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The features of the morphology of the heart of *Clarias gariepinus* (Siluriformes, Clariidae)

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One of the promising fish species that has relatively recently started to be farmed in Ukraine is the African catfish (*Clarias gariepinus* Burchell, 1822) from the catfish family. It is a freshwater, warm-water, omnivorous fish that can breathe atmospheric air. The purpose of this study is the morphological evaluation of the macroscopic structure of the heart of the African catfish, a member of the class Actinopterygii, family Clariidae. It is shown that the heart of the African catfish is topographically located in the cranial part of the body, on the ventral side, near the head in the triangle between the shoulder girdle bones, occupying a central position between the gills. The heart of the African catfish consists of the venous sinus, atrium, ventricle, and arterial cone, which are separated by valves, allowing blood to move only in one direction – from the venous sinus to the arterial cone and not vice versa. As a distinct structure, the atrium is located to the right of the ventricle, with an incomplete septum partially dividing the atrium into right and left halves (chambers). The ventricle of the heart is a hollow organ with an elongated oval shape. The cranial part of the ventricle has an expanded base, while the caudal part has a convex apex. The arterial cone of the heart has an expanded base, which adjoins the ventricle, and its opposite part is narrowed, giving the structure a conical (funnel-like) shape. According to organometry results, the linear dimensions of the heart components vary and depend on their functional load during the rhythmic contractions of the heart muscle in the cardiac rhythm, during which blood flows through the vessels to all organs. The ventricle's largest linear parameters – length, width, and thickness – are characteristic. In contrast, the linear parameters of the arterial cone and atrium are significantly smaller. Based on the ventricular development index, the heart of the African catfish is classified as narrow-elongated. It has been established that the thickness of the ventricle wall is the greatest among all its anatomical structures, measuring 3.2 ± 0.4 mm. The wall of the arterial cone is statistically 1.47 times thinner than that of the ventricle wall and the atrial wall thickness is the smallest (8.0 times smaller) compared to the ventricle wall. The absolute and relative masses of the ventricle, arterial cone, and atrium correlate with their linear parameters: the greatest absolute mass is found in the ventricle – 0.52 ± 0.02 g, followed by the arterial cone – 0.21 ± 0.03 g, and the atrium – 0.16 ± 0.03 g. According to these morphometric results, the coefficient of the ratio of the ventricle's absolute mass to the total heart mass is 1:0.58, the ratio of the arterial cone's absolute mass to the total heart mass is 1:0.24, and the ratio of the atrium's absolute mass to the total mass of the ventricles is 1:0.18. The study of the structural characteristics of the cardiovascular organs serves as a foundation for ichthyologists and fish farmers to conduct disease prevention measures and to mitigate the impact of stress and adverse environmental factors on the fish during aquaculture.

Keywords: Siluriformes; Clariidae; cardiovascular system; ventricle; atrium; arterial cone; morphometry.

Introduction

In recent years, there has been a trend in the food industry towards increasing the production of animal products. In this context, the role of fisheries is crucial, including the extraction, processing, reproduction, and increase of fish and other aquatic organisms in natural and artificial water bodies. At the same time, to achieve maximum production volumes of fish food products, the focus is on fish farming in aquaculture, a field that is currently developing dynamically (Yu et al., 2020; Roobab et al., 2022; Hashemi et al., 2023).

The advantages of this direction include farming the African catfish, which is associated with its biological properties: its tolerance of farming conditions, dominance in growth and development, resistance to diseases, and so on. These factors have significant economic importance in reducing the cost of fish production (Juin et al., 2017; Ukagwu et al., 2017; Strauch et al., 2018; Truter et al., 2023).

In many countries, the African catfish holds significant economic value due to its rapid growth rate, hardiness, omnivorous diet, ability to reproduce under artificial conditions, and tolerance to high stocking densities, as well as low demands for water quality (Baßmann et al., 2017; Lawal et al., 2017; Zadorozhnii & Bekh, 2024).

