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TEMPERATURE PREFERENCE AND TOLERANCE OF GRASS CARP *(CTENOPHARYNGODON IDELLA)*

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ABSTRACT

Grass carp, acclimated at 24 °C, were tested for temperature preference in a laboratory, horizontal gradient tank. After a 6-day period of exploration the grass carp gravitated to a final thermal preferendum of 35 °C. In the temperature tolerance test the ultimate upper incipient lethal temperature (TL50), was estimated as 41.5 °C. The results are compared to those of a similar study with hybrid carp (female grass carp x male bighead carp).

INTRODUCTION

Knowledge of temperature tolerance and preference of a fish species is valuable in understanding interactions between fish and their environment especially regarding distribution, growth, and viability. This paper reports on the temperature preference and tolerance of grass carp, *Ctenopharyngodon idella,* under laboratory conditions.

MATERIALS AND METHODS

The temperature preferendum experiment was conducted in a horizontal gradient tank filled with 160 l of water. The gradient tank was divided into six compartments (each 112 cm long × 66 cm wide × 36 cm deep) by plexiglass partitions having openings (15.5 × 13.5 cm) that could be closed by a sliding plexiglass plate. The static thermal gradient was maintained by the placement of a variable number of 200 and 150 watt immersion heaters in the compartments and a cooling coil at one end of the tank. Thermal stratification was prevented by aerating with air stones. A relatively uniform gradient existed in each compartment except occasionally in the area in or immediately adjacent to the intercompartmental openings. Water temperatures were measured at least 4 cm away from the openings when determining the mean water temperature of each compartment.

The grass carp used in this study were obtained from Malone's Fish Hatchery, Lonoke, Arkansas in April 1982. Twenty-one juvenile fish (total length range 250-300 mm, weight range 130-250 g) were individually marked by numbered anchor tags and were acclimated to 24 °C over a one month period prior to testing in the gradient. The fish were maintained on a diet of water cress *(Nasturtium sp.).*

On the 8th of August, 1982, at the end of the acclimation period, the grass carp were released into the compartment corresponding to their acclimation temperature. They were given two hours to adjust and settle down before the intercompartmental doors were opened. At 24 h intervals at approximately 1500 CST, the openings in the intercompartmental partitions were covered and the presence of fish and water temperatures in each of the compartments were recorded. The temperature preferendum experiment was conducted for 11 days employing the gravitational method. Due to the extended length of the study period, each of the compartments was provided daily with 100 g of water cress as a maintenance ration for the fish. Water clarity was somewhat reduced due to feeding but the fish could be clearly observed throughout the study. Uneaten plant remains were removed and water added periodically to make up for evaporative loss.

After completion of the temperature preferendum experiment, six grass carp (average total length and weight, 277 mm; 185.5 g) acclimated to 34 °C, were placed in a glass tank (89 cm long × 46 cm wide × 51 cm deep) with 170 l of water and aerated with air stones, to determine temperature tolerance (upper ultimate incipient lethal temperature). The water temperature was raised by 1 °C per day increments by the addition of hot water and was maintained thermostatically. At each of the test temperatures, the fish were observed for 24 h for the occurrence of mortalities. Criteria for death were cessation of body, fin, and opercular movements. The upper ultimate incipient lethal temperature (UUILT), (Cocking 1959), was estimated by interpolation at which 50% of the test population died (TL50). During the temperature tolerance test a small amount of water cress (<75 g) was provided for approximately the first hour after raising the test temperature.

RESULTS

Temperature Preferendum

Fish were released into the gradient at 24 °C, at all subsequent observations the fish were in compartments with a minimum temperature at or above 28.8 °C. There was evidence of exploratory behavior during the first six days of the study. During this exploratory period

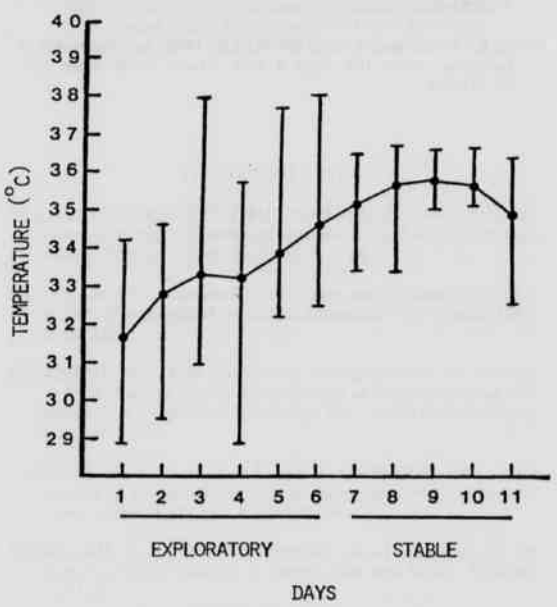

Figure. Daily mean preferred temperature and range of occurrence of grass carp in a thermal gradient.

Table. Frequency of occurrence of grass carp in the thermal gradient.

