DRAFT Western Mosquitofish (*Gambusia affinis*) Thermal Tolerance Analyses – Juvenile and Adult, Summer
April 2016

Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult western mosquitofish 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 western mosquitofish 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 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 the western mosquitofish, EPA has not recommended a chronic thermal tolerance value. Based upon the available information, NDEP concluded that a chronic thermal tolerance value of 32°C is appropriate. This value is within the range of values derived from the literature.

Table 1. Summary of Chronic Temperature Tolerances

Category	Temperature (°C)
Laboratory Optimal Growth Studies	
Optimum	25 – 30
Upper Optimum	35
Laboratory Temperature Preference Studies	
Average Preferences	24.4 – 33.6
Upper Preferences	28.9 – 38.8
Final Preferendum	33.7 – 35.1
Field Studies	
Preferred	31
Range	12 – 40
Upper Avoidance	37
Threshold from Colorado (MWAT)	29.0
Recommended Chronic Temperature Tolerance (MWAT)	**32**

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for western mosquitofish for various lines of evidence. These values are based upon a review of 8 papers and publications, the details of which are summarized in Attachment B.

For ease of presentation, the CTM values have been summarized by acclimation temperature. However, as discussed in the methodology document, only CTM values for acclimation temperature near the recommended chronic criterion (32°C) are to be included in the acute criterion development process. For western mosquitofish, UILT and CTM values for acclimation temperatures of 30 – 35°C 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. = 5 – 10°C	29.5 – 32.5	
Acclim. = 15°C	33.0 – 35.4	
Acclim. = 20°C	35.5 – 37.3	
Acclim. = 25°C	35.5 – 37.5	
Acclim. = 30 – 35°C	37.3 – 38.0	35.3 – 36.0[1]
UUILT	37.3	35.3[1]
Laboratory Lethal Studies – CTM		
Acclim. = 10°C	36.9 – 38.5	
Acclim. = 18.5°C	33.7 – 38.5	
Acclim. = 25°C	38.0 – 39.8	
Acclim. = 30 – 35°C	40.6 – 42.3	35.1 – 36.8[2]
Threshold from Colorado (MDMT)	34.6	
Recommended Acute Temperature Tolerance (MDMT)	**35**	

[1]UILT values reduced by 2°C to provide 100% survival (See *Methodology*)
[2]CTM values reduced by 3.5°C to estimate quasi-UILT values. Quasi-UILT then reduced by 2°C to provide 100% survival

A review of the literature suggests that an appropriate acute criterion should fall between 35.1 and 36.8°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. However, in the case of western mosquitofish, EPA did not provide an acute thermal threshold recommendation. Based upon the available information, NDEP concluded that an acute thermal tolerance value of 35°C is appropriate. This value is consistent with the value established by the State of Colorado and within the range identified by the UILT and CTM studies.

References

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ATTACHMENT A
Detailed Summary of Chronic Thermal Tolerance Values for Western mosquitofish, Juvenile and Adult, Summer

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
Wurtsbaugh and Cech, Jr. (1983)	Juvenile	20	25 – 30		35	With adequate food, rapid growth rates of mosquitofish juveniles can be expected between 25 and 35°C.

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
Cherry et al. (1976)	Adult	6 – 36	24.4 – 33.6		28.9 – 38.8	Based upon 95% confidence limits	34.7 – 35.1	
Kelsch (1998)	Unknown						33.7	

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

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
Cherry et al. (1976)	Adult	12	30	
		18	33	
		24	36	
		30	39	
		36	39	

Table A-4. Chronic Temperature Tolerances – Field Studies

Reference	Temperature (°C)	Comment
Bennett and Goodyear (1978)	12 – 40	Mosquitofish from three thermally affected stations inhabited waters from 28 to 40°C, whereas mosquitofish at the unaffected stations were found in waters from 12 to 29°C. Mosquitofish collected from water at 40°C were reproductively active.
	39.5	Shoreline observations revealed that mosquitofish seemed to "select" temperatures at 39.5°C when higher and lower temperature waters were available.
Winkler (1978)	31	Females defended territories at a preferred temperature of 31°C
	37	Females avoided water above 37°C

Table A-5. Chronic Temperature Tolerances – Colorado

Reference	Temperature (°C)	Comments
Colorado WQCD (2007)	29.0	Recommended level as MWAT

ATTACHMENT B
Detailed Summary of Acute Thermal Tolerance Values for Western mosquitofish, 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
Hart (1952)	Unknown	15	1-d	35.4		37.3	Estimated by NDEP based upon UILT data
		20		37.3			
		30		37.3			
		35		37.3			
Otto (1973)	Adult	5	7-d	29.5 – 32.0[1]			
		10		30.5 – 32.5[1]			
		15		33.0 – 34.5[1]			
		20		35.5 – 36.5[1]			
		25		36.0 – 37.5[1]			
		35		38.0[2]			
Otto (1974)	Adult	25	7-d	35.5			
		35		37.5			

[1]Lower value for coldwater adapted fish collected from Utah; higher value for warmwater adapted fish collected from Arizona
[2]Watermwater adapted fish collected from Arizona.

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)	Adult	25	0.3°C/min (18°C/hour)	39.7	Loss of equilibrium
				39.8	Death
		30		40.6	Loss of equilibrium
				40.9	Death
Johnson (1976)	Adult	18.5	0.3°C/min (18°C/hour)	33.7 – 36.9[1]	Loss of orientation
				33.3 – 38.0[1]	Onset of spasms
				33.8 – 38.5[1]	Death
Lutterschmidt and Hutchison (1997)	Not reported[2]	10	1°C/min (60°C/hour)	36.9	Loss of righting response
				38.5	Onset of spasms
Otto (1974)	Adult	25 (constant)	0.3°C/min (18°C/hour)	38.0	Death
		25 (baseline with daily peaks ranging from 30 – 40.5°C)		39.4 - 41.6	
		30 (constant)		41.0	
		35 (constant)		42.3	
		35 (baseline with daily peaks ranging from 40 – 41.5°C)		43.3 – 43.7	

[1]Study quantified CTM variability throughout a 24-hour period
[2]Collected by seining streams and reservoirs in Oklahoma

Table B-3. Acute Temperature Tolerances – Colorado

Reference	Temperature (°C)	Comments
Colorado WQCD (2007)	34.6	Recommended level as DM