Technical Supporting Information for Proposed Revisions to the Connecticut Water Quality Standards: Water Temperature

Connecticut Department of Environmental Protection
Bureau of Water Protection and Land Reuse
Planning & Standards Division
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Background

Pollution is defined by Connecticut statutes (CGS 22a-423) and includes harmful thermal effects, which are furthered defined by the statute as:

> "harmful thermal effect" means any significant changes in the temperature of any waters resulting from a discharge therein, the magnitude of which temperature changes does or is likely to render such waters harmful, detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life;

In order to prevent harmful thermal effects on aquatic resources resulting from discharges to surface water bodies, the Water Quality Standards includes temperature criteria. As part of the triennial review of Connecticut's Water Quality Standards, revisions to the water quality criteria for temperature are proposed for consistency with EPA recommended criteria and to improve protection of aquatic resources. This document provides a description of the process to derive the proposed criteria for the evaluation and regulation of thermal discharges.

EPA Criteria for Temperature

In the current table of nationally recommended water quality criteria (available at http://www.epa.gov/waterscience/criteria/wqctable/) EPA includes temperature criteria but does not provide numerical values. Instead, the table recommends the adoption of species dependent criteria for water temperature and references the following documents:

Quality Criteria for Water 1986 (Gold Book) EPA 440/5-86-001

U.S. EPA. 1973. Water Quality Criteria 1972. EPA-R3-73-033. National Technical Information Service, Springfield, VA.; U.S. EPA. 1977.

U.S. EPA. 1977.Temperature Criteria for Freshwater Fish: Protocol and Procedures. EPA 600/3-77-061. National Technical Information Service, Springfield, VA.

These reports include data from studies documenting the thermal tolerance of various fish species. Data are presented to identify temperatures associated with lethal exposures for each species as well as acceptable temperature ranges associated with growth and spawning periods. Critical thermal exposures for individual species are modeled to identify acceptable short term (maximum daily exposure) and average conditions (average weekly) for each species which would be acceptable during spawning periods and as well as separate estimates for growth periods. Additionally, general restrictions on incremental temperature changes to protect against thermal shock due to exposures to sudden changes in temperature are provided. These recommended criteria are presented by EPA in the Gold Book for the management of thermal plumes from discharges to aquatic environments to prevent unacceptable impacts to aquatic resources. Similar to the consideration of harmful thermal effects in Connecticut Statutes, they are not presented as a tool to assess ambient water temperatures outside of these thermal discharges.

Protection of Fisheries Resources

Fish are poikilothermic, that is, their body temperature is not internally regulated but is affected by the temperature of their surrounding environment. Critical biological functions such as spawning and growth in fish populations are affected by temperature. Additionally, different fish species respond in differing degrees to ambient temperatures and thermal stress. Fisheries biologists have long recognized that there is a relationship between ambient water temperature and the composition of fish communities found within streams. Current research identifies three major groupings of fish species based on their thermal preference. These communities are generally identified as coldwater, coolwater and warmwater (Lyons et al, 2009) and can be associated with the distribution and abundance of certain fish species. For example, trout are considered a cold water fish species while fish such as minnows or perch tend to be found in warmwater streams. Walleye and pike are likely to be found in coolwater streams. In order to adequately protect these fish communities from the effects of thermal stress, temperature criteria needs to recognize these key fish communities and establish acceptable temperature criteria for thermal discharges to surface waters that are protective of these various groups.

Proposed Revisions to Temperature Criteria

Revisions to current temperature criteria are proposed to a) address short term, average and incremental thermal exposures using the EPA model adapted to species commonly found in Connecticut and b) address the three major fish community groups. The procedure for deriving the criteria is as follows:

Freshwater Temperature Criteria:

1. Data on the thermal tolerance of fish species was obtained from Temperature Criteria for Freshwater Fish: Protocol and Procedures (EPA 1977). Data from species not typically found in Connecticut were not used in the evaluation.

2. Fish species were separated into three groups representing species generally characterized as coldwater, cool water and warm water fish.

