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Notes on the swim-bladder physiology of cod *(Gadus morhua)* investigated from the underwater laboratory "Helgoland"

G. SUNDNES, B. GULLIKSEN & J. MORK

Biological stasjon; Trondheim, Norway

ABSTRACT: In situ sampling of gas from cod swim-bladders took place during a fortnight's saturation mission with the underwater laboratory "Helgoland" in May–June 1975. These samples were compared to those done by the conventional method of transporting the fish to the surface for sampling. Based upon these in-situ measurements, the mean O_2-concentration was 55.7 % in buoyant cod at 15 m depth. Repeated sampling of the same fish showed a change in gas composition. Compared to the conventional method of transporting fish for sampling to the surface, in-situ sampling gave results with less variation, and indicated that surface-sampling does not give the correct gas composition of buoyant fish at depth of catch.

INTRODUCTION

Physiological investigations of fish swim-bladder have usually been performed near the surface, i.e. at about one atmosphere pressure. It means that fish were usually brought to the surface from their natural habitat of high water pressure to reduced pressure before experiments were performed and samples taken. Even in experiments with fish in pressure chambers, the gas samples of the swim-bladder were taken at one atmosphere pressure. Gas samples from fish at the depth of buoyancy have rarely been reported.

The development of the underwater laboratory has given marine biologists a better opportunity to work under hydrostatic pressure whereby fish are kept under "natural" experimental conditions. The present investigation, conducted from the underwater laboratory "Helgoland", is an attempt to compare and evaluate conventional surface-gas sampling with in situ methods using submerged fish under ambient pressure.

MATERIAL AND METHODS

The experiments were performed between May 28 and June 13, 1975 during a saturation mission with the underwater laboratory "Helgoland" which was located

on nearly-level ground at 15 m depth in Lübeck Bay. Cod *(Gadus morhua)* was the only fish available for experiments in the area. They were caught in traps located within about 100 m of the underwater laboratory. The eight fish caught ranged in length from 27 to 31 cm. One of the fish died during sampling, but the remaining 7 went through sampling without pathological effects. Gas samples from the swim-bladders were taken either while the fish were in traps at 15 m depth or in baskets near the bottom. 2 to 4 ccm of gas were usually extracted from the swim-bladders. The syringes were immediately sealed with rubber plugs and brought to the laboratory for analyses.

CO_2 and O_2 in the gas samples were analyzed in the underwater laboratory with the gas analyzer described by Scholander et al. (1955). The difference between total gas volume and the volume of CO_2 and O_2 was assumed to be N_2 and inert gases. Gas samples were also brought to the surface for control analyses. In addition, cod were brought to the surface, and gas samples were taken there. Repeated sampling of the same fish was also done after intervals to see if the gas composition of the same fish changed with time.

The O_2 amounts in the fish swim-bladders were primarily used, both for comparison of parallels with the same analyzer, and comparison of the UWL analyzer and the surface analyzer. When two sub-samples of the same gas sample were analyzed with the same analyzer, the mean difference in O_2-percentage between the two subsamples was 0.55 % (SD $\pm$ 0.63) based upon 14 measurements. When two sub-samples of the same gas sample were analyzed with each of the analyzers, the mean difference in O_2-percentage between two sub-samples was 1.28 % (SD $\pm$ 0.72) based upon 16 measurements.

RESULTS AND DISCUSSION

The average O_2 concentration for the 7 fish sampled in situ was 55.7 % (SD $\pm$ 2.30) in Table 1. Taking the accuracy of the analyzers into account, there is little variation in the O_2 concentration in a buoyant cod from this area of the Lübeck Bay when the samples are taken in situ. The highest value for CO_2 was 2.5 %, and this gas does not contribute appreciably to the buoyancy of the fish.

The O_2 concentrations in the swim-bladders of fish brought to the surface showed large variations with a maximum value of 76.7 % and a minimum of 16.1 %. Three of the samples taken at the surface had a O_2 concentration close to the value in air (20.9 %), and air may accidentally have entered the syringes. However, these values are not necessarily due to error in sampling as O_2-values lower than the values usually found in air were also recorded (Table 1).

