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Thermal tolerance and oxygen consumption of Indian Major Carps acclimated to four temperatures

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Abstract

Critical thermal maxima (CTMax), critical thermal minima (CTMin), lethal temperature maxima (LTMax) and lethal temperature minima (LTMin) were determined in Indian Major Carps (*Labeo rohita*, *Catla catla* and *Cirrhinus mrigala*) acclimated to 26°C, 31°C, 33°C and 36°C for 30 days. At each acclimation temperatures, CTMax, CTMin were 40.63, 41.91, 42.65, 42.86 and 13.73, 14.2, 15, 15.58 (*L. rohita*), 40.45, 41.39, 42.63, 42.73 and 13.92, 14.4, 15.2, 15.63 (*C. catla*), 42.25, 42.55, 42.76, 43.07 and 12.12, 13.7, 13.81, 13.95 (*C. mrigala*), respectively. Similarly, LTMax and LTMin at 26°C, 31°C, 33°C and 36°C were 41.16, 42.3, 43.06, 43.31 and 13.31, 14.71, 14.43, 14.9 (*L. rohita*), 41.03, 41.7, 42.96, 43.06 and 13.6, 13.95, 14.81, 14.98 (*C. catla*), 42.51, 42.93, 43.11, 43.68 and 11.9, 13.3, 13.45, 13.56 (*C. mrigala*), respectively.

Rate of oxygen consumption with and without acclimation were determined at 26°C, 31°C, 33°C and 36°C and were significantly ($p < 0.05$) different.

Final preferred temperature in Indian Major Carps was estimated through Q_{10} to be between 31°C and 33°C.

Thermal tolerance polygon values over entire range of tolerance region (12–40°C were 744.8°C^2 in *L. rohita*, 728.8°C^2 in *C. catla* and 801.8°C^2 in *C. mrigala*, respectively.

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Keywords: Critical thermal maxima; Critical thermal minima; Lethal temperature maxima; Lethal temperature minima; Thermal tolerance polygon; Preferred temperature; Oxygen consumption rate; Indian Major Carps; *Labeo rohita*; *Catla catla*; *Cirrhinus mrigala*

1. Introduction

Temperature affects virtually all biochemical, physiological activities of fishes. The survival and growth of poikilothermal teleosts are immediately influenced by temperature fluctuations in their environments. All teleostean species have developed their own specific adaptive mechanism, both behavioural and physiological, to cope up with temperature fluctuations (Prosser and Heath, 1991). These adaptive capabilities enable them to survive through acclimation and adaptation to stressful temperature conditions (Hazel and Prosser, 1974).

Higher temperatures up to certain limit favour aquaculture by reducing the time required to produce marketable sized animals and allow more generations per year. On the contrary, temperature adversely affects the health of the animal by increasing metabolic rate and subsequent oxygen demand, invasiveness and virulence of bacteria and other pathogens that cause a variety of pathophysiological disturbances in the host (Wedemeyer et al., 1999).

The United States National Research Council proposed that the global mean air temperature may increase

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by 1.5–4.5°C in the next half century (Beitinger et al., 2000). The potential effect of global warming makes important efforts to define thermal tolerance, temperature adaptation of fishes and their consequences on fish health. However, little is known about the adaptive responses of tropical fishes. Indian Major Carps (*Labeo rohita*, *Catla catla* and *Cirrhinus mrigala*) are widely cultured freshwater fishes throughout India, owing to their high commercial value. In this context, we investigated the thermal tolerance and oxygen consumption of Indian Major Carps at different acclimation temperatures. We also estimated the final preferred temperature for Indian Major Carps and their ability to maintain homeostasis by acclimation procedures.

2. Materials and methods

2.1. Animals

Advanced fingerlings of Indian Major Carps, i.e. *L. rohita*, *C. catla* and *C. mrigala* (mean weight ± SE: 30 ± 1.24 g, 28 ± 1.65 g and 25 ± 1.48 g), respectively, were brought from Pancham fish farm, Saphale, Maharashtra, to the wet laboratory of Central Institute of Fisheries Education, Mumbai and held in the laboratory (26 ± 1°C) for 30 days. During this period, fishes were fed with supplementary feed before thermal tolerance studies.

