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This report describes the methodology and results of an effort to compile upper thermal tolerance data for New England freshwater fish species including diadromous species. This database provides the basis for utilizing a Fish Temperature Model (FTM; Yoder 2008) that can be used to evaluate thermal impacts to fish from a site-specific to river reach basis. It can also be used to develop seasonal temperature criteria for specific water bodies or river basin areas. It has previously been used for this purpose to develop temperature criteria options for Ohio rivers and streams (Ohio EPA 1978), the Ohio River mainstem (Yoder et al. 2006), and the lower Des Plaines River in Illinois (Yoder and Rankin 2005). Herein we are using it to evaluate existing and proposed thermal criteria for the Connecticut River mainstem, but the database should be applicable to all of New England. The result of this review process is Appendix Table 1 that will serve as the thermal effects database for the purposes included in Phase II of this project (described below).

The primary input variables to the Fish Temperature Model described in the Connecticut River RIS report are four thermal parameters for each representative fish species: a physiological or behavioral optimum temperature, a maximum weekly average temperature for growth, an upper avoidance temperature, and an upper lethal temperature. These will be derived from an existing thermal tolerance database (Yoder et al. 2006), which is being supplemented by additional references for New England freshwater fish species (including diadromous species). This database will be used to assign these thermal parameters to each Connecticut River fish species for which sufficient thermal data can be found. When multiple values are available for a particular species, the most ecologically and geographically relevant data will be used *or* an average of multiple values will be derived from geographically relevant areas. In either case, the FTM permits the substitution of different values to determine the effect on its primary outputs. Four lists of RIS for the Connecticut River appear in the RIS report (Yoder 2012), and the availability of thermal tolerance data is indicated for each.

Methodology

Review of the Literature

For this project, a comprehensive review of the literature was undertaken to supplement the thermal database that was originally compiled by Yoder et al. (2006), and specifically to add data for New England freshwater fish species that were not included in that effort. The first compilation of literature that served as the basis for that of the Yoder et al. (2006) effort was accomplished by Ohio EPA in the late 1970s, focused on Midwest and Great Lakes fish species. It also occurred during the zenith of the first flurry of studies on thermal effects, specifically 316[a] demonstrations that were then being conducted nationwide. This included a mix of laboratory and field studies, some of which integrated both lab and field studies in their scope and conduct. Some of these studies lingered into the early 1980s, thus some literature of that time period was not captured by the original Ohio EPA (1978a) compendium. Other than two early compilations of temperature effects data by Brown (1974) and Brungs and Jones (1977), no other compilations were available at that time.

Several thermal effects compendia were later compiled in the late 1980s and early 1990s. These include the compendia produced by Wismer and Christie (1987), Hokanson (1990), and Beitinger et al. (2000). After screening more than 500 titles and abstracts, Yoder et al. (2006) reviewed more than 200 individual references in addition to these compendia. In all, data for 125 freshwater fish species, 2 subspecies, 5 hybrids, and 28 macroinvertebrate taxa were compiled, which almost doubled the species included by the original Ohio EPA (1978) effort. These reviews of individual studies included classifying the methods and types of experimental tests and/or field studies. The reviews are categorized in the key to Appendix Table 1. So called "grey literature[1]" was admitted so long as the citation could be validated, either by examination of the original report or as cited by one of the major compendia noted above. Above all, a report or publication was required to detail the study design, methods, and analyses in order for its thermal effects data to be accepted into Appendix Table 1. All peer reviewed journal articles were also accepted. While our current literature search to supplement Yoder et al. (2006) produced some overlap with the major compendia, it has also added previously unknown literature sources for several New England fish species.

Each potential new literature source was reviewed for relevancy, i.e., is the methodology described, is the geographic representation described, are the specific thermal tolerance endpoints readily apparent, are the experimental endpoints valid, and does the species fit our depiction of RIS (Yoder 2012). Acceptable data were then recorded in the master thermal effects database with appropriate notations as to the type of study and thermal endpoints derived (Appendix Table 1). These notations are important to the application of specific thermal endpoints from a particular study. As such, the database is structured with the understanding that a particular piece of data in Appendix Table 1 could be included or excluded at the point of FTM application. We attempted as much as possible to examine the original literature source prior to accepting the data in the master database. However, we accepted some indirect citations within some of the comprehensive compendia that were previously mentioned. We noted where the original citation was made for such references whenever possible. We did find in some of these and other compendia a practice of citing one of the major compendia as the source in lieu of the original literature source. We attempted to avoid this practice by citing the original literature source whenever feasible. One conclusion that we can make out of this exercise is that no single compendium of thermal effects literature, including this study, contains all of the possible literature sources that exist. Instead, we see this as an ongoing process that captures most of the older and historic references and updates the database with readily available and newly published information.

[1] "Grey literature" is defined as . . . "That which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers." (Fourth International Conference on Grey Literature, 1999)

In our current review of the thermal effects literature, priority was given to finding data for new species, for endpoints that were lacking for extant species, and filling gaps in geographical coverage. We also included data for species that may not occur in New England, but which do occur in neighboring basins of the eastern U.S. (e.g., Great Lakes-St. Lawrence, Hudson River) and which may qualify as proxies under our definition of RIS (Yoder 2012) for temperature criteria derivation purposes.

Appropriate Thermal Tolerance Thresholds

The FTM described by Yoder (2008) principally relies on the Upper Incipient Lethal Temperature (UILT) as the preferred lethal endpoint for calculating short and long term survival thresholds. This has been the accepted lethal endpoint for assessing potential thermal effects for the past 45 years (Brown 1974). The other commonly available lethal endpoint, the critical thermal maximum (CTM), is thought to produce lethal temperature thresholds that are too high to be protective in nature because the procedure subjects test organisms to relatively rapid increases in test temperature (e.g., >1°C/hour). Hence the long standing concern that such steady and rapid increases in test temperature do not reflect the temperature at which an organism has already experienced irreversible effects. We are therefore using the UILT as the preferred lethal endpoint and using adjusted CTM values when that is the only data that is available. However, lethality is not the only endpoint of concern in the FTM methodology. Thermal endpoints that reflect chronic exposure and responses are also recorded and include physiological optima (gametogenesis, growth, development, spawning), and behavioral

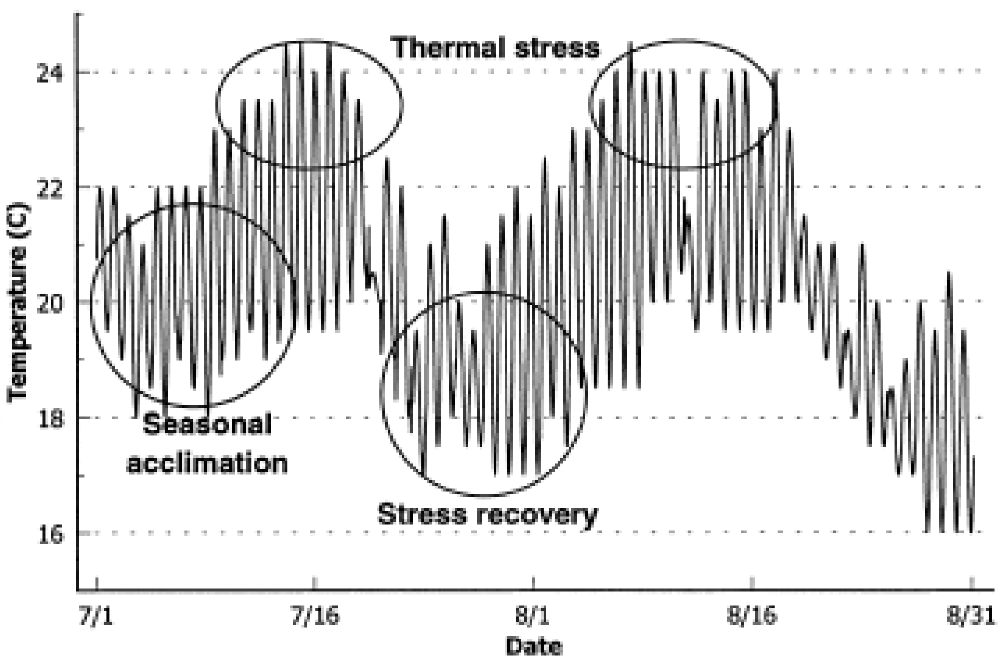

Figure 1. Features of the thermal regime that are important in determining the effects of temperature on fish (after Bevelheimer and Bennet 2000).

endpoints (e.g., final preferenda, preferred range, upper avoidance). Together these provide the basis for the optimum and growth outputs of the FTM.

Concern has always been and continues to be expressed about the potential disconnect between the inherently steady-state assumptions of thermal tolerance tests and the reality that exposure to high temperatures in nature cannot be judged solely by a maximum "not-to-be-exceeded" temperature. The concept is illustrated by Figure 1 from Bevelheimer and Bennet (2000), in which the accumulation of thermal stress experienced by an organism is dependent on seasonal acclimation, the extent and severity of the periods of thermal stress and exposure, and the occurrence and duration of recovery periods, i.e., lower temperatures that are closer to their physiological and behavioral optima. This concept strongly supports the need to employ seasonal average criteria in addition to daily maxima as part of a temperature criterion. While thermal resistance seems to increase with *slowly* (e.g., <1°C per day) increasing temperatures, does it represent reality in the ambient environment where temperatures fluctuate within a season? The few studies that have attempted to examine the effect of fluctuating test temperatures have sometimes produced conflicting results. Unfortunately, sufficient experimental data for a sufficient number of species has not been produced to support what might be viewed as "real time" temperature criteria in lieu of the current technology of fixed seasonal criteria. In addition, other stress factors that affect aquatic organisms including flow, the age and size of an organism, and pollution other than thermal can affect organisms in nature, but are seldom if ever simulated in thermal tolerance tests. As a result of these uncertainties, safety factors are applied in deriving and applying temperature criteria and in keeping with the exposure dynamics depicted by Figure 1.

