

SHORT NOTES

SWIMBLADDER GAS PRESSURE OF COD IN RELATION TO HYDROSTATIC PRESSURE

INTRODUCTION

The swimbladder plays among other functions a role as a hydrostatic organ in fish. It has to maintain a constant volume at all depths to keep the fish in neutral buoyancy. There are two physically possible principles to keep the fish buoyant, *i.e.* to keep a constant swimbladder volume either by manipulating the gas in and out of the swimbladder to compensate the outside hydrostatic pressure, or to keep the swimbladder volume constant independent of the outside pressure.

The first principle is described in a great number of papers over decades and a recent article by FÄNGE (1966) has reviewed the extensive literature on gas filling mechanisms.

Papers dealing with pressure measurements in the swimbladder of fishes are relatively few. EVANS and DAMANT (1929) found in buoyant fish positive gas pressure in the swimbladders of Cyprinids in relation to the surrounding hydrostatic pressure. The pressure measurements were performed after the fish was killed and the maximum positive pressure values were found as high as 120 mm Hg.

Also ALEXANDER (1959) has demonstrated by volume measurements a positive pressure in the swimbladder of buoyant Cyprinids. The interesting reports of McCUTCHEON (1958, 1966 and 1970) describes buoyancy control by swimbladder volume adjustment by muscular activity. ROMER (1957) concludes that the origin of the amphibian lung and the swimbladder of modern fish may be found in the respiratory bladder of primitive teleosts. An idea that a fish should be able to maintain a negative pressure in the swimbladder relative to the surrounding hydrostatic pressure has not been mentioned in the literature. However, the analogy between the body cavity of a fish with the swimbladder and the body cavity of mammals with the lungs lends credence to a theory of analogous physical functions. To clarify this question the present investigation of the swimbladder was carried out.

MATERIALS AND METHODS

By a transducer technique the gas pressure in the swimbladder was measured in relation to the surrounding hydrostatic pressure in a pressure aquarium (SUNDNES, 1962) and in open aquaria 1.5 m deep. The gas pressure in the swimbladder was measured through a hypodermic needle inserted through the dorsal muscular layers of the fish into the swimbladder (Fig. 1). The hypodermic needle was connected to a pressure transducer in a detector unit where the surrounding hydrostatic pressure was also measured by a second pressure transducer. The signal from the detector unit was measured as the difference between the two transducers in mV. The transducers were connected to the recording instrument through the cover of the pressure aquarium. "Free

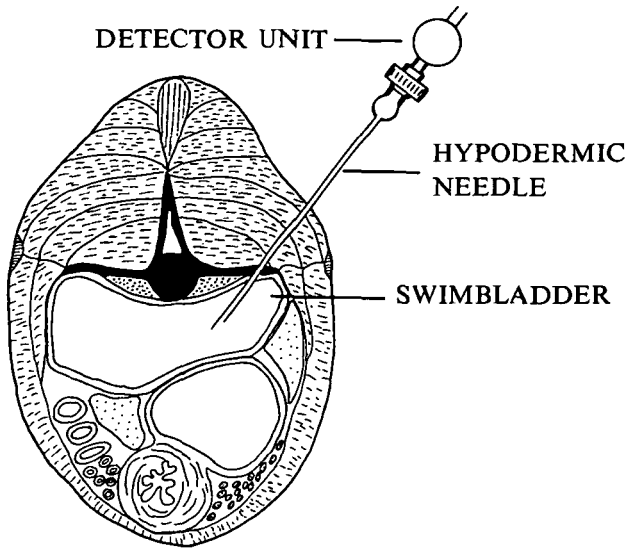


Figure 1. Transverse section of fish. The canula is inserted into the swimbladder through the dorsal muscular layer of the fish.

swimming” was facilitated by coiling up the wire connection in the aquarium.

By using various transducers with pressure sensitivities from 1 to 10 cm of water, the gas in the swimbladder of cod (*Gadus morhua* (L.)) and the hydrostatic pressure were measured in the pressure aquarium.

RESULTS AND DISCUSSION

In the open aquaria experiments buoyant fish near the surface did not show any swimbladder gas pressure different from the surroundings within the sensitivity of the detector. An overflotated fish of 450 g with a positive drag of 11 g had a positive pressure in the swimbladder less than 2 cm H₂O. At depths of 40 cm buoyant fish from the upper 20 cm of the open aquaria showed negative pressure of the swimbladder. Vertical swimming of the fish were immediately recorded by the detectors due to their sensitivity. Horizontal swimming did not effect the balance between the transducers.

