Early ontogeny of Clarias gariepinus and its features under artificial cultivation at different temperature conditions

Uliyana Alexandrova¹,*, Andrey Kotelnikov², Svetlana Kotelnikova², Angelina Firsova¹,², and Anton Kuzov¹
¹Federal research centre the Southern scientific centre of the Russian academy of sciences, Chekhov ave., 41, Rostov-on-Don, 344006, Russia
²Astrakhan State Technical University, Tatishchev St., 16, Astrakhan, 414056, Russia

E-mail: ulyana.aleksandrova.00@mail.ru

Abstract The influence of different temperature regimes (28 °C and 25 °C) on the early ontogeny of Clarias gariepinus was studied. Heterochronism in the development of the main systems has been provided: the central nervous system and the digestive system are actively developing, the formation of the cardiovascular, respiratory and genitourinary systems occurs more slowly. The duration of embryonic development within the membranes was 18-22 hours. The initial stages of development changed insignificantly with decreasing temperature. The duration of the larval period was 14 days at 28 °C and 15 days at 25 °C. The fry period lasted 30 and 32 days, respectively. In terms of the duration of embryogenesis and the timing of the release of free embryos, the indicators did not go beyond the norm. The percentage of ugly embryos (underdevelopment of the operculum, underdevelopment of the tail, head and fins) was small and amounted to 3.2%, in the first and 4% in the second temperature regime. Incubation at temperatures below the optimum temperature of this species makes it possible to obtain viable offspring, adapted to the change in temperature regime.

1. Introduction

Aquaculture has a long history and plays an important role in providing humanity with high quality proteins (Gui et al., 2018) [1]. Aquaculture is currently the fastest growing agricultural sector. Global aquaculture production continues to grow to meet the ever-increasing demand for fish (Dauda et al., 2018) [2]. Since 2013, aquaculture production has exceeded that of wild fisheries (FAO, 2020) [3]. Over the past 50 years, scientific advances and the introduction of new technologies in the development of aquaculture have contributed to its rapid development (Yeu, Shen, 2021) [4]. Today, the production of products in the fish industry is associated with the progress of fish farming in inland waters, as well as fish farming and rearing. Industrial methods (Kalinina et al., 2020) [5]. Improving the efficiency of fisheries can be achieved through intensification of production, as well as the introduction of new aquaculture facilities with rapid growth. Improved technologies in relation to the reproductive system of fish have allowed people to shorten the life cycles of aquaculture species, which ensures the diversification of species in aquaculture (Weber, Lee, 2014) [6]. This allows you to get marketable products in the shortest possible time with minimal labor and material costs (Ndimele, Owodeinde, 2012) [7].

Clarias gariepinus may be considered one of the promising objects of cultivation in RAS. It is distinguished by its rapid growth, not whimsical to environmental conditions, which provides low equipment costs, as well as the ability to grow at high stocking densities (Kareem et al., 2017; Puspita, Sari, 2018) [8, 9]. The chemical composition of the muscles and caviar of the African catfish indicates the high nutritional value of the representatives of this fish species, since they contain a full range of amino acids, including a sufficient amount of essential amino acids. Scientists classify the African catfish as a food that reduces the risk of cardiovascular disease (Shadyeva et al., 2019) [10].

The biological characteristics of the African catfish allow not to spend a lot of energy on optimizing the environmental parameters in industrial cultivation methods; besides, catfish have a high efficiency of assimilation of consumed food (Owodeinde, Ndimele, 2011) [11].
At the same time, the African catfish, like many other aquaculture objects, at the early stages of development of ontogeny may be vulnerable to changes in environmental conditions. The optimum temperature of the African catfish is within the range of 25-28 °С, with these indicators, good growth and survival of the object was observed. However, temperatures below 25 °C are critical for this object. The correlation of growth and development processes is species-specific and plastic to varying degrees. In this regard, the search for ways to increase the efficiency of growing African catfish in artificial conditions continues, and in this process, an important role is played by the study of the features of the early ontogenesis of this species.

The task of the research was to study and analyze the duration of the embryonic development of the Clarias gariepinus (Burchell, 1822) during artificial cultivation, to determine changes in the rate of passage of the stages of development of the African catfish under different temperature conditions.

2. Object and research methods

The studies were carried out in the aqua complex of the coastal scientific expeditionary base "Kagalnik" of the Southern Scientific Center of the Russian Academy of Sciences in a closed water supply (RAS) and at the Federal State Budgetary Educational Institution of Higher Education "Astrakhan State Technical University".

