DRAFT Striped Bass (*Morone saxatilis*) Thermal Tolerance Analyses – Juvenile and Adult, Summer
March 2016

Introduction

Recommended summer chronic and acute thermal tolerance values for juvenile and adult striped 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 striped bass 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 striped bass, EPA did not recommend a chronic thermal threshold. 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 30°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 Optimal Growth Studies – Constant Temperature	
Optimum	25 – 28.5
Upper Optimum	28 – 31
Laboratory Temperature Preference Studies	
Average Preferences	22.1 – 27
Upper Preferences	24.1 – 33
Laboratory Upper Temperature Avoidance Studies	26.4 – 28.3
Temperature Preference Field Studies	8 – 31
Thresholds from Colorado (MWAT)	29.6
Recommended Chronic Temperature Tolerance (MWAT)	**30**

Acute Thermal Tolerance Thresholds

Table 2 provides a summary of the range of acute temperature tolerance values for striped bass 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 ranges. However, as discussed in the methodology document, only the UILT and CTM values for acclimation temperature near the recommended chronic criterion (30°C) are to be included in the acute criterion development process. For striped bass, UILT and CTM values for acclimation temperatures of 25 - 30°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	24.4 – 27.2	
Acclim. = 10 - 15°C	27.2 – 29.7	
Acclim. = 15 - 20°C	28.5 – 31.1	
Acclim. = 20 - 25°C	30.6 – 31.2	
Acclim. = 25 - 30°C	31.8 – 33.9[1]	29.8 – 31.9
Laboratory Lethal Studies – CTM		
Acclim. = 5 - 10°C	27.4 – 31.6	
Acclim. = 10 - 15°C	29.5 – 32.7	
Acclim. = 15 - 20°C	31.6 – 34.7	
Acclim. = 20 - 25°C	33.7 – 34.7	
Acclim. = 25 - 30°C	36.2 – 38.8[2]	30.8 – 33.4
Recommended Acute Temperature Tolerance (MDMT)	**32**	

[1]UILT and UUILT values reduced by 2°C to provide 100% survival (See *Methodology*)
[2]CTM values reduced by 3.4°C to estimate quasi-UILT values. Quasi-UILT values then reduced by 2°C to provide 100% survival (See *Methodology*)

A review of laboratory studies suggests that an appropriate acute criterion should fall between 29.8 and 33.4°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 striped bass, EPA did not recommend an acute thermal threshold for striped bass. Based upon the available information, NDEP concluded that an acute thermal tolerance value of 32°C is appropriate. This value is within the range of values found in the literature and is slightly higher than the chronic threshold of 30°C.

References

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ATTACHMENT A
Detailed Summary of Chronic Thermal Tolerance Values for Striped Bass, 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
Cox and Coutant (1981)	Juvenile	Unknown	25 - 26	Optimum growth temperature	28	Growth rate = 80% of optimum
Kellogg and Gift (1983)	Juvenile	Unknown	27 – 28.5	Optimum growth temperature	31	Growth rate = 75% of optimum

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
Coutant et al. (1984)	Juvenile	22 – 24	22.1 – 26.7		24.1 – 28.3	Average + 1 standard deviation		
Kellogg and Gift (1983)		24	27		33	Upper limit of preference for individual fish		

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

Reference	Age or Size	Acclim. Temp. (°C)	Temperature (°C)	Comment
Coutant et al. (1984)	Juvenile	unknown	26.4	Average
			28.3	Average + 1 standard deviation

Table A-4. Chronic Temperature Tolerances – Field Studies

Reference	Temperature (°C)	Comment
Bettoli (2005)	8 - 24	Temperature range for all fish for May-October
	22.0	Upper temperature limit for 90% of fish
Coutant and Carroll (1980)	20 – 24	Preferred temperature range
	22	Final preferendum
	25	Avoided high temperature
Coutant et al. (1984)	14.6 – 28.2	Full range of temperature occupied by fish
Van Den Avyle and Evans (1990)	21.6	Average temperature inhabited by tagged fish May-October
	24	Temperature at which tagged fish would move to cooler spring areas
Waddle et al. (1980)	14 – 31	Full range of temperature occupied by fish
	16 – 25	Range of temperatures mostly occupied (average $\pm$ standard deviation)
	18 – 22	Mean of temperatures occupied by individual fish
	21	Final preferendum

Table A-5. Chronic Temperature Tolerances –Colorado

Reference	Temperature (°C)	Comments
Colorado WQCD (2007)	29.6	Recommended level as MWAT

ATTACHMENT B
Detailed Summary of Acute Thermal Tolerance Values for Striped Bass, 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
Cook et al. (2006)	Juveniles	5	3-d	24.4			
		10		27.2			
		15		29.7			
		16		28.5 – 29.7			
		20		31.1			
		23		30.6 – 31.2			
		26		31.8			
		30		33.9			

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

Reference	Size or Age	Acclim. Temp. (°C)	Rate	Temperature (°C)	Endpoint
Cook et al. (2006)	Juvenile	5	0.3°C/min (18°C/hour)	27.4	Loss of equilibrium
				28.1	Loss of righting response
				28.6	Onset of spasm
		10		29.5	Loss of equilibrium
				30.1	Loss of righting response
				30.6	Onset of spasm
		15		31.6	Loss of equilibrium
				32.2	Loss of righting response
				32.7	Onset of spasm
		20		33.7	Loss of equilibrium
				34.2	Loss of righting response
				34.7	Onset of spasm
		26		36.2	Loss of equilibrium
				36.7	Loss of righting response
				37.2	Onset of spasm
		30		37.9	Loss of equilibrium
				38.3	Loss of righting response
				38.8	Onset of spasm
Lutterschmidt and Hutchison (1997)	Unknown	10	1.0°C/min (60°C/hour)	29.4	Loss of righting response
				31.6	Onset of spasm