Temperature (°C)	Frequency of occurrence (%)	
	Exploratory phase	Stable phase
29	21.0	-
30	-	-
31	11.3	-
32	-	-
33	19.4	18.8
34	19.4	-
35	19.4	45.8
36	-	35.4
37	8.9	-
38	0.8	-

the fish had an average daily water temperature range of occurrence in the gradient of 6 °C (Figure), with no clear mode in their distribution (Table). On the 3rd, 5th, and 6th days of the experiment, 7, 4, and 1 fish, respectively, were observed in compartments with a mean water temperature above 37 °C.

On the 7th through 11th days the fish had an average daily range of occurrence of 2.5 °C (Figure), indicating that they had stabilized around their final thermal preferendum. The final thermal preferendum was estimated to be 35 °C based upon the occurrence of a single mode during the stable period (Table). Schooling behavior was observed throughout the temperature preferendum experiment.

Temperature Tolerance

There were no mortalities up to the 41 °C test temperature, however all the fish died at 42 °C. The UUILT was estimated as 41.5 °C. The observed normal feeding activity of entering vegetation clumps, and tearing loose and consuming plant material was observed up through 40 °C. From 34 to 40 °C schooling behavior was not affected and no apparent change in opercular movements were observed. At 41 °C feeding activity was markedly reduced, opercular movements were increased, and the fish often swam with their mouth near the air-water interface. The fish did, however, maintain at least some schooling behavior. At 42 °C the fish showed no interest in feeding. Opercular movements became very fast, the fish were nervous or excitable, moving around constantly and erratically, and surfacing frequently. At 42 °C the fish died within 2.5 h.

DISCUSSION

The thermal preference test was conducted for an extended period of time (11 days), thus each compartment was provided daily with water cress. All compartments received the same amount of food, thus availability probably had little effect on the results.

The final thermal preferendum of grass carp (35 °C), was much higher than the temperatures reported for spawning activities, 14 to 22 °C, (Kuronuma, 1958; Martino, 1974). Due to the lack of published information concerning the temperature preferendum and tolerance of Chinese carps, comparisons are made with that of a hybrid carp, female grass carp × male bighead carp *Aristichthys nobilis* (Kilambi and Galloway, 1985).

It has been reported that for most fish species of North America, one to three days in the thermal gradient is sufficient time for the final thermal preferendum to be reached, (Richards et al., 1977; Reynolds and Casterlin, 1979). In this study the exploratory phase represents that part of the test period when the fish are still gravitating to the final thermal preferendum and are exploring a relatively wide range of available temperatures. The stable phase represents that part of the test period when the fish have gravitated to the final thermal preferendum and are exploring a relatively narrow range of available temperatures. Both the grass carp and hybrid carp had extended exploratory phases, of 6 and 9 days, respectively. The ranges of temperatures being encountered during this phase were relatively greater than during the stable phase; 6 vs 2.5 °C for grass carp and 4.5 vs 1.3 °C for the hybrid carp. During the exploratory phase the grass carp had a steady upward gravitation toward the final thermal preferendum (35 °C), and only a few fish explored temperatures as high as 38 °C. The grass carp thus avoided temperatures near the UUILT (41.5 °C). In contrast, Kilambi and Galloway (1985), showed a bimodal distribution during the exploratory phase for the hybrid carp. The hybrid carp had a nine day exploratory phase. On the first day they explored temperatures 3 to 9 °C above their final thermal preferendum and near their UUILT of 39.2 °C with some occurrence of mortalities due to heat stress. Then the fish gravitated downward to temperatures near their final thermal preferendum for two days followed by a second upward gravitation to a temperature of approximately 34 °C. Subsequently, the hybrids gravitated to a final thermal preferendum of 29 °C.

In the temperature tolerance experiment, the grass carp remained behaviorly unstressed up to 40 °C. At 41 °C the fish showed signs of heat stress, however, the grass carp were still exhibiting at least some schooling behavior. After raising the temperature to 42 °C, grass carp moved as very excitable individuals, opercular movements were rapid, and all fish lost equilibrium and died within 2.5 h, thus the UUILT was determined as 41.5 °C. In contrast the hybrid carp exhibited stress as early as 35 °C, when schooling and feeding behavior were first effected (Kilambi and Galloway, 1985). Schooling behavior ceased at 37 °C with one fish surviving as high as 41 °C. The UUILT was estimated as 39.2 °C.

Studies of both the grass carp and hybrid carp indicate that extended studies may be necessary to determine the final thermal preferendum of these subtropical-temperate species. The grass carp was similar to many species of North American fish as the difference between the initial (acute) preferred temperature and final thermal preferendum was less than 5 °C, and the gravitation was steady and upward with some evidence of overshooting. The hybrid carp behavior is unique with their two large overshoots of the final thermal preferendum, including exploration of highly stressful water temperatures near their UUILT by the majority of the fish. Further elucidation of this phenomenon will await temperature preference and tolerance studies on the bighead carp.

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