3. For each species, acceptable maximum and average temperatures were tabulated for both growth and spawning bioperiods, using the thermal tolerance temperature model recommended by EPA and presented in the 1977 EPA document. The geometric means of the values were calculated (See tables 1 through 3)

Table 1: Proposed Temperature Criteria (degrees Fahrenheit) for Freshwater Waterbodies Designated as Cold Water Fisheries.

Species	Max Weekly Avg Temp Growth	Max temp for survival of short exposure	Max Weekly Avg Temp Spawning	Max temp embryo survival
	Spring-Summer		Fall	Fall
Atlantic Salmon	68	73	41	52
Brown Trout	63	75	46	59
Rainbow Smelt			46	59
Brook Trout	66	75	48	55
Slimy sculpin				
Rainbow Trout	66	75	48	55
Geomean	66	74	46	56

Table 2: Proposed Temperature Criteria (degrees Fahrenheit) for Freshwater Waterbodies Designated as Cool Water Fisheries.

Species	Max Weekly Avg Temp Growth	Max temp for survival of short exposure	Max Weekly Avg Temp Spawning	Max temp embryo survival
	Spring-Summer		Fall	Fall
Walleye	77		46	63
Northen Pike	82	86	52	66
White Sucker	82		50	68
Geomean	80	86	49	66

Table 3: Proposed Temperature Criteria (degrees Fahrenheit) for Freshwater Waterbodies Designated as Warm Water Fisheries.

Species	Max Weekly Avg Temp Growth	Max temp for survival of short exposure	Max Weekly Avg Temp Spawning	Max temp embryo survival
	Spring-Summer		Fall	Fall
Yellow Perch	84		54	68
White Perch			59	68
Black Crappie	81		63	68
Smallmouth Bass	84		63	73
White Bass			63	79
Stiped Bass			64	75
White Crappie	82		64	73
Carp			70	91
Largemouth Bass	90	93	70	81
Alewife			72	82
Brown Bullhead			75	81
Fathead Minnow			75	86
Bluegill	90	95	77	93
Pumpkinseed			77	84
Channel Catfish	90	95	81	84
Geomean	86	94	68	79

4. Calculated geometric mean values were reviewed and compared both with current temperature criteria as well as ambient temperature data for representative warmwater and coolwater streams in Connecticut (Table 4). Ambient temperature data used in this evaluation are presented in Appendix B.

Table 4: Comparative Analysis of the Proposed Temperature Criteria (degrees Fahrenheit) for Freshwater Waterbodies Designated by Fish Community Type.

	Spawning Period		Growth Period			CT Ambient Data	
Fish Community	Max Weekly Avg Temperature Spawning Bioperiod	Max temperature embryo survival	Max Weekly Avg Temperature Growth Bioperiod	Max temperature for survival of short duration exposure	2002 Temperature Criteria in CT WQS	Maximum Observed Ambient Temperature	75 % Temperature
Coldwater	46	56	66	74	85		
Coolwater	49	66	80	86	85	77	72
Warm	68	79	86	94	85	88	75

5. The final changes to the freshwater criteria that are proposed based on the comparative analysis and are summarized in Tables 5 and 6. The current temperature criterion for incremental increase of $4^{\circ}F$ is proposed to be retained.

Table 5: Proposed Temperature Criteria (degrees Fahrenheit) for Freshwater Waterbodies.

Fish Community	Spawning Bioperiod	Average Weekly	Maximum Daily	Criteria Basis
Coldwater	October - March	46	56	Thermal Tolerance Data
Coolwater	October - March	49	66	Thermal Tolerance Data
Warm	October - June	68	79	Thermal Tolerance Data

°F	Growth Bioperiod	Average Weekly	Maximum Daily	Criteria Basis
Coldwater	April - September	66	74	Thermal Tolerance Data
Coolwater	April - September	72	77	Representative CT Data
Warm	July - September	85	88	Max based on CT Data, Average set equal to 2002 Criteria

***Note : The criteria values for cold water fisheries differ slightly from the 12/22/2009 public notice version of the Water Quality Standards. This table presents the correct values. This correction will be identified in a separate errata sheet for the proposed Water Quality Standards**.

