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Larval Development of the Blue Dolphin Cichlid (*Cyrtocara moorii* Boulenger, 1902): Morphological Changes

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ABSTRACT

In this study, the larval development of *Cyrtocara moorii* was examined morphologically and compared with other Cichlidae species. The important morphological changes and critical developmental stages that *C. moorii* larvae undergo were determined during the process from hatching up to 20 days. It was observed that the larvae had a large yolk sac, transparent bodies, and undeveloped fins in the first days. Important developmental events such as eye development, mouth opening, onset of free swimming behavior, fin formation, and increased pigmentation were recorded. It was determined that the larvae started free swimming between 6-9 days, the yolk sac was completely depleted on the 10th day, and the larval development was completed, reaching the juvenile form on the 15-20th days. When the larval development of *C. moorii* was compared with other Cichlidae species, species-specific differences were observed as well as some similarities. It is thought that these differences may be related to the ecological adaptations, reproductive strategies, and evolutionary history of the species. It is suggested that future research should comparatively examine the larval development processes of more Cichlidae species and elucidate the mechanisms underlying this diversity.

KEYWORDS: *Cyrtocara moorii*, Cichlidae, larval development, morphology.

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1. Introduction

The Cichlidae family is one of the most diverse and widespread groups among freshwater fish (Kocher, 2004). *Cyrtocara moorii* Boulenger, 1902, a species within this family, is endemic to Lake Malawi (Ribbink et al., 1983). In addition to playing a significant role in the lake ecosystem, *C. moorii* is also a widespread species in the aquarium trade (Stauffer & Hert, 1992). However, limited information is available on the larval development of this species. The aquarium fish trade is a significant industry on a global scale, with a market volume of billions of dollars annually (Livengood & Chapman, 2007). The Cichlidae family is one of the most popular and economically valuable groups in the aquarium trade (Helfman, 2007). Cichlid species obtained from the African Great Lakes region (Victoria, Tanganyika, and Malawi) are particularly interest to aquarium enthusiasts due to their color diversity, interesting behaviors, and reproductive strategies (Barley & Coleman, 2010). *C. moorii* is a cichlid species exported from Lake Malawi and commonly found in the aquarium trade (Stauffer et al., 1997). Understanding the larval development of this species is also crucial for aquarium breeding. Larval development in fish is a critical process from hatching to the juvenile stage (Balon, 1975). During this period, larvae grow rapidly, undergo organogenesis, and acquire the characteristics of adult individuals (Kendall et al., 1984). Larval development is of great importance for the survival, growth, and reproduction of fish (Fuiman & Werner, 2009). Furthermore, understanding larval development is fundamental for fish farming, fisheries management, and conservation efforts (Houde, 1987). Although studies have been conducted on the larval development of many species in the Cichlidae family (Holden & Bruton, 1994; Meijide & Guerrero, 2000), there is no detailed research on the larval development of *C. moorii*. Morphological examination of the larval development of this species will enable the understanding of ontogenetic processes and comparison with other Cichlidae species (Balon, 1986). This information will provide important clues about the species' biology, ecology, and evolutionary relationships (Meyer, 1993). Additionally, the findings will contribute to the aquarium breeding of *C. moorii*. The aim of this study is to examine and document the larval development of *C. moorii* in morphological detail. The findings will provide comprehensive information about the ontogeny of the species and allow comparative analyses with other species in the Cichlidae family (Stiassny & Meyer, 1999). Moreover, this study will serve as a foundation for future research on the larval development of *C. moorii* (Noakes, 1991). In conclusion, this research will make significant contributions to both the accumulation of fundamental biological knowledge and the aquarium industry.

2. Materials and Methods

Fish Material and Rearing Conditions

In this study, the dolphin cichlid (*C. moorii*) species belonging to the Cichlidae family was used. Two-year-old adult individuals were selected as broodstock. For egg production, colonies were established in 100-liter aquariums with a ratio of 1 male to 8 females. The broodstock was fed commercial aquarium fish feed three times a day. In the broodstock tanks, the water temperature was kept constant at 29°C (± 0.5°C), and the pH values were measured in the range of 7.6 - 8.3. During the production period, no water change was performed, and sponge filters were used for aeration. All broodstock was stocked simultaneously in the production tanks.

