DRAFT Common Carp (*Cyprinus carpio*) Thermal Tolerance Analyses – Juvenile and Adult, Summer
April 2016

Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult common carp 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 common carp for various lines of evidence. These values are based upon a review of 13 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 common carp, 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 consistent with the upper end of the Final Preferendum values and within the range of values derived from the literature.

Table 1. Summary of Chronic Temperature Tolerances

Category	Temperature (°C)
Laboratory Optimal Growth Studies	
Optimum	27
Upper Optimum	30
Laboratory Temperature Preference Studies	
Average Preferences	17 – 34
Upper Preferences	31
Final Preferendum	27.4 – 32
Laboratory Upper Temperature Avoidance Studies	34.5
Field Studies	
Average	21.6
Range	5.1 – 39.2
Recommended Chronic Temperature Tolerance (MWAT)	**32**

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for common carp for various lines of evidence. These values are based upon a review of 3 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 (32°C) are to be included in the acute criterion development process. For common carp, none of the UILT values are close enough to the recommended chronic criterion for acute criterion development. CTM values for acclimation temperatures of 30 – 35°C are utilized for acute criterion development.

Table 2. Summary of Acute Temperature Tolerances

Category	Temperature Tolerances (°C)	Potential Acute Criteria (°C)
Laboratory Lethal Studies – UILT/UUILT		
UILT		
Acclim. = 20°C	31 – 34	
Acclim. = 26°C	35.7	
Laboratory Lethal Studies – CTM		
Acclim. = 25°C	39.7 – 39.8	
Acclim. = 30°C	40.6 – 40.9	36.6 – 36.9[2]
Acclim. = 35°C	42.9	38.9[2]
Laboratory Lethal Studies – Other Lethal Temperatures	35.5 – 39	
Recommended Acute Temperature Tolerance (MDMT)	**37**	

[1]UILT values reduced by 2°C to provide 100% survival (See *Methodology*)
[2]CTM values reduced by 2.0°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 35.5 and 38.9°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 common carp, EPA did not provide an acute thermal threshold recommendation. Based upon the available information, NDEP concluded that an acute thermal tolerance value of 37°C is appropriate. This value is within the range of values derived from the literature and similar to the level suggested by the CTM studies.

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DRAFT

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ATTACHMENT A
Detailed Summary of Chronic Thermal Tolerance Values for Common Carp, 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
Goolish and Adelman (1984)	Juvenile	12 – 30	27[1]		30	Growth reaches an overall maximum at ~27°C, although differences are small the temperature range 24-30°C.

[1]The overall maximum scope for growth, defined as the difference between the ration size for maximum growth and maintenance ration size, was estimated to occur at a temperature of 27°C. It should be noted that the temperature for a maximum scope for growth (27°C) is only valid for a maximum ration and that in nature such rations may rarely be consumed.

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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
Golovanov (2006)							29.5	
Neill et al. (1972)			27 – 34	Lower and upper limits of temperatures occupied by 1 fish				
Neill and Magnuson (1974)	< 1 year 81 – 97 mm	20 – 22	28.5 – 33.5					
Pitt et al. (1956)	Underyearling 2-3 inches	10 – 35	17 - 32	Mode values			32	
Reutter and Herdendorf (1974 and 1976)	Adult	Unknown[1]					27.4 - 29.7[2]	
Reynolds and Casterlin (1977)	Adult	Unknown	29	Temperature most frequently occupied	31	Upper limit of temperatures occupied	29[3]	

[1]Fish for summer experiments were held less than 7 days at lake temperatures.
[2]Final preferenda: summer study = 29.7°C and spring study = 27.4°C.
[3]Reynolds and Casterlin (1977) noted that, whereas short-term temperature preference (within about 2 h or less) varies with acclimation temperature, the final preferendum as measured here does not; it is a species-specific characteristic that is relatively little affected by environment.

DRAFT

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

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
Neill and Magnuson (1974)	< 1 year 81 – 97 mm	20 – 22	34.5	

Table A-4. Chronic Temperature Tolerances – Field Studies

Reference	Temperature (°C)	Comment
Eaton et al. (1995)	31.4	Based upon 95th percentile of 5% highest weekly average temperatures.
Gammon (1973)	33.0 – 35.0[1]	
Marcy (1976)	5.1 – 39.2	Temperature range
	21.6	Mean temperature
Neill and Magnuson (1974)	30.0 – 33.5	Thermoregulatory behavior of young carp indicated that they preferred temperatures between 30.0°C and 33.5°C.
Wehrly et al. (2003)	18 – 26	Mean temperatures at sites where carp were present at average or above-average standing stocks ranged from 18°C to 26°C.
Yoder and Gammon (1975)	26 – 34	Temperature range where largemouth bass where captured by electrofishing and in D nets in the summer.

[1]Range of temperatures which probably includes the final temperature preferendum of *Cyprinus carpio*.

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ATTACHMENT B
Detailed Summary of Acute Thermal Tolerance Values for Common Carp, 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
Black (1953)	5.3 – 64.6 g	20	1-d	31 – 34			
		26		35.7			

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

Reference	Size or Age	Acclim. Temp. (°C)	Rate	Temperature (°C)	Endpoint
Chatterjee et al. (2004)	Fingerling 0.8 g	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
		35		42.9	Loss of equilibrium
				42.9	Death

Table B-1. Acute Temperature Tolerances – Other Laboratory Lethal Temperatures

Reference	Size or Age	Lethal Temperature
Meuwis and Heuts (1957)	< 67 g	Common carp of 67 grams and less have lethal temperatures at 38°C and 39°C.
	> 67 g	Common carp greater than 67 grams have lethal temperatures between 35.5°C and 37°C.

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