

DRAFT Largemouth Bass (*Micropterus salmoides*) Thermal Tolerance Analyses – Juvenile and Adult, Summer
January 2016

Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult bluegill sunfish and their justification are discussed below. The recommended tolerance values were developed in accordance with the “*DRAFT Methodology for Developing Thermal Tolerance Thresholds for Various Fish in Nevada – Juvenile and Adult, Summer*” (September 2015).

Chronic Thermal Tolerance Thresholds

Table 1 provides a summary of the range of chronic temperature tolerance values for bluegill sunfish for various lines of evidence. These values are based upon a review of 25 papers and publications, the details of which are summarized in Attachment A.

There is obviously a wide range of temperatures from which to select an appropriate value and best professional judgment is called for. NDEP’s approach is to accept the EPA recommendations from Brungs and Jones (1977) unless the literature review provides a compelling reason to utilize other values. EPA’s chronic value of 32°C falls within the upper end of the range of potential criteria found in the literature, and is recommended as the chronic thermal tolerance level for adult/juvenile bluegill sunfish. As discussed in the methodology, chronic temperature criteria are generally not set to ensure the most optimum conditions. In fact, Brungs and Jones (1977) recommends chronic criterion for a given fish species that is between the optimum temperature and the UUILT.

Table 1. Summary of Chronic Temperature Tolerances

Category	Temperature (°C)
Laboratory Optimal Growth Studies – Constant Temperature	
Optimum	25 – 32
Laboratory Optimum Temperature for Fastest Feeding Events	
Optimum temperature	25
Laboratory Temperature for Optimum Swimming Performance	
Optimum temperature	25 – 30
Laboratory Temperature Preference Studies	
Average Preferences	22 – 32
Final Preferendum	29.0 – 32.2
Laboratory Upper Temperature Avoidance Studies	27 – 39
Temperature Preference Field Studies	24 – 34
Thresholds from EPA and Colorado (MWAT)	32 – 31.4
Recommended Chronic Temperature Tolerance	32

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for largemouth bass for various lines of evidence. These values are based upon a review of 16 papers and publications, the details of which are summarized in Attachment B.

For ease of presentation, the UILT and CTM values have been summarized by acclimation temperature ranges. However as discussed in the methodology document, only the UILT and CTM values for acclimation temperature near the recommended chronic criterion (32°C) are to be included in the acute criterion development process. For largemouth bass, UILT and CTM values for acclimation temperatures 25 – 31°C and 30 – 36°C, respectively, are utilized for criterion development.

Table 2. Summary of Acute Temperature Tolerances

Category	Temperature Tolerances (°C)	Potential Acute Criteria (°C)
Laboratory Lethal Studies – UILT/UUILT		
UILT		
Acclim. = 10 – 15°C	30.0 – 31.5	
Acclim. = 15 – 20°C	31.8 – 32.5	
Acclim. = 20 – 25°C	28.9 – 34.5	
Acclim. = 25 – 31°C	32.7 – 36.4	29.7 – 34.4 ¹
Laboratory Lethal Studies – CTM		
Acclim. = 8 – 10°C	29.2 – 33.4	
Acclim. = 10 – 15°C	na	
Acclim. = 15 – 20°C	33.6 – 36.7	
Acclim. = 20 – 25°C	35.0 – 39.1	
Acclim. = 25 – 30°C	35.0 – 39.1	
Acclim. = 30 – 36°C	38.2 – 39.8	32.5 – 34.1 ²
Thresholds from EPA and Colorado		34 – 34.1
Recommended Acute Temperature Tolerance		34

¹UILT and UUILT values reduced by 2°C to provide 100% survival (see *Methodology*)

²CTM values reduced by 3.7°C to estimate quasi-UILT values. Quasi-UILT values then reduced by 2°C to provide 100% survival (see *Methodology*)

A review of laboratory studies suggest that an appropriate acute criteria should fall between 29.7 and 34.4°C. This is obviously a wide range from which to select an appropriate value and best professional judgment is called for. NDEP’s approach is to accept the EPA recommendations from Brungs and Jones (1977) unless the literature review provides a compelling reason to utilize another value. EPA’s acute value of 34°C falls within the upper end of the range of potential criteria found in the literature, and is recommended as the acute thermal tolerance level for adult/juvenile largemouth bass.