In addition to the criteria proposed in Table 5, the following criteria are proposed for surface waters that are identified in the most recent Connecticut Angler's Guide as a water body that is stocked with trout, even if that surface water body does not support or have suitable habitat to support a self-sustaining, naturally reproducing population of trout (Family Salmonidae). This proposal is made in support of the recreational opportunities afforded by the trout stocking program administered by the Connecticut Department of Environmental Protection.

Table 6: Additional Proposed Criteria (degrees Fahrenheit) for Stocked Trout Streams:

Fish Community	Stocked Trout Stream	Average Weekly	Maximum Daily
Coldwater	April - June	66	74
Coolwater	April - June	66	74
Warm	April - June	66	74

***Note : The criteria values for cold water fisheries differ slightly from the 12/22/2009 public notice version of the Water Quality Standards. This table presents the correct values. This correction will be identified in a separate errata sheet for the proposed Water Quality Standards**.

Marine/Estuarine Temperature Criteria:

Temperature criteria contained in the EPA Gold Book and in the current Connecticut Water Quality Standards were reviewed in conjunction with ambient temperature data for Long Island Sound (Tables 7 and 8). The proposed criteria are presented in Table 9. The current temperature criterion for incremental increases is proposed to be retained. During the months of July, August, and September, the temperature increase to marine waters is 1.5 ^{o}F. At all other times, the allowable increase in marine waters is 4 ^{o}F.

Table 7: Review of EPA and CTDEP Marine Temperature Criteria (degrees Fahrenheit).

Marine Waters	^{o}F
Gold Book Short Term Maximum	87
Gold Book Daily Mean	82
Current CT DEP Criteria	83

Table 8: Summary of Ambient Temperature Data (degrees Fahrenheit) for Long Island Sound from CT DEP Long Island Sound Study 1991-2008.

	Surface Water	Bottom Water
Average	62	54
Maximum	80	75

Table 9: Proposed Temperature Criteria for Marine Waters (degrees Fahrenheit).

Criterion	Proposal	Basis
Maximum Daily Mean	82	EPA Gold Book
Hourly Maximum	83	2002 CTDEP Criteria

Bibliography

Lyons, J. T. Zorn, J. Stewart, P. Seelbach, K. Wehrly, and L. Wang. 2009 Defining and Characterizing Coolwater Streams and Their Fish Assemblages in Michigan and Wisconsin, USA. North American Journal of Fisheries Management 29:1130-1151.

U.S. EPA. 1973. Water Quality Criteria 1972. EPA-R3-73-033. National Technical Information Service, Springfield, VA.; U.S. EPA. 1977.

U.S. EPA. 1977.Temperature Criteria for Freshwater Fish: Protocol and Procedures. EPA 600/3-77-061. National Technical Information Service, Springfield, VA

U.S. EPA. 1986. Quality Criteria for Water 1986 (Gold Book) EPA 440/5-86-001

Appendix A

Temperature Criteria Recommended for Various Fish Species

Reproduced from:

Temperature Criteria for Freshwater Fish: Protocol and Procedures. EPA 600/3-77-061.

TABLE 1. TEMPERATURE CRITERIA FOR GROWTH AND SURVIVAL OF SHORT EXPOSUR

(24 HR) OF JUVENILE AND ADULT FISH DURING THE SUMMER (° C (° F))