2.2. Acclimation of experimental fishes

(i) *For critical temperature maximum (CTMax), critical temperature mininum (CTMin), lethal temperature maximum (LTMax), lethal temperature minimum (LTMin) and oxygen consumption*: Acclimation of fishes (6/aquarium) was carried out in a thermostatic aquarium (52 l water capacity, sensitivity ± 0.2°C) to determine CTMax, CTMin, lethal temperatures (LTMax and LTMin) and oxygen consumption at, i.e. Δ5, Δ7 and Δ10 at 1°C day^{-1} from ambient temperatures (26°C) to reach test acclimation temperatures (26°C, 31°C, 33°C and 36°C) and maintained for a period of 30 days prior to the experiment. Pretrial acclimation periods and experimental acclimation temperatures suggested for conducting experiments in fishes remain as a debatable topic among physiologists across the globe. As there were no data available on acclimation studies on Indian Major Carps, CTM test on other fishes were considered for assessing the duration of acclimation in our test animals. Sheepshead minnow, *Cyprinodon variegatus* was completely acclimated to laboratory conditions after 30 days (Bennett and Beitinger, 1997). Therefore, we assume that the test animals were completely acclimated prior to CTM tests.

(ii) *For thermal tolerance polygon*: A similar experimental set-up was used for determining complete zone of thermal tolerance polygon of Indian Major Carps. Acclimation was carried out at 1°C day^{-1} from ambient temperature (26°C) to reach the test acclimation temperatures (12°C, 15°C, 20°C, 26°C, 31°C, 33°C, 36°C, 38°C and 40°C) and maintained for a period of another 30 days prior to the CTM studies. Below 12°C and above 40°C, fishes were not surviving throughout the acclimation period (30 days). Therefore, thermal tolerance polygon was carried out over a temperature range of 12–40°C in Indian Major Carps.

2.3. Experimental protocol

2.3.1. Critical thermal temperature and lethal temperature

Animals acclimated to a particular temperature were subjected to constant rate of increase or decrease (0.3°C/min) until loss of equilibrium (LOE) was reached. LOE was designated as CTMax and CTMin, respectively (Paladino et al., 1980; Beitinger et al., 2000). This technique has been critically evaluated by numerous workers (Hutchinson, 1976; Reynolds and Casterlin, 1979) and is well established as a powerful tool for studying the physiology of stress and adaptation in fishes (Paladino et al., 1980; Beitinger and McCauley, 1990). Dissolved oxygen concentration was maintained at 5.5 ± 0.5 mg l^{-1} throughout the temperature tolerance studies by continuous aeration using a 2HP centralized air blower. A similar experimental set-up was used for performing lethal temperature tests (LTMax and LTMin) at 26°C, 31°C, 33°C, and 36°C i.e. Δ5, Δ7 and Δ10 over average ambient temperature. LTMax and LTMin were determined by observing the cessation of operculum movement (Tushida et al., 1995).

2.3.2. Oxygen consumption

Relative oxygen consumption was measured at 26°C, 31°C, 33°C and 36°C i.e. Δ5, Δ7 and Δ10 over the ambient temperature (26°C). Acclimated fishes were kept individually in a sealed glass chamber (5 l) with 6.4 mm-thick glass lid, cut to cover the top portion completely. An opening in the lid fitted with a gasket to ensure an air-tight seal permitted the insertion of a dissolved oxygen probe. A magnetic stir bar was used to maintain constant water circulation. A plastic-mesh shield was placed over the stir bar to prevent incidental contact with the animal. The chamber was placed inside the thermostatic aquarium at their respective temperatures for an hour. All four sides of the aquarium were covered with opaque screen to minimize visual disturbances of the experimental animal. The initial and final oxygen content was measured using a digital oxymeter 330 (sensitivity $0.01\,mg\,O_2\,mg\,l^{-1}$) (Merck, Germany). Similarly another set of 24 fishes of all three species were acclimated to 26°C for 30 days. The test temperature was immediately increased to 31°C, 33°C and 36°C, so as to delineate the effect of a sharp increase of temperature vs. acclimation procedure on oxygen consumption rate. Temperature quotients (Q_{10}) in both cases were calculated to assess the acclimatory effect on oxygen consumption rate by using the formulae

