Influence of Water Level on the Exit of Climbing Perch *Anabas testudineus* out of the Water and Specific Features of Its Movements

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Abstract—The study presents the behavior and movement characteristics of climbing perch *Anabas testudineus* in the “dry maze” installation. Two types of behavior were identified in climbing perch when the water level in the starting tank decreases to the critical value: waiting (often in a compact group at the bottom of the starting tank) or exit to ashore (land) and moving (migration). Movements usually take place in a group of two to four individuals. The fish chose a tank with the water randomly and remained there until the end of the experiment. If individuals become to an empty tank, they, as a rule, leave it and continue to search for water. Thus, the search for a new waterbody is determining the terrestrial migration of climbing perch.

Keywords: climbing perch *Anabas testudineus*, water level, migration behavior, the terrestrial migration

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INTRODUCTION

Migration is one of the most important evolutionarily formed adaptations aimed at increasing the species survival rate. In addition to feeding and spawning migrations, usually confined to a particular time of the year, fish migrations could be triggered by unfavorable habitat conditions, such as a decrease in food availability and water level, a reduction of the number of shelters, etc. (Olsson et al., 2006; Pavlov et al., 2007; Ferguson et al., 2019).

Climbing perch *Anabas testudineus* in contradistinction to most fish is able to move not only in water, but also on land. This species can remain outside the water for a long period due to breathing in a three-phase cycle of air change in the supragillary cavity, which process is not requiring water (Liem, 1987; Kasumyan et al., 2021). Terrestrial migration allows climbing perch to settle in the nearest unconnected waterbodies (Das, 1928; Smith, 1945; Liem, 1987; Davenport and Matin, 1990; Graham, 1997; Perera et al., 2013). Information about migrations and peculiarities of climbing perch orientation on land and the factors triggering terrestrial migrations are incredibly scarce (Kasumyan et al., 2021). It is known that the frequency of exiting out of the water in climbing perch is significantly increased with starvation and food competition in the waterbody (Liem, 1987). Earlier in the experiment (Pavlov et al., 2019) was shown that

jumping is one of the types of terrestrial migration in climbing perch, and the change in its frequency is also associated with fish starvation. Climbing perch migrate over land in the dark—at night or early morning (Das, 1928; Liem, 1987).

The goal of the present study is to experimentally estimate the influence of water level on the exit of climbing perch out of the water to land and investigate specific features of its movements in search of a new waterbody.

MATERIALS AND METHODS

The studies were carried out in January–February 2020 at the Coastal Branch of Russian-Vietnamese Tropical Research and Technological Center (Socialist Republic of Vietnam, Khanh Hoa province, Nha Trang). Climbing perch individuals (mean body length (*TL*) 71 ± 1.9 mm, body weight 12 ± 1.2 g) were captured in ponds (depth 70 cm, water transparency up to 30 cm, temperature 24°C) included in the system of rice fields, near Ninh Hoa City ($12^\circ30'34''$ N; $109^\circ09'40''$ E, Khanh Hoa Province). For the fish capture was using artificial shelters-traps. In the laboratory, individuals were kept in four 100 L aquariums at a water temperature of $25\text{--}26^\circ\text{C}$, with 25 specimens in each. The aquarium was filled with water on a half (50 L) and covered with glass lids (with a small gap for

Fig. 1. Installation “dry maze”: (a) top view, (b) starting tank, side view; (▨)—space accessible for climbing perch *Anabas testudineus* during the experiment; (----)—water level in the starting tank at the beginning of the experiment.

air access) to exclude attempts of climbing perch to jump out. During the acclimation period (for three days), in the aquarium water exchange was twice a day; on the following days, once a day. The fish were fed twice a day (at 07:00 and 19:00) with dry pelleted food Humpy Head (Yi Hu Fish Farm Trading, Singapore) with a pellet diameter of ~3 mm and an average weight of 10 mg; the nutrition was excessive. Most fish began to consume pelleted food within the first three days.

The study of terrestrial movements of climbing perch was in a specialized “dry maze” installation (Fig. 1a). The unit consisted of three tanks 0.4 m long and 0.4 m wide, and 0.5 m high. To exclude the possibility of fish jumping out of the tank, the water level was ≥ 32 cm under the height of the wall. In each tank were mounted ladders, going with an inclination of 27° from the bottom to the entrance of the horizontal passageway. The horizontal passageway no. 1 has a length of 0.8 m, going up to the intersection with passageway no. 2 with a length of 1.8 m. There was a tap to drain the water at the bottom of each tank, under the

ladder. The passageways were placed at the height of 0.2 m relative to the bottom of the tanks. The installation was made of white plastic. The ladders and the bottom of the passageways were covered with a yellow cotton fabric to increase the adhesion of the climbing perch to the surface. The white inner surface of the walls around the ladder is shaded with black oblique lines 2–3 mm wide to facilitate the visual orientation of the fish in the “dry maze” (installation). The inner side of the passageway walls was not shaded.