Thermal Endpoints

Four thermal input variables are used in the Fish Temperature Model to first determine summer season (e.g., June 16–September 15) average and daily maximum temperature criteria. In developing these baseline input variables, six thermal parameters are first considered. General concepts of thermal responsiveness (e.g., acclimation) are also considered and are discussed in more detail elsewhere (Brown 1974). Of the six thermal parameters that are inventoried for each fish species (Appendix Table 1), the upper incipient lethal temperature (UILT) and the critical thermal maximum (CTM) are considered lethal thresholds and the remaining four (optimum, final preferendum, growth, and upper avoidance) are considered sublethal thresholds. At the time the Ohio EPA methodology was developed, the rapid transfer method (from which the UILT is derived) was viewed as providing a firmer basis for physiological response than the faster heating method on which the CTM is based (Brown 1974). Each of the six thermal thresholds is defined as follows:

Upper Incipient Lethal Temperature (UILT) – at a given acclimation temperature this is the maximum temperature beyond which an organism cannot survive for an indefinite period of time;

Chronic Thermal Maximum (ChTM) – the temperature at which a test organism dies resulting from a slow and steady increase in temperature (<1.0°C/day); this newly available endpoint is representative of the upper lethal temperature in Appendix Table 1. However, it is available for only a handful of fish species.

Critical Thermal Maximum (CTM) – the temperature at which a test organism experiences equilibrium loss resulting from a rapid and steady increase in temperature (>0.5-1.0°C/hr.);

Optimum – the temperature at which an organism can most efficiently perform a specific physiological or ecological function;

Final Preferendum – the temperature at which a fish population will ultimately congregate regardless of previous thermal experience (Fry 1947);

Upper Avoidance Temperature (UAT) – a sharply defined upper temperature which an organism at a given acclimation temperature will avoid (Coutant 1977);

Mean Weekly Average Temperature (MWAT) – the Mean Weekly Average Temperature for growth (Brungs and Jones 1976). The MWAT is calculated based on a formula that requires an optimum and upper lethal temperature.

Compilation of Temperature Effects Data

Appendix Table 1 serves as the "raw data" for the FTM, which requires four input parameters as follows:

- a physiological or behavioral optimum;
- a mean weekly average temperature for growth (calculated after Brungs and Jones 1977);
- an upper avoidance temperature, and;
- an upper lethal temperature based on the UILT.

In the case of lethal temperatures, data for acclimation temperatures that are relevant to the waterbody of concern should be used. While the Upper Incipient Lethal Temperature (UILT) is the preferred lethal endpoint (Brown 1974), the literature for some species is comprised mostly of critical thermal maximum (CTM) data. Hence, a conversion factor similar to that found in Appendix Table Z.2 from Yoder et al. (2006) or a default conversion to a value more representative of the UILT will be used (e.g., UILT = CTM – 2°C).

Data gathered from the comprehensive review of the thermal effects literature were characterized as one or more of the preceding thermal endpoints in the compilation of temperature effects data (Appendix Table 1). This compilation included all data compiled by Yoder et al. (2006) and new references that we obtained for New England fish species in this study. The result is that data for 68 species of New England freshwater fish species (plus one non-New England surrogate species) have been considered and included in Appendix Table 1. A

Table 1. Summary of the availability of thermal effects data for 68 New England (NE) freshwater fish species (plus 1 non-NE surrogate species) including the number of studies found by major thermal endpoint. The RIS status after Yoder (2012) for the upper Connecticut R. is included (na – not applicable). The upper thermal tolerance data are compiled in Appendix Table 1.

Species	Original RIS	Physiological Optimum	Behavioral Optimum	Upper Avoidance	Lethal Endpoint(s)	Connecticut River RIS[3]
Sea lamprey		2	5	-	4	VP,BF,BF/HO,CTL
American brook lamprey		1	-	-	-	na
Hogchoker		-	1	-	-	na
Atlantic sturgeon		-	1	-	-	na
Alewife		2	3	1	5	VP,BF,BF/HO,CTL
Blueback herring		-	1	1	2	na
American shad	**X**[1]	1	-	1	4	VP,BF,BF/HO,CTL
Gizzard shad		-	2	1	3	-
Lake Trout		1	1	-	1	-
Brook trout		2	3	2	4	CTL
Rainbow trout		2	9	5	10	BF,BF/HO,CTL
Atlantic salmon	**X**[1]	-	-	-	1	BF,BF/HO,CTL
Brown trout		1	3	3	6	BF,BF/HO,CTL
Cisco		2	-	1	4	-
Lake whitefish		1	-	-	1	-
Smelt		-	2	2	1	-
Central mudminnow		-	-	1	1	-
Chain pickerel		-	-	1	-	VP,BF,BF/HO,CTL
Redfin pickerel		1	-	-	-	-
Northern pike		5	2	-	6	BF,BF/HO,CTL
Muskellunge		1	1	-	2	-
White sucker	**X**[2]	3	3	3	10	VP,BF,BF/HO,CTL
Longnose sucker		-	1	-	1	CTL
Common carp		-	6	5	4	VP,BF,BF/HO,CTL
Golden shiner		1	4	1	3	VP,BF,BF/HO,CTL

Table 1. (continued).

Species	Original RIS	Physiological Optimum	Behavioral Optimum	Upper Avoidance	Lethal Endpoint(s)	Connecticut River RIS[3]
Emerald shiner		2	6	3	6	-
Common shiner		-	2	-	6	BF,BF/HO,CTL
Mimic shiner		-	1	-	-	CTL
Spottail shiner	**X**[1]	2	7	3	6	VP,BF,BF/HO,CTL
Creek chub		-	2	1	4	CTL
Fallfish	**X**[2]	-	2	-	-	VP,BF,BF/HO,CTL
Fathead minnow		1	3	3	4	-
Bluntnose minnow		-	4	6	7	CTL
E. Blacknose dace		-	1	3	4	CTL
Longnose dace		-	1	1	1	BF/HO,CTL
No. Redbelly dace		-	2	-	1	CTL
Finescale dace		-	-	-	1	-
Pearl dace		-	2	-	1	-
E. Banded killifish		-	3	-	2	CTL
American eel		-	3	-	1	VP,BF,BF/HO,CTL
Striped bass		4	3	-	2	-
White perch		3	2	-	1	-
Channel catfish		3	9	7	8	BF/HO
White catfish		2	2	-	2	BF,BF/HO,CTL
Brown bullhead		3	6	1	6	VP,BF,BF/HO,CTL
Yellow bullhead		-	3	-	2	VP,BF,BF/HO,CTL
Black bullhead		-	-	-	2	-
Stonecat madtom		-	1	-	1	-
Atlantic tomcod		1	1	-	1	-
Burbot		-	3	1	-	CTL
White crappie		1	3	3	4	CTL
Black crappie		2	4	2	4	VP,BF,BF/HO,CTL
Rock bass		1	5	4	3	VP,BF,BF/HO,CTL
Largemouth bass	**X**[2]	5	6	7	7	VP,BF,BF/HO,CTL

Table 1. (continued).

Species	Original RIS	Physiological Optimum	Behavioral Optimum	Upper Avoidance	Lethal Endpoint(s)	Connecticut River RIS[3]
N. Largemouth bass	**[X[2]]**	1	2	-	2	[VP,BF,BF/HO,CTL]
Smallmouth bass	**X**[1]	3	7	8	3	VP,BF,BF/HO,CTL
Bluegill		2	12	11	14	VP,BF,BF/HO,CTL
Green sunfish		1	6	3	5	-
Pumpkinseed sunfish		1	6	2	5	VP,BF,BF/HO,CTL
Redbreast sunfish		-	1	-	-	CTL
Yellow perch	**X**[1]	5	10	5	9	VP,BF,BF/HO,CTL
Walleye	**X**[1]	7	-	1	3	VP,BF,BF/HO,CTL
Johnny darter[4]		-	1	-	4	[BF,BF/HO,CTL]
Tessellated darter		-	1	-	-	BF,BF/HO,CTL
Brook stickleback		-	1	-	1	-
Three-spine stickleback		-	1	-	1	-
Nine-spine stickleback		-	1	-	-	-
Mottled sculpin		-	1	-	2	-
Slimy sculpin		-	2	1	1	CTL

[1] - one of the six original RIS; [2] – one of the 3 species added to most recent 316a RIS at request of VANR; [3] – VP – Vernon Pool to MA/NH State line (RM 92.5-83.3); BF – Bellows Falls to Turners Falls (RM 120.9-67.9); BF/HO - Bellows Falls to Holyoke (RM 120.9-32.3); CTL – Third Connecticut Lake to Turners Falls (RM 330.0-67.9); [4] – surrogate RIS for tessellated darter.

summary of each species and the number and types of thermal studies available for each are included in Table 1. Of the information available to date, 42 of the possible RIS for the Connecticut River mainstem (Yoder 2012) are included in Appendix Table 1.

FTM Thermal Input Variables

Thermal parameters compiled in Appendix Table 1 will be used as the primary database for choosing the thermal input variables for the FTM. Because all four endpoints needed for the FTM are usually not available for most species, an extrapolation procedure will be used to fill missing parameters. Ohio EPA (1978) estimated missing parameters by calculating relationships between the six thermal parameters that are compiled for each species — at least three of the six parameters need to be available for a species before this procedure is used. Estimates of missing thermal parameters include accomplishing calculation of the differences between:

- optimum (physiological or behavioral) and UAT;
- optimum and UILT or ChTM;
- optimum and critical thermal maximum (CTM);
- UAT and UILT/ChTM;
- UAT and CTM; and,
- UILT/ChTM and CTM.

