surface salinity of the whole bay was 31.91 0/00. The maximum variation of surface salinity during the season was from 31.51 0/00 to 32.25 0/00, and the highest salinity recorded, 32.45 0/00, was near the bottom at the mouth of the bay. The least saline water occurred at the head and the most saline at the mouth of the bay, but the variation at any one time was never of very great magnitude, the maximum recorded being 0.54 0/00. The average salinity from surface to bottom of the whole bay during the season was 32.04 0/00.

HYDROGRAPHICAL OBSERVATIONS AT STATIONS WEST OF FRENCHMANS BAY

Blue Hill Bay (station 17) depth 80 meters. Temperature ranged, July 26, from 14.06° surface to 10.06° bottom, and on August 20, 13.81° surface to 11.10° bottom. The temperature below twenty-five meters was one to two degrees higher than in Frenchmans Bay. Salinity ranged, July 26, 31.60 0/00 surface to 32.12 0/00 bottom, and on August 20, 31.83 0/00 surface to 32.34 0/00 bottom. The surface salinity was about 0.50 0/00 lower than in Frenchmans Bay.

Penobscot Bay (station 18) depth 58 meters. Temperature ranged, July 27, 14.98° surface to 8.70° bottom, and on August 21, 13.07° surface to 10.0° bottom. The temperature below twenty-five meters was a little higher than in Frenchmans Bay. Salinity ranged, July 27, 27.72 0/00 surface to 31.98 0/00 bottom, and on August 21, 30.30 0/00 surface to 32.09 0/00 bottom. The surface salinity was the lowest observed in the region investigated and was 2.00 0/00 to 4.00 0/00 lower than in Frenchmans Bay.

Sommes Sound (station 16) depth 27 meters. Temperature ranged, July 26, 14.95° surface to 11.0° bottom, the temperature below five meters was a little higher than in Frenchmans Bay. Salinity ranged, 31.91 0/00 surface to 32.05 0/00 bottom, about the same as at the upper shallow end of Frenchmans Bay.

HYDROGRAPHICAL OBSERVATIONS AT STATIONS EAST OF FRENCHMANS BAY

Prospect Harbor (station 12) depth 16 meters. Temperature ranged, July 23, 12.59° surface to 9.11° bottom; salinity ranged 32.09 0/00 surface to 32.08 0/00 bottom. Both temperature and salinity were about the same as at the mouth of Frenchmans Bay.

Gouldsboro Bay (station 13) depth 18 meters. Temperature ranged, July 23, 12.86° surface to 10.40° bottom, the whole column of water was 0.3 to 1.3 degrees warmer than Prospect Harbor. Salinity ranged, 32.09 0/00 surface to 32.14 0/00 bottom, about the same as previous station.

Dyers Bay (station 14) depth 9 meters. Temperature ranged, July 23, 10.72° surface to 10.01° bottom; salinity 32.10 0/00 surface to 32.14 0/00 bottom. Temperature and salinity were about the same as at the mouth of Frenchmans Bay.

HYDROGRAPHICAL OBSERVATIONS AT STATIONS SOUTH OF FRENCHMANS BAY

On July 16 the surface temperature at station 10 was 10.42°, or about 1 degree lower than the temperature at the mouth of Frenchmans Bay lying ten miles to the north, while the temperature at 50 meters, 7.4°, was practically the same. On August 3, the surface temperature at station 11 was 10.0°, or 1.2 degrees lower than at the mouth of Frenchmans Bay lying fifteen miles to the north, while the temperature at 50 meters 8.1° was about 0.2° lower.

The surface salinity at station 10 on the former date was 32.10 0/00, or 0.06 0/00 lower, and the 50-meter salinity 32.52 0/00, or 0.18 0/00 higher than at the mouth of Frenchmans Bay. On the latter date the surface salinity at station 11 was 32.54 0/00, or 0.34 0/00 higher, and the 50-meter salinity 32.70 0/00, or 0.35 0/00 higher than at the mouth of the bay.

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THE RELATION OF THE OXYGEN TENSION IN THE EXTERNAL RESPIRATORY MEDIUM TO THE OXYGEN CONSUMPTION OF FISHES

RECENTLY two American articles by Powers and Shipe[1] and F. G. Hall[2] have had the above relation as their subject, and in both cases the conclusion was drawn that the fish's oxygen consumption is proportional to the oxygen tension of the environment, even when a restricted range of the latter within the normal concentration of natural waters is considered. It is perhaps unnecessary to emphasize the theoretical and methodological importance of such a conclusion. Unfortunately it appears for a number of reasons quite certain that this conclusion can not be accepted without qualification.