Fish in the “dry maze” and aquarium were kept in water that previously settled for at least three days in an accumulator basin. The starting tank was filled almost to the passageway level (18 cm height), and ten experimental fish were placed (Fig. 1b). At the beginning of the experiments, the fish had not eaten for ~18 hours. A plastic removable white partition blocked the exit from the starting tank to the passageway. The same water level was in one of the other two tanks, the last—remained without water, but the fabric on the ladder was moistened. The duration of fish acclimation was 20 min, and then the experiment was started: the partition was removed, and the tap was opened to drain water from the starting tank. The water level in the basin decreased from 18 to 0 cm in 5 minutes; its change was recorded using a video camera installed above the tank according to a scale applied to its wall. The air temperature in the “dry maze” was $26\text{--}27^\circ\text{C}$, the water temperature in the installation tanks and the aquarium in which the fish were kept was $25\text{--}26^\circ\text{C}$. The experiments were conducted from 7 am to 4 pm; illumination during this period varied from 215 lx in the daytime to 32 lx in the evening, averaging 153 lx (Amtast LX1330B light meter). The differences in illumination in the left and right parts of the passageway No. 2 did not exceed 16 ± 5.2 (1–55)¹ lx.

The fish movements in the passageways were recorded during the entire experiment (30 min) using a GoPro Hero 7 Black video camera. The camera was installed at a height of ~1.5 m above the passageways. The duration of each specimen stay in the tanks and their exit into the passageway was recorded with video cameras Yi Basic Edition and SjCam A10 mounted above them. Real-time monitoring and video recording were controlled remotely using a tablet and a smartphone with specialized software to prevent the fish react to the operator. The video records were used to determine: the number of air swallowed by the fish and the number of jumps out of the water; the time required for the fish to enter the passageways; the duration of stay in tanks No. 1 and No. 2; the direction of movements. The speed of fish movements along the passageways was calculated using specimens that did not make long stops (in total, for the transition from tank to tank >30 s) and moved mainly in one direction. The exit of climbing perch out of the water (to land)

¹ Hereinafter: before the brackets— $M \pm m$, into the brackets—min–max.

Fig. 2. Number of swallowing of the atmospheric air (□) and jumps out of the water (■) of climbing perch *Anabas testudineus* (totally 10 specimens) depending on the water level in starting tank; (I)—error of mean. Due to low variability of number of jumps no error of means for this parameter is given.

was taken when the fish completely climbed the ladder. In total, ten experiments were conducted on 50 specimens (each fish was used for experiments twice with a one-day break).

The data were processed statistically applying non-parametric analysis of variance (Kruskal–Wallis *H*-test) and Student's test for fractions.

RESULTS

During the 20-minute acclimation period in the starting tank, the fish swam freely, located at its bottom or on the underwater part of the ladder with their heads up. From time to time, climbing perch made jumps, directed mainly towards the walls of the tank, very rarely jumped onto the ladder.

At the beginning of the experiment, a decrease in the water level in the starting tank from 18 to 16 cm caused anxiety in the fish: they were swimming in the tank more active than during the acclimation period, more often moved to the water surface and swallow air, and approached the water's edge on the ladder. At a water level of 16–8 cm, the number of fish moves to the water surface for swallowing air was increased and decreased from a level of 6 cm and below (Fig. 2). On average, during the period when the water level dropped from 18 to 4 cm, five moves to the surface of the water were recorded with a group of 10 specimens. The change in the water level during the experiment in the starting tank is shown in Fig. 3.

Climbing perch jumps out of the water was observed at a level of 14 cm and below (Fig. 2). Non-parametric analysis of variance showed that the jumping frequency of fish depends (*H*-test: $p < 0.001$) on the water level—it increases with a decrease in the

Fig. 3. Dynamics of the water level drop (—) and exit of climbing perch *Anabas testudineus* specimens from the starting tank (■) during the first 10 min of the experiment.

water level 8–4 cm. Specimens equally (50%) jumped both towards the walls of the starting tank and on the ladder. When the water level was < 2 cm, the fish did not make jumps because they did not have enough depth for their implementation.