Species	Maximum weekly average temperature for growth[a]	Maximum temperature for survival of short exposure[b]
Alewife	--	--
Atlantic salmon	20 (68)	23 (73)
Bigmouth buffalo	--	--
Black crappie	27 (81)	--
Bluegill	32 (90)	35 (95)
Brook trout	19 (66)	24 (75)
Brown bullhead	--	--
Brown trout	17 (63)	24 (75)
Carp	--	--
Channel catfish	32 (90)	35 (95)
Coho salmon	18 (64)	24 (75)
Emerald shiner	30 (86)	--
Fathead minnow	--	--
Freshwater drum	--	--
Lake herring (cisco)	17 (63)[c]	25 (77)
Lake whitefish	--	--
Lake trout	--	--
Largemouth bass	32 (90)	34 (93)
Northern pike	28 (82)	30 (86)
Pumpkinseed	--	--
Rainbow smelt	--	--
Rainbow trout	19 (66)	24 (75)
Sauger	25 (77)	--
Smallmouth bass	29 (84)	--
Smallmouth buffalo	--	--
Sockeye salmon	18 (64)	22 (72)
Striped bass	--	--
Threadfin shad	--	--
Walleye	25 (77)	--
White bass	--	--
White crappie	28 (82)	--
White perch	--	--
White sucker	28 (82)[c]	--
Yellow perch	29 (84)	--

[a] Calculated according to equation:
maximum weekly average temperature for growth = optimum for growth + (1/3) (ultimate incipient lethal temperature - optimum for growth).

[b] Based on: temperature (° C) = (log time (min) - a)/b - 2° C, acclimation at the maximum weekly average temperature for summer growth, and data in Appendix B.

[c] Based on data for larvae.

TABLE 2. TEMPERATURE CRITERIA FOR SPAWNING AND EMBRYO SURVIVAL OF SHORT EXPOSURES DURING THE SPAWNING SEASON (° C (° F))

Species	Maximum weekly average temperature for spawning[a]	Maximum temperature for embryo survival[b]
Alewife	22 (72)	28 (82)[c]
Atlantic salmon	5 (41)	11 (52)
Bigmouth buffalo	17 (63)	27 (81)[c]
Black crappie	17 (63)	20 (68)[c]
Bluegill	25 (77)	34 (93)
Brook trout	9 (48)	13 (55)
Brown bullhead	24 (75)	27 (81)
Brown trout	8 (46)	15 (59)
Carp	21 (70)	33 (91)
Channel catfish	27 (81)	29 (84)[c]
Coho salmon	10 (50)	13 (55)[c]
Emerald shiner	24 (75)	28 (82)[c]
Fathead minnow	24 (75)	30 (86)
Freshwater drum	21 (70)	26 (79)
Lake herring (cisco)	3 (37)	8 (46)
Lake whitefish	5 (41)	10 (50)[c]
Lake trout	9 (48)	14 (57)
Largemouth bass	21 (70)	27 (81)[c]
Northern pike	11 (52)	19 (66)
Pumpkinseed	25 (77)	29 (84)[c]
Rainbow smelt	8 (46)	15 (59)
Rainbow trout	9 (48)	13 (55)
Sauger	12 (54)	18 (64)
Smallmouth bass	17 (63)	23 (73)[c]
Smallmouth buffalo	21 (70)	28 (82)[c]
Sockeye salmon	10 (50)	13 (55)
Striped bass	18 (64)	24 (75)
Threadfin shad	19 (66)	34 (93)
Walleye	8 (46)	17 (63)[c]
White bass	17 (63)	26 (79)
White crappie	18 (64)	23 (73)
White perch	15 (59)	20 (68)[c]
White sucker	10 (50)	20 (68)
Yellow perch	12 (54)	20 (68)

[a] The optimum or mean of the range of spawning temperatures reported for the species.

