experiment 4:

1. Battery jars painted black were substituted for mason jars. This was to prevent photosynthesis which apparently had occurred in the earlier studies (Fig. 1).

2. 3100 ml of sea water were used in each jar.

3. For siphoning samples, a pair of glass tubes were placed in each jar, and melted paraffin was poured on the surface of the water around the tubes, sealing the jar.

4. The oysters in these experiments were smaller, averaging 57 gms.

5. Water temperature was 22.0°C, salinity was 29.8 ppt, and oxygen in all aquaria was 3.71 ppm.

6. Water samples were siphoned for determination of oxygen content after 6, 7, 8, 9, 10, 11 hours.

Discussion: In this series, with more water and smaller oysters, oxygen was not exhausted in any aquaria containing live or dead oysters (Table 4). Oxygen was reduced at about the same rate in both sets of aquaria. As considerable quantities of oxygen remained in all jars after 11 hours, it was decided to repeat the experiments but to wait longer before sampling.

Table 4. Studies of utilization of oxygen by live and dead oysters. Experiment 4.

Time	O_2 content in ppm after lapse of Zero hr.	Set 18 6 hr.	Set 19 7 hr.	Set 20 8 hr.	Set 21 9 hr.	Set 22 10 hr.	Set 23 11 hr.
Live oysters	3.71	2.02	1.61	2.10	2.14	1.17	1.93
Dead oysters	3.71	2.98	2.90	2.94	2.42	2.10	1.77
Controls	3.71	3.51	3.51	3.83	3.80	3.39	3.55

Experiment 5. This experiment was like Experiment 4, with the following exceptions:

1. The time intervals for sampling oxygen consumption were from 15½ to 20½ hours (see Table 5).

2. The oysters used in this series averaged 61 gms.

3. At the beginning of the studies the water temperature was 23.5°C, the salinity was 30.65 ppt, and the oxygen measured 5.00 ppm.

Discussion: After 15½ hours the dead oysters had reduced the oxygen to a point below 1.0 ppm while the oxygen in live oyster aquaria remained above 2.0 ppm (Table 5). By seventeen hours the live oysters reduced the oxygen to less than 1 ppm. In set 28 and set 29, the oxygen was above 2.0 ppm after 19½ and 20½ hours. It is uncertain that