Currently, farming African catfish in artificial conditions in Ukraine is an exceptionally new development in the fishing industry, which has only started to grow relatively recently (Zadorozhnii, 2023; Zadorozhnii & Bekh, 2024). For the successful development of this industry, which includes improving productive qualities, preventing diseases of various origins, etc., alongside organizational and economic measures, there is a need for in-depth studies of the organism, its morphological structure, and the anatomy of all organs and systems at the organ, tissue, and cellular levels (Muller & Marc, 1984; Olson, 1991; Gould et al., 2013).

An essential aspect of this is the study of the structural features of the organs of the cardiovascular system, which has both cognitive value for biologists and serves as a basis for ichthyologists and fish farmers for disease prevention and to mitigate the impact of stress and adverse environmental factors on the organism when growing fish in aquaculture (Belão et al., 2011; Song & Song, 2012; Ghedotti et al., 2021). The cardiovascular system plays an essential role in regulating the functions of organs and body systems, participating in the provision of trophic, respiratory, and excretory functions (Zhurenko et al., 2018; Goralskyi et al., 2021; Horalskyi et al., 2022; Horalskyi et al., 2023). Through the cardiovascular system, which is part of the systemic (large) and pulmonary (small) circulations in mammals, essential substances, hormones, and oxygen are delivered to the tissues of organs, while metabolic waste products are removed from them (Svendsen et al., 2019; Horalskyi et al., 2023; Rahulia et al., 2023).

The central organ of the cardiovascular system is the heart, and it is thanks to the contraction of the cardiomyocytes of the myocardium that blood flows through the closed system of blood vessels, thus ensuring the gas exchange in the organism (Ben-Shachar et al., 1985; Goralskyi et al., 2021; Horalskyi et al., 2022).

In bony fish, the muscles of the atrium and ventricle contract and relax alternately (replacing each other), which helps move blood through the vessels (Spaink et al., 2014; Martins et al., 2021; Chan et al., 2022). Venous blood flows through the heart via the large artery- the aorta-moving from the heart to the small gill vessels, where it becomes oxygenated, thus turning into arterial blood.

In dipnoan fish, represented by the African catfish (*Clarias gariepinus* Burchell, 1822, Siluriformes, Clariidae), the morphological structure of the cardiovascular organs is characterized by a distinctive feature due to the presence of both gill and pulmonary respiration from atmospheric air, which served as the aim of our research. Therefore, we conducted a comparative morphological and morphometric assessment of the heart's morphological structures in the dipnoan fish – African catfish.

Materials and methods

The research was conducted following the international principles of the European Convention for the Protection of Vertebrate Animals Used for Experimental and Other Scientific Purposes (Strasbourg, 1986) and the Rules for Conducting Work with the Use of Experimental Animals, approved by the Ministry of Health Order No. 281 on November 1, 2000, On Measures for Further Improvement of Organizational Forms of Work with Experimental Animals, as well as the relevant Law of Ukraine On the Protection of Animals from Cruel Treatment (No. 3447-IV from February 21, 2006, Kyiv). When conducting experiments on animals, the requirements of the general rules of good laboratory practice (GLP, 1981) and the provisions of the General Ethical Principles of Animal Experiments, approved by the First National Congress on Bioethics (Kyiv, 2001), were adhered to.

Clarias gariepinus was raised under controlled conditions using artificially created aquatic ecosystems that met the necessary maintenance conditions (temperature, pH, and water salinity). The fish were raised in tanks (up to 500 liters in volume) equipped with appropriate technical devices and systems, including mechanical, biological, and bacteriological filtration systems – Eheim Professional 3 1200XL (Germany), UV sterilizers Resun UV-08 24W (China), and Resun ACO-001 compressor-type aerators (China) for oxygenating the water. The rooms with the tanks were darkened during the daylight hours.

The quality of the water environment for the fish, as well as the stocking density, met the requirements for raising the African catfish (Hecht et al., 1995). The water supply source was tap water, which was pre-settled, heated to the tank's temperature, and replenished by 10% of the total volume daily. The water temperature (25–28 °C) was monitored and, if necessary, maintained using an external JBL ProTemp e500 heater (Germany), with a power of 500 W.

