Thermal tolerance of South American cichlid, Geophagus brasiliensis

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SUMMARY

The upper and lower lethal temperatures of Geophagus brasiliensis *were determined after acclimation at: 12.5, 15.0, 20.0, 25.0, 30.0 and 32.5 °C. For each acclimation temperature the upper lethal temperatures were: 32.9, 33.0, 35.1, 36.5, 38.5 and 38.5 °C, and the lower lethal temperatures: 8.0, 7.8, 9.5, 13.1, 16.0 and 17.8 °C respectively. The species presented a zone of thermal tolerance, calculated by plotting lethal temperatures against acclimation temperatures, equivalent to 703 °C², a low thermal tolerance when compared with most of the teleosts already studied.*

KEY WORDS : Lethal temperatures — Thermal tolerance — Acclimation — *Geophagus brasiliensis* — Fish.

RÉSUMÉ

TOLÉRANCE THERMIQUE DU CICHLIDE D'AMÉRIQUE DU SUD, *Geophagus brasiliensis*

Les températures léthales supérieures et inférieures de Geophagus brasiliensis *furent déterminées après acclimatation à: 12,5, 15,0, 20,0, 25,0, 30,0 et 32,5 °C. Pour chaque température d'acclimatation, les températures léthales supérieures furent: 32,9, 33,0, 35,1, 36,5, 38,5 et 38,5 °C, et les températures léthales inférieures: 8,0, 7,8, 9,5, 13,1, 16,0 et 17,8 °C, respectivement. L'espèce présente une zone de tolérance thermique, calculée graphiquement en portant les températures léthales en fonction des températures d'acclimatation, équivalente à 703 °C². Cette tolérance thermique est basse comparée à celles de la majorité des téléostéens déjà étudiés.*

MOTS-CLÉS : Températures léthales — Tolérance thermique — Acclimatation — *Geophagus brasiliensis* — Poisson.

INTRODUCTION

The lethal limits of temperature have been studied for a relatively large number of fish species. Most of the researches carried out on the temperature effects of fishes have envolved: *a)* Lacustrine teleosts of temperate region, where the temperature varies from approximately 4 °C, in the winter, up to the summer temperatures, near to 23-24 °C (Brett, 1944). *b)* Fishes inhabiting polar regions, where the temperature is practically constant around — 1.8 °C (Scholander *et al.*, 1953). *c)* Fishes living in thermal springs, where the water temperature is normally few degrees below their upper lethal temperatures (Lowe and Heath, 1969; Brown and Feldmeth, 1971; Otto and Gerking, 1973; Otto, 1974). *d)* Fishes subjected to the effects of thermal pollution (Coutant, 1969; Bridges 1971; Cherry *et al.*, 1976). On this aspect few attention has been focused for tropical fishes which are commonly found living in rivers and lakes of very peculiar thermal regimes.

The cichlid, *Geophagus brasiliensis*, known in Brazil as "acará", is widely distributed in rivers,

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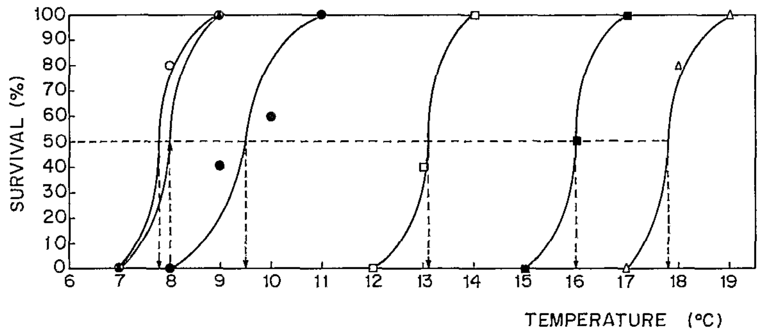

FIG. 1. — Lower lethal temperatures of *Geophagus brasiliensis* calculated graphically by plotting percentage of survival (y) versus temperature (x)

Températures léthales inférieures de Geophagus brasiliensis *calculées graphiquement en portant le pourcentage de survie (y) en fonction de la température (x)*

lakes and shallow waters of South America since the Amazon Basin until north of Argentina and Uruguay (AXELROD and SCHULTZ, 1955), experiencing many different thermal regimes. The temperature of the Amazon River and its marginal lakes and "várzeas" is normally very constant, ranging from 30 to 37 °C (MARLIER, 1965; JUNK, 1970). In Rio Grande do Sul State, southern Brazil, the rivers, streams and ponds present temperatures since 11-12 °C, in the winter, until 27-28 °C in the summer.

The main purpose of the present study is to determine the temperature range at which *G. brasiliensis* can be acclimated and its degree of eurythermicity by settling the upper and lower thermal lethal limits for the different acclimation temperatures.

