CLXX. ON THE INFLUENCE OF THE HYDROGEN ION CONCENTRATION UPON THE OXYGEN CONSUMPTION IN SEA-WATER FISHES.

BY JAYME REGALLO PEREIRA.

From the Rio de Janeiro Medical Faculty, Brazil.

(Received October 22nd, 1924.)

THE oxygen consumption of fishes has been studied by several workers but, so far as I know, the only workers who have attempted to observe the effect of varying the conditions of the water are Gardner and King [1923], who observed the influence of temperature on the oxygen consumption in fresh-water fishes. Variation in temperature, however, is not the only abnormal condition which can occur, and this paper deals with experiments on the influence of the hydrogen ion concentration upon oxygen consumption in sea-water fishes.

The estimation of the oxygen was made by using the titration method of Winkler [1888, 1889] as modified by Birge and Juday [1911]. This method has given very reliable results in the hands of different investigators [see Butler and Coste, 1923; Lund, 1918; McClendon, 1917; Chlopin, 1896, and Amberson with his associates, 1924]. The fishes used in my experiments were *Fundulus heteroclitus*, which were placed in large reservoirs containing 10 litres of fresh sea-water. On the top of the water a layer of half a centimetre of paraffin oil was placed in order to avoid direct contact of air and continuous solution of oxygen in the water. Samples were collected each 10 or 15 minutes in the manner already described in the paper of Amberson and his associates. Different numbers of fishes were used in each reservoir, and their weight was carefully determined before and after the experiments. The experiments were carried out until the dissolved oxygen was reduced to one-tenth. Two reservoirs were employed containing sea-water of different p_H . In order to check the results, in some experiments the groups of fishes used in the two reservoirs were interchanged and the same p_H again tested after a suitable interval, during which the fishes were allowed to recover in fresh sea-water.

The fact that organic matter as well as bacteria, introduced into the water by the fish, consumes oxygen, has been invoked as a serious error in the use of Winkler's method. Gardner and Leetham [1914], however, have shown that this assumption does not hold. On the other hand, the objection that the carbon dioxide produced by the fish may increase the acidity of the water to a higher degree than that chosen for experiment, has also no value; Amberson

INFLUENCE OF p_H ON OXYGEN CONSUMPTION OF FISH 1295

and his associates say that the production of carbon dioxide only causes a slight change in the hydrogen ion concentration of the water (from p_H 8.1 to 7.6) when the oxygen tension of the water is reduced to 10 %. Further, they found that "changes in CO_2 tensions much exceeding this amount have no effect upon the rate of oxygen consumption." Titration of the hydrogen ion concentration of the sea-water was made by using the colorimetric method, and the increase in the acidity of the water by adding the necessary number of drops of a $N/10$ hydrochloric acid solution, according to the following table:

p_H	$N/10$ HCl to 100 cc. (drops)
8.0	0
7.0	12
6.0	33
5.0	57
4.0	65

The irritant action of an acid medium on the skin, bringing about a possible muscular activity of the fish, led me to anticipate a greater oxygen consumption. Such an assumption appeared not to be true, for I observed in thirteen experiments that in sea-water of various hydrogen ion concentrations, in general, the more acid the medium the less is the oxygen consumption per g. of fish per litre of water per hour. This was tested between p_H 8.0 and 4.0 as follows:

p_H	Temperature ° C.	Total weight of the fish (in g.)	O_2 used per gram per litre per hour	Average
8	22.0	139	.018724	
8	22.0	153	.016220	
8	21.0	189	.017070	.017338
7	22.0	167	.016838	
7	20.5	282	.016186	.016512
6	22.0	170	.014626	
6	21.0	130	.017600	
6	21.5	211	.015180	.015802
5	22.0	352	.010280	
5	20.5	293	.013160	.011720
4	22.0	193	.013804	
4	22.0	295	.010170	
4	21.0	237	.012320	.012098

The oxygen consumption is seen to be a minimum at p_H 5.

Two further experiments were made on the alkaline side of neutrality. With p_H 9.0 a consumption of 0.18006 was observed, and with p_H 10.0 of 0.017580. These results seem to indicate that there is an optimal hydrogen ion concentration which can be located around p_H 8.0, which is the reaction of the normal sea-water. As was expected, a greater activity of the fish was observed in a more acid medium. On the other hand, I found that the fish remained for a long time with their mouths closed, thus avoiding contact of the irritant water with their gills. The diminution of the respiratory movements corresponded with the lowered oxygen consumption when the acidity of the medium was increased.

The low oxygen tension in the water at the end of the experiments only once caused the death of a fish. On the other hand, *fainting* was observed in some fishes when approaching the end of the experiment; in such an abnormal state, however, they did not stop breathing and recovered completely in fresh sea-water.

This work was carried out in the Laboratory of Physiology of the Marine Biological Laboratory, at Wood's Hole, Mass. I am indebted to S. Culver Williams, who assisted me in the course of the experiments.

REFERENCES.

- Amberson, Mayerson and Scott (1924). *J. Gen. Physiol.* 7, 171.
Birge and Juday (1911). *Wisc. Nat. Hist. Surv. Bull.* No. xx.
Butler and Coste (1923). *Biochem. J.* 17, 49.
Chlopin (1896). *Arch. Hydrog.* 27, 18.
Gardner and King (1923). *Biochem. J.* 17, 170.
Gardner and Leetham (1914). *Biochem. J.* 8, 374.
Lund (1918). *Amer. J. Physiol.* 45, 351.
McClendon (1917). *J. Biol. Chem.* 32, 275.
Winkler (1888, 1889). *Ber. deutsch. chem. Ges.* 21, 2843; 22, 1864.