Egg Collection and Artificial Incubation

Spawning monitoring was carried out periodically between 08:00 and 18:00 during the day. When spawning was detected, the completion of spawning was awaited, and a few hours later, the female with a mouth full of eggs was regurgitated. The eggs taken from the female's mouth were subjected to artificial incubation under the same water conditions. Artificial incubation was carried out in 500 ml glass containers by agitating the eggs with water flow. Using a small water pump, water was continuously pumped into the glass containers containing the eggs, and during the incubation period, especially when the eggs had not yet hatched, they were kept in constant motion. This method prevented the eggs from fungal growth or death. Dead eggs were removed from artificial incubation. No disinfectants were used in artificial incubation, only clean water was used. The water temperature in artificial incubation was kept constant at 29°C (± 0.5°C).

Morphological Examinations

Physiological changes in the embryonic and larval development stages of eggs and larvae were monitored by photographing from the first day onwards. For morphological examinations, an Olympus BX51 research microscope (Tokyo, Japan) was used, and larvae were photographed with a Q Imaging Micropublisher 3.3 RTV camera (Canada) attached to the microscope. After the photographing process was completed, live specimens were returned to the incubation unit.

3. Results

The morphological changes that the dolphin cichlid (*C. moorii*) larvae undergo from the first day after hatching (Days After Hatching) until the juvenile stage are described below.

1 DAH (Days After Hatching): The newly hatched dolphin cichlid (*C. moorii*) larva possesses a large, egg-shaped yolk sac (Fig. 1). The body appears transparent, with the head proportionally larger than the body, and the eyes have not yet completed their development. Due to the body's transparency, the heart is visible externally. The fins are not formed and are in a primordial form (Fig. 1). The larva is on the bottom and can perform short-term tail movements.

2 DAH: The eyes have completed their development and have taken their normal form (Fig. 1). The larva still has a large yolk sac on the second day. The mouth has not opened. The formation of the pelvic fins can be observed. However, other fins have not formed (Fig. 1). The tip of the vertebra in the caudal fin is about to curve. The larva is still on the bottom today. Tail movements have increased compared to the first day. The body color is transparent. However, pigmentation has begun to increase in the head region.

3 DAH: The mouth has opened (Fig. 2). The notochord tip has curved. The ray formations in the caudal fin have become more distinct (Fig. 2). Free swimming has not started. The vertebral structure has further developed. Pigmentation continues to intensify, especially in the head region.

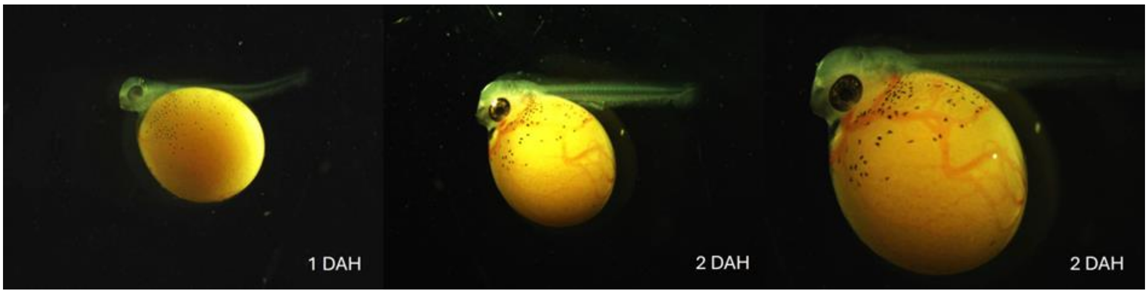

Figure 1. Larval development and morphological changes in the dolphin cichlid (*C. moorii*) at 1-2 days after hatching (DAH).

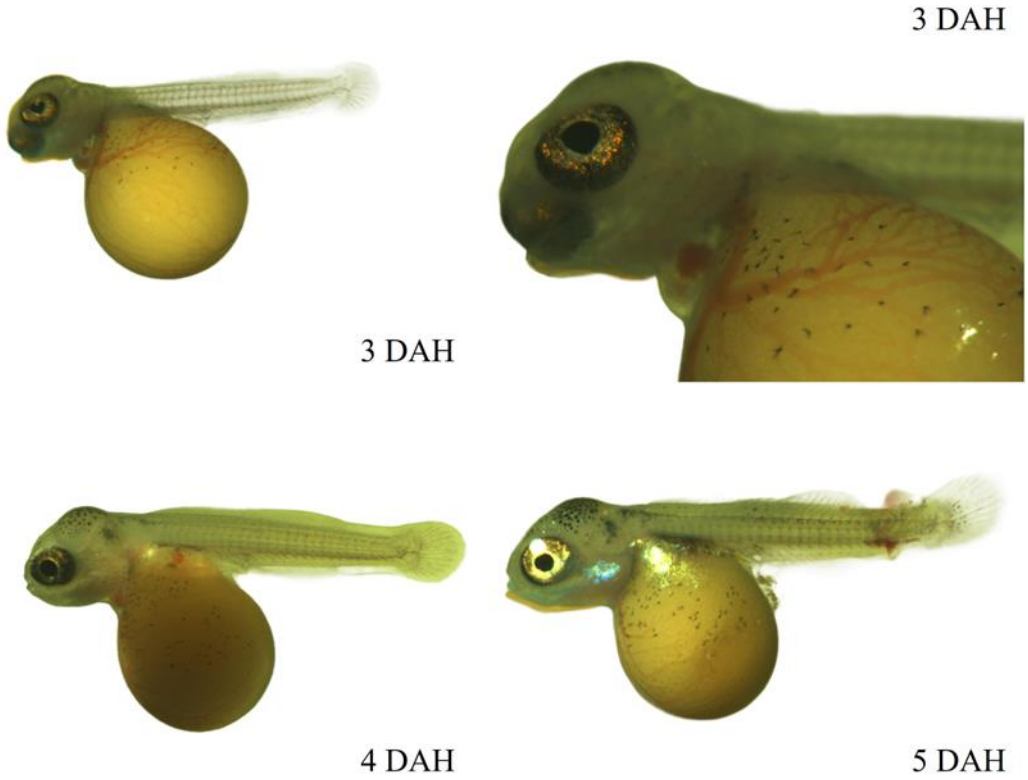

Figure 2. Larval development and morphological changes in the dolphin cichlid (*C. moorii*) at 3-5 DAH.

4-5 DAH: The larva still has a large yolk sac (Fig. 2). Dorsal and anal fin formations begin during these days (Fig. 2). The larva can perform short-term free swimming movements. The intensity of pigmentation in the head region has further increased (Fig. 2). Coloration in the remaining parts of the body is in the form of small black spots.

6-9 DAH: The yolk sac has continued to shrink day by day (Fig. 3). During these days, external food intake can be provided to the larvae. Free swimming has started on the 6th day. The duration of free swimming has extended with each passing day. The larva can now swim completely freely during these days.

10 DAH: The yolk sac has been completely absorbed (Fig. 4). The dorsal and anal fin structures have become more distinct (Fig. 4). Pigmentation has spread throughout the body. The transparent appearance of the larva begins to disappear after these days.

11-13 DAH: The dorsal and anal fins are distinct (Fig. 4). However, they continue to develop. Body coloration is darker (Fig. 4). These days represent the transition stage between the larva and juvenile.

15-20 DAH: During these days, fin formations are completed, and the body is colored. The body form has transformed into the body form of the parents. Therefore, during these days, larval development is completed, and the transition from the larval stage to the juvenile stage has occurred.

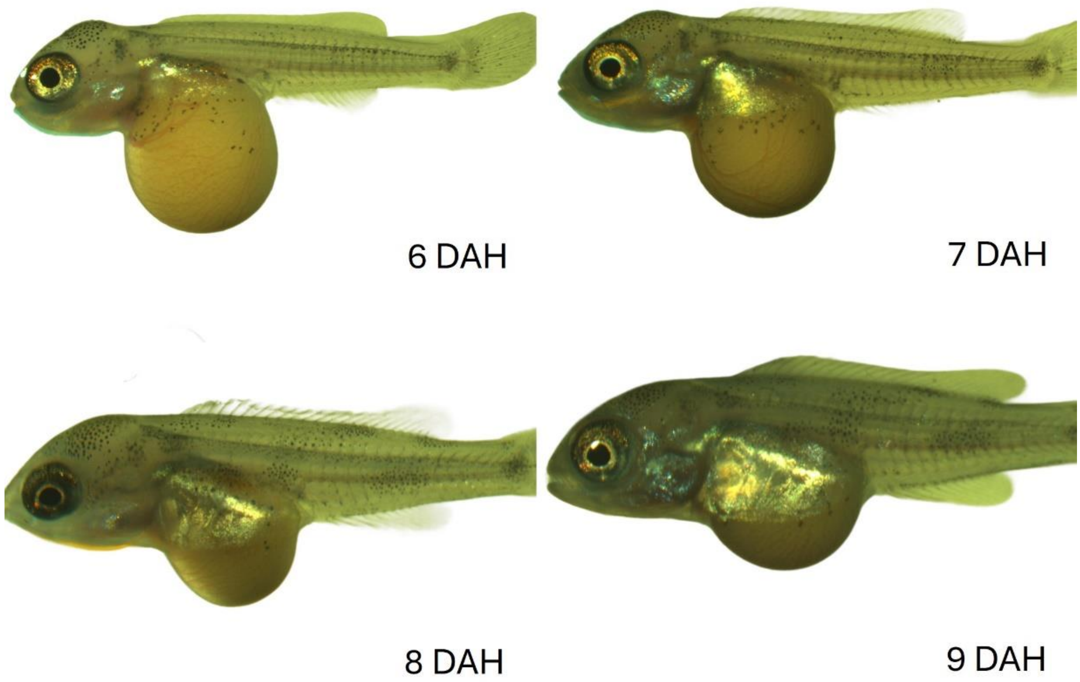

Figure 3. Larval development and morphological changes in the dolphin cichlid (*C. moorii*) at 6-9 DAH.

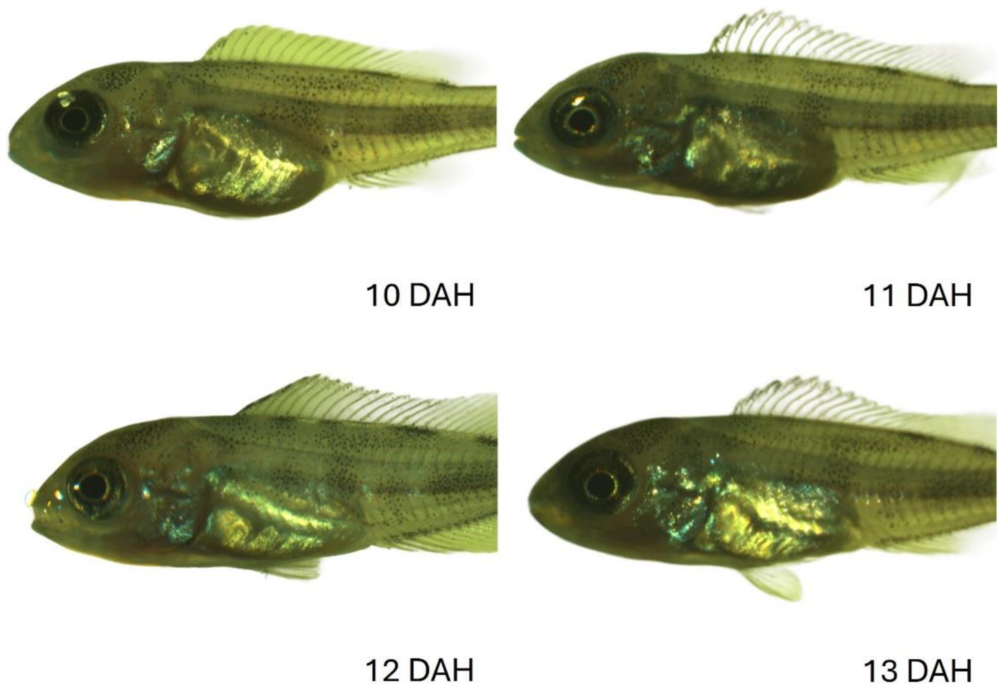

Figure 4. Larval development and morphological changes in the dolphin cichlid (*C. moorii*) at 10-13 DAH.

4. Discussion

The morphological development process of the dolphin cichlid (*C. moorii*) larvae after hatching shows similarities with the larval development processes observed in other cichlid species (Fujimura & Okada, 2007; Meijide & Guerrero, 2000). However, there are also some differences between species (Holden & Bruton, 1994).

In general, cichlid larvae exhibit common characteristics such as having a large yolk sac after hatching, transparent body structure, undeveloped eyes, and fins (Fujimura & Okada, 2007; Kratochwil et al., 2015). However, the rate and duration of development of these characteristics may vary among species (Meijide & Guerrero, 2000; Balon, 1999).

For example, in *Oreochromis niloticus* (Nile tilapia) larvae, mouth opening and free swimming behavior have been observed earlier compared to *C. moorii* (Rana, 1988). *O. niloticus* larvae typically exhibit free swimming behavior around 2-3 DAH, while in *C. moorii* larvae, this behavior starts between 6-9 DAH (Fujimura & Okada, 2008).