Conversion factors for New England fishes will need to be developed using a similar approach. Extrapolations for missing values will then be made in a stepwise procedure as follows:

- based on the species family or subfamily relationships (i.e., by family or distinct subfamily groupings, e.g., Alosids); or
- based on the next closest family if information for a parameter did not exist within that species family; or,
- based on the average of all families as a last choice.

Finally, the extrapolated thermal parameter(s) will need to make "biological sense", *i.e.,* it must be "in line" with our knowledge of that species or family and within the same magnitude as differences between empirical values. For example, an estimated upper avoidance temperature (UAT) should be higher than the optimum and the MWAT for growth and it should be lower than the upper lethal temperature. The relationships between the species used by Ohio EPA (1978) and Yoder et al. (2006) for the four baseline input temperature thresholds for the FTM included extrapolated values.

FTM Outputs

An example of the first output of the FTM is presented in Table 2 using some of the options considered in the derivation of Ohio River temperature criteria (Yoder et al. 2006). This represents the calculated output from the FTM and includes exceedence thresholds for the

Table 2. Fish Temperature Model (FTM) outputs (°F[°C]) for two lists of RIS for the upper, middle, and lower Ohio River mainstem (adapted from Yoder et al. 2006).

Thermal Endpoint	Proportion of Representative Fish Species 100%	90%	75%	50%
Upper Mainstem *(all possible RIS included)*				
Optimum	67.5 [19.7]	71.6 [22.0]	75.9 [24.4]	81.3 [27.4]
Growth (MWAT)	73.9 [23.3]	78.3 [25.7]	80.8 [27.1]	85.1 [29.5]
Avoidance (UAT)	72.9 [22.7]	83.5 [28.6]	85.5 [29.7]	88.0 [31.1]
Survival (Long-term)	75.2 [24.0]	85.1 [29.5]	87.3 [30.7]	89.4 [31.9]
Survival (Short-term)	78.8 [26.0]	88.7 [31.5]	90.9 [32.7]	93.0 [33.9]
Upper Mainstem *(mainstem restricted RIS)*				
Optimum	68.2 [20.1]	72.7 [22.6]	78.1 [25.6]	82.8 [28.2]
Growth (MWAT)	75.9 [24.4]	78.8 [26.0]	82.8 [28.2]	86.9 [30.5]
Avoidance (UAT)	80.6 [27.0]	84.0 [28.9]	86.4 [30.2]	88.9 [31.6]
Survival (Long-term)	84.2 [29.0]	86.7 [30.4]	88.2 [31.2]	91.4 [33.0]
Survival (Short-term)	87.8 [31.0]	90.3 [32.4]	91.8 [33.2]	95.0 [35.0]
Middle Mainstem *(all possible RIS included)*				
Optimum	67.5 [19.7]	72.3 [22.4]	77.0 [25.0]	81.7 [27.7]
Growth (MWAT)	73.9 [23.3]	78.4 [25.8]	82.0 [27.8]	85.8 [29.9]
Avoidance (UAT)	72.9 [22.7]	83.4 [28.8]	86.0 [30.0]	88.2 [31.2]
Survival (Long-term)	75.2 [24.0]	86.2 [30.1]	87.6 [30.9]	90.3 [32.4]
Survival (Short-term)	78.8 [26.0]	89.8 [32.1]	91.2 [32.9]	93.9 [34.4]
Middle Mainstem *(mainstem restricted RIS)*				
Optimum	68.2 [20.1]	73.2 [22.9]	77.9 [25.5]	82.8 [28.2]
Growth (MWAT)	75.9 [24.4]	79.2 [26.2]	83.3 [28.5]	86.9 [30.5]
Avoidance (UAT)	80.6 [27.0]	84.0 [28.9]	87.1 [30.6]	89.1 [31.7]
Survival (Long-term)	84.2 [29.0]	86.7 [30.4]	88.3 [31.3]	91.6 [33.1]
Survival (Short-term)	87.8 [31.0]	90.3 [32.4]	91.9 [33.3]	95.1 [35.1]
Lower Mainstem *(all possible RIS included)*				
Optimum	68.2 [20.1]	72.3 [22.4]	77.0 [25.0]	82.4 [28.0]
Growth (MWAT)	73.9 [23.3]	78.4 [25.8]	82.2 [27.9]	86.2 [30.1]
Avoidance (UAT)	72.9 [22.7]	83.7 [28.7]	86.0 [30.0]	88.5 [31.4]
Survival (Long-term)	75.2 [24.0]	86.4 [30.2]	87.8 [31.0]	90.9 [32.7]
Survival (Short-term)	78.8 [26.0]	90.0 [32.2]	91.4 [33.0]	94.5 [34.7]
Lower Mainstem *(mainstem restricted RIS)*				
Optimum	71.1 [21.7]	74.7 [23.7]	77.9 [25.5]	82.9 [28.3]
Growth (MWAT)	77.4 [25.2]	79.5 [26.4]	84.0 [28.9]	86.9 [30.5]
Avoidance (UAT)	80.6 [27.0]	84.4 [29.1]	87.3 [30.7]	89.1 [31.7]
Survival (Long-term)	84.2 [29.0]	86.9 [30.5]	88.5 [31.4]	91.8 [33.2]
Survival (Short-term)	87.8 [31.0]	90.5 [32.5]	92.1 [33.4]	95.4 [35.2]

four major thermal endpoints that are applicable to the summer season which in this case was defined as June 16-September 15. At that latitude it represents the period when ambient seasonal temperatures are at their highest and are most stable. This example also shows the effect of using different aggregations of RIS, which is a major consideration in any FTM application. Four aggregations of RIS were described by Yoder (2012) and provide a key input variable for applying the FTM to the Connecticut River mainstem. FTM outputs for the Connecticut River could include up to four variations among the different RIS aggregations plus additional variations of each if different thermal tolerance values are at issue for selected species.

Other Considerations

While the consideration of the summer season endpoints depicted in Table 2 has been sufficient for prior applications of the FTM in the Midwestern U.S., the presence of an entire guild of diadromous species is an additional consideration for applying the FTM framework in New England. As used previously, the term "non-summer" has typically applied to the period from September 16 – June 15. However, as applied to the Connecticut River it would need to encompass migratory periods that might otherwise overlap with the "summer" period. That is, whether "summer" or "non-summer," the tolerance temperatures for these life stages would need to be accounted for as part of the FTM output. Hence critical "non-summer" season endpoints for diadromous and perhaps other species, while captured in the layout of Appendix Table 1, may need to be applied differently than how the FTM process has been used in previous applications to Midwestern rivers and streams. Essentially the approach for deriving "non-summer" seasonal temperature criteria thus far has been to maintain the "normal" inter and intra-seasonal temperature regime. As such, "non-summer" season thermal requirements and endpoints for diadromous and other species will need to be considered as part of the evaluation of a protective seasonal thermal regime in New England rivers and streams and the Connecticut River in particular.

The consideration by the FTM of "normal seasonal cycles" for deriving temperatures that are protective throughout the year requires sufficient knowledge of the *ambient* temperature regime. This means that a robust and long term ambient temperature database to ensure accuracy and representativeness is needed. An inherent assumption of the FTM is that if the natural seasonal cycle is maintained, then non-summer functions such as gametogenesis, movement, spawning, egg hatching, larval development, and growth will be maintained. Ambient non-summer temperatures almost never approach lethal endpoints (even considering lower acclimation temperatures) and in almost all cases warmer than normal ambient temperatures during the late fall, winter, and early spring will be attractive to most fish species. Hence, the concern herein needs to be on whether the ambient seasonal regime is being altered such that important non-summer functions are interfered with. An example might be with warmer winter temperatures attracting and concentrating fish. While this may be viewed as entirely acceptable and harmless by some, causing fish to stay active and expend energy for an elevated level of activity during colder ambient temperature periods could exert a deleterious effect on gametogenesis, a concern that was documented by Hokanson (1977) for Percids. Because of the present unknowns

Table 3. An example of seasonal average and daily maximum temperature criteria (°F) for the upper Ohio River mainstem based on mainstem restricted RAS (Yoder et al. 2006).

Month- Dates	Average[2]	Maximum[3]	Basis for Criteria
January 1-31	37.0	43.0	Consistent with seasonal temperature measured at the upper mainstem monitoring locations (see Table 2).
February 1-28	37.0	44.0	
March 1-31	42.0	51.0	
April 1-15	50.0	57.0	Consistent with spawning criteria for most representative fish species in March, April, May, and June.
April 16-30	55.0	61.0	
May 1-15	60.0	68.0	
May 16-31	64.0	72.0	
June 1-15	69.0	76.0	
June 16-30	84.2 [75.0]	87.8 [86.0]	Average and maximum provide for short and long-term survival of 100% of representative fish species; average exceeds MWAT for growth of 3 recreational RIS; average exceeds UAT for 3 RAS; average meets long-term survival of listed RIS.
July 1-31	84.2 [80.0]	87.8 [87.0]	
August 1-31	84.2 [81.0]	87.8 [83.0]	
September 1-15	84.2 [80.0]	87.8 [83.0]	
September 16-30	75.0	80.0	Consistent with seasonal temperature measured at the upper mainstem monitoring locations (see Table 2).
October 1-15	70.0	77.0	
October 16-31	64.0	70.0	
November 1-30	54.0	63.0	
December 1-31	42.0	55.0	

[2] Average criterion for the representative period set at the 50th percentile of the period of record based on aggregated data from upper mainstem monitoring locations (Table 2); ambient values between June 16 and September 15 are in brackets for comparison to summer average derived criteria.