The object of the study was the African catfish (Clarias gariepinus, Burchell, 1822).

The offspring were obtained from catfish breeders at the age of two years. The ratio of males and females participating in the spawning campaign was 1: 1. Spawning was carried out according to the proposed recommendations (Shourbela et al., 2014; El-Hawarry et al., 2016; Romanova et al., 2020) [12, 13, 14]. For the incubation of eggs, a Weiss apparatus was used. The grown African catfish larvae were kept in ICA pools with a volume of 400 liters.

During the entire research period, the main parameters of the environment were monitored. The indicators were within the technological norm: pH 7.5 with fluctuations of 6.5-8.2, oxygen 65-70% saturation, nitrites 0.17-0.19 mg N/l, nitrates 28-34 mg N/l.

The eggs were incubated in two temperature regimes: 25°C and 28°C.

The material for histological studies was fixed in Bouin's fluid, embedded in paraffin, and sections with a thickness of 7 μm were made. The obtained sections were stained with hematoxylin-eosin and photographed with an Olimpus BX 53 microscope.

The time of transition to mixed and then to exogenous feeding of the larvae was determined, and a detailed description of the stages of embryonic and postembryonic development of the African catfish was made. The morphological signs were determined, indicating the sequential onset of stages of the process of morphogenesis.

Statistical data processed using Student's t test.

3. Research results and their discussion

3.1 The embryonic period of growth of the African catfish

The embryonic period of the African catfish included several stages.

The first stage is swelling, formation of the perivitelline space and blastodisc (Olaniyi, Omitogun, 2013) [15]. The duration of the stage at different temperatures differed insignificantly, but at a temperature of 28.5°C it was 20 minutes, and at 25.5°C it was 25 minutes.

The second stage of embryonic development of the African catfish is the cleavage of the blastodisc to the formation of the blastula. The duration of the second stage at 28.5°C was 60 minutes, at a lower temperature (25.5°C) it was longer and lasted 1 hour 25 minutes.

The third stage of embryonic development is the overgrowth of the yolk with blastoderm. At this stage the death of 3% of fertilized eggs was noted at 25.5°C, and 4% at a temperature and 28.3°C. At the age of 3 hours 25 minutes, the end of gastrulation and closure of the yolk plug (blastopores) were observed at a temperature of 28.3°C, and at 25.5°C, the end of gastrulation was observed at the age of 4 hours 45 minutes.

The fourth stage is the differentiation of the head and trunk sections of the embryo (segmentation of the embryonic body begins). At a temperature of 28.5°C, the body of the embryo covered three-fifths of the circumference of the yolk after 8 hours 18 minutes, and at 25.5°C - after 8 hours and 45 minutes.
The formation of eye vesicles and the onset of segmentation of the mesoderm into somites occurred at the age of 10 h 45 min at 28.3°C, and at 25.5°C after 11 h 15 min.

The appearance of a slit-like depression in the eye rudiments and segmentation of the mesoderm at a higher temperature was observed at the age of 12 hours 28 minutes, and at a lower temperature - after 12 hours 58 minutes.

The fifth stage is the isolation of the tail section and the beginning of the movement of the embryo (continuation of the segmentation of the trunk section, the body of the embryo makes weak movements inside the shell). The yolk sac acquired a pear-shaped shape, the tip of the tail was elongated, reaching up to the head. The size of the embryo increased and filled almost the entire space of the egg. Embryo movements and heartbeat began after 14 hours and 10 minutes, at a temperature of 25.5°C and after 14 hours 40 minutes at 28.5°C.

The sixth stage is the exit of the embryo from the shell. The embryonic period of development of the African catfish in the envelope ranged from 18 h 15 min at a temperature of 28.5°C to 22 h 15 min at a temperature of 25.5°C. The duration of exit from the shell was 4 hours and 4 hours 30 minutes, respectively.

Should be noted that for the entire embryonic period, the difference in the onset of subsequent stages in the options under consideration ranged from 4-20 minutes at the initial stages of development to 30 minutes at the final stages of development of the African catfish. The length of the hatched larvae was 3.05–3.58 mm (on average 3.32 ± 0.16 mm).