The main importance of the present data is the lower O_2-content in the swim-bladder when the fish is brought to a lower hydrostatic pressure (i.e. brought to the surface). This can be explained by overflotation which occurs in fish, and can thereby initiate the reabsorbing mechanism. Due to the higher solubility of oxygen, there is a higher loss of oxygen than nitrogen to diffusion (Sundnes, 1959).

From Table 1, the opposite mechanism is also evident. When the fish is brought

Table 1

Gas composition in cod. T = Time in hours and minutes from the first sample when repeated sampling. UWL = underwater laboratory (in situ), B = boat at the surface

Fish No.	T	Sampling location	Gas composition in the swim-bladder		
			O_2	CO_2	N_2 and inert gases
1	0	UWL	54.6	1.8	43.6
	27 h	UWL	46.9	1.6	51.5
	29 h 30 min	B	45.4	0.4	54.2
	30 h	B	21.0	1.1	77.9
	33 h 30 min	UWL	46.8	1.3	51.9
2	0	UWL	58.9	0.5	40.6
	2 h	B	21.6	0.5	77.9
	2 h 30 min	B	16.1	0.9	83.0
	48 h 15 min	UWL	54.3	2.1	43.6
	48 h 45 min	UWL	54.4	1.6	44.0
	55 h 15 min	UWL	56.5	0.7	42.8
	98 h 30 min	B	76.7	1.2	22.1
	99 h	B	64.1	0.7	35.2
3	0	UWL	57.7	2.5	39.8
	1 h 15 min	B	21.2	0.7	78.1
	1 h 45 min	B	19.5	0.3	80.2
	71 h 45 min	UWL	59.1	1.1	39.8
	73 h 15 min	B	58.7	1.1	40.2
	73 h 45 min	B	56.1	0.6	43.3
4	0	UWL	57.8	1.3	40.9
	40 min	B	54.1	0.8	45.1
	1 h 10 min	B	52.2	2.4	45.4
5	0	UWL	54.0	1.9	44.1
	2 h 40 min	UWL	51.6	1.4	47.0
6	0	UWL	53.8	0	46.2
	3 h 25 min	UWL	36.2	2.0	61.8
	3 h 40 min	UWL	47.5	1.9	50.6
7	0	UWL	53.4	1.1	45.5
	2 h 10 min	B	51.8	0.1	48.1
	2 h 40 min	B	46.8	0.5	52.7

back to a higher hydrostatic pressure, gas secretion occurs whereby the oxygen content in the swim-bladder increases again (Steen, 1971). Fish 6 (Table 1) is an exception from the general trend, but "emotional" effects in fish can be of major influence in basic physiological functions (Sundnes, 1957).

CONCLUSION

Due to the limited supply of fish, more data should be collected before absolute conclusions are drawn from these experiments. However, these investigations indicate that gas composition when fish are brought to the surface is different and shows more variation than gas composition when samples were taken at the depth of

buoyancy. It suggests that divers taking in situ sampling of gas from the swim-bladder of fish is the method to be preferred. Gas samples from a fish brought to the surface are probably not representative of the situation at depth of catch. The underwater laboratory showed itself to be a very convenient and helpful tool for this type of experiment.

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LITERATURE CITED

Scholander, P. F., van Dam, L., Lloyd Claff, C., & Kanwisher, J. W., 1955. Micro gasometric determination of dissolved oxygen and nitrogen. Biol. Bull. mar. biol. Lab., Woods Hole **109**, 328–334.

Steen, J. B., 1971. The swim-bladder as a hydrostatic organ. In: Fish Physiology 4. Ed. by W. S. Hoar & D. J. Randall. Academic Press, New York, 413–443.

Sundnes, G., 1957. On the transport of live cod and coalfish. J. Cons. perm. int. Explor Mer. **22**, 191–196.

— 1959. Gas secretion in Coregonids. Nature, Lond. **183**, 986–987.

First author's address: G. Sundnes
Biological stasjon
N-7001 Trondheim
Norway