[3] Daily maximum criterion for the representative period set at the 95th percentile value of the period of record based on aggregated data from upper mainstem monitoring locations (Table 2); ambient values between June 16 and September 15 are in brackets for comparison to summer maximum derived criteria.

about applying the FTM with diadromous species we will be examining this issue as it is applied to the Connecticut River in particular.

The final output of the FTM process is then a set of seasonal average and maximum temperatures that are protective of all functions including those that occur during the "non-summer" season. Again, one of the Ohio River options is presented as an example of summer average and maximum and non-summer season monthly and bi-monthly temperatures with the rationale described for each (Table 3; note that these temperatures will not be applicable to the Connecticut R.). For our purposes herein a similar template for application in New England will be developed, but will likely include differing rationales for determining some of the "summer" and "non-summer" season thresholds. This could include relying on thresholds other than the short and long-term survival outputs based on the particular requirements of one or more RIS. Any application of the FTM to the Connecticut River or any other New England river with diadromous species will need to be consistent with these concepts, including the consideration of non-summer season tolerance thresholds.

Possible Uses of the FTM Process in New England

We intend for the FTM process to serve a number of needs where temperature and thermal effects are a concern. This includes not only providing a means to re-evaluate existing state temperature criteria, but also providing a resource to assess site-specific impacts from thermal discharges, predicting effects from changes in stressors that result in thermal alterations, and as endpoints for TMDLs and similar planning activities. The data compiled herein can be updated as new information is made known and, as such, it is a dynamic process intended to reflect our best understanding of thermal effects on fish and other aquatic organisms.

References

Beitinger, T.L., W.A. Bennett, and R.W. McCauley. 2000. Temperature tolerances of North American freshwater fishes exposed to dynamic changes in temperature. Env. Biology Fishes 58: 237-275.

Bevelheimer, M. and W. Bennett. 2000. Assessing cumulative stress in fish during chronic intermittent exposure to high temperatures. Env. Science & Policy: S211-S216.

Brown, H. W. 1974. Handbook of the effects of temperature on some North American fishes. American Electric Power Serv. Corp. (Dec. 1974) : 431 pp. [with supplements May 1975; March 1976].

Brungs, W. A. and B. R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures, EPA-600/3-77-061. U.S. EPA Ecological Research Series.

Fourth International Conference on Grey Literature. 1999. New Frontiers in Grey Literature. GreyNet, Grey Literature Network Service. Washington D.C. USA, 4-5 October 1999. http://www.nyam.org/library/online-resources/grey-literature-report/what-is-grey-literature.html.

Hokanson, K.E.F. 1990. A national compendium of freshwater fish and water temperature data. Vol. II. Temperature requirement data for thirty fishes. U.S. EPA, Office of Research and Development, Environmental Research Laboratory, Duluth, MN. 178 pp.

Hokanson, K. E. F. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. J. Fish. Res. Bd. Can. 34, no. 10: 1524-50.

Ohio Environmental Protection Agency. 1978a. Methods and rationale used for establishing seasonal average and daily maximum temperature limitations as proposed in OAC 3745-1. Office of Wastewater Pollution Control, Division of Industrial Wastewater, Columbus, OH. 48 pp. + Appendices.

Wismer, D.A. and A.E. Christie. 1987. Temperature relationships of Great Lakes fishes: a data compilation. Great Lakes Fishery Commission Special Publication 87-3. 165 pp.

Yoder, C.O. 2012. Selection of Representative Important Species for the Connecticut River in the Vicinity of the Vermont Yankee Electric Generating Facility. MBI Technical Report MBI/2012-2-2. Columbus, OH. 15 pp.

Yoder, C.O. 2008. Challenges with modernizing a temperature criteria derivation methodology: the fish temperature modeling system, pp. 1-1 to 1-19. *in* Robert

Goldstein and Christine Lew (eds.). Proceedings of the Second Thermal Ecology and Regulation Workshop, Electric Power Research Institute, Palo Alto, CA.

Yoder, C.O., E.T. Rankin, and B.J. Armitage. 2006. Re-evaluation of the technical justification for existing Ohio River mainstem temperature criteria. Report to Ohio River Valley Water Sanitation Commission. Tech. Rept. MBI/05-05-2. Columbus, OH. 56 pp. + 4 appendices.

Yoder, C.O. and E.T. Rankin. 2005. Temperature Criteria Options for the Lower Des Plaines River. Final Report to U.S. EPA, Region V and Illinois EPA. Center for Applied Bioassessment and Biocriteria, Midwest Biodiversity Institute, Columbus, OH. EPA Grant X-97580701. 87 pp.

Appendix Table A-1. Key to footnotes: behavioral and physiological temperature criteria for all life stages of New England freshwater fish species. Criteria may vary from the original author's interpretation and are denoted by an asterisk (*). All values are °C.

Field A: Field studies designed to evaluate population and assemblage response to a wide range of temperatures including artificially induced changes beyond ambient.

Field B: Based on field occurrences under ambient conditions.

Lab A: Lethal dose/response based on rapid transfer from a given series of acclimation temperatures (classic UILT).

Lab A-1: Lethal endpoint derived from slow heating laboratory test; temperature raised <1°C/day (revised UILT).

Lab A-2: Lethal endpoint derived from constant increase in temperature of >0.5°C/minute (classic CTM).

Lab B: Physiological optimum determined (growth, gametogenesis, fertilization, egg & larval development, etc.).

Lab C: Behavioral preferenda determined in a horizontal gradient.

Lab D: Behavioral preferenda determined in an electronic shuttle box.

Lab E: Behavioral preferenda determined in a vertical gradient.

Lab F: Lethal dose/response with multiple stressors.

Lab G: Behavioral preferenda with multiple stressors.

Experimental Endpoints:

a - growth
b - net biomass gain
c - swimming
d - egg viability
e - egg hatching
f - egg fertilization
g - egg incubation

Appendix Table A-1. Key to footnotes (continued)

Experimental Endpoints: (continued)

h - gonad development
i - based on body temperature
j - upper avoidance temperature (UAT)
k - day
l - night
m - endpoint not specified in original publication; estimated from data presented
n - 12 hour TL_{50}
o - 24 hour TL_{50}
p - 48 hour TL_{50}
q - 96 hour TL_{50}
r - >96 hour TL_{50}
s - selection of mean modal temperature
t - ultimate upper incipient lethal temperature (UUILT) reported (Fry et al. 1946; Brett 1952)
u - starved test fish
v - fed test fish
w - growth determined under constant temperature ($\pm$0.5°C)
x - growth measured during diel temperature cycle
y - zero net biomass gain
z - combined dissolved oxygen/temperature stress
aa - test conducted under falling temperature
bb - test conducted under rising temperature
cc - endpoint derived from field observations
dd - final preferendum (Fry 1947)
ee - critical thermal maximum (CTM)
ff - variable photoperiod
gg - death endpoint (DP used in CTM)
hh - ${}_{(a)}KL_{m(b)}$ – median rate temperature limit for 50% survival for fish acclimated to (a) and transferred to (b)
ii - rate of temperature change allowing 99% survival
jj - salinity stress combined with temperature
kk - preferred range
ll - 0% mortality
mm - 100% mortality

Appendix Table A-1. Key to footnotes (continued)

Experimental Endpoints: (continued)

nn - physical deformities
oo - upper physiological limit of distribution in the field
pp - mortality observed in field
qq - short day length (light 9 hrs., dark 16 hrs.)
rr - long day length (light 16 hrs., dark 9 hrs.)
ss - scope for activity (Coutant 1975)
tt - mean temperature selected
uu - test fish injected with *Aeromonas hydrophila*
vv - upper "safe" limit recommended by investigators
ww - ultimate upper incipient lethal temperature (UUILT) reported using method described by Hokanson and Koenst (1986)
xx - no avoidance of lethal temperature – all fish died
yy - 30 minute TL_{50} (to simulate entrainment effects)
zz - >50-75% mortality
aaa - spawning interrupted, eggs and sperm became unviable
bbb - reported as tolerable range
ccc - upper zero growth temperature
ddd - mortality resulting from aggressive behavior associated injuries

Other Footnotes:

Su - Summer (generally mid-June through mid-September)
Fa - Fall (generally mid-September through October)
Wi - Winter (generally November through mid-March)
Sp - Spring (generally mid-March through mid-June)
gamete - development and maturation of gonads in adult fish (gametogenesis)
embryo - embryonic development including fertilization
larval - larval development (sac fry)
fry - post-larval free-swimming development
yoy - young-of-year
yearl yearling
juv - juvenile
Ad - adult

Appendix Table A-1 Upper thermal tolerances for New England freshwater fish species (includes diadromous and fresh and brackish water tidal species).