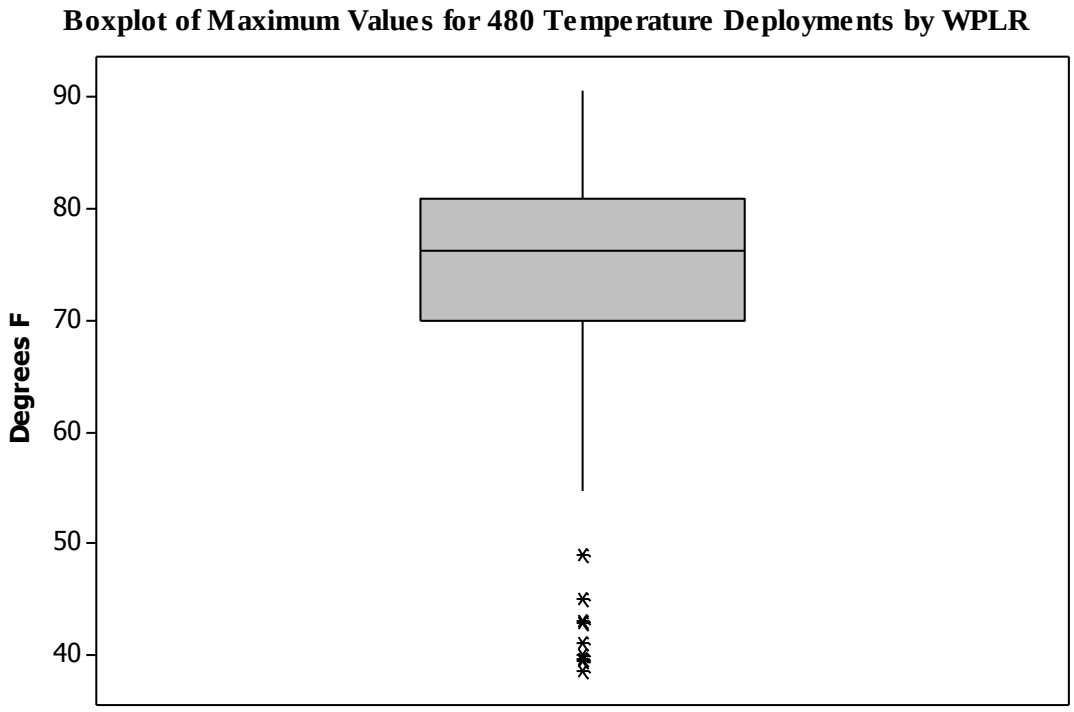
[b] The upper temperature for successful incubation and hatching reported for the species.

[c] Upper temperature for spawning.