The morphological characteristics of the hatched larvae were the same, the body color was golden yellow and translucent, without pigmentation. The yolk sac was greenish and transparent, with a volume of 0.80 ± 0.31 mm³, extended along the entire body. Body segmentation is complete. The eyes are large, not pigmented, and only below had a small black pigmented spot. The mouth was not open, and the head was tilted towards the yolk sac. The digestive tract was a short tube up to the back of the yolk sac. Two hours after hatching, the head was detached from the yolk sac. Blood circulation at this stage is poorly developed, represented only by a pulsating heart, consisting of the rudiments of the ventricle and atrium.

3.2 Postembryonic period of growth of the African catfish

On the 24-hour period after leaving the shell, the prelarvae were at rest for 6 hours, fed on the yolk sac, mainly lay on the bottom, then began to make translational movements at the bottom of the pool (Figure 1).

Fig. 1. Prelarvae of the African catfish, the first day after leaving the shell. Without coloring, magnification 200

On the second day after leaving the shell, the prelarvae switched to mixed feeding, due to the yolk sac and small forage invertebrates, the yolk sac was absorbed by 30% (Figure 2).
The prelarvae acquired the ability to move in jerks. After 7 hours, there was an exit to the "floating". The prelarval period of the African catfish was rather short, lasting 2–3 days.

On the third day, the yolk sac was absorbed by 70%.

On the fourth day, the larvae of the African catfish completely switched to external feeding.

As the part of the study, a histological analysis of preparations of the prelarvae and larvae of the African catfish was carried out. No significant morphological differences were found during the incubation of catfish in the studied temperature regimes.

After two days of growth, the yolk sac of the prelarvae was rather large. Most of the yolk remained unused. The developing digestive system was represented by the intestinal tube - a long canal lined with columnar cells (Figure 3).

After hatching, on the 3–4th day, the prelarvae of the clary catfish had forming branchial arches I, II, III, and IV, covered with cubic epithelium (Figure 4). Thus, on histological sections, four branchial arches were observed, between which there was a branchial cleft. The branchial arches are covered from above by the operculum. Hyaline cartilage was located at the base of the branchial arches. There was a thin blood vessel inside the gill arches. The branchial arches covered the branchial filaments, consisting of a blood vessel covered with young connective tissue. The filaments had small branchial lamellae covered with respiratory epithelium.
By the 4th day of growth, morphogenetic transformations in the mesonephros proceeded extremely rapidly. Thus, formed mesonephrons were found in the kidneys. Renal corpuscles, renal tubules of the first, second, third and fourth types, and intertubular tissue were noted.

Before the appearance of gills, the process of gas exchange in embryos and prelarvae of fish is carried out by various provisional adaptations, the degree of development of which is inversely related to the oxygen content in the water.

In the larvae, on the 5th day (Figure 5), after hatching, the atrium and the large stomach of the heart, the cavities of which were filled with embryonic blood, became distinguishable. The reproductive system begins to form (Figure 6).
Fig. 6. Reproductive system of African catfish larvae, magnification 200

4. Conclusion

Thus, in the early ontogenesis of the African catfish, heterochronism in the development of the main systems was established: the central nervous system and the digestive system are actively developing, the formation of the cardiovascular, respiratory and genitourinary systems occurs more slowly.

The duration of embryonic development inside the membranes was 18-22 hours.

The initial stages of development with a decrease in temperature changed insignificantly, as there was an addiction to these conditions. At different temperatures, the ratio of the stages of development of embryos changes. With changes in the stages of development, the ratio is constant, but with a decrease in the temperature factor, the stage of cleavage is reduced and the stripe of the embryo is formed. The stage of embryo formation increased and accounted for almost half of embryogenesis.

The duration of the larval period of the African catfish was 14 days at an optimum temperature of 28 °C and 15 days at 25°C. Consequently, the fry period lasted 30 and 32 days. In terms of the duration of embryogenesis and the timing of the release of free embryos, the indicators did not go beyond the norm. The percentage of ugly embryos (underdevelopment of the operculum, underdevelopment of the tail, head and fins) was small and amounted to 3.2%, in the first and 4% in the second temperature regime.

The data obtained on the development of the African catfish indicate that there was a slight decrease in the rate of embryonic development at a temperature of 25°C, compared with incubation at a temperature of 28°C. At the same time, the yield coefficient of juvenile fish was 82% at a temperature of 28°C and 85% at a temperature of 25°C.

Thus, incubation at a temperature below the optimum temperature of a given species makes it possible to obtain viable offspring, adapted to a change in temperature regime.

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