$$Q_{10} = (\text{Rate 2}/\text{Rate 1})^{(10/\text{Temp 2}-\text{Temp 1})}.$$

Final preferred temperature was estimated from expected relationships between acclimation temperature and oxygen consumption. The final preferred temperature was determined by using the point where a drop in the Q_{10} becomes apparent (Kita et al., 1996).

2.3.3. Thermal tolerance polygon

Thermal tolerance polygon for the entire range of tolerance region of Indian Major Carps was determined by distributing a total of 108 fishes into nine acclimated temperatures groups (12°C, 15°C, 20°C, 26°C, 31°C, 33°C, 36°C, 38°C and 40°C) and CTMax and CTMin were determined (Beitinger et al., 2000). The thermal tolerance range was determined by the difference between CTMax and CTMin.

2.4. Statistical analyses

Acclimation temperature-dependent relation on the tested parameters (CTMax, CTMin, LTMax, LTMin, oxygen consumption with and without acclimation) in each species (*C. catla*, *L. rohita and C. mrigala*) were investigated by using one-way analysis of variance (ANOVA). The effect on acclimation temperatures and variations among the species on the above parameters were investigated by using two-way ANOVA. Post hoc test in both cases were carried out using Tukey's multiple comparison procedures, if they are significantly different. Two-way ANOVA were also used to delineate the temperature-dependent differences in thermal tolerance polygon (12–40°C range) due to different acclimation temperatures and between species. All the statistical analyses were performed via SPSS 11.0 for Windows.

3. Results

3.1. Critical thermal limit and lethal temperature

CTMax increased with increasing acclimation temperatures (26°C, 31°C, 33°C and 36°C) and the mean CTMax were significantly ($p<0.05$) different for all three species (Table 1). Similarly mean CTMin values also increased with increasing acclimation temperature and were significantly ($p<0.05$) different (Table 1). None of the test fishes died during a 24 h observation period subsequent to CTM trials. Means of LTMax and LTMin were also increased with increasing acclimation temperature (Table 1). Interspecific variation of all the parameters (CTMax, CTMin, LTMax, LTMin) were observed irrespective of acclimation temperatures and were significantly different ($p<0.05$) (Table 1). Species specific variation was evident at each acclimation temperatures (26°C, 31°C, 33°C and 36°C) for CTMax, CTMin, LTMax, LTMin except at 31°C (CTMin) and 33°C (LTMax) (Table 2). Highest CTMax and lowest CTMin values were observed in *C. mrigala* at all acclimation temperatures followed by *L. rohita* and *C. catla* (Table 3).

3.2. CTM thermal tolerance polygons

Thermal tolerance polygon over the entire range of tolerance region (12–40°C) was generated from mean CTMax and mean CTMin values based on 108 points for all the three species of our study. The values were recorded as 744.8°C^2 (*L. rohita*), 728.8°C^2 (*C. catla*) and 801.8°C^2 (*C. mrigala*), respectively (Fig. 1). Zone of thermal tolerance for *C. mrigala* was the largest among Indian Major Carps, followed by *L. rohita* and *C. catla* (Table 3) and were significantly different ($p<0.05$).

3.3. Metabolic activity

Relative oxygen consumption rates increased significantly ($p<0.05$) with increasing acclimation temperatures for all species (Table 1). Interspecific variation of oxygen consumption with and without acclimation was evident irrespective of acclimation temperatures ($p<0.05$) (Table 1) and at each acclimation temperatures (26°C, 33°C and 36°C) except at 31°C ($p>0.05$) (Table 2).