MATERIAL AND METHODS

Adult specimens of *Geophagus brasiliensis* (mean total length = 10 cm) were collected in Broa Reservoir and Monjolinho Reservoir, state of São Paulo, Brazil. The fishes were kept in 3 tanks of 250 l provided with a system of water purification and aeration. Before and during acclimation to different temperatures the animals were daily fed on commercial fish food and living earth-worms.

To acclimate the fishes to low temperatures a climatic chamber of 250 l was specially developed. A Climax compact air-conditioning system was adapted to cool water and it was fitted with an electronic circuit of temperature control using a Jumo MS 121s contact thermometer as sensor. The circulation of water among the tank and the cooling system was done by means of an ordinary water pump.

Acclimation to high temperatures were carried out in a tank of 250 l coupled to a LP-201 MTA-Kutesz Ultrathermostat with circuits duly modified. Both the climatic tanks, for low and high temperatures, were also equiped with water aeration and purification systems.

Lower lethal temperatures were determined by using a 50 l test chamber endowed with a cooling system as described above. Measurements of the upper lethal temperatures were taken in a 50 l test chamber controlled by a 607 MTA-Kutesz Ministat.

The upper and lower lethal temperatures were determined according to an adaptation of the methods of HUNTSMAN and SPARKS (1924) and HATHAWAY (1927). Samples of 10 fish were placed in the test chambers and heated — or cooled — with a constant rate of 15°C per hour until the first individuals show the initial symptoms of thermal coma, like loss of equilibrium. Such a temperature was then kept constant for a period of 14 hours (BRETT, 1941; FRY *et al.*, 1942). After observation of the first test other experiments were conduced according to the same procedure in temperatures above and bellow of that of the initial test, in intervals of 1 °C, until obtaining 0 % and 100 % of survival of the samples. The lethal temperatures were calculated by graphical interpolation of the survival curves, obtained from the percentage of survival (y), plotted against test temperature (x). By this way the lethal temperature was defined as being the one at which 50 % of fish of the sample survive (FRY *et al.*, 1942; BLACK, 1953; OTTO, 1973). Although in the present study the survival curves were adjusted freely, they followed the tendency of the linear regression curve among the experimental points.

The lethal limits of temperature were determined according to the method of FRY *et al.* (1942). Before these determinations fish were acclimated to 12.5, 15, 20, 25, 30 and 32.5 °C. It was not possible to acclimate fish above 32.5 °C and bellow 12.5 °C since they started to die after 3 or 4 days of exposure at 35 °C and 10 °C respectively. Fish were considered fully acclimated after 4 weeks of exposure to each constant temperature. The temperature of climatic chambers was raised or lowered at the rate of 1 °C per day until the selected temperature for acclimation was reached.

RESULTS

The results of lower and upper lethal temperatures of *Geophagus brasiliensis*, for each acclimation temperature, calculated graphically from the survival curves are shown in the figures 1 and 2 respectively. No difference was obtained in the lower lethal temperatures for fish acclimated to 15 and 12.5 °C (fig. 1) and among fish acclimated to 30 and 32.5 °C (fig. 2), meaning that there was no further gains in

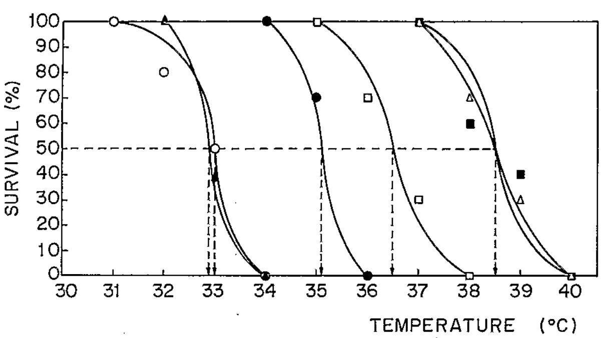

FIG. 2. — Upper lethal temperatures of *Geophagus brasiliensis* calculated graphically by plotting percentage of survival (y) versus temperatures (x)

Températures léthales supérieures de Geophagus brasiliensis *calculées graphiquement en portant le pourcentage de survie (y) en fonction de la température (x)*

both lower and upper lethal temperatures for fish acclimated below 15 °C and above 30 °C respectively.

Figure 3 presents the lethal limits of temperature or zone of thermal tolerance for *G. brasiliensis*. The area of the polygon delimited by the lethal temperatures was calculated as being of 703 °C².