In experiments with the pressure aquarium, the fish was forced to a certain “depth” *i.e.* by applying hydrostatic pressure. Negative pressure in the swimbladder was always noted at this point. The measurements indicated a definite rigidity of the fish body which was able to maintain a negative pressure in the swimbladder gas in relation to the surrounding hydrostatic pressure. The fish could reduce the negative pressure to zero *i.e.* eliminate the pressure difference at certain depths in a few seconds by yawning (Fig. 2A). This function is similar to the results of McCUTCHEON (1958, 1966). Also the opposite took place: fish forced to a certain “depth” not only maintained a negative pressure in the swimbladder but they also were able to actively increase it (Fig. 2B

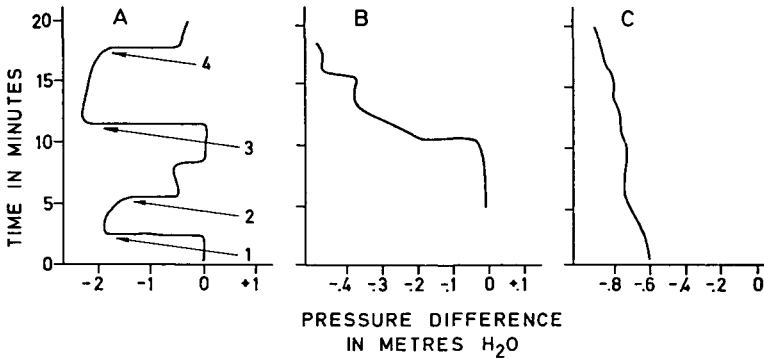


Figure 2. The curves demonstrate the relationship between the swimbladder gas pressure and the surrounding hydrostatic pressure of the fish. The left side of the 0 point on the abscissa indicates a negative pressure in the swimbladder, and the right a positive pressure. A. The fish was forced to a "depth" of 14 m at 1. Yawning occurred at 2. The fish was forced to a "depth" of 20 m at 3. Yawning again occurred at 4. B. A balanced pressure situation at 40 m "depth". C. A fish at 100 m "depth".

and C). This is possible by an expansion of the body cavity. By the present findings and the results of EVANS and DAMANT (1929), ALEXANDER (1959) and McCUTCHEON (1958, 1966) there are seemingly possibilities for fish to be neutral buoyant in a depth range rather than at a level only where the pressure of the swimbladder gas is balanced with the outside hydrostatic pressure. This means that also muscular tensions play an important role in the volume regulation of the swimbladder. The present findings support the theory of the physical functions of the swimbladder being analogous to those of the vertebrate lung with respect to pressure distribution in relation to the surrounding pressure on the animal.

The further explanations of the pressure distribution in the swimbladder as part of the swimbladder physiology has to be more clarified by further investigations.

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FLUCTUATIONS IN GULF OF MAINE SEA TEMPERATURE AND SPECIFIC MOLLUSCAN ABUNDANCE

Relict hard clam, *Mercenaria mercenaria* (L.), populations survive in anomalous warm water pockets of the northern Gulf of Maine. Extensive soft clam, *Mya arenaria* (L.), populations occupy the same shallow coves as well as many other areas too cold for hard clam reproduction and survival (LOOSANOF, MILLER and SMITH, 1951; PRATT and CAMPBELL, 1956; WELLS, 1957). Abundance peaks of the two species frequently coincide in geographical location but not in time.

Fossil molluscan assemblages from the post-Wisconsin sea intrusion of Maine contain many shells of soft clam but none of hard clam, supporting the assumption that hard clam survival in the northern Gulf of Maine is extremely tenuous except during favorable sea temperature periods.

Undated prehistoric kitchen middens about one metre in depth and located at approximately N43°48'30" W69°51'40" adjacent to a major growing area contain four alternate strata of hard and soft clam shells, indicating a cyclic abundance relationship of the two species comparable to that which occurred between 1939 and 1970 (Fig. 1). Other stratified middens near presently sparsely occupied hard clam sites contain only occasional shells of the species, further supporting the assumption that periodically fluctuating prehistoric environmental conditions limiting abundance have been duplicated by sea temperature trends of the most recent climatic cycles. Samples from these middens have a carbon-14 age range from 1600 to 1900 ± 250 BP (BROECKER, KULP, and TUCEK, 1956). Associated early woodland artifacts suggest similar cultural age for the two sites.

Historic information on consecutive year production of each species is available only since 1938; soft clam data have been sporadically recorded from 1887 (Anon, 1898–1938); hard clam data from 1931. Daily sea temperature observations have been made at Boothbay Harbor, Maine, by the U.S. Fish and Wildlife Service since 1905 (WELCH, 1967).

Demand for both species increased markedly during and after World War II and higher prices induced intensive utilization of available stocks. Population surveys to maintain continuing inventories have been conducted periodically by state and other biologists since 1946. Survey results support the assumption that production is an acceptably reliable indicator of the relative abundance of commercial size clams (Dow, 1952).