Q_{10} (between 26°C and 36°C) values after acclimation were 1.69, 1.73 and 1.66 in *L. rohita*, *C. catla* and *C. mrigala*, respectively (Table 2). Similarly Q_{10} (between 26°C and 36°C) without acclimation were 2.17 (*L. rohita*), 2.16 (*C. catla*) and 2.15 (*C. mrigala*), respectively (Table 2).

The highest Q_{10} values were recorded between 26 and 31°C acclimated temperatures in all three species, *Labeo rohita* (1.60), *Catla catla* (1.48) and *Cirrhinus mrigala* (1.69). The Q_{10} values between 31 and 33°C acclimated temperatures were *Labeo rohita* (3.79), *Catla catla* (3.53) and *Cirrhinus mrigala* (1.75). Between 33 and 36°C acclimated temperatures, Q_{10} values were *Labeo rohita* (1.09), *Catla catla* (1.41) and *Cirrhinus mrigala* (1.54) (data extracted from Table 1). These results suggest that the final preferred temperature of Indian Major Carps (*L. rohita*, *Catla catla* and *Cirrhinus mrigala*) is between 31 and 33°C.

Table 1
The effect on acclimation temperatures and species specific variations on CTMax, CTMin, LTMax, LTMin, oxygen consumption with and without acclimation of *C. catla*, *L. rohita* and *C. mrigala* acclimated to 26°C, 31°C, 33°C and 36°C

Parameters	Acclimation temperature (°C)	Species variation					
		C. catla	Mean±SE	*L. rohita*	Mean±SE	*C. mrigala*	Mean±SE
CTMax (°C)							
	26	40.45 ± 0.38^{a}		40.63 ± 0.17^{a}		42.25 ± 0.14^{a}	
	31	41.39 ± 0.38^{a}		41.91 ± 0.22^{b}		42.55 ± 0.01^{b}	
	33	42.63 ± 0.02^{b}		42.65 ± 0.01^{c}		42.76 ± 0.05^{bc}	
	36	42.73 ± 0.02^{b}	41.8 ± 0.65^{A}	42.86 ± 0.05^{c}	42.01 ± 0.45^{A}	43.07 ± 0.08^{c}	42.6 ± 0.3^{B}
CTMin (°C)							
	26	13.92 ± 0.01^{a}		13.73 ± 0.07^{a}		12.12 ± 0.22^{a}	
	31	14.40 ± 0.03^{b}		14.20 ± 0.25^{a}		13.70 ± 0.31^{b}	
	33	15.20 ± 0.09^{c}		15.00 ± 0.18^{b}		13.81 ± 0.22^{b}	
	36	15.63 ± 0.13^{d}	14.7 ± 0.35^{A}	15.58 ± 0.06^{b}	14.6 ± 0.4^{A}	13.95 ± 0.10^{b}	13.4 ± 0.45^{B}
LTMax (°C)							
	26	41.03 ± 0.38^{a}		41.16 ± 0.17^{a}		42.51 ± 0.14^{a}	
	31	41.70 ± 0.38^{a}		42.30 ± 0.22^{b}		42.93 ± 0.01^{ab}	
	33	42.96 ± 0.02^{b}		43.06 ± 0.01^{c}		43.11 ± 0.05^{bc}	
	36	43.06 ± 0.02^{b}	42.2 ± 0.45^{A}	43.31 ± 0.05^{c}	42.4 ± 0.4^{B}	43.68 ± 0.08^{c}	43.06 ± 0.2^{C}
LTMin (°C)							
	26	13.60 ± 0.01^{a}		13.31 ± 0.07^{a}		11.90 ± 0.22^{a}	
	31	13.95 ± 0.03^{b}		13.71 ± 0.25^{a}		13.30 ± 0.31^{b}	
	33	14.81 ± 0.09^{c}		14.43 ± 0.18^{b}		13.45 ± 0.22^{b}	
	36	14.98 ± 0.13^{d}	$14.3 + 0.03^{A}$	14.90 ± 0.06^{b}	14.09 ± 0.3^{B}	13.56 ± 0.10^{b}	13.05 ± 0.35^{C}
Oxygen consumption (with acclimation) $mg\,O_2\,kg^{-1}\,h^{-1}$							
	26	81.00 ± 1.65^{a}		72.33 ± 2.17^{a}		70.33 ± 1.35^{a}	
	31	98.66 ± 2.72^{b}		91.66 ± 2.21^{b}		91.55 ± 1.66^{b}	
	33	127.00 ± 2.26^{c}		119.66 ± 1.76^{c}		102.50 ± 2.26^{c}	
	36	140.83 ± 2.28^{d}	111 ± 12^{A}	122.83 ± 1.40^{c}	101 ± 10.5^{B}	116.83 ± 1.30^{d}	95 ± 8.5^{C}
Oxygen consumption (without acclimation) $mg\,O_2\,kg^{-1}\,h^{-1}$							
	26	81.16 ± 0.7^{a}		75.66 ± 1.85^{a}		69.83 ± 0.54^{a}	
	31	113.33 ± 4.66^{b}		106.00 ± 1.67^{b}		101.33 ± 3.15^{b}	
	33	134.50 ± 3.53^{c}		122.00 ± 3.32^{c}		118.33 ± 2.84^{c}	
	36	175.66 ± 3.56^{d}	125 ± 17.5^{A}	164.55 ± 1.46^{d}	$117 + 16.5^{B}$	150.33 ± 3.36^{d}	109 ± 15^{C}

