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COMPARATIVE ANATOMICAL STUDY OF SWIMBLADDER IN DIFFERENT SPECIES OF FISH

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Abstract

Fish are the most numerous group of vertebrates in the world and their anatomy is still not completely studied. This article is aimed to present the morphological study of swimbladder in different species of ray-finned fish which have industrial value - namely Russian sturgeon, American paddlefish (order Acipenseriformes), rainbow trout (order Salmoniformes), northern pike (order Esociformes), zander (order Perciformes) - and to compare it's structure and shape with the swimbladder of common carp (order Cypriniformes). Also the analysis of functions of swimbladder is given. The research was carried out in the Department of Animal Anatomy of National University of Life and Environmental Sciences of Ukraine. The study was performed by anatomical dissection on cadavers of 3 fish of each species with further macroscopic examination of swimbladderes. The research showed that in all investigated species this organ has significant differences and is composed of one chamber. The swimbladder of common carp is composed of two chambers (anterior and posterior). Almost all investigated species of fish have connection between the swimbladder and the gut (pneumatic duct), so they are believed to be physostomes. The study highlighted characteristic features of swimbladder in different species of fish that has practical value for better understanding of fish anatomy and possible swimbladder disorders.

Key words: *anatomy, fish, physoclisti, physostomes, swimbladder.*

INTRODUCTION

Swimbladder (synonyms: gas bladder, air bladder; Latin: *vesica natatoria*) is a hollow organ filled with a gas.

It is found in ray-finned fish, but not in every specie. It seems that evolution of fish developed in different directions and created physoclisti (i.e. fish that do not have connection between the swimbladder and the digestive tract) and physostomes (i.e. fish that have pneumatic duct which connects the swimbladder to the digestive tract). In some deep sea fish, fish that live in surf zone or in fast-flowing water streams the gas bladder is absent (Kilarski, 2012). Because for these fish there is no need to come to the surface frequently and the hydrostatic function of the swimbladder is lost. In addition at great depth the water pressure is in several times bigger than at the surface and any gas considerably compresses. In some quick swimming fish (e.g. mackerel, sand lance) the air bladder is also absent (Kilarski, 2012).

In species that possess the swimbladder this organ performs many important functions. It is well known that the gas bladder helps fish to maintain its depth and control its buoyancy without wasting energy for swimming (Harden Jones, 1967). Oxygen storage and respiratory functions enabled scientists to consider the air bladder to be the homologue of the lung (Hall, 1924; Fänge, 1983). Comparative transcriptome analyses provided molecular proofs of the relatedness of the fish swimbladder and mammalian lung (Zheng et al., 2011). Together with another data concerning shared vascular supply of lungs and gas bladders, the theory of their homology was provided with concrete evidences (Longo et al., 2013). Sound production of the gas bladder plays important role in fish communication. It should be noticed that sound-producing muscles attached to the swimbladder are the fastest known vertebrate muscles. (Fine et al., 2001). Due to the connection between the swimbladder and the inner ear the hearing ability of otophysines (carps, minnows, catfishes, characins, knifefishes) is significantly improved in comparison with fish that do not have Weberian apparatus

(Blaxter J.H.S., 1981; Lechner and Ladich, 2008; Ladich, 2012). Pressure receptors that are located in the swimmblader's wall help fish to adapt to pressure changes (Tytler and Blaxter, 1973). The laterophisic connection between the gas bladder and the lateral line system in some teleost fish expand the functional abilities of the mechanosensory lateral line system (Webb, 1998; Webb et al., 2006).
Therefore, it may be said that the swimbladder is not such a simple organ as it may look like. Although its functions are not equally presented or developed, the anatomical features of the air bladder in different species is still not completely studied. I think that the variety of structure and functions of the swimbladder is greater than any other organ of fish. That is why my paper is aimed to present the analysis of morphological features and differences of the swimbladder in some industrial species of fish. The study contributes to the extension of knowledge of fish anatomy and can be useful for understanding of possible swimbladder disorders.

MATERIALS AND METHODS

The study was carried out in the Department of Animal Anatomy of National University of Life and Environmental Sciences of Ukraine.
The research material were swimbladders of matured males of Russian sturgeon (*Acipenser gueldenstaedtii Brandt et Ratzeburg, 1833)*, American paddlefish (*Polyodon spathula Walbaum, 1792*), rainbow trout (*Oncorhynchus mykiss Walbaum, 1792*), northern pike (*Esox lucius Linnaeus, 1758*), zander (*Sander lucioperca Linnaeus, 1758*) and common carp (*Cyprinus carpio Linnaeus, 1758*).
Anatomic dissection of the ventral part of the trunk with farther removal of the lateral part of the abdominal wall was performed on cadavers of 3 fish of each species. Then the swimbladders were examined and removed for macroscopic investigation.