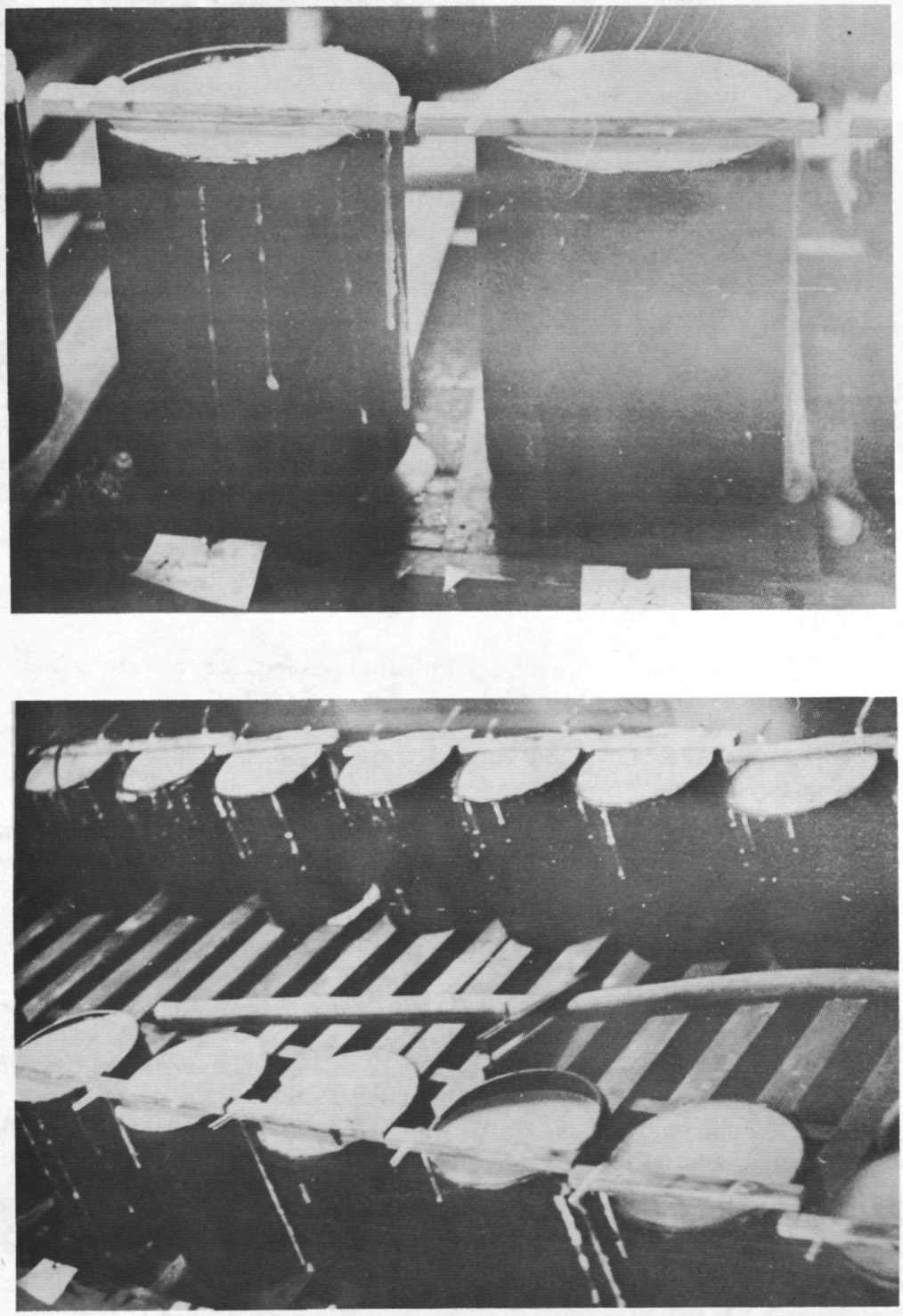

Fig. 1. Battery jars painted black and sealed with paraffin.

Table 5. Studies of utilization of oxygen by live and dead oysters. Experiment 5.

Time	O_2 content in ppm after lapse of Zero hr.	Set 24 $15\frac{1}{2}$ hr.	Set 25 $16\frac{1}{2}$ hr.	Set 26 $17\frac{1}{2}$ hr.	Set 27 $18\frac{1}{2}$ hr.	Set 28 $19\frac{1}{2}$ hr.	Set 29 $20\frac{1}{2}$ hr.
Live oysters	5.00	2.02	2.26	0.64	0.60	2.18	2.24
Dead oysters	5.00	0.32	1.17	0.36	0.85	0.00	0.76
Controls	5.00	4.60	4.44	4.96	4.28	4.35	4.60

the latter is the case, since rises occurred at approximately the same time in the dead oyster aquaria and in the control aquaria. Because the living oysters had failed to utilize all the oxygen within the time limits of these experiments and because the oxygen appeared to be rising in the dead oyster and control aquaria, it was decided to continue the experiments, but to sample at longer intervals. All dead oysters in this series had a strong odor and were beginning to lose their shape and become "soupy".

Experiment 5. These studies duplicated the previous series with the following exceptions:

1. The oysters used ranged from 12 to 30 grams in weight, averaging 21.6 grams.

2. Samples were taken 24, 48, 72, 144, 168 and 192 hours after the experiments were started.

3. At the beginning of the studies the water temperature was 17.0°C, the salinity was 25.0 ppt, and the oxygen measured 7.32 ppm.

Discussion: During the experimental period the dead oysters reduced the oxygen more quickly than did the live oysters (Table 6). Within 72 hours, however, the live oysters had reduced the oxygen to less than 1 ppm. It is of interest that there was a decided loss of oxygen in the control vessel, due, it is presumed, to respiration and bacterial decomposition of the plankton. The live oysters in this series were all alive at the end of each period; the oyster in Set 35 presumably survived at least 120 hours in water containing less than 1.0 ppm of oxygen. The dead oysters had a strong odor and were almost completely disintegrated at the end of the series.