Different superscripts (a, b, c) in the same column indicate significant difference amongst different acclimation temperatures in each species. Different superscripts (A, B, C) in the same row indicate significant difference ($p < 0.05$) (overall mean values) amongst different species (Turkey's multiple range test, $\alpha = 0.05$). Values are expressed as mean ± SE ($n = 6$).

4. Discussion

Over a range of acclimation temperatures of 26°C–36°C, CTMax and CTMin values increased significantly (Table 1) with increasing acclimation temperatures. These results are consistent with previous investigations on CTMin in *Lepomis gibbosus* L. (Becker et al., 1977), *Micropterus salmoides* Lacapede (Currie et al., 1998) and *Pygocentrus natteri* Kner (Bennett et al., 1997) and for CTMax in *M. salmoides* (Currie et al., 1998; Smith and Scott, 1975). However, our results suggest that species specific physiological responses are evident in response to thermal acclimation if similar life stages are considered (Tables 1 and 2).

Similarly lethal temperatures (LTMax and LTMin) were also determined over an acclimation range of

Table 2
Species specific variations on CTMax, CTMin, LTMax, LTMin, oxygen consumption with and without acclimation of *C. catla, L. rohita* and *C. mrigala* acclimated to 26, 31, 33 and 36°C. Values is parenthesis against each species indicate Q_{10} values (26–36°C). Different superscripts (a, b, c) in the same column indicate significant difference amongst different species at each acclimation temperatures ($p<0.05$). Turkey's multiple range test ($\alpha=0.05$).Values are expressed as mean ± SE ($n=6$)