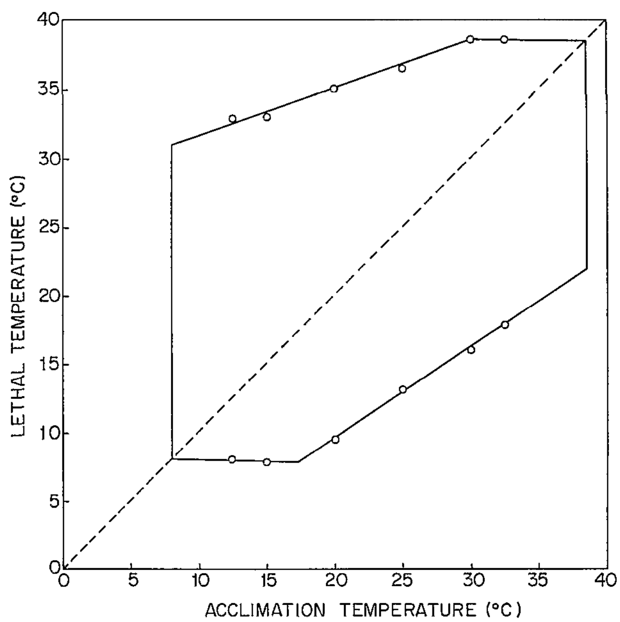

FIG. 3. — Thermal tolerance of *Geophagus brasiliensis*, calculated by plotting the upper and lower lethal temperatures versus acclimation temperatures. The area of the polygon correspond to 703 °C²

Tolérance thermique de Geophagus brasiliensis, *calculée en portant les températures léthales supérieures et inférieures en fonction des températures d'acclimatation. L'aire du polygone correspond à 703 °C²*

DISCUSSION

The lethal limits of temperature for *Geophagus brasiliensis*, corresponding to the degree of eurythermicity of this species, resulted in an area equivalent to 703 °C² (fig. 3). A comparison among the thermal tolerance of *G. brasiliensis* and 30 other species already studied is presented by the Table I, where it is observed that this fish is more stenothermal than most of those species.

The lethal temperatures of *G. brasiliensis* are close related to other species of cichlid. *Oreochromis mossambica* collected in South Africa showed lower lethal temperatures between 9 and 12 °C and upper lethal temperature around 38.2 °C after acclimation at 25-26 °C (ALLANSON and NOBLE, 1964; ALLANSON

Table I

Comparison among the thermal tolerance of some fish species already studied and that of *Geophagus brasiliensis*. (*) Marine species. (**) Antarctic species. (+) Compiled from Brett (1956). (++) Compiled from Brett (1970)

Comparaison entre les tolérances thermiques de la plupart des espèces de poissons déjà étudiées et celle de Geophagus brasiliensis. *(*) Espèces marines. (**) Espèces antarctiques. (+) Révision par* Brett *(1956). (++) Révision par* Brett *(1970)*

SPECIES	FAMILY	THERMAL TOLERANCE ($^{o}C^{2}$)	REFERENCES
Trematomus (**)	Nototheniidae	100(++)	Somero and De Vries (1967)
Oncorhynchus gorbuscha	Salmonidae	450	Brett (1956)
Oncorhynchus keta	Salmonidae	468	Brett (1952)
Oncorhynchus nerka	Salmonidae	505	Brett (1952)
Oncorhynchus kisutsh	Salmonidae	528	Brett (1952)
Oncorhynchus tshawytscha	Salmonidae	529	Brett (1952)
Spheroides maculatus	Tetraodontidae	550	Hoff and Westman (1966)
Salvelinus fontinalis	Salmonidae	625	Fry et al. (1946)
Pseudopleuronectes americanus (**)	Pleuronectidae	635-685	Hoff and Westman (1966)
Geophagus brasiliensis	Cichlidae	703	present study
Menidia menidia (*)	Atherinidae	715	Hoff and Westman (1966)
Perca flavescens	Percidae	742(+)	Hart (1947)
Notropis aterinoidea	Cyprinidae	747(+)	Hart (1947)
Catostomus commersonii	Catostomidae	770(+)	Hart (1947)
Rutilus rutilus	Cyprinidae	770	Cocking (1959)
Rhinichthys atratulus	Cyprinidae	790	Hart (1952)
Girella nigricans (*)	Kyphosidae	800	Doudoroff (1942)
Notropis cornutus	Cyprinidae	803(+)	Hart (1947)
Semotilus atromaculatus	Cyprinidae	808	Hart (1952)
Dorosoma cepedianum	Clupeidae	880(+)	Hart (1952)
Pimephales promelas	Cyprinidae	903(+)	Hart (1947)
Lepomis macrochirus	Centrarchidae	910(+)	Hart (1952)
Notemigonus crysoleucas	Cyprinidae	940	Hart (1952)
Micropterus salmoides	Centrarchidae	965(+)	Hart (1952)
Ictalurus lacustris	Ictaluridae	970(+)	Hart (1952)
Gambusia affinis	Poeciliidae	1110(+)	Hart (1952)
Gambusia affinis	Poeciliidae	1033-1065	Otto (1973)
Ictalurus nebulosus	Ictaluridae	1162	Brett (1944)
Carassius auratus	Cyprinidae	1220	Fry et al. (1942)