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
Petromyzontidae	Sea lamprey (*Petromyzon marinus*)	Great Lakes - Canada	1963	Lab A	larvae					(20) 29[m,n] (20) 29.7[m,o] (20) 30.3[m,p] (20) 31.1[m,q] (20) 31.4[m,r]	McCauley 1963
				Lab B	eggs	12-26[e]	18[e]				Spotilla et al. 1979
				Lab B	larvae (ammocoetes)					(5) 29.5[ee] (15) 30[ee] (25) 31[ee]	Spotilla et al. 1979
		Fish Creek - New York	1975	Lab A	larvae (ammocoetes)					(5) 29.5[q] (15) 30[q] (25) 31[q] 31.4[t]	Potter and Beamish 1975
					larvae (ammocoetes)			13.6[dd]		31[t]	Jobling 1981
					Ad.			(10) 14.3[dd]			Talmadge and Coutant 1979
		L. Superior tribs.			Ad.			(Su) 6-15[kk]			Moman et al. 1980
					larvae (ammocoetes)			(Sp) 10-26.1[kk] (Su) 15-20[kk]			
					larvae (ammocoetes)		15-20				Farmer et al. 1977
		Great Lakes region	?	?	?			10.5[dd]			Coker et al. 2001
		Ocquecoc R. - Michigan	1976	Lab D	larvae (ammocoetes)	10-19[kk]		14[dd]			Reynolds and Casterlin 1978
	American brook lamprey (*Lampetra appendix*)	Great Lakes region	?	?	?			10.5[dd]			Coker et al. 2001
Achiridae	Hogchoker (*Trinectes maculatus*)	Hudson River - New York	1976-7	Lab E	yoy			(24) 26[dd]			Ecological Analysts 1978
Acipenseridae	Atlantic sturgeon (*Acipenser oxyrhynchus*)	Hudson River - New York	1976-7	Lab E	yoy			(8.5) 18[dd]			Ecological Analysts 1978
Clupeidae	Alewife (*Alosa pseudoharengus*)	Delaware R. - Delaware	1971	Lab C	juv.			(21.1) 21.7 (17.8) 20	(17.2) 26.1 (17.8) 24.2 (25) 30		Meldrim and Gift 1971
		L. Michigan - Illinois	1976	Lab A	Ad.					(10)23.5[r], 29.5[ee] (15)23,5[r],30.1[ee] (20)24.5[r],31.2[ee]	Otto et al. 1976

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Alewife (cont'd)	L. Michigan - Illinois	1976	Lab A	yoy					(10-12)26.5[r],28.3[ee] (18-20)30.3[r],32.7[ee] (24-26)32.1[r],34.4[ee]	McCauley 1981
		L. Michigan - Illinois		Lab E	Ad.			May (9-11) 21[s] June(10-11) 19[s] Aug (15-18) 16[s] Sep (10-12) 16[s] Nov (5-9) 16[s] Dec (1-4) 11[s] Jan (1-3) 12[s]			McCauley 1981
					yoy			May (7-10) 21[s] Aug (15-18) 25[s] (24-25) 25[s] Sep (10-12) 24[s] Nov (5-9) 21[s] [illegible]			
		W. L. Erie - Ohio	1973-74	Lab A, C	Ad.			(Su) 21.3[tt,dd]		(16.4) 28.3[t]	Reutter and Herdendorff 1974
		W. L. Erie - Ohio	1973-74	Lab A	Ad.					(18.2) 30.2[t]	Reutter and Herdendorff 1976
		L. Michigan - Wisconsin	1979	Lab A	yoy					(27) 28.2[t] (30) 31-34[ww]	McCauley and Binkowski 1982
		Hudson River - New York	1978	Lab A, B	yoy		26.4[b]			(23) 31.7[q] (25) 32.6[q] (25) 36.0[yy]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab B	eggs		20.8-23.9[e] 26.4[q,nn]				Ecological Analysts 1978
		Hudson River - New York	1976-7	Lab A	Juv.					(24.5) 36.4[yy] (25) 37.3[yy]	Ecological Analysts 1978
		Hudson River - New York	1976-7	Lab A	Ad.					(14.5) 25.5[q] (20.5) 28.4[q]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab E	Juv.			(21) 19[dd] (25) 20[dd]			Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab E	Ad.				(16) 26[j] (20) 30[j]		Ecological Analysts 1978
		Kalamazoo R. - Michigan	1966-7	Lab B	eggs		(20) 17.8-21.1[e]			25.6-28.3[zz]	Edsall 1970
		Kalamazoo R. - Michigan	1966-7	Lab B	larvae		(20) 15[vv]				Edsall 1970
		Kalamazoo R. - Michigan	1966-7	Lab B	Adults (spawners)		27.8[aaa]				Edsall 1970
	Blueback Herring *(Alosa aestivalis)*	Hudson River - New York	1976-7	Lab A	yoy			(25) 27[dd]		(25) 33.1[q]	Ecological Analysts 1978
		Connecticut R. - Connecticut	1967-71	Field B	yoy				(19) 30[j]	(19) 32.3[zz] (22.7) 32.9[mm]	Marcy et al. 1972
	American shad *(Alosa sappadissima)*	Hudson River - New York	1976-7	Lab A	yoy			(24) 24[dd]		(24) 31.5[q]	Ecological Analysts 1978

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	American shad (cont'd)	Connecticut R. - Connecticut	1967-71	Field B	yoy				(19) 30[j]	(19) 31.2[ll] (19) 32.2[mm]	Marcy et al. 1972
		Connecticut R. - Connecticut	c1967	Lab A	yoy					(24) 32.5[mm] (28) 32.2[mm]	Moss 1970
		Eastern U.S.	Various	Field B	Egg		8-30[bbb]				Greene et al. 2009 (Review chapter)
		Eastern U.S.	Various	Field B	Larvae		15-25[cc]			27-28[nn,oo]	Greene et al. 2009 (Review chapter)
		Eastern U.S.	Various	Field B	Juv.		15-25[cc]				Greene et al. 2009 (Review chapter)
		Eastern U.S.	Various	Field B	Adults (spawners)		14-24.5[cc]				Greene et al. 2009 (Review chapter)
		Neuse R. - North Carolina	1973	Lab A-2	Juv.					34-35[ee]	Horton and Bridges 1973 cf. Greene et al. 2009 (Review chapter)
	Gizzard shad (*Dorosoma cepedianum*)	Wabash R.- Indiana	1968-73	Field A	Ad.			(Su) 28.5-31[kk]	32[m]		Gammon 1973
		Tennessee R. - Alabama	1972-73	Field A	Ad. - juv.				36[yy]		Wrenn 1976
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 19[tt,dd] (Fa) 20.5[tt,dd]			Reutter and Herdendorff 1974
		W.L. Erie - Ohio	1973-74	Lab A						(15.9) 31.7[t]	Reutter and Herdendorff 1976
		Put-in-Bay - Ohio	1945-47	Lab A	Ad. - juv.					(25) 34[o] (30) 36[o] (35) 36.5[o]	Hart 1952
		Knoxville, Tenn.	1945-47	Lab A	Ad. - juv.					(25) 34.6[o] (30) 35.8[o]	
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad. - juv.	(Su) 26-34[kk] (Fa) 10-22[kk] (Wi) 4-10[kk]					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad. - juv.	(Su) 26-29[m,kk]		(Su) 30[m]			Yoder and Gammon 1976a
		White R. - Indiana	1965-72	Field A	Ad. - juv.						Proffitt and Benda 1971
		Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 28.5[p]	Cvancara et al. 1977
		Tennessee - Reservoirs		Field B	Ad.			22.5-23.0[dd]			Dendy 1948
		Tennessee - Reservoirs		Field A	Ad.				33.9-34.4[j]		Churchill and Wojtalik 1969
Salmonidae	Lake trout (*Salvelinus namaycush*)	L. Minnewanka - Canada (Alberta)	1951	Lab B	Ad.					(10) 22.9m,n (15) 24m,n (15) 23.6m,o (20) 25.1m,n (20) 24.6m,o (20) 24m,p (20) 23.5m,q	Fry and Gibson 1953

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Lake trout (cont'd.)	Hatchery - Canada	1953, 1964	Lab E	yr.			(5) 11.7[s] (10) 11.6[s] (15) 11.9[s] (20) 11.8[s] 11.7[dd]			McCauley and Tait 1970
		L. Michigan - Wisconsin	1972-73	Field A	Ad.	9.9 - 14.1[i]	11.8[i,tt]				Spigarelli 1975
	Brook Trout *(Salvelinus fontinalis)*	Hatchery - Virginia	1974+	Lab C[bb]	Juv.	(12) 12.8-15.0[kk] (15) 14.5-16.1[kk] (18) 16.0-17.3[kk] (21) 17.2-18.8[kk] (24) 18.2-20.5[kk] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa]		(12) 13.7[tt] (15) 15.2[tt] (18) 17.2[tt] (21) 18.3[tt] (24) 19.0[tt] (27) [aaa] (30)[aaa] (33)[aaa] (36)[aaa] 16.8[dd]	(12) 15[j] (15) 18[j] (18) 21[j] (21) 24[j] (24) 26[j] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa]	(24) 24[xx]	Cherry et al. 1977
		Hatchery - Virginia	1973+	Lab C[aa]	yoy	(6) 9.4-12.2[kk] (9) 11.1-13.4[kk] (12) 12.9-14.6[kk] (15) 14.4-16.0[kk] (18) 15.8-17.6[kk] (21) 17.1-19.3[kk] (24) 18.3-21.1[kk] (27)[aaa] (30)[aaa]		(6) 11.2[tt] (9) 11.3[tt] (12) 13.7[tt] (15) 15.2[tt] (18) 18.0[tt] (21) 18.3[tt] (24) 19.0[tt] (27)[aaa] (30)[aaa]	(6) 14[j] (9) 15[j] (12) 16[j] (15) 18[j] (18) 20[j] (21) 23[j] (24) 25[j] (27)[aaa] (30)[aaa]		Cherry et al. 1975
		Ord Creek - Arizona	pre 1980	Lab A-2	Juv.					(10) 28.7[ee] (20) 29.8[ee] (10) 22-28[ww]	Lee and Rinne 1980
		Hatchery - Minnesota	1970+	Lab C	yoy		15.6[a]			20.1[t]	McCormick et al. 1972
		Hatchery - Minnesota	1970+	Lab C	Ad./Juv.		16.1[a]			25.3[t]	Hokanson et al. 1973b
		Great Lakes region	?	?	?			16[dd]			Coker et al. 2001