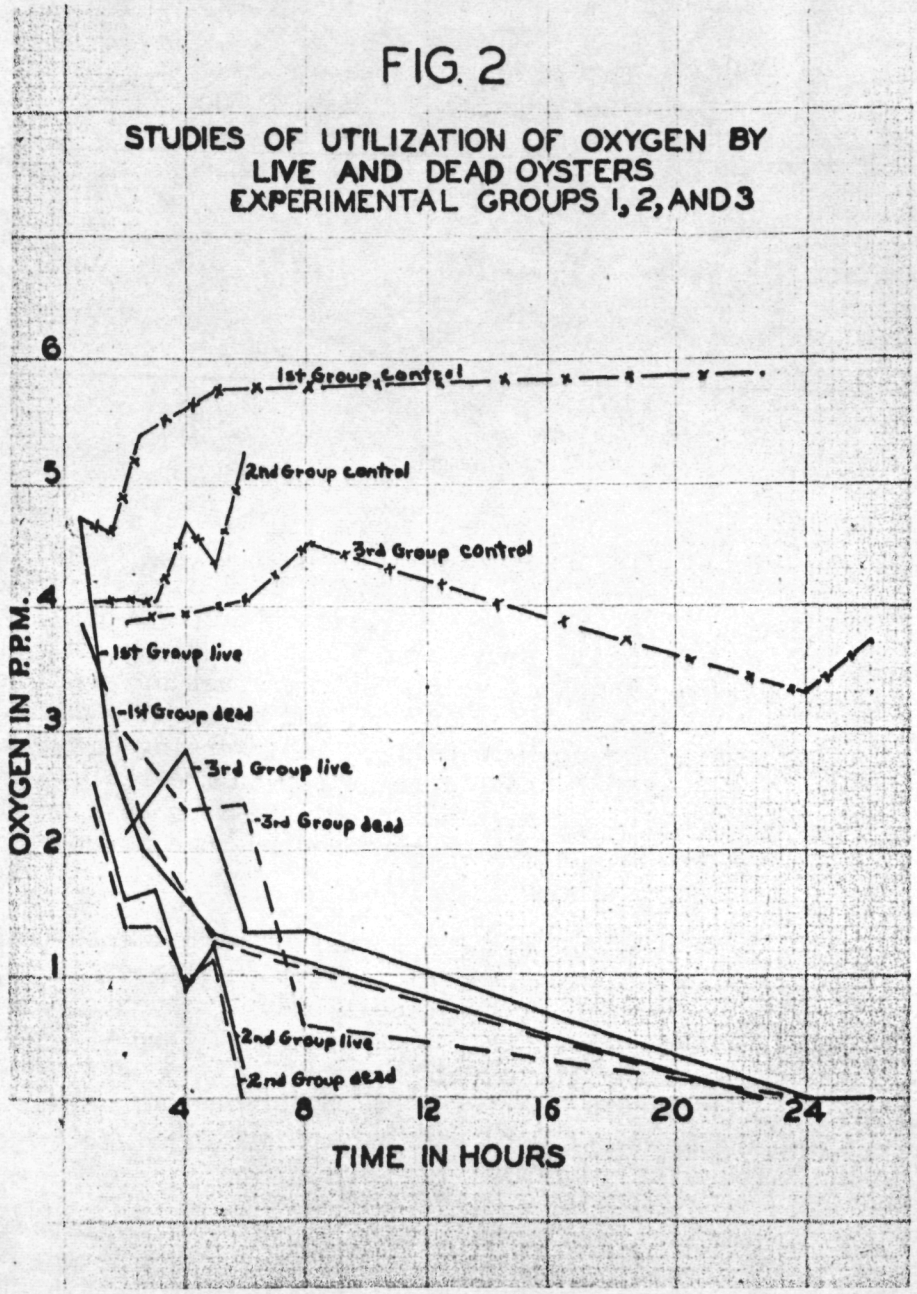

Fig. 2. Utilization of oxygen by live and dead oysters.

Table 6. Studies of utilization of oxygen by live and dead oysters. Experiment 6.