A daily hydrochemical analysis of the water quality was conducted, measuring the pH level (using a laboratory pH meter SX-620), temperature (with an electronic thermometer), and the levels of NH_3, NH_4, NO_2, and NO_3 (using the Ptero water quality test kit).

The fish were fed with compound feed, administered twice daily – morning and evening. The clinical condition of the fish was assessed through daily visual inspection, considering their mobility, overall behavior (activity), appetite, etc.

Morphological, morphometric, and statistical methods were used in the research. The study object was the African catfish's dissected heart (n = 5). Clinical examination of freshly caught fish, including the assessment of their exterior (appearance, body weight) and interior (linear parameters, absolute and relative heart mass) measurements, was performed after anatomical dissection following the recommendations from ichthyological and morphological guides (Horalskyi et al., 2019). To prevent the negative effects of stress factors, the fish were euthanized before dissection using a solution of Hypnodil (5–10 ml/L).

The body weight of the African catfish was determined by weighing with the VTD-3/0.1FD scales (Dniproves, Ukraine) with an accuracy of 0.1 g. The absolute mass of the heart and its structural elements were determined using electronic scales. The relative mass (RM) of the heart was calculated using the formula:

$$RM = (\text{absolute heart mass}/\text{body mass}) \times 100\%.$$

The heart's length, width, and thickness were measured using a caliper. The heart development index (HDI) was calculated by the total length ratio to the width, using the following formula:

$$HDI = \text{heart length}/\text{heart width} \times 100.$$

Morphological terms for the structural parts of the heart are presented according to the International Veterinary Anatomical Nomenclature.

The digital processing of morphometric studies was carried out statistically using the Statistica 7.0 software package (StatSoft, Tulsa, USA). Differences between values were determined using ANOVA, considering them significant at $P < 0.05$ (with Bonferroni correction for error).

Results

The heart of the African catfish, according to the results of our research, is topographically located in the cranial part of the trunk on the ventral side of the body, close to the head, in a triangular area between the bones of the pectoral girdle, occupying a central position between the gills (Fig. 1). It is a two-chambered heart and is situated within the pericardial sac.

The morphological structures of the heart of the African catfish include the venous sinus, atrium, ventricle, and arterial cone (Fig. 2a, 2b), representing a sequentially formed anatomical network through which deoxygenated (venous) blood flows. The heart chambers are separated by valves that allow the blood to move only in one direction during heart wall contractions (from the venous sinus to the arterial cone), but not vice versa.

The ventricle of the African catfish heart is a hollow organ with an elongated oval shape. Cranially, the ventricle has an expanded base, and caudally, it has a convex apex (Fig. 2a, 2b).

The ventricle wall consists of three layers: the inner (endocardium), middle muscular (myocardium), and outer (epicardium) layers (Fig. 2c). The most developed layer of the ventricle wall is the muscular layer – the myocardium, which is lined on the inside by a single layer of flat epithelium (endothelium), forming a thin connective tissue layer known as the endocardium. Externally, the myocardium is covered by the heart's outer connective tissue layer – the pericardium (Fig. 2c).

At the base of the ventricle cranially, there is a pulsating, hollow organ in the form of a thick-walled muscular tube, conical (trumpet-like) in shape, called the arterial cone (Fig. 2a, 2b). Its wall is thickened and formed of muscular tissue (Fig. 2d). Externally, the arterial cone has an expanded base that is adjacent to the cranial part (base) of the ventricle. The opposite side of the cone, its upper surface, narrows and transitions into the abdominal aorta (Fig. 2a, 2b).

The atrium of the heart in the *Clarias* catfish has a dark brown color (Fig. 2b). Unlike the heart structure of vertebrates in the classes of birds and mammals, where the atrium and ventricles form a single morphological structure, in the *Clarias* catfish, the atrium is a thin-walled sac, separated from the ventricle. It is located to the right of it, connecting to the ventricle through an opening.

