

DRAFT Lake Trout (*Salvelinus namaycush*) Thermal Tolerance Analyses – Juvenile and Adult, Summer

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Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult lake trout 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 lake trout for various lines of evidence. These values are based upon a review of 12 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 lake trout, EPA has not recommended a chronic thermal tolerance value. 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. Based upon the available information, NDEP concluded that a chronic thermal tolerance value of 16°C is appropriate. This value is consistent with the upper end of the range of values derived from the literature.

Table 1. Summary of Chronic Temperature Tolerances

Category	Temperature (°C)
Laboratory Optimal Growth Studies	
Optimum	10 – 12.5
Upper Optimum	13 - 16.5
Laboratory Temperature for Maximum Swimming Speed	
Maximum swimming speed temperature	16
Laboratory Temperature Preference Studies	
Average Preferences	9.0 – 12.6
Upper Preferences	10.7 – 14.5
Final Preferendum	10.2 – 11.7
Laboratory Upper Temperature Avoidance Studies	15
Field Studies	1 - 21
Recommended Chronic Temperature Tolerance (MWAT)	16

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for lake trout for various lines of evidence. These values are based upon a review of 2 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. However, as discussed in the methodology document, only UILT and CTM values for acclimation temperature near the recommended chronic criterion (16°C) are to be included in the acute criterion development process. For lake trout, UILT values for acclimation temperatures of 8 – 15°C are utilized for criterion development. For lake trout, CTM values for acclimation temperatures of 17°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. = 8 – 15 °C	22.5 – 23.5	20.5 – 21.5 ¹
Acclim. = 20°C	23.5	
UUILT	23.5	21.5 ¹
Laboratory Lethal Studies – CTM		
Acclim. = 17°C	25.9	20.0 ²
Recommended Acute Temperature Tolerance (MDMT)	21	

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

²CTM values reduced by 3.9°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 20.0 and 21.5°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 lake trout, EPA did not provide an acute thermal threshold recommendation. Based upon the available information, NDEP concluded that an acute thermal tolerance value of 21°C is appropriate. This value is within the range of values derived from the literature and similar to the level suggested by the UILT and CTM studies.

References

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ATTACHMENT A

Detailed Summary of Chronic Thermal Tolerance Values for Lake trout, 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
Edsall and Cleland (2000)	Fry		12.5 ¹		16.5 ¹	Temperature at growth rate = 80% of optimum
O'Connor et al. (1981)	Yearling	10	10 – 12		13 - 16	Temperature at growth rate = 80% of optimum

¹Third-order polynomial fit used to estimate optimum growth temperature; four temperature actually studied (5°C, 10°C, 15°C, and 18°C).

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
Gibson and Fry (1954)	1-yr and 2-yr		16			

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	
Edsall and Cleland (2000)	Fry	5.2 – 18.1	9.7 – 11.5					10.2	
Goddard et al. (1974)	Yearling	10	11.5		13.0	Estimated upper temperature preferred based upon 90 th percentile of observations			
Mac (1985)	Juvenile	10	9.2 – 12.6	Preferred temperature depends on ration	12 – 14.5	Estimated upper temperature preferred based upon 90 th percentile of observations			
McCauley and Tait (1970)	Yearling	5 – 20	11.5 – 11.9	Mean of modal temperature	12 – 13.2	Based upon 1 stand. dev. above mean of modal temperatures		11.7	
Peterson et al. (1979)	Fingerling	12.1	10.8		12.4	Based upon 1 stand. dev. above avg.			
	Fry	12.7	9.0 – 10.0		10.7				

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

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
McCauley and Tait (1970)	Yearling	10	15	

Table A-5. Chronic Temperature Tolerances – Field Studies

Reference	Temperature (°C)	Comment
Donald and Alger (1993)	6.9 – 17.7	Midsummer temperatures range from 6.9 - 17.7 C for lakes with lake trout, or up to 20 C is Flathead Lake is included.
Gunn (2002)	20	Fish exposed to bottom water temperatures of 20 C for several weeks resulted in the loss of all hatchery-reared juveniles. A few adults survived the temperature spike by making use of cold water refuge areas (groundwater seepage).
Michaud (1981)	1 – 17	Lake trout found at temperatures as low as 1°C and as high as 17°C.
	4 – 14	Majority of lake trout found at temperatures between 4 and 14°C.
Sellers et al. (1998)	4 – 21	Lake trout found at temperatures as low as 4°C and as high as 21°C.
Snucins and Gunn (1995)	9.4	Mean temperature of lake trout occurrence in Whitepine Lake.
	13	Upper avoidance temperature of lake trout in Whitepine Lake.
	16 - 18	Highest temperature of lake trout occurrence in Pedro Lake.

ATTACHMENT B

Detailed Summary of Acute Thermal Tolerance Values for Lake trout, Juvenile and Adult, Summer

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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
Gibson and Fry (1954)	1-yr and 2-yr	8		22.5		23.5	
		15		23.5			
		20		23.5			

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

Reference	Size or Age	Acclim. Temp. (°C)	Rate	Temperature (°C)	Endpoint
Grande and Anderson (1991)	2-3 months posthatch	17	2°C/day	25.9	Death ¹

¹Critical thermal maxima LT₅₀ (temperature giving 50% mortality).