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THE GAS CONTENT IN THE COREGONID SWIMBLADDER

By

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INTRODUCTION

The gas content in the swimbladder of coregonid fishes has been described from different species and localities by several authors (HÜFNER 1892, SAUNDERS 1953, SCHOLANDER, VAN DAM and ENNS 1956, SUNDNES, ENNS and SCHOLANDER 1958, SUNDNES 1959 and SUNDNES 1963). The swimbladder gas in the investigated species is found to contain 99 vol% N_2. The classical example is HÜFNER's paper on *Coregonus acronius* Rapp. In *Coregonus lavaretus* (L.), however, the gas composition was different to other investigated coregonids (SUNDNES, ENNS and SCHOLANDER 1958). In this species the O_2 percentage increased with depth as for physoclist fish (SCHOLANDER, CLAFF, TENG and WALTERS 1951).

Rete structures are found both in the vascularisation of the swimbladder wall of *C. lavaretus* (FAHLÉN 1959) and *C. acronius* (FAHLÉN 1967), and there are seemingly no anatomical background for expecting a different gas mixture to be deposited in the two species.

The findings of 15.2–18.2 vol.% O_2 in the swimbladder of *C. acronius* in the autumn (SUNDNES 1959) and the different distribution of *C. acronius* and *C. lavaretus* with respect to depth (SUNDNES 1963) lend support to the theory that the higher nitrogen content in the coregonid swimbladder is a secondary result of the swimbladder physiology. In the present paper a comparative investigation of the swimbladder gas in two coregonid species is presented.

MATERIAL AND METHODS

The species investigated in the present paper are *Coregonus acronius* from Bodensee (Lake Constanze), Germany and *Coregonus lavaretus* from the lake Randsfjord, Norway.

Contribution given in honour of Gunnar Rollefsen at his 70th birthday.

The fish were caught by gillnets at depths varying from 15—35 m in Bodensee, and at 70 m in Randsfjord in October and November respectively. The gas samples were drawn from live fish immediately after reaching the surface. The gas analyses were performed in the 0.5 cc gas analyzer (SCHOLANDER 1947). The O_2 content of the fish blood was analysed in a syringe analyzer (SCHOLANDER and VAN DAM 1956). A few specimen of *C. lavaretus* were transported live to the Institute of Marine Research, Bergen for shallow water experiments.

RESULTS

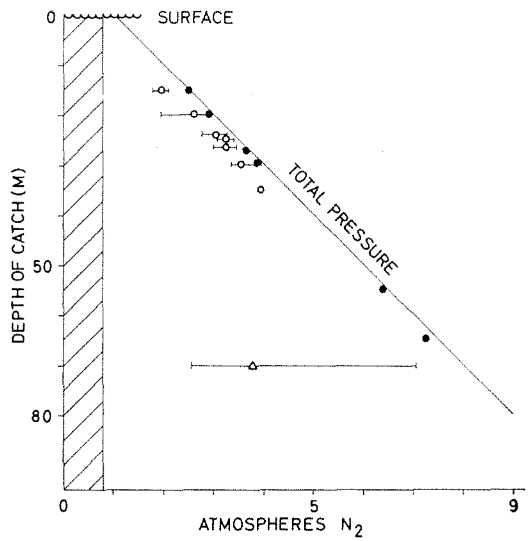
C. acronius was only found in depths down to 35 m probably due to the increasing pollution of the deeper fishing grounds. A single specimen caught at 25 m had a N_2 content in the swimbladder of 98 vol.%. The highest O_2 content measured in *C. acronius* was 33.9 vol.% in a specimen caught at 20 m. Among *C. lavaretus* from 70 m depth in Randsfjord the highest N_2 content was 88.6 vol. %.

The variation in the swimbladder gas content of *C. acronius* and *C. lavaretus* at different depths are shown in Table 1.

Table 1.