Caudally, the venous sinus (venous sinus) is adjacent to the atrium (Fig. 2e, 2f). In the *Clarias* catfish, the atrium has a small (incomplete) septum that partially divides it into right and left halves (chambers), which is especially noticeable during diastole (the relaxation of the ventricles and atria) of the cardiac cycle (Fig. 2f). This is related to the emergence of both gill and pulmonary respiration in dipnoan fish, which is absent in bony fish. In dipnoan fish, due to the unique structure of the respiratory and cardiovascular systems, a second circulatory loop – the pulmonary circulation – appears in addition to the sizeable circulatory loop. In the large circulatory loop, venous (deoxygenated) blood from the atrium enters the ventricle and then flows into its arterial cone.

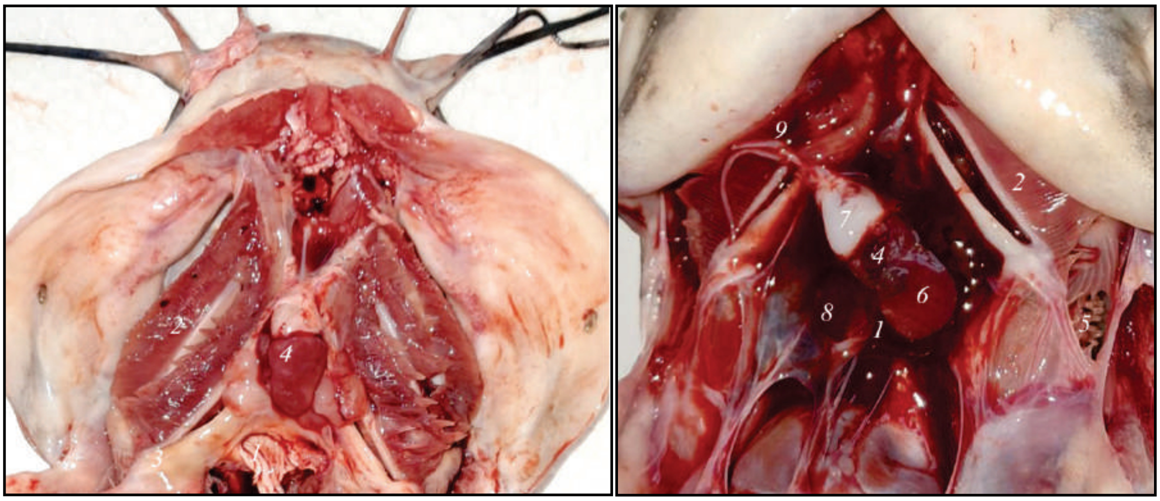

Fig. 1. Topography of the heart of the African catfish: *1* – cranial part of the trunk; *2* – gills; *3* – pectoral girdle bones; *4* – heart; *5* – lungs; *6* – ventricle; *7* – arterial cone; *8* – atrium; *9* – abdominal aorta; macroscopic preparation

The abdominal aorta enters the gills via the outgoing gill arteries (Fig. 1b), where it becomes oxygenated. The oxygenated (oxygen-rich) blood then flows through the gill vessels (arteries) to the organs and tissues, where gas exchange occurs, and returns through the gill veins to the right side of the atrium.

In the small circulatory loop, venous blood from the atrium enters the ventricle, then flows into the arterial cone, from where, through the abdominal aorta, the blood enters the lungs via the outgoing pulmonary arteries, where gas exchange occurs. Oxygenated blood (oxygen-rich) from the lungs then enters the left side of the atrium via the pulmonary veins.

Next, blood from both the right and left sides of the atrium enters the ventricle again, from where partially mixed blood enters the arterial cone, which is connected by an incomplete septum. From the arterial cone, blood flows through the pulmonary and gill arteries to the gills and lungs again, where gas exchange occurs.