Time	O_2 content in ppm after lapse of Zero hr.	Set 30 24 hr.	Set 31 48 hr.	Set 32 72 hr.	Set 33 144 hr.	Set 34 168 hr.	Set 35 192 hr.
Live oysters	7.32	4.15	4.76	0.61	0.61	0.12	0.24
Dead oysters	7.32	4.19	0.41	0.12	0.00	0.00	0.00
Controls	7.32	7.24	7.20	6.26	3.41	2.64	0.81

Summary

The principal difference between the living and dead oysters in these experiments is that use of oxygen by living oysters is affected by opening and closure of the shell, while dead oysters utilize oxygen at a rate determined by the type and load of bacteria present at the beginning of the studies. Because of reactions to the stimuli of handling and moving when the experiments were set up, oysters remained closed for considerable lengths of time and apparently failed to remove any oxygen from the water. Mitchell (1914), working on oxygen requirements of shellfish, found that "a light tap on the table or water bath, a heavy step in the room, the slamming of the door in a neighboring part of the building was surely registered by some movement of the shell."

A graph of the first three series of experiments (Fig. 2) shows that, in general, the oxygen utilization of the live oysters and the dead oysters follows the same trend. The control jars in each of these series showed that a factor other than utilization by oysters was influencing the oxygen content. It was assumed that this factor was photosynthetic activity of phytoplankton. For this reason the remaining experiments were carried out in battery jars painted black and sealed with paraffin.

Experiments 4 and 5 are plotted in Figure 3. Experiment 4 indicates a more rapid utilization of oxygen by the living oyster for the first ten to eleven hours. The increase in oxygen in all battery jars at the eighth to ninth hour may be due to light penetrating the paraffin seal. The increase in oxygen occurred at 1:00 p.m., a time of maximum light in the laboratory.

Oxygen in the battery jars was not exhausted by live or dead oysters within the eleven-hour duration of Experiment 4. Subsequently, another series of experiments was set up in which the first samples were taken after $15\frac{1}{2}$ hours. The results of these experiments, plotted on Figure 3, appear to fit rather well on the end of the previous