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Rainbow trout (*Oncorhynchis mykiss*)	Firehole R. - Montana	1974, 1975	Field A	Ad.				25[cc]		Kaya et al 1977
		Hatchery - Ontario	1967	Lab C	juv.			(10) 15.8[s] (15) 17.5[s] (20) 22[s]			Javaid and Anderson 1967a
		Hatchery - Ontario	1967	Lab C	juv.			(20) 18.2[u] (20) 21.4[v]			Javaid and Anderson 1967b
		L. Superior - Minnesota	1972	Lab A	juv.					(16) 25.6[q] (16) 25.7[o]	Hokanson et al 1977
				Lab B	juv.	17.2-18.6[w] 15.5-17.3[x]	17.2[w] 15.5[x] 23[y,w] 21[y,x]				
		Hatchery - Ontario	1955	Lab E	yoy			(5) 16[s] (10) 15[s] (15) 13[s] (20) 11[s] 13[t]			Garside and Tait 1958
		England	1962	Lab F	yoy					(18) 26.7[n] (18) 26.4[o] (18) 26.2[p] (18) 26.1[n,z]	Alabaster and Welcomme 1962
		Great Lakes - Ontario	1969	Lab A	yoy					(15) 25-26[q]	Bidgood and Berst 1969
		Hatchery - Ontario	1971	Lab C	yoy	17-20[kk]		19s,18.4[tt]			McCauley and Pond 1971
				Lab E	yoy	17-18[kk]		18s,18.4[tt]			
		Hatchery - Ontario	1966	Lab C	yoy			(20) 22[s,bb] (10) 15.2[s,aa]			Jaraid 1972
		Horsetooth Res. - Colorado	1960	Field B	juv. - Ad.	18.9 - 21.1[s]					Horak and Tanner 1964
		L. Michigan - Wisconsin	1972-73	Field A	Ad.	8.5 - 23.5[i]	16.5i,tt				Spigarelli 1975
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(6.3) 17.5[ee]	Reutter and Herdendorf 1976
		Hatchery - England	1966	Lab A	juv.					(15) 25.3[o] (20) 26.6[o]	Alabaster and Downing 1966
		Hatchery - Maryland	1980+	Lab C	yoy			14.7[tt]	(6) 18[j] (12) none[xx] (18) 24[j] (24) 27[j]	(6) 24.6[t] (12) 25.9[t] (18) 26.7[t] (24) 26.0[t]	Stauffer et al. 1984
		Hatchery - Michigan	198	Lab C	Juv.			(12) 14.1[dd] (18) 18.6[dd]	(12) 18[j] (18) 21[j]	(12) 25[ww]	Cherry et al. 1982

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Rainbow trout (cont'd)	Hatchery - Virginia	1974+	Lab C[bb]	Ad.	(12) 13.4-15.7[kk] (15) 15.7-17.3[kk] (18) 17.8-19.1[kk] (21) 19.6-21.1[kk] (24) 21.2-23.4[kk] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa]		(12) 14.1[tt] (15) 17.1[tt] (18) 18.6[tt] (21) 20.2[tt] (24) 22.2[tt] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa] 19.8[dd]	(12) 15[j] (15) 18[j] (18) 21[j] (21) 24[j] (24) 25[j] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa]	(24) 23[xx]	Cherry et al. 1977
		Hatchery - Virginia	1973+	Lab C[aa]	yoy	(6) 10.6-11.7[kk] (9) 12.5-13.4[kk] (12) 14.4-15.1[kk] (15) 16.2-16.9[kk] (18) 17.9-18.7[kk] (21) 19.7-20.6[kk] (24) 21.4-22.5[kk] (27)[aaa] (30)[aaa]		(6) 11.6[tt] (9) 12.6[tt] (12) 14.4[tt] (15) 16.9[tt] (18) 18.1[tt] (21) 20.1[tt] (24) 22.0[tt] (27)[aaa] (30)[aaa]	(6) 13[j] (9) 15[j] (12) 17[j] (15) 19[j] (18) 19[j] (21) 23[j] (24) 25[j] (27)[aaa] (30)[aaa]		Cherry et al. 1975
		Hatchery - Missouri	1995+	Lab A-2	yoy					(10) 28.0[ee] (15) 29.1[ee] (20) 29.8[ee]	Currie et al. 1998
		Hatchery - Arizona	pre 1980	Lab A-2	Juv.					(10) 28.5[ee] (20) 29.4[ee] (10) 21-27[ww]	Lee and Rinne 1980
		Great Lakes region	?	?	?			19.8[dd]			Coker et al. 2001
	Atlantic salmon (*Salmo salar*)	River Leven - United Kingdom	c1974	Lab A	yoy					(15) 32.9[ee] (20) 32.8[ee]	Elliott and Elliott 1995
		River Leven - United Kingdom	c1974	Lab A	Juv.					(15) 32.8[ee] (20) 32.9[ee]	Elliott and Elliott 1995
	Brown trout (*Salmo trutta*)	Firehole R. - Montana	1974, 1975	Field A	Ad.				25[cc]		Kaya et al 1977
		England	1960	Lab A	larvae					(5) 24.6[o],24,2[p],23.1[q] (10) 26[n],25[o],24.5[p],23[r] (20) 26[o],24.8[p],23.8[q],23[r],22[ee]	Bishai 1960 (58)
		L. Michigan - Wisconsin	1972-73	Field A	Ad.	7.1 - 21.3[i]	13.8[i,tt]				Spigarelli 1975 (27)
		Hatchery - England	1966	Lab A	juv.					(6) 23.2[o] (15) 26[o] (20) 26.4[o]	Alabaster and Downing 1966 (100)
				Lab C	Juv.			15 - 18[kk,m]	20[m]		

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Brown trout (cont'd.)	Hatchery - Virginia	1974+	Lab C[bb]	Ad.	(12) 9.5-16.2[kk] (15) 12.4-17.0[kk] (18) 14.7-18.4[kk] (21) 16.0-20.8[kk] (24) 16.6-22.8[kk] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa]		(12) 11.7[tt] (15) 15.5[tt] (18) 17.9[tt] (21) 18.8[tt] (24) 18.5[tt] (27)[aaa] (30) [aaa] (33)[aaa] (36)[aaa] 17.8[dd]	(12) 18[j] (15) 21[j] (18) 21[j] (21) 27[j] (24) 26[j] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa]	(24) 25[xx]	Cherry et al. 1977
		Ord Creek - Arizona	pre 1980	Lab A-2	Juv.					(10) 29.0[ee] (20) 29.9[ee] (10) 21-27[ww]	Lee and Rinne 1980
		Great Lakes region	?	?	?			21.1[dd]			Coker et al. 2001
		River Leven - United Kingdom	c1974	Lab A	Juv. (1+)					(15) 30[ee]	Elliott and Elliott 1995
		River Leven - United Kingdom	c1974	Lab A	Juv. (2+)					(20) 30[ee]	Elliott and Elliott 1995
Coregonidae	Cisco *(Coregonus artedii)*	Clearwater L. - Minnestoa	1970	Lab A,B	larvae		13 - 18[a]			(3) 19.8o (3) 21(75% mortality) (3) 18(9% mortality)	McCormick et al. 1971
		Clearwater L. - Michigan	1969	Lab B	eggs		5.6[g]			12[mm]	Colby and Broake 1970
	Cisco (cont'd)	Pickerel L. - Michigan	1967	Lab A						(2) 19.8[r] (5) 21.8[r] (10) 24.3[r] (20) 26.3[r] (25) 25.8[r] 25.8[t]	Edsall and Colby 1970
		Halfmoon L. - Michigan	1968	Field A						(<10) >20[pp]	Colby and Broake 1969
		Lakes - Indiana	1955	Field A,B					20[oo]		Frey 1955
	Lake whitefish (*Coregonus clupeaformis*)	L. Huron - Ontario	1970	Lab A	yoy					(5) 20.6[r] (10) 22.7[r] (15) 25.8[r] (20) 26.6[r] (22.5) 26.6[r] 26.6[t]	Edsall and Rottiers 1976
		L. Erie - Ohio	1934-38	Lab B	egg	0.5 - 6[e]	0.5[e]				Price 1940
Osmeridae	Smelt *(Osmerus mordax)*	W.L. Erie - Ohio	1973-74	Lab A	Ad.					(6) 24.9[t]	Reutter and Herdendorff 1976
				Lab A-2						(15) 28.5[ee]	Ellis 1984

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Smelt (cont'd.)	Canada - L. Ontario		Lab A-2	Ad.					(1) 22.6[ee] (1.6) 22.8[ee] (3.1) 23.3[ee] (5.4) 24.1[ee] (6.5) 20.1[ee] (8.2) 25.2[ee] (12.2) 26.4[ee]	McCauley 1981
		Wisconsin - L. Michigan			Ad.			(Fa) 6-8[dd] (Fa) 7.8[dd] (Fa) 11-16[dd]	14[j]		Brandt et al. 1980
		L. Superior & L. Erie		Field A	Ad.			(Su) 7-8[kk] [L. Erie] (Su) 11-16[kk] {L. Superior]	(Su) 15.5[j]		Heist and Swenson 1983
Umbridae	Central mudminnow *(Umbra limi)*	Michigan - Pond		Field B						38[cc]	Beltz et al. 1974
		Ontario - streams		Field A	Ad.				28.9[cc]		Scott and Crossman 1973
Esocidae	Chain pickerel (*Esox niger*)	? - Pennsylvania	1977	Lab D	Ad.			24[s]			Reynolds and Casterlin 1977
	Redfin pickerel *(Esox americanus)*	Canada	1958	Lab C			26 (Su)				Ferguson 1958
	Northern pike (*Esox lucius*)	Cow Horn L. - Minn.	1968, 1969	Lab A,B	egg larvae (1 day)	6 - 17.7[e]	11.7[e]			19.2 - 19.9[r] (6.1) 22[o],20.6[q],20.6[r] (11.8) 28[o],26.5[q],24.1[r] (17.7) 28.4[o],27.1[q],25[r]	Hokanson et al. 1973a
					larvae (swimming)	18 - 25.6[b]	25.6[a] 20.8[b]			(7.2) 23.6[o],23.4[q],23.4[r] (12.6) 26.4[o],26.3[q],26.3[r] (17.7) 28.4[o],28.4[q],28.4[r]	
		Westensee- Germany	1966	Lab B	egg	9 - 18[e]	15[e]			19.7[r]	Lillelund 1966
		Brahmsee - Germany	1966	Lab B	egg					19.3[r]	Hokanson et al. 1973a
		England	1965	Lab B	egg	6-16[e]	16[e]			18.9[r]	Switt 1965
		Hatchery - Ontario	1963	Lab A	juv.					(25) 32.2[o] (27.5) 32.7[o] (30) 33.2[o]	Scott 1964
		Hatchery - Wisconsin	1968	Lab B	eggs		12.2 - 13.3[e]				Steucke 1968
		Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 30.8[p]	Cvancara et al. 1977
		Ottawa R. - Canada	1978	Review			28.3[bbb]				Christie 1979
		Canada		Lab C	juv.			23.7[dd]			McCauley 1980
		Great Lakes region	?	?	?			22.5[dd]			Coker et al. 2001