According to our morphometric studies on the analysis of linear dimensions (height, width, thickness, circumference, developmental index) of the structural components of the heart in the *Clarias* catfish, their values differ and are directly dependent on the functional load they perform. Thus, the most significant values – length, width, and thickness – are characteristic of the ventricle of the heart, which are 14.0 ± 0.7, 8.12 ± 0.81, and 6.30 ± 0.78 mm, respectively. The circumference of the heart (ventricle) is 28.9 ± 1.95 mm (Table 1). The development index of the heart in the *Clarias* catfish, based on the linear parameters of its ventricle, is 172.7 ± 5.6%. Therefore, the heart of the *Clarias* catfish is described as narrow and elongated. The arterial cone's linear parameters are significantly smaller than the ventricle's: its length is 10.0 ± 0.4 mm, width – 6.32 ± 0.54 mm, and thickness – 5.1 ± 0.3 mm. The length of the atrium is 13.8 ± 0.8 mm, width – 7.3 ± 0.7 mm, thickness – 3.6 ± 0.4 mm (Table 1).

The thickness of the ventricle wall in the *Clarias* catfish is the largest and is 3.2 ± 0.4 mm. The thickness of the wall of the arterial cone is significantly smaller, 1.47 times ($P < 0.01$), and is 2.18 ± 0.21 mm. Accordingly, the thinnest ($P < 0.001$) is the wall of the atrium, which is 0.41 ± 0.05 mm, 8.0 times thinner compared to the wall of the ventricle and 5.4 times thinner($P < 0.001$) compared to the wall of the arterial cone (Table 1).

According to the analysis of the morphometry results we conducted, the absolute weight of the heart of the *Clarias* catfish is 0.89 ± 0.03 g, and the relative weight is 0.07 ± 0.01% (Table 2). According to the results of the studies on the absolute and relative mass of the structural components of the heart, their values directly correlate with their linear parameters, with the highest values observed for the ventricle, followed by the arterial cone and the atrium. The absolute mass of the heart ventricle is the largest, amounting to 0.52 ± 0.02 g (58.3 ± 3.7%), while the absolute mass of the arterial cone is significantly ($P < 0.01$) slower than that of the ventricle, equaling 0.21 ± 0.03 g (23.3 ± 2.9%). The lowest absolute mass ($P < 0.001$) is that of the atrium, which is 0.16 ± 0.03 g (17.6 ± 3.1%, Table 2).

Table 1
Linear heart parameters of the African catfish (x ± SD, n = 5)

Indicators	Numeric values
Ventricle length, mm	14.0 ± 0.7
Width of the ventricle, mm	8.12 ± 0.81
Ventricle thickness, mm	6.30 ± 0.78
Ventricular wall thickness, mm	3.21 ± 0.42
Circumference of the heart (ventricle), mm	28.9 ± 2.0
Development index (ventricle) of the heart, %	172.7 ± 5.6
The length of the arterial cone, mm	10.0 ± 0.4
Width of the arterial cone, mm	6.32 ± 0.54
Thickness of the arterial cone, mm	5.1 ± 0.3
Thickness of the wall of the arterial cone, mm	2.18 ± 0.21
Atrial length, mm	13.8 ± 0.8
Width of the atrium, mm	7.3 ± 0.7
Atrial thickness (mm)	3.6 ± 0.4
Atrial wall thickness (mm)	0.41 ± 0.05

Table 2
Morphometric indicators of the structural parts of the heart of the African catfish (x ± SD, n = 5)

Indicators	Numeric values	
	absolute mass, g	relative mass, %
1. Heart weight (relative to animal body weight)	0.89 ± 0.03	0.07 ± 0.01
2. Weight of the ventricle (relative to the absolute mass of the heart)	0.52 ± 0.02	58.3 ± 3.7
3. Arterial cone (relative to the absolute mass of the heart)	0.21 ± 0.03	23.3 ± 2.9
4. Atrium (relative to absolute mass heart)	0.16 ± 0.03	17.6 ± 3.1

Based on these parameters, the ratio of the ventricle mass to the total heart mass is 1:0.58, the ratio of the arterial cone mass to the total heart mass is 1:0.24, and the ratio of the atrium mass to the ventricle mass is 1:0.18. This is because the contractile cardiomyocytes in the ventricular muscles and, correspondingly, the arterial cone, during their function, experience increased load as they pump blood under pressure to the organs and tissues. In contrast, the contractile cardiomyocytes of the atrium pump blood only into the ventricle, thus performing a significantly lower workload.