Number of fish	Depth in meters	Total range in gas content			
		C. acronius		*C. lavaretus*	
		vol.% N_2	vol.% N_2	vol.% O_2	vol.% N_2
5	15	11.5—28.8	70.8—87.4	—	—
48	20	2.0—33.9	63.4—97.5	—	—
15	24	1.8—17.0	82.3—97.5	—	—
3	25	1.2—12.1	87.5—98.3	—	—
2	27	5.1—17.7	82.8—94.2	—	—
6	30	4.2—14.9	84.4—94.9	—	—
1	35	12.0	87.7	—	—
42	70	—	—	10.6—68.8	30.7—88.6
3	Shallow water aquarium			9.3—25.6	70.4—90.1

The mean values and the range of pN_2 for the two species at different depths are plotted against the total hydrostatic pressure in Fig. 1. The pN_2 in the swimbladder of *C. acronius* caught at different depths in May are also plotted against total hydrostatic pressure. Using average values is not quite correct since the spread of data really reflects different biological situations of the fish.



Figur 1. Mean pN_2 in the swimbladder of coregonids in relation to depth. ● *C. acronius*, May. ○ *C. acronius*, October. △ *C. lavaretus*, November. ⊢⊣ indicate total range. ▨ partial pressure of dissolved N_2 in the lakes.

DISCUSSION

The primary gas deposited into the swimbladder has an O_2 content higher than that of the air. This is definite in *C. lavaretus* which inhabits relative shallow water. During the spawning period it migrates to deeper areas and has a much higher O_2 content than that of air. (Sundnes, Enns and Sholander 1958). A prolonged stay in the deep areas without even small vertical migrations would result in an absorption of the oxygen. It is very unlikely that the oxygen exposed to living tissue in the swimbladder behave like inert gases. The gas will immediately enter the energy metabolism. During a prolonged stay at a certain depth, the O_2 in the swimbladder lost by metabolism will be replaced by a mixture of O_2 and N_2 to keep the fish buoyant at that depth. By a continous replacement of the O_2 partly by N_2, the N_2 content of the swimbladder gas will increase asymptotically. This is seemingly the process in *C. acronius* which is abundant in deeper areas. A similiar process is also possible in *C. lavaretus*, as shown by the high N_2 values in Table 1. Also in shallow water the same situation occur when vertical migrations are possible. *C. lavaretus* kept for 2 months in a 40 cm deep tank had a swimbladder gas consisting of 90.1 vol.% N_2 and 9.3 vol.% O_2.

Like *C. lavaretus* also *C. acronius* is able to deposit a gas mixture into the swimbladder having an O_2 higher than that of air. (Table 1). Due to the different vertical distribution of the two species (SUNDNES 1963), a high O_2 content as found in *C. lavaretus* should not be expected in *C. acronius*.

As an example, a stationary, buoyant *C. acronius* at a depth of 30 m will have a swimbladder gas consisting of about 99 vol.% N_2. By migration to a depth of 10 m, the volume of the swimbladder is kept constant by releasing gas. The gas left in the swimbladder has the same high N_2 content. When migrating back to 30 m, the swimbladder will be compressed to half the volume. To be neutrally buoyant a gas deposition corresponding to half the volume of the swimbladder in that depth is necessary. E.g. a maximum mixture of O_2 like those found in *C. lavaretus* consisting of nearly 70% O_2, will give a maximum O_2 content of 35 vol.% O_2 in the swimbladder of a buoyant *C. acronius*. In the present investigation a O_2 content of 33.9 vol% is found in the swimbladder of *C. acronius*.

CONCLUSION

The present findings support the theory that the high N_2 content found in the coregonid swimbladder is a compensation of the loss of O_2 to the surrounding tissue and not due to a primary deposition of a gas mixture containing a high percentage of N_2.

The replacement of the gas volume is made by a mixture og O_2 and N_2, and the continous loss and replacement function gives an increase in the N_2 content.

The high O_2 content in both species support the theory that the gas is deposited into the coregonid swimbladder from the vascular system of the fish.

The underlaying mechanism of the deposition of gases into the coregonid swimbladder, however, is still an open question.

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SUMMARY

The present investigation support the theory that there are no differens in the swimbladder physiology of *Coregorus acronius* in Bodensee and *Coregonus lavaretus* in Randsfjord. The high N_2 content found in *C. acronuis* is due to absorption of the O_2 content of the swimbladder.

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