DRAFT Green Sunfish (*Lepomis cyanellus*) Thermal Tolerance Analyses – Juvenile and Adult, Summer
March 2016

Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult green 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 green sunfish for various lines of evidence. These values are based upon a review of 7 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. However in the case of green sunfish, EPA does not provide a chronic thermal threshold recommendation.

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. Therefore, NDEP recommends a chronic value of 31°C which is within the upper range of the tolerances taken from the literature.

Table 1. Summary of Chronic Temperature Tolerances

Category	Temperature (°C)
Laboratory Temperature Preference Studies	
Average Preferences	10.6 – 30.6
Upper Preferences	16 – 34.6
Final Preferenda	27.3
Laboratory Upper Temperature Avoidance Studies	20 – 33
Temperature Preference Field Studies	20 – 31.7
Thresholds from EPA and Colorado (MWAT)	31.1
Recommended Chronic Temperature Tolerance (MWAT)	**31**

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for green sunfish for various lines of evidence. These values are based upon a review of 6 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 (31°C) are to be included in the acute criterion development process. For green sunfish, CTM values for acclimation temperatures 25 - 30°C are utilized for criterion development. The UILT value was not used in the analyses as the acclimation level was unknown.

Table 2. Summary of Acute Temperature Tolerances

Category	Temperature Tolerances (°C)	Potential Acute Criteria (°C)
Laboratory Lethal Studies – UILT/UUILT		
UILT		
Acclim. = Unknown	35.4	
Laboratory Lethal Studies – CTM		
Acclim. = 10 - 20°C	31.1 – 35.9	
Acclim. = 20 - 25°C	35.8 – 39.3	
Acclim. = 25 - 30°C	37.4 – 41.5[1]	31.6 – 35.6
Thresholds from Colorado	35.1	
Recommended Acute Temperature Tolerance (MDMT)	**34**	

[1]CTM values reduced by 3.8°C to estimate quasi-UILT values, and reduced by 2°C to provide 100% survival (See *Methodology*)

A review of laboratory studies suggest that an appropriate acute criteria should fall between 31.6 and 35.6°C. 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. However in the case of green sunfish, EPA did not provide an acute thermal threshold recommendation. Based upon the available information, NDEP concluded that an acute thermal tolerance value of 34°C is appropriate. This value is within the range of values found in the literature and is slightly higher than the chronic threshold of 31°C.

References

Beitinger, T.L., J.J. Magnuson, W.H. Neill, and W.R. Shaffer. 1975. Behavioural thermoregulation and activity pattern in the green sunfsh, Lepomis cyanellus. Animal Behaviour 23:222-229.

Boswell, T.O. 1967. The effects of water hardness on the upper lethal temperature of the green sunfish (Lepomis cyanellus). Master's thesis. New Mexico State University, Las Cruces, NM. Cited in: 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.

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.

Carrier, R., and Beitinger, T.L. 1988. Resistance of temperature tolerance ability of green sunfish to cadmium exposure. Bulletin of Environmental Contamination and Toxicology 40:475-480.

Carveth, C.J., Widmer, A., Bonar. 2006. Comparison of upper thermal tolerances of native and nonnative fish species in Arizona. Transactions of the American Fisheries Society 135:1433-1440.

Cherry, D.S., K.L. Dickson, and J. Cairns, Jr. 1975. Temperature selected and avoided by fish at various acclimation temperatures. Journal of the Fisheries Research Board of Canada 32:485-491

Colorado Water Quality Control Division. 2007. Colorado temperature database.

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.

Hill, L.G., G.D. Schnell, and J. Pigg. 1975. Thermal acclimation and temperature selection in sunfishes (Lepomis, Centrarchidae). The Southwestern Naturalist, 20(2):177-184.

Jones, T.C., Irwin, and W.H. 1965. Temperature preferences by two species of fish and the influence of temperature on fish distribution. Proc. 26th Annual Conf. of the Southeast Assoc. Game. Fish. Comm. 26:323-333.

Lutterschmidt,W.I. and V.H. Hutchison. 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.

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.

ATTACHMENT A
Detailed Summary of Chronic Thermal Tolerance Values for Green Sunfish, Juvenile and Adult, Summer

Table A-1. 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
Beitinger et al. (1988)	Adult	20 - 22	27.6 – 30.6	Median preferences	29.2 – 33.2	Median upper limits of preferred range		
Cherry et al. (1975)	<1 year	6 - 30	16.9 – 30.6		18.8 – 34.6	Upper 95% confidence limits on averages		
Hill et al. (1975)	Yearling	16 – 26	18.9 - 26		23.6 – 31.5	Average + 1 standard deviation		
Jones and Irwin (1965)	Juvenile/adult	4-30	10.6 – 27.0	Average mode of 10 tests	<16 - <32	Temperatures occupied about 80% of time	27.3	

Table A-2. Chronic Temperature Tolerances – Laboratory Upper Temperature Avoidance Studies

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
Cherry et al. (1975)	<1 year	6 - 30	20 - 33	

Table A-3. Chronic Temperature Tolerances – Field Studies

Reference	Temperature (°C)	Comment
Eaton et al. (1995)	31.7	Based upon 95th percentile of 5% highest weekly average temperatures
Stauffer et al (1976)	20 – 30	Collection temperatures of 15 green sunfish.

Table A-4. Chronic Temperature Tolerances –Colorado

Reference	Temperature (°C)	Comments
Colorado WQCD (2007)	31.1	Recommended level as MWAT

ATTACHMENT B
Detailed Summary of Acute Thermal Tolerance Values for Green Sunfish, Juvenile and Adult, Summer

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

Reference	Size or Age	Acclim. Temp. (°C)	Test Duration	UILT		UUILT	
				Temp. (°C)	Comment	Temp. (°C)	Comment
Boswell (1967)	Juvenile	Unknown	2-d	35.4			

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

Reference	Size or Age	Acclim. Temp. (°C)	Rate	Temperature (°C)	Endpoint
Carrier and Beitinger (1988)	Juvenile	20	0.3°C/min (18°C/hour)	35.8 – 35.9	Death
Carveth et al. (2006)	Juvenile, adult	25	0.3°C/min (18°C/hour)	37.4	Loss of equilibrium
				39.3	Death
		30		40.2	Loss of equilibrium
				41.5	Death
Lutterschmidt and Hutchison (1997)	Juvenile, adult	10	1°C/min (60°C/hour)	31.1	Loss of righting response
				34.2	Onset of spasms
Smale and Rabeni (1995)	Juvenile, adult	26	2°C/hour	37.9	Loss of equilibrium

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

Reference	Temperature (°C)	Comments
Colorado WQCD (2007)	35.1	Recommended level as DM