et al., 1971). *Oreochromis aureus* and *O. macrochir* displayed upper lethal temperatures of 39 °C against 36 °C for *Haplochromis mellandi* (Spaas, 1959). Reite *et al.* (1974) demonstrated that *Oreochromis alcalicus* (previously *Tilapia grahami*) from Lake Magadi, Kenya, when kept at 22-23 °C presented upper lethal temperature of 35-36 °C and 40 °C after acclimation at 35-38 °C. The lower lethal temperatures for this cichlid were around 12-16 °C. The critical thermal maximum and minimum for *Oreochromis niloticus*, cultivated in Brazil and acclimated at 20 °C, were respectively 40.7 °C and 8.2 °C, and 43.6 °C and 14.0 °C for fish acclimated at 38 °C (Fernandes and Rantin, 1983).

Studies on the lethal temperatures of newly collected *Geophagus brasiliensis*, adult and young, developed by Rantin (1980) during one year, showed that in the adults there is a gain of 1.6 °C on heat tolerance and a loss of 1.2 °C on cold temperatures, starting from winter and running into the summer month, whereas a 1.0 °C gain and a 1.0 °C loss were observed for the young fishes. Adults showed more tolerance to low temperatures than the young ones but no difference was observed in the upper thermal tolerance of both adult and young fishes.

The thermal tolerance of fishes, like other ectothermic organisms, is adaptatively related to the variations of temperature found by the animals in their natural habitat. Brett (1970) estimated the degree of eurythermicity for the nototheniid fish *Trematomus sp* (from the data of Somero and De Vries, 1967) as being of only 100 $^{o}C^{2}$ (Table I). These Antarctic fishes live in a region of very constant temperature, around — 1.8 °C, where the mean seasonal variation is approximately 0.1 °C (KINNE, 1970). In another way, the catfish, *Ictalurus nebulosus* of Lake Opeongo, Algonkin Park — Canada, subjected to a seasonal variation of near 20 °C, showed a degree of eurythermicity of 1 162 °C (BRETT, 1944), the second largest thermal tolerance among the teleosts already studied (Table I). The puffer, *Spheroides maculatus* (Tetraodontidae) studied by HOFF and WESTMAN (1966) presented an area of thermal tolerance of 550 °C² (Table I). For that study the samples of *S. maculatus* were collected in New Jersey coast, where the annual temperature variation of the Atlantic Ocean, according to SVERDRUP *et al.* (1963), is approximately 8-9 °C. Although in lower temperatures, this variation is very similar to that experienced by *Geophagus brasiliensis* in Broa Reservoir and Monjolinho Reservoir (winter: 16-17 °C; summer: 25-26 °C). Both *Geophagus brasiliensis* and *Spheroides maculatus* presented very similar tolerance polygon, not only by the low tolerance to cold temperatures but also by the shape of polygon, classified by PRECHT (1973) as being of ectothermic animals with moderate adaptation to cold and warm.

According to the observation above it is possible to suppose that *G. brasiliensis* adapted to different regions of South America present distinct thermal tolerances. The temperature variation of some Amazonian lakes was measured by BRAUN (1952) as being of 1.4 to 1.9 °C, between the dry and rainy season. Under those conditions *G. brasiliensis* would display a smaller degree of eurythermicity than the one observed in the present study, with more tolerance to high temperatures and much less tolerant to lower temperatures. In contrast, *G. brasiliensis* of Rio Grande do Sul would show also a peculiar thermal tolerance. The seasonal variation of temperature for rivers and lakes of that region is about 16 °C. In such a thermal regime it is expected that *G. brasiliensis* would be more tolerant to lower temperatures, consequently presenting a wide polygon of thermal tolerance.

Geophagus brasiliensis showed a gain of 1 °C for each alteration of 3.1 °C and 1.8 °C in the acclimation temperature, respectively for the upper and lower lethal temperatures. According to FRY (1971) the upper and lower lethal temperatures of teleosts generally change 1 °C for each alteration of respectively 3 °C and 2 °C in the acclimation temperature.

The ultimate lower and upper acclimation temperatures for *G. brasiliensis* were 12.5 °C and 32.5 °C, that is to say, approximately 3.5 °C below and 6.5 °C above the extreme mean temperatures of winter and summer found by the species in its natural environment, in the region where the specimens were collected. From the adaptative point of view this seems to be an important aspect since tropical aquatic environments are more subjected to variations in the upper temperatures during the summer and dry seasons than in the lower ones, even in a severe winter.

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