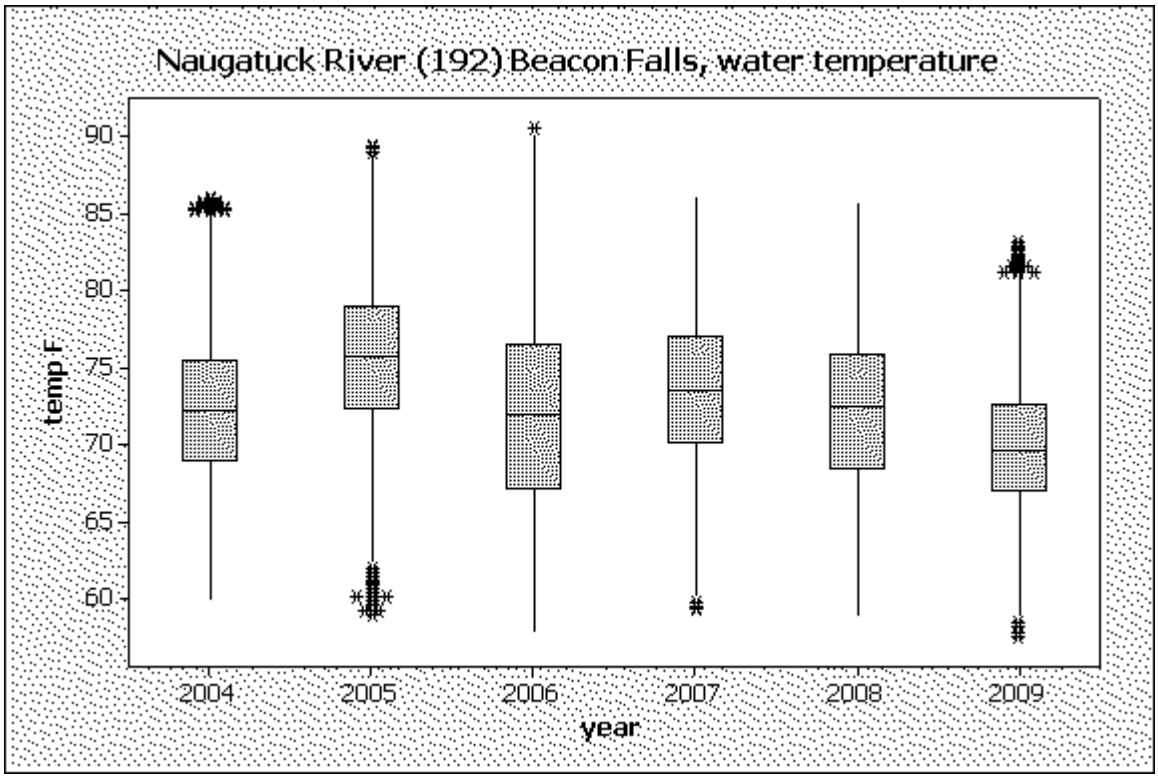
Appendix B

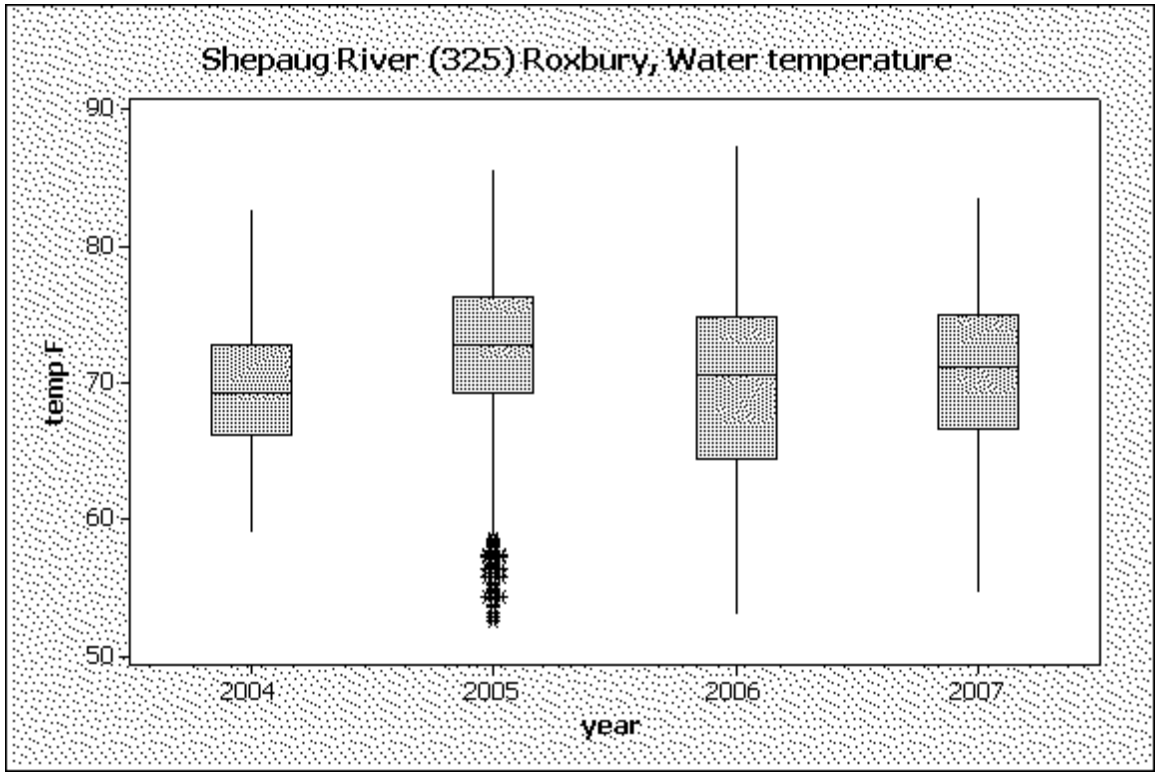
Distribution of Ambient Stream Temperature Data in CT

Boxplot of the maximum water temperature (Degrees Fahrenheit) from 480 station deployments in Connecticut streams. Data were collected by CTDEP Water Protection and Land Reuse (WPLR) staff.



Warmwater stream data:





Coolwater stream data: