

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

Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult smallmouth bass 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 smallmouth bass for various lines of evidence. These values are based upon a review of 17 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 29°C falls within the range of potential criteria found in the literature, and is recommended as the chronic thermal tolerance level for adult/juvenile smallmouth bass. 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 – 26
Upper Optimum	29 – 33
Laboratory Optimal Temperature for Swimming Speed	
Optimum	20 – 30
Upper Optimum	33
Laboratory Temperature Preference Studies	
Average Preferences	20.2 – 31.3
Upper Preferences	23.7 – 35.1
Laboratory Upper Temperature Avoidance Studies	26 – 36
Temperature Preference Field Studies	18 – 29.5
Thresholds from EPA and Colorado (MWAT)	29
Recommended Chronic Temperature Tolerance	29

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for smallmouth bass for various lines of evidence. These values are based upon a review of 4 papers and publications, the details of which are summarized in Attachment B.

For ease of presentation, the UILT values have been summarized by acclimation temperature ranges (no studies were found which examined the Critical Thermal Maximum of juvenile/adult smallmouth bass. However as discussed in the methodology document, only the UILT/CTM values for acclimation temperature near the recommended chronic criterion (29°C) are to be included in the acute criterion development process. For smallmouth, CTM values for acclimation temperatures 26°C are utilized for criterion development.

Table 2. Summary of Acute Temperature Tolerances

Category	Temperature Tolerances (°C)	Potential Acute Criteria (°C)
Laboratory Lethal Studies – CTM		
Acclim. = 10°C	28.3 – 34.8	
Acclim. = 26°C	36.9	31.1 ¹
Other Studies		35
Thresholds from Colorado ²		34
Recommended Acute Temperature Tolerance		31

¹ CTM values reduced by 3.8°C to estimate quasi-UILT values. Quasi-UILT values then reduced by 2°C to provide 100% survival (see *Methodology*)

²EPA did not recommend an acute temperature threshold for smallmouth bass (Brungs and Jones 1977).

A review of laboratory studies suggest that an appropriate acute criteria should be around 31.1°C, while another study concluded that an acute value around 35.0°C would be appropriate. NDEP's general approach is to accept the EPA recommendations from Brungs and Jones (1977) unless the literature review provides a compelling reason to utilize another value. However in the case of smallmouth bass, there is no EPA acute threshold recommendation. It is recommended that the smallmouth bass acute threshold be based upon the CTM results and be set at 31°C.

References

- Barans, C.A. and R.A. Tubb. 1973. Temperatures selected seasonally by four fishes from western Lake Erie. *Journal of the Fisheries Research Board of Canada* 30:1697–1703.
- Bevelhimer, M.S. 1996. Relative importance of temperature, food, and physical structure to habitat choice by smallmouth bass in laboratory experiments. *Transactions of the American Fisheries Society* 125:274-283.
- Brungs, W.A. and B.R. Jones. 1977. *Temperature Criteria for Freshwater Fish: Protocol and Procedures*. EPA-600/3-77-061. Environmental Research Laboratory, Duluth, Minnesota.
- Cherry, D.S., K.L. Dickson, and J. Cairns Jr. 1975. Temperatures selected and avoided by fish at various acclimation temperatures. *Journal of the Fisheries Research Board of Canada* 32:485-491.
- Cherry, D.S., K.L. Dickson, J. Carns, Jr., and J.R. Stauffer. 1977. Preferred, avoided, and lethal temperatures offish during rising temperature conditions. *Journal of the Fisheries Research Board of Canada* 34:239-246.
- Colorado Water Quality Control Division. 2007. Colorado temperature database.
- Coutant, C. C. and D.L. Deangelis. 1983. Comparative temperature-dependent growth rates of largemouth and smallmouth bass fry. *Transactions of the American Fisheries Society* 112(3):416-423.
- Eaton, J.G., J.H. McCormick, B.E. Goodno, D.G. O'Brien, H.G. Stefan, M. Hondzo, and R.M. Scheller. 1995. A field information-based system for estimating fish temperature tolerances. *Fisheries* 20(4):10-18.
- Eaton, J. G., and R. M. Scheller. 1996. Effects of climate warming on fish thermal habitat in streams of the United States. *Limnology and Oceanography* 41:1109–1115.
- Gerber, G.P. and Haynes, J.M. 1987. Movements and behavior of Smallmouth Bass, *Micropterus dolomieu*, and Rock Bass, *Ambloplites rupestris*, in Southcentral Lake Ontario and Two Tributaries. Environmental Science and Biology Theses.
- Horning, W.B., II and R.E. Pearson. 1973. Growth temperature requirements and lower lethal temperatures for juvenile smallmouth bass (*Micropterus dolomieu*). *Journal of the Fisheries Research Board of Canada* 30:1226-1230.
- Larimore, R.W. and M.J. Duever. 1968. Effects of temperature acclimation on the swimming ability of smallmouth bass fry. *Transactions of the American Fisheries Society* 97:175-184.
- Lutterschmidt, W.I., and Hutchison, V.H. 1997. The critical thermal maximum: data to support the onset of muscle spasm as the definitive end point. *Canadian Journal of Zoology* 75:1553–1560.
- Reutter, J.M and C.E. Herdendorf. 1974. Laboratory estimates of the seasonal final temperature preferenda of some Lake Erie fish. *Proceedings of the 17th Conference on Great Lakes Research* 59-67.

Reutter, J.M and C.E. Herdendorf. 1976. Thermal discharge from a nuclear power plant: predicted effects on Lake Erie Fish. Ohio Journal of Science 76(1):39-45.

Reynolds, W.W., Casterlin, M.E. 1976. Thermal preferenda and behavioral thermoregulation in three centrarchid fishes. In Thermal Ecology II, Esch, G.W., McFarlane, R.W. (eds.). Energy Research and Development Administration. Springfield, VA.

Reynolds, W.W., Casterlin, M.E. 1978. Complementarity of thermoregulatory rhythms in *Micropterus salmoides* and *M. Dolomieu*. Hydrobiologia 60:89-91.

Smale, M. A., and C. F. Rabeni. 1995. Hypoxia and hypothermia tolerances of headwater stream fishes. Transactions of the American Fisheries Society 124:698-710.

Stauffer, J.R., K.L. Dickson, J. Cairns Jr. and D.S. Cherry. 1976. The potential and realized influences of temperature on the distribution of fishes in the New River, Glen Lyn, Virginia. Wildlife Monographs 50: 4-40.

Wehrly, K.E., M.J. Wiley, and P.W. Seelbach. 2003. Classifying regional variation in thermal regime based on stream fish community patterns. Transactions of the American Fisheries Society 132:18–38.

Wrenn, W.B. 1980. Effects of elevated temperature on growth and survival of smallmouth bass. Transactions of the American Fisheries Society 109:617-625.

ATTACHMENT A

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

DRAFT

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 DeAngelis (1983)	Fry	17	25 – 26		30	The temperature range of fastest growth is 23 – 30°C.
Horning and Pearson (1973)	Juvenile	15	26		29	This study indicates that juvenile smallmouth bass grow well in the 26 – 29°C range.
Wrenn (1980)	Mean length = 111 mm; mean weight 14 g	na			32 - 33	Wrenn concluded that a MWAT = 32 - 33°C would permit satisfactory growth

Table A-2. Chronic Temperature Tolerances – Laboratory Temperature for Maximum Swimming Speed

Reference	Age or Size	Acclim. Temp. (°C)	Temperature of Maximum Swimming Speed		Upper Temperature of Maximum Swimming Speed	
			Temp. (°C)	Comment	Temp. (°C)	Comment
Larimore and Duever (1968)	Fry 20-25 mm	5	20	The fastest swimming recorded was for fish acclimated to 30°C and tested at 30°C.	33	Optimum performance temperature for fish acclimated to 35°C.
		10	23			
		15	25			
		20	28			
		25	30			
		30	30			
		35	33			

Table A-3. 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
Barans and Tubb (1973)	Underyearling	23 ¹	29 – 31 ²		32.5	Highest temperature of 95% of observations.		
	Adult		30 – 31 ²					
Bevelhimer (1996)	239-299 mm 160-332 g	20	25.5					
Cherry et al. (1975)	> 1 year old	15	20.2		23.7	Upper 95% confidence limits on averages		
		18	22.9		25.3			
		21	26.5		27.2			
		24	29.8		29.5			
		27	30.1		32.2			
		30	31.3		35.1			
Cherry et al. (1977)	< 1 year old 50 – 100 mm	15	20.2		25.7	Upper 95% confidence limits on averages		
		18	25.5		26.6			
		21	25.8		27.5			
		24	28.2		28.8			
		27	29.7		30.6			
		30	30.9		32.6			
Reutter and Herdendorf (1974 and 1976)	YOY	Unknown ³					26.6 ⁴	
Reynolds and Casterlin (1976)	100-145 mm	20 - 24	30.3 ⁵		34.4	The range of preferred temperature was 25.6 – 34.4°C.		

Table A-3. Chronic Temperature Tolerances – Laboratory Preference Studies (cont'd)

Reference	Age or Size	Acclim. Temp. (°C)	Average Preference Temperature		Upper Preference Temperature		Final Preferendum	
			Temp. (°C)	Comment	Temp. (°C)	Comment	Temp. (°C)	Comment
Reynolds and Casterlin (1978)	Yearling 100-200 g	22	28.4		30.1	The range of preferred temperature was 26.6 – 30.1°C.		
Stauffer et al. (1976)	Unknown						30.8	

¹Acclimation temperature approximated from Figure 1 in Barans and Tubb (1973).

²The most frequently occupied temperatures, indicated by the range in 80% of the modal temperatures (C) selected within the gradient during the summer.

³The water temperature in the acclimation tank was maintained as close to lake temperature as possible (usually within 2°C of lake temperature).

⁴Final preferendum during a fall study. Reutter and Herdendorf (1974) found that winter preferenda were several degrees lower than summer preferenda. A summer study was not conducted for smallmouth bass by Reutter and Herdendorf (1974).

⁵The preferred temperature was calculated by averaging the day and night modes, 31.1°C and 29.4°C respectively. The range of preferred temperature range was 25.6 – 34.4°C.

Table A-4. Chronic Temperature Tolerances – Laboratory Upper Temperature Avoidance Studies

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
Cherry et al. (1975)	> 1 year old	15	26	
		18	27	
		21	30	
		24	31	
		27	31	
		30	33	
Cherry et al. (1977)	< 1 year old 50 – 100 mm	18	27	
		21	30	
		24	33	
		27	33	
		30	33	
		33	35	
Stauffer et al. (1976)	Unknown	18	27	
		21	30	
		24	33	
		27	33	
		30	33	
		33	36	

Table A-5. Chronic Temperature Tolerances – Field Studies

Reference	Temperature (°C)	Comment
Eaton et al. (1995)	29.5	Based upon 95 th percentile of 5% highest weekly average temperatures.
Gerber and Haynes (1987)	20 – 22	Smallmouth bass occupied 20-22 degrees Celsius temperatures in lake and tributary habitats when available.
Wehrly et al. (2003)	18 – 26	Mean temperatures at sites where smallmouth bass were present at average or above-average standing stocks ranged from 18°C to 26°C.

Table A-6. Chronic Temperature Tolerances – EPA and Colorado

Reference	Temperature (°C)	Comments
EPA (1977)	29	Recommended level as MWAT
Colorado WQCD (2007)	29	Recommended level as MWAT

ATTACHMENT B

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

DRAFT

Table B-1. Acute Temperature Tolerances – Laboratory Lethal Temperatures, Critical Thermal Maximum

Reference	Size or Age	Acclim. Temp. (°C)	Rate	Temperature (°C)	Endpoint
Lutterschmidt and Hutchinson (1997)	Unknown	10	1.0°C/min (60°C/hour)	28.3 – 34.8	Loss of equilibrium – onset of opercular spasms
Smale and Rabeni (1995)	4.2-13.5 g	26	0.033°C/min (2°C/hour)	36.9	Loss of equilibrium

Table B-2. Acute Temperature Tolerances – Other Studies

Reference	Comments
Wrenn (1980)	Wrenn concluded that a maximum temperature of 35°C for short-term exposure (24 hours) during the summer growth period would avoid lethal effects.

Table B-3. Acute Temperature Tolerances – Colorado

Reference	Temperature (°C)	Comments
Colorado WQCD (2007)	34	Recommended level as DM