Two types of exit to the ladder were typical in climbing perch. The first was easygoing (crawling) with body and operculum movements. The second was a jump in the direction of the ladder, usually achieved with a hit on the first third of it. Individuals made an easygoing exit to the ladder when the water in the tank was present or completely absent. When fish were jumping onto the ladder, most of the fish individuals went out into the maze while the rest fish rolled back into the water. Climbing perch began to emerge on the ladder at a water level of < 3 cm (4th min of the experiment), and most intensively when it dropped to 0 cm: during the 5–6th min, more than half of the fish were exit from the tank and left it during the entire experiment or 36% of the total number of specimens (Fig. 3). Individuals significantly less often reached the trap (Student's *t*-test for fractions: $p = 0.0047$) individually (40% of all exited individuals) than in a group (2–3 specimens, less often 4), forming a chain in which the next fish rushed after the first one. As a rule, the distance between neighboring specimens moving in a group, did not exceed 1.5 total lengths (*TL*). The exit of fish in group mainly occurred at a water level of ≤ 1 cm. The group of fish remained in the passageways, but the length of their chain changed due to individual characteristics. Thus, individuals moving from behind could reach and overtake fish that had previously moved in front. In the passageways, the

Fig. 4. Scheme of directions (→) of moves of climbing perch *Anabas testudineus* in the “dry maze” and the proportion of fish in the tanks and passageways at the end of the experiments (□). Next to the arrows, the proportion of individuals moving during the experiment is indicated.

number of fish in the group never increased due to the adjoining specimens, but could disintegrate. From time to time, in the passageways, the fish stopped for a short time, then continued to move in the same direction as a rule. Upon reaching the intersection (passageway No. 2), the number of individuals in the group could decrease due to the choice by the fish of different directions of further movement.

At moving along the passageways, the fish mainly went along the walls. The time of movement of specimens from one tank to another (between any two tanks) was 75 ± 7.0 (18–292) s ($n = 83$). The noticeable variability is determined by the fact that some of the fish faster reached the new tank, while others moved more slowly, with frequent, sometimes long stops (>10 s), and changed the direction of movement. The speed of fish movement in the passageways was 4.3 ± 0.24 (1.6–10.6) cm/s ($n = 71$). The fish constantly rolled down the ladders, rolling over the longitudinal axis of the body.

By the end of the experiment, significantly more fish left the starting tank (69%, Student's test for fractions: $p < 0.001$) than remained in it (31%) (Fig. 4). The remaining specimens were lying at the bottom of the tank either individually or in groups, forming compact immobile aggregations. During the experiment, some of the fish that entered the maze could return to the starting tank. In some cases (16% of all speci-

mens), the fish that entered the passageways returned to the tank they left (starting or a tank without water). Later, they could exit into the passageways again. Individuals in approximately equal proportions (Student's test for fractions: $p = 0.30$) reached the tank with water (30%) or without water (37%). Differences in the illumination of the left and right parts of passageways No. 2 did not affect (H -test: $p = 1.0$) the direction of specimens' movement. Two-thirds of the fish that got into the dry tank left it after 2.5 ± 0.7 (0.6–11.2) min and moved along the passageways to the starting tank or tank with water. While moving from the dry tank, they sometimes met in the passageways with fish that had not reached this tank yet. At the same time, neither one nor the other individuals encountered changed the direction of movement. By the end of the experiments, 40% of fish were in the starting tank, 44 and 14% were in the tank with and without water, respectively, and only 2% of the fish remained in the passageways. Significantly (Student's test for fractions: $p = 0.0001$) more fish (44%, or 2/3 of the specimens that left the starting tank) were in the tank with water.

DISCUSSION

The study revealed that a decrease in the water level in the waterbody is one of the most important factors stimulating climbing perch to migrate overland. A decrease in the water level to almost zero within 5 minutes stimulates the fish to respond quickly: to move overland in search of a new waterbody. The water level ≤ 3 cm may be considered critical for the studied fish and experimental conditions at which the climbing perch begins to exit on land. Note that in the experiment, the tank was drained rapidly, which is not observed in nature. The influence of the rate of water level decline on the motivation of climbing perch to travel on land needs further research.

The climbing perch migrations overland are usually related to starvation and increased food competition (Liem, 1987). In our experiment, we used individuals that did not feed for ~18 h. During the acclimation period, noted no attempts for fish to exit along a ladder into the passageways of the installation. It indicates that this fasting period is insufficient for the climbing perch to leave the aquatic environment in search of food. Previous studies (Pavlov et al., 2019) showed that an increase in the migratory activity of climbing perch requires a longer fasting time of individuals (>2 days).