RESULTS AND DISCUSSIONS

The air bladder is located dorsally over the internal organs and adjoins to the kidney and vertebras. The dorsal aorta (*aorta dorsalis*) gives branch vessels that are clearly visualized on its surface. Venous vessels that carry blood from the swimbladder drain into the postcardinal veins (*v. cardinalis posterior*).
The gas bladders of Russian sturgeon, American paddlefish, rainbow trout, northern pike and zander consist of one chamber, while the swimbladder of common carp consists of two chambers – anterior and posterior. These chambers are linked by the constriction - *ductus communicans*. In Cyprinidae the anterior part of the anterior chamber is connected with the tripus of the Weberian apparatus (Muir Evans, 1925). In the dissected species of common carp the anterior chamber is relatively bigger than the posterior (Figure 1).

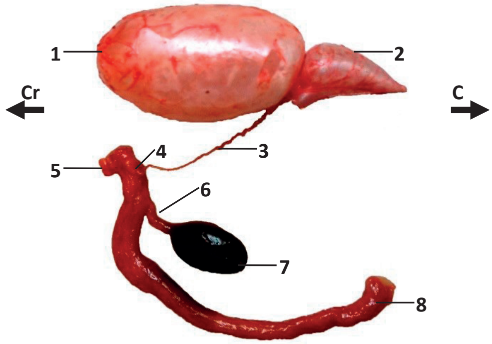

Figure 1. Swimbladder of common carp (*Cyprinus carpio*) in lateral view. Cr – cranial, C – caudal, 1 – anterior chamber, 2 – posterior chamber, 3 – pneumatic duct, 4 – pneumatic bulb, 5 - oesophagus, 6 - bile duct, 7 - gall bladder; 8 - intestine

Zander has no connection between the swimbladder and the digestive tube. Therefore, it is considered to be physoclist fish. It should be noted that physoclisti usually pass through a physostome stage during their larval development (Fänge, 1983; Kilarski, 2012).
Zander's swimbladder occupies all the dorsal part of the pleuroperitoneal cavity and is tightly attached. The shape of zander's

swimbladder has significant peculiarity: on the cranial part it bifurcates into two tube-like horns that curved slightly dorsally approaching the posterior skull and inner ears (Figure 2). Resent research showed that the size of the gas bladder and the extension of its anterior chamber are important factors for hearing sensitivity in cichlids that also belong to the order Perciformes (Schulz-Mirbach et al., 2012). Thus, zander may possess a high auditory sensitivity.

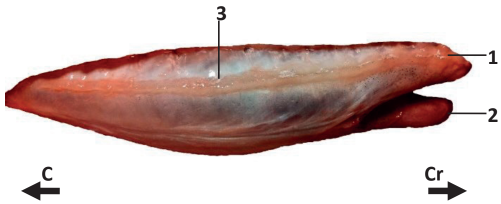

Figure 2. Swimbladder of zander (*Sander lucioperca*) in laterovenral view. Cr – cranial, C – caudal, 1 – right horn, 2 – left horn, 3 – lateral muscle

At the same time, the gas bladders of American paddlefish, Russian sturgeon, rainbow trout and northern pike have pneumatic ducts (*ductus pneumaticus*). That fact enables us to consider these fish to be physostomes as a common carp. But the length of their pneumatic ducts is much shorter in comparison with the pneumatic duct of common carp.

In common carp the pneumatic duct originates ventrally from the anterior part of the posterior chamber, passes cranially, swells into a pneumatic bulb and enters dorsally the middle part of oesophagus before the attachment of the bile duct of the liver (Figure 1).

In all physostomes the excess of gas can be removed from the air bladder through this duct by the sphincter mechanism. Gas that fills the swimbladder is produced by the gas gland which is located on its internal surface. In physoclisti gas resorption occurs by simple diffusion into the blood stream through the oval which is located on the dorsal internal surface of the swimbladder (Harden Jones, 1967). This foramen is placed in the same place, where was the outlet of the pneumatic duct in embryonic period (Kilarski, 2012).

In rainbow trout and northern pike the gas bladder is attached to the dorsal wall of the pleuroperitoneal cavity. However, it can be easily dissected. The pneumatic duct is narrow and short. It originates on the anterior part of the swimbladder and enters dorsally the oesophagus.