Parameters	Species	Acclimation temperatures (°C)			
		26	31	33	36
CTMax (°C)					
	C. catla	40.45 ± 0.38^a	41.39 ± 0.38^a	42.63 ± 0.02^a	42.73 ± 0.02^a
	L. rohita	40.63 ± 0.17^a	41.91 ± 0.22^{ab}	42.65 ± 0.01^{ab}	42.86 ± 0.05^a
	C. mrigala	42.25 ± 0.14^b	42.55 ± 0.01^b	42.76 ± 0.05^b	43.07 ± 0.08^b
CTMin (°C)					
	C. catla	13.92 ± 0.01^a	14.40 ± 0.03	15.20 ± 0.09^a	15.63 ± 0.13^a
	L. rohita	13.73 ± 0.07^a	14.20 ± 0.25	15.00 ± 0.18^a	15.58 ± 0.06^a
	C. mrigala	12.12 ± 0.22^b	13.70 ± 0.31	13.81 ± 0.22^b	13.95 ± 0.10^b
LTMax (°C)					
	C. catla	41.03 ± 0.38^a	41.70 ± 0.38^a	42.96 ± 0.02	43.06 ± 0.02^a
	L. rohita	41.16 ± 0.17^a	42.30 ± 0.22^b	43.06 ± 0.01	43.31 ± 0.05^a
	C. mrigala	42.51 ± 0.14^b	42.93 ± 0.01^c	43.11 ± 0.05	43.68 ± 0.08^b
LTMin (°C)					
	C. catla	13.60 ± 0.01^a	13.95 ± 0.03^a	14.81 ± 0.09^a	14.98 ± 0.13^a
	L. rohita	13.31 ± 0.07^b	13.71 ± 0.25^b	14.43 ± 0.18^b	14.90 ± 0.06^a
	C. mrigala	11.90 ± 0.22^c	13.30 ± 0.31^c	13.45 ± 0.22^c	13.56 ± 0.10^b
Oxygen consumption (with acclimation) mg $O_2\,kg^{-1}\,h^{-1}$					
	C. catla (1.73)	81.00 ± 1.65^a	98.66 ± 2.72	127.00 ± 2.26^a	140.83 ± 2.28^a
	L. rohita (1.69)	72.33 ± 2.17^b	91.66 ± 2.21	119.66 ± 1.76^a	122.83 ± 1.40^b
	C. mrigala (1.66)	70.33 ± 1.35^b	91.55 ± 1.66	102.50 ± 2.26^b	116.83 ± 1.30^b
Oxygen consumption (without acclimation) mg $O_2\,kg^{-1}\,h^{-1}$					
	C. catla (2.17)	81.16 ± 0.70^a	113.33 ± 4.66	134.50 ± 3.53^a	175.66 ± 3.56^a
	L. rohita (2.16)	75.66 ± 1.85^b	106.00 ± 1.67	122.00 ± 3.32^b	164.55 ± 1.46^b
	C. mrigala (2.15)	69.83 ± 0.54^c	101.33 ± 3.15	118.33 ± 2.84^b	150.33 ± 3.36^c

26–36°C. LTM values were increased significantly with increasing acclimation temperatures. This result confirms that the thermal tolerance is largely dependent on fish's prior thermal exposure history or acclimation. As a result, typical seasonal acclimation allows fish to be more tolerant to higher temperatures in summer than in winter (Bevelhimer and Bennett, 2000). CTM values are also influenced by a variety of factors differential rate of change of temperature during thermal tolerance studies, size and condition factor (*K*) of the animals (Baker and Heidinger, 1996), as well as the presence of toxic chemicals (Beitinger et al., 2000). Our results suggest that species also influence the CTM values (Tables 1 and 2).

Of the three species tested, *C. mrigala* was the most tolerant fish followed by *L. rohita* and *C. catla*. Values were recorded as 744.8°C^2 (*L. rohita*) 728.8°C^2 (*C. catla*) and 801.8^2 (*C. mrigala*) (Fig. 1), respectively, over a range of 12–40°C. There is no parallel report on CTM test in these fish species. Indian Major Carps are known to be eurythermal due to their capacity to tolerate a wider range of temperatures (Kasim, 2002). The present investigation clearly indicates that *C. mrigala* is the most tolerant fish species among the Indian Major Carps. The reason may be due to their feeding habits. As they are bottom feeders, they are more physiologically adapted to adverse conditions. *C. catla* is the least temperature tolerant species. The same hypothesis may be applied to *C. catla* too. As they are surface feeders, they are accessible to better environmental conditions.