During a period of drought, climbing perch can burrow into the ground (Smith, 1945; Mookerjee and Mazumdar, 1946—cited in Datta et al., 1976) or crawl overland into new water bodies (Linke, 1992). In the present experiments, the fish exhibited different reactions to a decrease in the water level—while some individuals waited at the bottom of the starting tank, others were exit to land. Specimens who were waiting in unfavorable conditions commonly formed compact

groups at the bottom of the tank that allowed them to maintain body moisture longer apparently. Probably, such aggregation of fish, as well as their burrowing into the ground during drought, has an adaptive implication. The second type of behavior is aimed at an active search for new habitats—other waterbodies. The success of the type of behavior with a critical decrease in the water level completely depends on the environmental conditions that are formed further. At high air humidity and a nearby location of a new waterbody, an active search could be more favourable than waiting. At the same time, waiting allows fish to preserve energy resources for a long time, since the movement over land has a higher energetically value (Sayer and Davenport, 1991). We observed fishes initial reactions (time-limited to 30 min), while the two types of identified behavior were not stable. It was indicated by a change in the initial direction of movement of each specimen in the passageways, their return to the starting tank, and the exit of fish from the starting tank only at the end of the experiment. In contrast, a decreased rate of fish in the passageways till 2% to the end of the experiment indicates a different degree of motivation (different behavior) of fish to move over land.

Climbing perch could exit to land both individually and in groups (≥ 2 sp.). The probability of the exiting of fish in a group increased at a water level of ≤ 1 cm. The group movement of climbing perch in the maze was also maintained: however, at the intersection of passageways, the number of fish in a group may decrease as a result of the specimens individual reaction: the choice of a specific direction of move (towards tank no. 1 or no. 2). Earlier, we showed that the movement of climbing perch in the aquatic environment usually occurs in a group (Pavlov et al., 2020). Consequently, this species could maintain group behavior both in the water and on land. The configuration of a group of fish on land is probably possible only directly after leaving the tank. A group of moving fish could separate in the passageways but did not expand it with new members: oncoming specimens did not make a “follower” reaction. Note that climbing perch on the ladder was moved both individually and in a group, present an uncontrolled descent down: a roll along the longitudinal axis of the body. This phenomenon is also observed in nature when climbing perch rolls from a steep bank into the water with a splash (Smith, 1945).

In the experiments, climbing perch has searched a tank with water randomly. Thus, when the fish initially reached the intersection of the passageways, approximately in equal proportions, they turned both in the direction to the tank without water (37%) and with water (30%). Some specimens changed the direction of movement in the passageways to the opposite, which indicated an absence of specific landmarks. Moving in the maze, as a rule, proceeded until the fish found a tank with water: most of the specimens that initially got into the dry tank continued to search. The

fish that got in the tank with water did not attempt to leave it (mainly). Consequently, the search for water determined the terrestrial movement (migration) of climbing perch.

The average speed of climbing perch move in the maze was 4.3 cm/s (0.6 *TL*/s); the maximal rate was 10.6 cm/s. In nature, climbing perch overcomes over 90 m of a challenging route in about 30 min (5 cm/s) (Smith, 1945); in a laboratory experiment, the maximal speed of larger individuals (*TL* 14.3 cm) approached 25.6 cm/s (Davenport and Matin, 1990). Our data are consistent with these results. Obviously, the speed of climbing perch overland mostly depends on its physiological state and the composition of the ground.

An increase in the frequency of swallowing the air and the number of jumps, noted with a decrease in the water level, are indicated an acceleration in the fish stress. An expansion in the number of moves of climbing perch to the surface of the water for swallowing atmospheric air with a decrease in the water level has indicated an increase in respiration intensity: air exchange in the supragillary region of the labyrinth organ (Kasumyan et al., 2021). The frequency of climbing perch jumps could indicate increased migration activity (the initial type of terrestrial migration) (Pavlov et al., 2019, 2020). With a sufficient (> 2 cm) water level, jumping towards the ladder helps climb to land into the passageway of the “dry maze”. Jumps of climbing perch towards the bank could be considered as an innate reflex (primitive reflex) that helps exit to land, for example, on a steep bank slope.

It must be emphasized that, despite the variety of climbing perch movements in the “dry maze” installation, the move stops after the specimen enters the tank with water. This suggests that the only reason for fish to migrate overland is to seek water. There is no evidence that this search is targeted. Currently, in addition to absent information on the orientation of the climbing perch on land, there are no data on its group behavior outside the aquatic environment, the timing and period of migrations, which will become the subject of future study.

CONCLUSIONS

(1) A decrease in the water level to a critical value (< 3 cm), at which fish are not able to completely submerge in water, is a motivation for climbing perch exit to the ground.

(2) Two types of behavioral response to a decrease in the water level to a critical value were identified in climbing perch: waiting at unfavorable conditions on position, often in a compact group of fish, or terrestrial move (migration) in search of optimal habitat conditions.

(3) Under the experimental conditions, the search for a new waterbody is random.

(4) The fish movements in the maze ended when a new waterbody is found, i.e. the search for waterbody determines the terrestrial migration of climbing perch.

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COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interests. The authors declare that they have no conflicts of interest.

Statement on the welfare of animals. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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