Moreover, pigmentation development may also differ among species (Stiassny & Meyer, 1999). In some cichlid species, such as *Amphilophus citrinellus*, larval pigmentation is observed earlier and more intensely (Kratochwil et al., 2015), while in *C. moorii* larvae, pigmentation development progresses more gradually (Baroiller et al., 2009).

In terms of fin development, the timing and rate of dorsal and anal fin formation can vary in different cichlid species (Sfakianakis et al., 2011). In some species, fin development is completed earlier, while in others, this process may take longer (Koumoundouros et al., 2001).

In Maylandia zebra (Zebra cichlid) larvae, the yolk sac is rapidly depleted during the first few days after hatching, and the larvae begin to feed externally (Holden & Bruton, 1994). M. zebra larvae exhibit free-swimming behavior at an earlier stage (approximately 4-5 DAH) compared to *C. moorii* (Fujimura & Okada, 2007).

In *Labidochromis caeruleus* (Yellow princess) larvae, the yolk sac is preserved for approximately 2-3 days after hatching, and the larvae remain motionless during this period (Balon, 1977). *L. caeruleus* larvae start free swimming at a later stage (7-8 DAH) compared to *C. moorii* and *M. zebra* (Fujimura & Okada, 2007).

In *Aulonocara jacobfreibergi* (Peacock cichlid) larvae, the yolk sac is rapidly depleted during the first few days after hatching, and the larvae begin free swimming around 3-4 DAH (Holden & Bruton, 1994). In *A. jacobfreibergi* larvae, pigmentation development starts earlier and progresses faster compared to *C. moorii* and *M. zebra* (Baroiller et al., 2009).

In *Satanoperca pappaterra* (Pappaterra cichlid) larvae, the yolk sac is rapidly depleted during the first few days after hatching, and the larvae begin free swimming around 3-4 DAH (Pandolfi et al., 2009). In *S. pappaterra* larvae, pigmentation development progresses gradually, similar to *C. moorii* and *M. zebra* (Meijide & Guerrero, 2000).

Astronotus ocellatus (Oscar cichlid) larvae are dependent on the yolk sac for approximately 3-4 days after hatching and have limited movement ability during this period (Shibatta & Dias, 2006). *A. ocellatus* larvae start free swimming at a later stage (8-10 DAH) compared to *C. moorii* and *S. pappaterra* (Shibatta & Dias, 2006; Pandolfi et al., 2009).

Pterophyllum scalare (Angelfish) and *Symphysodon discus* (Discus fish) larvae are protected and fed by their parents for an extended period (10-14 days) after hatching (Chellappa et al., 1999; Buckley et al., 2010). In these species, larvae do not exhibit free swimming behavior immediately after hatching, and pigmentation development also progresses more slowly (Cacho et al., 2006; Buckley et al., 2010).

Crenicichla lepidota (Pike cichlid) larvae are dependent on the yolk sac for approximately 2-3 days after hatching and have limited movement ability during this period (Nakatani et al., 2001). *C. lepidota* larvae start free swimming around 5-7 DAH, similar to *C. moorii* and *S. pappaterra* (Nakatani et al., 2001; Pandolfi et al., 2009).

These comparisons reveal the diversity in larval development processes among different cichlid species. In some species (e.g., *P. scalare* and *S. discus*), parental care continues for a longer period, while in other species (e.g., *C. moorii*, *S. pappaterra*, *A. ocellatus*, and *C. lepidota*), larvae become independent at an earlier stage. The onset of pigmentation development and free swimming behavior also varies among species. These differences may have been shaped by each species' ecological niche, reproductive strategy, and evolutionary history (Salzburger & Meyer, 2004; Sefc, 2011).

Future studies comparing the larval development processes of more cichlid species may help elucidate the mechanisms underlying this diversity. Additionally, understanding how differences in larval development processes relate to species' adult morphological and ecological adaptations could be an important research topic (Henning & Meyer, 2014; Sefc, 2011).

In conclusion, although there are some similarities in larval development processes among different cichlid species, species-specific differences are also observed. These differences may be related to species' ecological adaptations, reproductive strategies, and evolutionary histories (Salzburger & Meyer, 2004; Takahashi 2003). Future research comparing the larval development processes of more cichlid species may help illuminate the mechanisms underlying this diversity (Henning & Meyer, 2014).

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