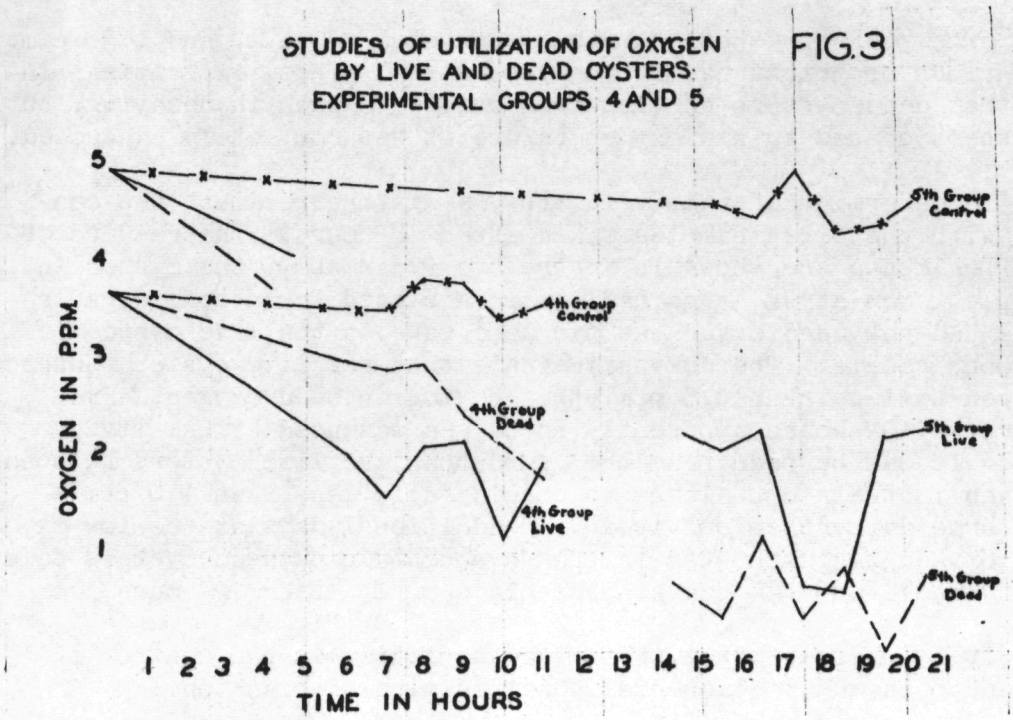

FIG. 4

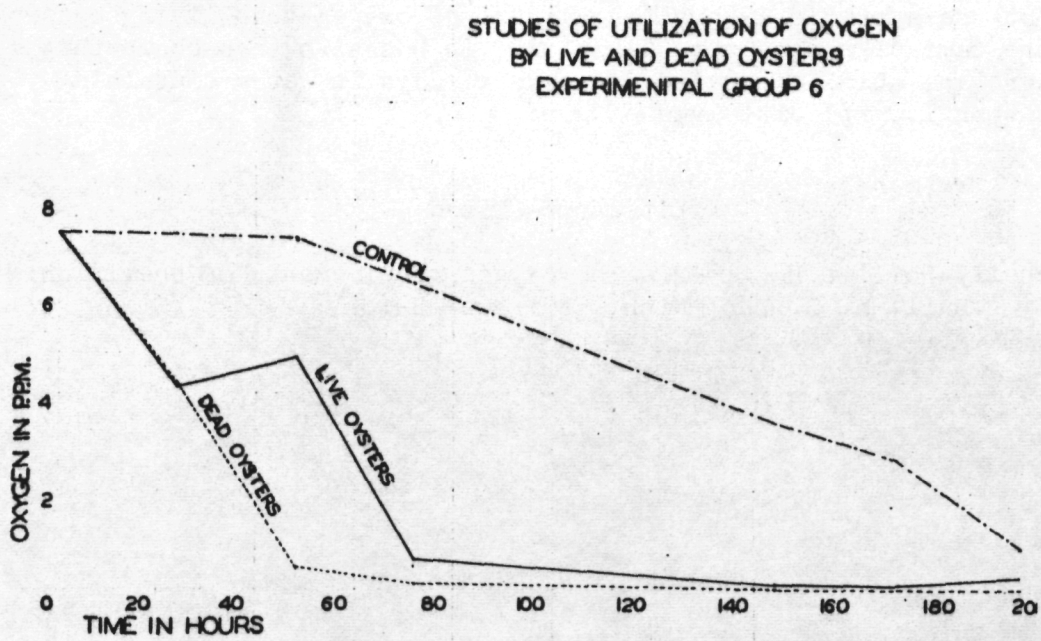

Fig. 3. & 4. Utilization of oxygen by live and dead oysters, groups 4 to 6.

curves. The peaks in these curves appear at 10:30 a.m. and 1:30 p.m., again periods of brightness in the laboratory. These experiments indicate that dead oysters continued to utilize oxygen in decaying, but live oysters ceased to use oxygen before it was completely exhausted.

To determine if this were true, a sixth experiment was conducted, with the first samples taken after 48 hours. The results of these experiments are shown in Figure 4. Presumably, the oyster in the sample taken at 48 hours had remained closed for a considerable time and had not used oxygen at the same rate as the live oyster in the 24-hour sample. The curves indicate that the live oyster reduced the oxygen to less than 0.5 ppm, then no longer used oxygen. From 144 hours to 192 hours apparently no oxygen was used by the living oysters. It can be seen from the graph that the live oysters reduced the oxygen in their containers to considerably less than 1.0 ppm within three days, then survived five additional days at the low oxygen level. Oxygen was exhausted in the jars containing dead oysters sometime between 72 and 144 hours, probably shortly after 72 hours.

It is presumed that the oxygen depletion in the control of Experiment 6 is due to bacterial decomposition of plankton.

Conclusions

It has been demonstrated that dead oysters in disintegration do not use appreciably greater amounts of oxygen than living oysters of the same size use in respiration. It has also been shown that oysters are able to survive for several days in water containing less than 1.0 ppm dissolved oxygen.

Literature Cited

Mitchell, Phillip H. 1912. The oxygen requirements of shellfish. Bull. U. S. Bur. Fish. 32: 209-222.