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Muskellunge (*Esox masquinongy*)	Hatchery - Ontario	1963	Lab A	juv.					(25) 32.2[o] (27.5) 32.7[o] (30) 33.2[o]	Scott 1964
		Hatchery - New York	1975	Lab A	larvae					(20-25) 32.8[ee]	Bonin and Spotila 1978
		Ottawa R. - Canada	1978	Review			27.0[bbb]				Christie 1979
		Great Lakes region	?	?	?			25.6[dd]			Coker et al. 2001
Catostomidae	White sucker (*Catostomus commersonii*)	L. Amikeus, L. Opeongo - Ontario	1941	Lab A	juv.					(25-26) 31.2[n],29[ll]	Brett 1944
		Greenwood L. - Michigan	1968-69	Lab A,B	eggs larvae larvae (newly hatched) larvae (swim-up)	9-17.2[e]	15.2[e] 26.9[a,b]			(15) 30[nn] (8.9) 29[o],29[p],28.6[r] (15.2)31.1[o],31[p],30[r] (21.1)31.5[o],21[p],28.2?[r] (10) 28.5[o],28.5[p],28.1r (15.8)30.7[o],30.7[o],30.7[r] (21.1)32[o],32[p],30.5[r]	McCormick et al. 1977
		Minnesota	1977	Lab A,B	larvae juv. Ad.	21-28[a] 21-26[a]	26[a] 26[a]			(26) 30.5[r] (26) 32.5[r]	Brungs and Jones 1977
		Pennsylvania	1978	Lab D	Ad.	22.8 - 26.1[kk]		(23)24.2[k,tt],25[k,s] (23)24[l,tt],24[l,s] (23)24.1[dd]			Reynolds and Casterlin 1978a
		Horsetooth Res. - Colorado	1960	Field B	juv. - Ad.	18.9 - 21.1[s]					Horak and Tanner 1964
		W.L. Erie - Ohio	1973-74	Lab C	Ad (3)			(Fa) 2.4[tt,dd]		(14.3) >29.9[t]	Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad (3)					(19) 31.6[t]	Reutter and Herdendorf 1976
		Don R. - Ontario	1945-46	Lab A	juv.					(5) 26.3[n] (10) 27.7[n] (15) 29.3[n] (20) 29.3[n] (25) 29.3[n]	Hart 1947
		Ohio R. - Ohio, Kentucky	1970-74	Field A	Ad.	(Su) 25-27[kk] (Fa) 16-19[kk]					Yoder and Gammon 1976a
		New R. - Virginia	1973	Field A	Ad. - juv.	20 - 23.9[cc,kk]			30.6[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A	Ad. - juv.				26.7		Stauffer et al. 1976
		Ottawa R. - Canada	1978	Review			(larval) 28.0[bbb] (Ad.) 25.1[bbb]				Christie 1979
		British Columbia	1950+	Lab A Lab A-2 Lab A-2 Lab A-2	Juv. larval Juv. Ad.					(23) 26.6-27.0[t] (23) 37.0[ee] (26.3-28) 40.6[ee] 35-36[ee]	Black 1953 Tatarko 1966 Horoszewicz 1973 Meuwis and Heuts 1957
		Great Lakes region	?	?	?			22.4[dd]			Coker et al. 2001

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	White sucker (cont'd.)	New R. - Virginia	?	Lab C	Juv.				(6) 15[j] (12) 15[j] (18) 27[j] (24) 30[j]		Cincotta and Stauffer 1984
	Longnose sucker *(Catostomus catostomus)*	British Columbia	1950+	Lab A	Juv.					(11.5) 27[j] (14) 26.5[t]	Black 1953
		Great Lakes region	?	?	?			12.5[dd]			Coker et al. 2001
Cyprinidae	Common Carp *(Cyprinus carpio)*	L. Monona - Wisconsin	1970	Lab D	juv.				34.4[m]		Neill et al. 1972
		L. Monona - Wisconsin	1970	Field A	Ad. Ad. Ad. Ad.			28.3 - 30.7[i,km,] 29.3 - 31.8[i,l,m]	32.6[i,k,m] 31[i,l,m] 33.2[l,m] 32.7[k,m]		Neill and Magnuson 1974
				Lab D	juv. Juv.			30.0 - 32.2[l,m] 29.8 - 31.9[k,m]	33.3[l,m] 32.2[k,m]		
		Belgium	1957	Lab A,B	juv. Ad.					38 - 39[r] 35.5 - 37[r]	Meuwis and Heuts 1957
		Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 33 - 35[kk]	34.5[m]		Gammon 1973
		Ontario	1956	Lab E	yoy			(10) 17[s] (15) 25[s] (20) 27[s] (25) 31[s] (30) 31[s] (35) 32[s] 32[dd]			Pitt et al. 1956
		Lichenskiel - Poland	1966	Lab A	Ad.					(26.7) 34[xx],40.2[ee] (24.5) 32.4[xx],40.3[ee]	Horoszewica 1973
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 29.7[tt,dd] (Sp) 27.4[tt,dd]		(23.3) 39[t]	Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23.3) 39[t]	Reutter and Herdendorf 1976
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 26-34[kk] (Fa) 16-20[kk] (Wi) 5-16[kk]					Yoder and Gammon 1976a
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su) 32-34[m,kk]			35.5[m]		Yoder and Gammon 1976b
		? - Pennsylvania	1977	Lab D	Ad.			29[s]			Reynolds and Casterlin 1977
		White R. - Indiana	1965-72	Field A	Ad.				36.1[yy]		Proffitt and Benda 1971
		Great Lakes region	?	?	?			29.7[dd]			Coker et al. 2001

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Golden shiner (*Notemigonus crysoleucas*)	L. Opeongo - Ontario	1941	Lab A	juv.					(14.2) 30.4[n,aa] (14.8) 30.3[n,bb] (16.8) 31.8[n,bb] (17.4) 31.6[n,aa] (19.3) 33.4[n,aa] (21.2) 32.8[n,aa] (21.7) 33.5[n,bb] (22.2) 33.2[n,bb]	Brett 1944
		New Jersey	1972	Lab A	juv.					(22) 39.5-40[ee]	Alpaugh 1972
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 22.3[tt,dd] (Fa) 21[tt,dd] (Wi) 16.8[tt,dd] (Sp) 23.7[tt,dd]		(14.4) 30.5[t]	Reutter and Herdendorf 1974
		Algonquin Park, Ontario	1945-47	Lab A	Ad. - juv.					(10) 29.3[o] (20) 31.8[o]	Hart 1952
		Put-in-Bay - Ohio	1945-47	Lab A	Ad. - juv.					(20) 32.1[o] (25) 33.7[o]	
		Welaka, Florida	1945-47	Lab A	Ad. - juv.					(15) 33.7[o] (20) 31.9[o] (25) 33.2[o] (30) 34.7[o]	
		Ottawa R. - Canada	1978	Review			29.3[bbb]				Christie 1979
				Field B	Ad.			28.9-32.2[kk]			Trembley 1961
		Hudson River - New York	1978	Lab E	yoy			(8.5) 18[dd] (23) 27[dd] (25.5) 28[dd]			Ecological Analysts 1978
		Great Lakes region	?	?	?			23.8[dd]			Coker et al. 2001
		New R. - Virginia	?	Lab C	Juv.				(6) 15[j] (12) 24[j] (18) 30[j] (24) 30[j] (30) 36[j] (36) 39[j]		Cincotta and Stauffer 1984
	Emerald Shiner (*Notropis atherinoides*)	L. Superior - Minnesota	1970	Lab A,B	yoy		28.9[a] (24 - 28.9)[a]			(20) 35.2[r] (20-25) 32.6[r]	McCormick and Kleiner 1976
		L. Erie - Ohio	1972	Lab C	Ad. Yoy				27 30		Barans 1972
		L. Simcoe - Ontario	1967	Lab E	yoy			(2.5) 13[s] (5) 18[s] (10) 21[s] (15) 24[s] (20) 25[s] (25) 26[s] (30) 25[s] 25[dd]			Campbell and MacCrimmon 1970