Discussion

Recently, many studies have been published that summarize modern concepts and achievements in morphological research regarding the patterns of structure and development of the heart and its components in a comparative species and age aspect in various animals of the classes Aves and Mammalia (Hnatiuk et al., 2016; Hnatiuk & Slabyi, 2016; Hnatiuk et al., 2017).

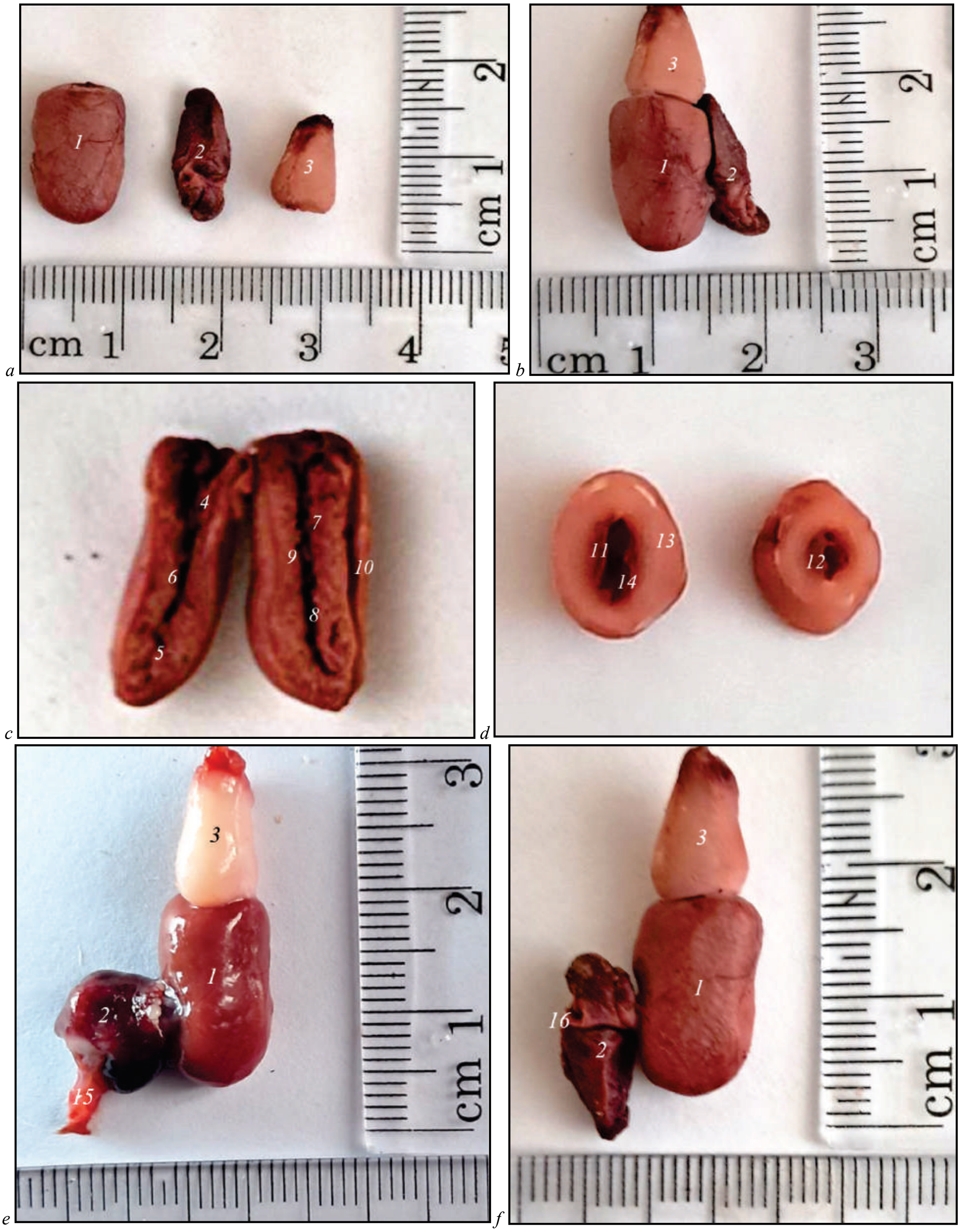

Fig. 2. Structure of the heart of the African catfish: *a* – anatomical structure of the heart; *b* – macroscopic structure of the heart (dorsal view); *c* – wall of the heart ventricle (longitudinal section); *d* – wall of the arterial cone (transverse section): *1* – ventricle; *2* – pericardium; *3* – arterial cone; *4* – base of the ventricle; *5* – apex of the ventricle; *6* – wall of the ventricle; *7* – ventricle cavity; *8* – endocardium; *9* – myocardium; *10* – epicardium; *11* – section of the expanded base; *12* – section of the apex; *13* – wall of the arterial cone; *14* – cavity of the arterial cone; *15* – venous sinus; *16* – incomplete septum; macroscopic preparation

Recent research on the cardiovascular system of vertebrate animals, especially domesticated ones, has led to the discovery of new, previously unknown facts that require further in-depth study of the heart and its structures in a comparative-anatomical, species, breed, and age aspect (Horalskyi et al., 2022; Rahulia et al., 2023; Horalskyi et al., 2024).

At the same time, there are significantly fewer publications in the literature regarding the heart structure in vertebrates (fish, Amphibia, and Reptilia). Therefore, the research we conducted on the morphotopography and macroscopic structure of the heart in dipnoan vertebrates, represented by the *Clarias* catfish, is a relevant task in biology (Weyl et al., 2016; Mahmoud et al., 2019; Mbokane & Moyo, 2022).

The circulatory system of fish, which includes the heart as the central organ, facilitates blood movement from the heart through the gills and body tissues. Unlike the hearts of other vertebrates (amphibians, reptiles, birds, mammals), a fish's heart is not adapted to separate (even partially) oxygenated blood from deoxygenated blood.