The forms of the filled rainbow trout's and northern pike's swimbladders are similar elongated (Figures 3, 5). But in rainbow trout the air bladder can also have a "pearl necklace" shape. In addition, the wall of the rainbow trout's swimbladder is very thin (Figure 4). The gas bladder of Russian sturgeon and American paddlefish has sick walls. It is easily separated from the adjacent tissues as the air

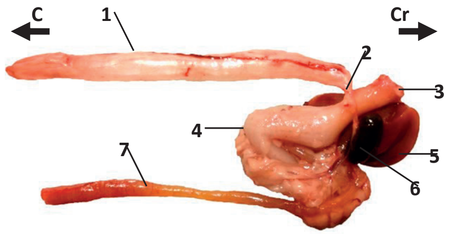

Figure 3. Internal organs of rainbow trout (*Oncorhynchus mykiss*) in lateral view. Cr – cranial, C – caudal, 1 – swimbladder, 2 – pneumatic duct , 3 – oesophagus, 4 – stomach, 5 - liver, 6 - gall bladder, 7 – rectum

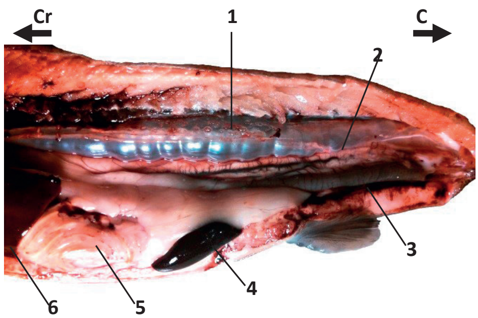

Figure 4. Abdominal cavity of rainbow trout (*Oncorhynchus mykiss*) in lateral view. Cr – cranial, C – caudal, 1 – swimbladder, 2 – testis, 3 – rectum, 4 – spleen, 5 – pyloric ceca, 6 – liver

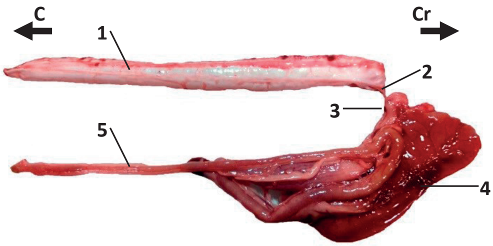

Figure 5. Internal organs of northern pike (*Esox lucius*) in lateral view. Cr – cranial, C – caudal, 1 – swimbladder, 2 – pneumatic duct, 3 – oesophagus, 4 – liver, 5 – rectum

bladder of common carp. The wide and short pneumatic duct arises from the cranioventral (in Russian sturgeon) or ventral (in American paddlefish) part of the swimbladder. It attaches on the left side of the laterodorsal wall of the cardinal part of the stomach. Nevertheless, the shapes of American paddlefish's and Russian sturgeon's swimbladders are considerably differ from each other. The gas bladder of American paddlefish has even half-round shape, while the caudal end of Russian sturgeon's swimmbladder is elongated and rounded (Figures 6, 7).

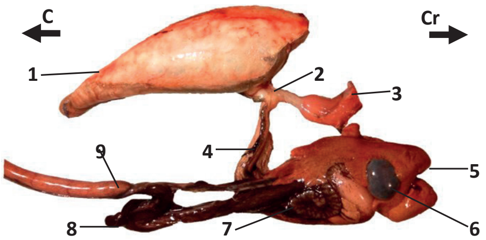

Figure 6. Internal organs of Russian sturgeon (*Acipenser gueldenstaedtii*) in lateral view. Cr – cranial, C – caudal, 1 – swimbladder, 2 – pneumatic duct, 3 – oesophagus, 4 – stomach, 5 – liver, 6 – gall bladder, 7 - pyloric gland, 8 – spleen, 8 - intestine

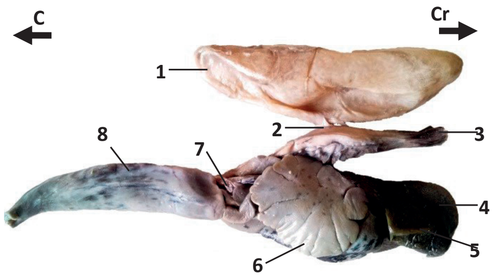

Figure 7. Internal organs of American paddlefish (*Polyodon spathula*) in lateral view. Cr – cranial, C – caudal, 1 – swimbladder, 2 – pneumatic duct, 3 – oesophagus, 4 – liver, 5 – gall bladder, 6 – pyloric gland, 7 – intestine, 8 – rectum

CONCLUSIONS

Anatomical division of fish into physoclisti and physostomes is important for understanding of their physiology. Swimbladder of fish serves a variety of vital functions. I can surmise that the swimbladder has unique structural characteristics in every investigated specie. In my opinion, the shape of gas bladder depends from the shape of fish and its mode of life, namely swimming behaviour and hearing sensitivity.

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