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ATTACHMENT A

Detailed Summary of Chronic Thermal Tolerance Values for Largemouth Bass, Juvenile and Adult, Summer

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Table A-1. Chronic Temperature Tolerances – Laboratory Optimal Growth Studies

Reference	Age or Size	Acclim. Temp. (°C)	Optimum Growth Temperature		Upper Optimum Growth Temperature	
			Temp. (°C)	Comment	Temp. (°C)	Comment
Coutant and Cox (1976)	Subadult 26–243 g	24.0 – 35.5	26 – 28			
Coutant and DeAngelis (1983)	Fry	17	27		30	The temperature range of fastest growth is 23 – 30°C.
Díaz et al. (2007)	Juvenile	20 – 32	28.1 – 28.6 ¹			
Lee (1969)			31 ²			
McCormick and Wegner (1981)	Juvenile	32 ³	32			
Niimi and Beamish (1973)	8-150 g	18 – 30	25			
Smagula and Adelman (1982)	Age 0 122-127 mm	14 – 26	25 – 30 ⁴			
Strawn (1961)	Fry	Unknown	27.5 – 30.0			

¹The theoretical temperatures for optimal growth for largemouth bass juveniles were calculated as 28.1 and 28.6°C. The difference between the preferred temperatures and optimum growth was only 0.5 - 0.9°C.

²Within the range of water temperatures tested (10 to 31°C), the food consumption and growth rates of largemouth bass fed to excess on mosquitofish increased with temperature.

³Study periods were 42 days after acclimation to test temperatures. Other test temperatures included: 28, 30, 34, 35, and 36.

⁴Optimal thermal conditions for glycine uptake by bass scales. Temperature of maximum uptake was associated with temperature of maximum body growth of largemouth bass which suggests that uptake may be integrated with growth.

Table A-1a. Chronic Temperature Tolerances – Laboratory Temperature for Fastest Feeding Events

Reference	Age or Size	Acclim. Temp. (°C)	Temperature for Fastest Feeding Events		Upper Temperature for Fastest Feeding Events	
			Temp. (°C)	Comment	Temp. (°C)	Comment
deVries and Wainwright (2006) ¹	157-190 mm	21 – 23	25			

¹25°C is the temperature at which the fastest feeding events occur for largemouth bass. deVries and Wainwright (2006) concluded that the rate of mouth opening during prey capture is fastest at the optimum temperature.

Table A-1b. Chronic Temperature Tolerances – Laboratory Optimum Temperature for Swimming Performance

Reference	Age or Size	Acclim. Temp. (°C)	Optimum Swimming Performance Temperature		Upper Optimum Swimming Performance Temperature	
			Temp. (°C)	Comment	Temp. (°C)	Comment
Hocutt (1973)	140 – 154 mm	27 - 31	30			
Johnson and Charlton (1960)	Fingerling	5 – 29	25			

Table A-2. Chronic Temperature Tolerances – Laboratory Preference Studies

Reference	Age or Size	Acclim. Temp. (°C)	Average Preference Temperature		Upper Preference Temperature		Final Preferendum	
			Temp. (°C)	Comment	Temp. (°C)	Comment	Temp. (°C)	Comment
Cincotta and Stauffer (1984)	Unknown						32.2	
Díaz et al. (2007)	Juvenile	20 – 32	27.1 – 29.2 ¹				29.0 – 28.1	
Koppelman et al. (1988)	Young of the year 50-60 mm	8	22.0 – 24.6					
		12	25.8 – 26.3					
		16	25.6 – 27.9					
		20	25.9 – 27.9					
		24	25.8 – 26.5					
		28	27.7 – 28.8					
		32	27.3 – 29.5					
Neill et al. (1972)			24 – 32					
Neill and Magnuson (1974)	<1 year 65-75 mm	20 – 22	29.0 ²					
Reynolds and Casterlin (1976)	100-150 mm	20 – 24	28.4 ³					
Reynolds et al. (1976)	50-460 g	24	30.2					
Reynolds and Casterlin (1978)	Yearling 100-200 g	22	27.1 – 29.5					
Venables et al. (1978)	Adult 232-1362 g	23	27 – 32					

¹In juvenile largemouth bass the preferred temperature estimated using the acute method was 29.0°C, and the influence of the acclimation temperature was not significant. In juvenile largemouth bass exposed to a light/dark cycle of 24 hours, the range of preferred temperature estimated using the gravitation method was 27.1-29.2°C, with a median value of 28.1°C.

²Preferred range midpoint. Median lower turnaround temperature = 27.5°C and median upper turnaround temperature = 30.5°C approximated from Figure 17.

³The preferred temperature was calculated by averaging the day and night modes, 30.0°C and 26.7°C respectively. The range of preferred temperature range was 21.7 – 33.3°C.