Morphologically, the heart of all fish is two-chambered and consists of one atrium and one ventricle, which are connected by a standard opening. Additionally, there is a venous sinus that is adjacent to the atrium. In cartilaginous fish, there is also another section called the arterial cone, which is a modified terminal part of the ventricle (evidenced by the cross-striated muscle fibers in its walls, similar to those in the ventricle itself) (Vlasenko & Kuzmenko, 2010).

The morphological structure and morphotopography of the heart in dipnoan fish, represented by the *Clarias* catfish, which, during its phylogenetic development has developed both branchial and pulmonary respiration, differs somewhat from that in bony fish.

This structure and the formation of the arterial cone at a particular stage of evolutionary development in vertebrates provided an advantage in accelerating blood flow because the sequential contraction of the ventricle, followed by the arterial cone, increases blood pressure, thereby accelerating the movement of blood through the vessels (Vlasenko & Kuzmenko, 2010).

During the evolutionary development and formation of the bony fish, due to the activation of all life processes within them, the arterial cone disappears as the ventricle walls become more powerful. Meanwhile, in bony fish, a thick-walled bulging of the initial part of the abdominal aorta – the aortic bulb – forms, whose muscular wall is composed of smooth muscle cells, softening the strong pulsatile shocks of the ventricle (Vlasenko & Kuzmenko, 2010).

Therefore, the aerial respiration in the *Clarias* catfish, which, in addition to gills, develops paired lungs during its historical evolution, allows it to survive for relatively long periods (up to 48 hours) without water or in murky water with low oxygen content, as well as to move across the surface of the terrestrial environment.

Thus, in bony fish, whose circulatory system has a two-chamber heart and a single circulatory circuit, blood flows through the gill veins into the venous sinus, then into the atrium, ventricle, arterial cone, and through the abdominal aorta into the gills, where gas exchange occurs. From the gills, oxygenated blood flows through the vessels to various organs, where it delivers oxygen and becomes saturated with carbon dioxide, turning into venous blood, which then returns to the heart through veins from different tissues and organs (Victor et al., 1999; Grant, 2015).