Metabolism is a physiological process reflecting the energy expenditure of living organisms. The metabolic rate of fish is usually indirectly measured as their rate of oxygen consumption (Brett, 1964, 1979; Kutty, 1968, 1981). In the present study, oxygen consumption rates were increased with increasing temperatures (Table 1)

Table 3
The effect on acclimation temperatures (12–40°C) on species specific variations of thermal tolerance polygon of *C. catla*, *L. rohita* and *C. mrigala* using two-way ANOVA

CTM values	Species variation		
	C. catla	*L. rohita*	*C. mrigala*
CTMax (°C)	40.31 ± 1.57[a]	40.61 ± 1.5[b]	41.13 ± 1.44[c]
CTMin (°C)	13.79 ± 1.06[a]	13.52 ± 1.1[a]	12.28 ± 1.20[b]

Different superscripts (a, b, c) in the same row indicate significant difference ($p < 0.05$) among different species Turkey's multiple range test ($\alpha = 0.05$). Values are expressed as mean ± SE ($n = 6$).

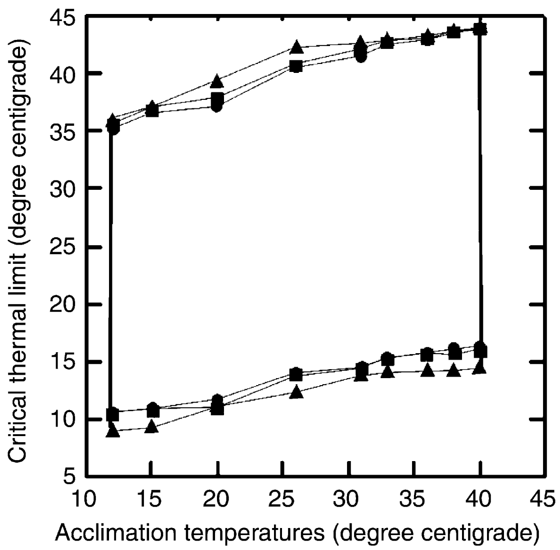

Fig. 1. Zone of thermal tolerance polygon (°C^2) of *C. catla* (—■—) *L. rohita* (—●—) and *C. mrigala* (—▲—) over 12–40°C range of acclimation temperatures using CTM values. The area of thermal tolerance polygon was calculated as 728.80°C^2 (*C. catla*) 744.8°C^2 (*L. rohita*) and 801.8°C^2 (*C. mrigala*), respectively. Two-way ANOVA of CTMax and CTMin with acclimation temperatures and species as main effects indicate significant difference among different species ($p < 0.05$) Turkey's multiple range test ($\alpha = 0.05$). Values are expressed as mean ± SE ($n = 6$).

suggesting increase in the total aerobic metabolism with rise in temperature (Kutty and Mohamed, 1975). The same trend was observed in all the species, when oxygen consumption rates were estimated without acclimation (Table 1). Oxygen consumption rate with and without acclimation are species specific (Table 2). This indicates that thermal tolerance and oxygen consumption of Indian Major Carps (*L. rohita*, *C. Catla* and *C. mrigala*) are dependent on acclimation period, acclimation temperatures and species. One of our investigation with *Macrobrachium rosenbergii*, a decapod crustacean revealed similar findings (Manush et al., 2004). Studies by Tsuchida (1995) and Kita et al. (1996) have reported that the preferred temperature coincides with the optimum temperature for growth (Brett, 1971; Kellog and Gift, 1983). The point where the Q_{10} for oxygen consumption starts to decrease with increasing acclimation temperatures also corresponds to the optimal temperature for growth (Kita et al., 1996). Thus the final preferred temperature may be estimated indirectly based on the relationship between oxygen consumption and acclimation temperature (Kita et al., 1996). In our study, the final preference temperature for Indian Major Carps was found to be in the range of 31–33°C.

The present investigation suggests that temperature adaptation is an essential physiological phenomenon in the life of poikilothermal organism and is strongly dependent on acclimation episode and temperature of their environment. Our investigation clearly indicates that *C. mrigala* shows remarkably high thermal adaptation owing to their specific ecological niches. So acclimation allows Indian Major Carps to themselves to new environment. This study supports that fishes have a remarkable resilience to altered temperature, especially with a prolonged time course and physiological changes during acclimation, which may help Indian Major Carps to adapt and accommodate global warming.

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