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Table A-3. Chronic Temperature Tolerances – Laboratory Upper Temperature Avoidance Studies

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
Cincotta and Stauffer (1984)	Unknown	6	27	
		12	30	
		18	33	
		24	36	
		30	36	
		36	39	

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Table A-4. Chronic Temperature Tolerances – Field Studies

Reference	Temperature (°C)	Comment
Block et al. (1984)	32 – 34	Small bass (<15 cm) occupied shallow water near shore where temperatures were 32 – 34°C.
	<31	Adults generally avoided temperature above 31°C.
Dendy (1948)	>26.7	
Eaton et al. (1995)	31.7	Based upon 95 th percentile of 5% highest weekly average temperatures.
Yoder and Gammon (1975)	24 – 31	Temperature range where largemouth bass were captured by electrofishing and in D nets in the summer.

Table A-5. Chronic Temperature Tolerances – EPA and Colorado

Reference	Temperature (°C)	Comments
EPA (1977)	32	Recommended level as MWAT
Colorado WQCD (2007)	31.4	Recommended level as MWAT
McCormick and Wegner (1981)	33.4 – 33.6 ¹	Recommended level as MWAT

¹The safe maximum weekly average temperature (MWAT) value was calculated as described in Water Quality Criteria 1972 published by the National Academy of Sciences and the National Academy of Engineering. 33.4°C is the safe MWAT for northern largemouth bass (Minnesota and Wisconsin) and 33.6°C is the safe MWAT for southern largemouth bass (Tennessee). Both geographic stocks are *Micropterus salmoides salmoides* (Lacepède).

ATTACHMENT B

Detailed Summary of Acute Thermal Tolerance Values for Largemouth Bass, Juvenile and Adult, Summer

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Table B-1. Acute Temperature Tolerances – Laboratory Lethal Temperatures, UILT/UIILT

Reference	Size or Age	Acclim. Temp. (°C)	Test Duration	UILT		UIILT	
				Temp. (°C)	Comment	Temp. (°C)	Comment
Black (1953)	5.1-127 g	20 – 21	24 hours	28.9			
Cvancara et al. (1977)	Young of the year 2.3 g 54.6 mm	25 – 31	48 hours	35.6			
Hart (1952)		20		31.8 – 32.5			
		25		32.7 – 34.5			
		30		33.7 – 36.4			
Hathaway (1927)	1-2 years	10	24 hours	30.0 – 31.5			
		21 ³		32.2			
		30		35.2 – 36.0			
McCormick and Wegner (1981)	Juvenile	22	24 hour	30.6 – 31.0			

Table B-2. Acute Temperature Tolerances – Laboratory Lethal Temperatures, Critical Thermal Maximum

Reference	Size or Age	Acclim. Temp. (°C)	Rate	Temperature (°C)	Endpoint
Carveth et al. (2006)	30-70 mm	25	0.3°C/min (18°C/hour)	37.8	Loss of equilibrium
				39.1	Death
Currie et al. (1998 and 2004)	Juvenile	20	0.3°C/min (18°C/hour)	35.4	Loss of equilibrium
		25		36.7	
		30		38.5	
		25 followed by 20 – 30 diel cycling		36.9	
Fields et al. (1987)	Juvenile 50-60 mm	8	0.2°C/min (12°C/hour)	29.2 – 30.8	Death
		16		33.6 – 34.4	
		24		36.5 – 37.9	
		32		40.9 – 41.9	
Guest (1985)	33-38 mm 0.4-0.5 g	30	0.001°C/min (0.083°C/hour)	39.4 – 39.8	Death
	81-99 mm 5.6-9.1 g	36		39.1 – 39.3	
		30		38.2 – 38.9	
	261-265 mm 200-218 g	30		38.8 – 39.1	
Lutterschmidt and Hutchinson (1997)	Unknown	10	1.0°C/min (60°C/hour)	30.7	Loss of equilibrium
				33.4	Onset of opercular spasms
Mulhollem et al. (2015)	250-370 mm	25	0.001°C/min (0.083°C/hour)	36.5 – 38.0	Cessation of opercular movement
Recsetar et al. (2012)	72-266 mm	25	0.3°C/min (18°C/hour)	35.0 – 35.4	Final loss of equilibrium
Smale and Rabeni (1995)	3.4-28.3 g	26	0.033°C/min (2°C/hour)	36.3	Loss of equilibrium

Table B-2. Acute Temperature Tolerances – Laboratory Lethal Temperatures, Critical Thermal Maximum (cont'd)

Reference	Size or Age	Acclim. Temp. (°C)	Rate	Temperature (°C)	Endpoint
Smith and Scott (1975)	Immature	20	1.0°C/min (60°C/hour)	36.7	Loss of equilibrium

Table B-3. Acute Temperature Tolerances – EPA and Colorado

Reference	Temperature (°C)	Comments
EPA (1977)	34	No metric (DM, MWMT, etc.) recommended
Colorado WQCD (2007)	34.1	Recommended level as DM