A modern priority research direction that allows the establishment of criteria for the development of animal organisms at the organ, tissue and cellular levels is morphometric research on organs and systems in clinically healthy animals in normal conditions, in experiments, in a species aspect, and so on (Dzau et al., 2006; Hnatiuk & Slabyi, 2016; Hnatiuk et al., 2017).

Therefore, mathematical analysis of the structures of morphological objects has gained recognition as a modern method characterized by objectivity and reliability, allowing a deeper understanding of the morphogenesis of organs and tissues during their individual and evolutionary development and logically interpreting the results of scientific research (Stakhurska & Pryshliak, 2014; Dunaievska et al., 2023; Horalskyi et al., 2024).

Morphological criteria for the growth and development of organs and their systems are linear parameters (length, width, thickness, circumference). These parameters enable the organs' shape, developmental index, etc to be determined . (Mits et al., 2016; Dukhnytskyi et al., 2024).

The shape, size, and mass of the heart in vertebrates are individual characteristics that depend on the class of animals, their species, age, sex, body structure, etc. The degree of elongation (shape) of the heart (its morphological components) is the ratio of its largest longitudinal (length) and transverse (width at the base) linear dimensions (Shevchenko, 2018).

An essential criterion for the physiological state of the heart's function is the thickness of its walls – the ventricle and atrium in birds and mammals, and, in dipnoan fish, the arterial cone, which, along with the ventricle and atrium, forms the anatomical structure of the heart (Melnyk et al., 2008; Vlasenko & Kuzmenko, 2010).

These ambiguous morphometric parameters of the wall thickness of the structural components of the heart, namely the considerable thickness of the ventricle and arterial cone walls and the negligible thickness of the atrium walls, can be explained by their functional load during the working of the heart. The thicker walls of the ventricle and arterial cone and significantly thinner walls in the atrium are associated with the fact that the contraction of the muscle layer of the ventricle and arterial cone moves blood under high pressure to the gills and lungs, where it is oxygenated. Then it reaches the organs and tissues, where gas exchange (carbon dioxide saturation) occurs and returns through the veins from the organs and tissues to the atrium under low pressure, from where it again enters the ventricle and arterial cone of the heart (Vlasenko & Kuzmenko, 2010).

The indicators of absolute and relative mass play a significant role in the development of organs and tissues of the organism. These indicators not only reflect the development and morphofunctional maturity of the organ (Mits et al., 2016), but also have informative value and serve as the basis for determining the shape of the organ, establishing its developmental index, etc. (Horalskyi et al., 2019; Horalskyi et al., 2024).

Conclusion

The heart of *Clarias* catfish is two-chambered and located in the cranial part of the body on the ventral side, near the head (in the triangle formed by the pectoral girdle bones), occupying a central position between the gills. The morphological components of the heart are the ventricle, atrium, and arterial cone. The heart's ventricle is an elongated, oval-shaped, hollow organ with an expanded base cranially and a convex apex caudally. The atrium is located to the right of the ventricle as a separate, isolated structure connected to the ventricle by an opening. The atrium has a slight (incomplete) septum that partially divides into right and left halves (chambers). The arterial cone is a conical (funnel-shaped) organ with an expanded base that adjoins the ventricle. The rear part of the cone is narrowed and transitions into the abdominal aorta.

The linear parameters of the structural parts of the heart are variable, depending on their functional load. The greatest length, width, and thickness are characteristic of the ventricle. The linear parameters of the arterial cone and atrium are significantly smaller. According to the ventricle's development index, the heart of *Clarias* catfish is narrowed and elongated. The absolute mass of the heart in *Clarias* catfish is 0.89 ± 0.03 g, and its relative mass is 0.07 ± 0.01%. The absolute and relative masses of the heart's structural components correlate with their linear parameters, with the largest mass found in the ventricle, followed by the arterial cone and atrium. The coefficient of the ratio of the ventricle mass to the heart mass is 1:0.58, the ratio of the arterial cone mass to the heart mass is 1:0.24, and the ratio of the atrium mass to the ventricle mass is 1:0.18.

Authors declare no conflict of interests.

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