Before demonstrating that this conclusion is unwarranted at the present time, let me hasten to say that, as would be expected, the respiration of fishes is undoubtedly depressed at low levels of oxygen tension of the environmental water. Such a depression of respiration as the oxygen tension approaches the asphyxial threshold by no means implies a depression of oxygen consumption brought about by deviations

[1] E. B. Powers and L. M. Shipe, *Publ. Puget Sound Biol. Sta.*, 5: 365–372, 1928.
[2] F. G. Hall, *Am. J. Physiol.*, 88(2): 212–218, 1929.

within the normal range of oxygen concentration in the environment. For sea water we may consider this normal range to be from 4.5 to 6.5 cc per liter at temperatures of 15° to 20° C.

A careful consideration of the data presented by Powers and Shipe in support of their contention fails to reveal any adequate indication of a direct relationship between O_2 tension and O_2 consumption in the restricted range we are considering. The fact that their experimental conditions were not standard may account for the fact that a number of their recorded values for oxygen consumption (cc per kilo per hour) are several times those previously reported for fishes. As for Hall's evidence, it is to be regretted that it is inadmissible on the grounds of faulty technique. Hall used a modified Ege and Krogh[3] apparatus in which the oxygen tension of the water was controlled by varying the rate of flow; in other words, the concentration of oxygen was diminished by the respiration of the fish and was then rebreathed in the large respiratory chamber used. It is obvious that the fish is excreting carbon dioxide at approximately the same rate that it is using oxygen and, even in a buffered system such as sea water, this will displace the hydrogen-hydroxyl-ion equilibrium and lower the pH. The marked effect of carbon dioxide on respiration is too well known to require comment. In addition, the accumulation of nitrogenous excretions in the water may possibly exert some effect.[4]

Hall mentions the work of Winterstein[5] in which it was concluded that the oxygen consumption of the fish (*Leuciscus*) is independent of the oxygen tension over a wide range. The important papers of Henze,[6] Gaarder[7] and Toryu[8] are apparently unknown to Hall and to Powers and Shipe. Henze concluded that the oxygen consumption of fishes is entirely independent of the oxygen of the water down to the threshold of asphyxia. Toryu drew similar conclusions from his experiments on the goldfish. Gaarder, using precise methods, found some indication of a direct relation between the oxygen tension in the water and the oxygen used by the fish, but concluded that, within a limited range, the oxygen consumption may be considered to be practically constant.

In my own experiments, water of really low oxygen tension was not used; the minimum concentration was 4.56 cc per liter. My methods were similar to those of Gaarder, but I did not narcotize the fishes as he did. Experiments on the same individual fishes (*Fundulus parvipinnis*), under identical conditions except for the oxygen tension of the water, did not give the slightest indication that the oxygen content of the water has any effect upon the respiration, but on the contrary the oxygen consumption was practically constant for any given fish. Experiments in which both the rate of flow and the oxygen concentration of the water were varied were likewise entirely negative, the respiration of the fish, based on the averages of a number of determinations, remaining remarkably constant, such deviations as were found having no relation to the available oxygen.

After considering all the available evidence it seems clear that the time has not yet come when we can make any very broad generalizations as to the relation of the oxygen tension of the environment to the oxygen consumed by the fish, but certain features are salient: (1) the respiration of fishes is very decidedly decreased at or near the asphyxial level of oxygen tension, and (2) in the respiration of the fishes so far investigated there seems to be practically a complete independence of deviations in the oxygen content of the water within a restricted range.

The practical importance of establishing this last point will be seen when it is pointed out that the methods which have previously been used for the estimation of the standard metabolism of fishes depend upon such an independence of the fish's respiration for their validity.

A more detailed discussion and presentation of evidence will shortly appear in the technical series of the bulletins of the Scripps Institution of Oceanography, University of California Press.

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[3] R. Ege and A. Krogh, *Internat. Rev. ges. Hydrobiol. Hydrog.*, 7(1): 48–55, 1914.

[4] H. W. Smith, *J. Biol. Chem.*, 81(3): 727–742, 1929.

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[6] M. Henze, *Biochem. Zeitsch.*, 25: 255–278, 1910.

[7] T. Gaarder, *Biochem. Zeitschr.*, 89: 94–125, 1918.

[8] Y. Toryu, *Sci. Rept. Tohoku Imp. Univ.*, 4 ser. 3 (1): 87–96, 1927.

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