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Emerald shiner (cont'd)	L. Erie - Ohio	1971	Lab C	yoy	(Su) 21-23[s] (Fa) 13-15[s] (Wi) 11-13[s] (Sp) 13-15[s]		(Su) 22[m,s] (Fa) 14[m,s] (Wi) 10.5[m,s] (Sp) 15[m,s]	(Su) 27.5[m] (Fa) 18.3[m] (Wi) 15.8[m] (Sp) 19[m]		Barans and Tubb 1973
					Ad.	(Su) 22-23[s] (Fa) 15-18[s] (Wi) 6-7[s] (Sp) 16-18[s]		(Su) 23[m,s] (Fa) 18[m,s] (Wi) 5.5[m,s] (Sp) 17.5[m,s]	(Su) 25.2[m] (Fa) 21.5[m] (Wi) 13[m] (Sp) 21.5[m]		
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Wi) 9.3[tt,dd]		(10.5) 27.1[t]	Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Wi) 8.3[tt,dd]		(7.8) 28.6[t]	Reutter and Herdendorf 1976
		Toronto, Ontario	1947	Lab A	Ad					(25-Wi)32.1[o],30.7[q]	Hart 1952
		Put-in-Bay - Ohio	1946	Lab A	Ad.					(25-Su)30.7[o]	
		L. Simcoe - Ontario	1945-46	Lab A	Ad.					(5) 23.2[n] (10) 26.7[n] (15) 28.9[n] (20) 30.7[p] (25) 30.7[r]	Hart 1947
		White R.-Indiana	1965-72	Field A	Ad.				31.1[yy]		Proffit and Benda 1971
		Arkansas/Oklahoma streams	198	Lab A Lab C	Ad.			19.4[tt]		(15) 34.5[ee]	Matthews 1981
		Ottawa R. - Canada	1978	Review			29.6[bbb]				Christie 1979
		Great Lakes region	?	?	?			24[dd]			Coker et al. 2001
	Common shiner *(Luxilis cornutus)*	L. Opeongo, L. Amikeus-Ontario	1941	Lab A	juv.					(25-26) 32[n],30[ll]	Brett 1944
		Toronto, Ontario	1947	Lab A	Ad.					(5) 26.7[o] (10) 28.6[o] (15) 30.3[o]	Brett 1952
		Don R. - Ontario	1945-46	Lab A	Ad.					(5) 26.7[n] (10) 28.6[n] (15) 30.3[o] (20) 31[p] (25) 31[r]	Hart 1947
		Buffalo Creek - New York	198	Lab A-2	Ad.					(15) 31.9-32[ee]	Schubauer et al. 1980
			1975+	Lab A-2	Ad.					(Dec.) 30.6[ee] (March) 31.9[ee]	Kowalski et al. 1976
		Missouri streams	1990+	Lab A-2	Ad.					(26) 35.7[ee]	Smale and Rabeni 1995
		Great Lakes region	?	?	?			21.9[dd]			Coker et al. 2001

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Common shiner (cont'd.)	Owens Creek - Illinois	1972-73	Lab C	Ad., Juv., yoy			Fa (5) 11.5[dd] Fa (10) 15.5[dd] Fa (14) 19[dd] Sp (5) 14.8[dd] Sp (10) 18[dd] Sp (14) 20.5[dd]			Ulvestad and Zar 1977
	Mimic shiner *(Notropis volucellus)*	New R. - Virginia	1973-74	Field A	Ad. - juv.				35[yy] 32.5[m]		Stauffer et al. 1976
	Spottail shiner *(Notropis hudsonius)*	Delaware R. - Delaware	1971	Lab C	Ad.			(15) 13.9[tt]			Meldrim and Gift 1971
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Wi) 10.2[tt,dd] (Sp) 14.3[tt,dd]		(10) 27.9[t]	Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A,C	Ad.			(Wi) 9[tt,dd]		(21.7) 32.8[t]	Reutter and Herdendorf 1976
		New R. - Virginia	1973	Field A	Ad. - juv.	23.3 - 27.2[cc,kk]			31.7m 35[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A	Ad. - juv.				35[yy]		Stauffer et al. 1976
		Susquehenna R. - Pennsylvania	1980+	Lab C	1-3 yrs.			29[tt]	(6) none[xx] (12) 27[j] (18) 21[j] (24) 33[j] (30) 36[j]	(6) 26.9[t] (12) 27.0[t] (18) 26.7[t] (24) 33.1[t] (30) 33.1[t]	Stauffer et al. 1984
		Hudson R. - New York	1977	Lab B, C	Juv.		27.3[a] 25.4-32.3[ddd]	29[dd]		(26) 34.7[t]	Kellog and Gift 1983
		Hudson R. - New York		Lab A	yoy, Juv.					(23) 36-37.3[t] (26) 36.8-37.9[t]	Jinks et al. 1981
		Hudson R. - New York	1976-7	Lab A, B	yoy		25.0-32.2[a]			(9) 27.7[q] (22) 33.1[r] (23) 33.1[q] (24) 32.8[q] (26) 34.4[q]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab A	Juv.					(23) 36.0[yy] (26) 36.8[yy]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab A	Ad.					(5) 22.6[q] (11.5) 29.4[q] (12) 29.4[q] (16) 27.5[q] (16.5) 28.6[q] (20) 27.6[q] (21.5) 30.7[q] (25) 33.8[q]	Ecological Analysts 1978

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Spottail shiner (cont'd)	Hudson R. - New York	1976-7	Lab E	Juv.			(4) 7[dd] (7) 11[dd] (8) 11.5[dd] (16) 25[dd] (23) 25[dd] (24) 27[dd] (25) 26.5[dd] (26) 28[dd]			Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab E	Ad.			(2.5) <4[dd] (8) 16.7[dd] (16) 19.5dd (15) 18[dd] (16) 20.5[dd] (20) 20[dd]			Ecological Analysts 1978
		Great Lakes region	?	?	?			14.3[dd]			Coker et al. 2001
	Fallfish (*Semotilus corporalis*)	Great Lakes region	?	?	?			22[dd]			Coker et al. 2001
		Juniata R. - Pennsylvania	1979	Lab C	Juv.			22.3[dd]			Stauffer et al. 1984
	Creek chub (*Semotilus atromaculatus*)	L. Opeongo - Ontario	1941	Lab A	juv.					(12.8) 28.2[n,bb] (14.7) 30[n,aa] (14.8) 29.9[n,b] (14.8) 30.3[n,bb] (16.1) 30.6[n,bb] (17.4) 31.0[n,aa] (19.3) 32[n,aa] (21) 31.8[n,bb] (22) 32.6[n,bb]	Brett 1944
		Toronto, Ontario	1947	Lab A	Ad.					(10) 27.3[o] (15) 29.3[o] (20) 30.3[o] (25-Su) 31.5[o] (25-Wi) 30.3[n]	Hart 1952
		Knoxville, Tenn.	1947	Lab A	Ad.					(25) 31.6[o]	
		Don R. - Ontario	1945-46	Lab A	Ad.					(5) 24.7[n] (10) 27.3[n] (15) 29.3[n] (20) 30.3[o] (25) 30.3[p]	Hart 1947
		New R. - Virginia	1973-74	Field A	Ad. -juv.				33.9[yy]		Stauffer et al. 1976
		Missouri streams	1990+	Lab A-2	Ad.					(26) 35.7[ee]	Smale and Rabeni 1995
		Great Lakes region	?	?	?			20.8[dd]			Coker et al. 2001
		Juniata R. - Pennsylvania	1979	Lab C	Juv.			26.4[dd]			Stauffer et al. 1984

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Fathead minnow *(Pimephales promelas)*	Ponds - Oklahoma	1965	Lab C	Ad.			(4) 8.8 (10) 15.2 (15) 23.3 (22) 20.7 (30) 22.6 23.4[dd]			Jones and Irwin 1965
		L. Amikeus - Ontario	1941	Lab A	Ad.					(9) 29[n,bb] (12.8) 30.1[n,bb] (15.3) 31.6[n,bb] (17.4) 30.8[n,aa] (19.8) 33.8[n,aa] (21) 31.3[n,bb] (21) 34[n,aa] (21.2) 33.6[n,bb]	Brett 1944
		Hatchery - Tennessee	1972	Lab A	Ad.					(6) 26.7[n]	Jensen 1972
		Don R. - Ontario	1945-46	Lab A	Ad.					(10) 28.2[o] (20) 31.7[o] (30) 33.2[r]	Hart 1947
		New R. - Virginia	1973-74	Field A Lab C	Ad. -juv. Ad. - juv.				25.6[yy] 26.2[dd]		Stauffer et al. 1976
		N. Texas State lab reared	1990+	Lab A-2	Ad.					(24) 36.9[ee] (non-spawn) 36.2[ee] (post-spawn)	Pyron and Beitinger 1993
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 17.0-20.7[kk] (15) 18.9-21.9[kk] (18) 20.8-23.2[kk] (21) 22.6-24.6[kk] (24) 24.0-26.4[kk] (27) 25.3-28.3[kk] (30) 26.5-30.3[kk] (33)[aaa] (36)[aaa]		(12) 19.5[tt] (15) 21.2[tt] (18) 20.9[tt] (21) 22.0[tt] (24) 25.4[tt] (27) 27.6[tt] (30) 28.7[tt] (33)[aaa] (36)[aaa] 26.0[dd]	(12) 18[j] (15) 24[j] (18) 24[j] (21) 27[j] (24) 30[j] (27) 33[j] (30) 32[j] (33)[aaa] (36)[aaa]		Cherry et al. 1977
		New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) - (9) - (12) 17.9-20.6[kk] (15) 20.0-22.1[kk] (18) 22.0-23.7[kk] (21) 23.8-25.5[kk] (24) 25.4-27.5[kk] (27) 26.9-29.6[kk] (30)[aaa]		(6) - (9) - (12) 19.8[tt] (15) 21.3[tt] (18) 22.1[tt] (21) 23.8[tt] (24) 26.6[tt] (27) 28.9[tt] (30)[aaa]	(6) - (9) - (12) 22[j] (15) 25[j] (18) 26[j] (21) 28[j] (24) 30[j] (27) 32[j] (30)[aaa]		Cherry et al. 1975
		Ottawa R. - Canada	1978	Review			30.1[bbb]				Christie 1979
	Bluntnose minnow *(Pimephales notatus)*	W. L. Erie - Ohio	1973-74	Lab A	Ad.					(6) 27.8[t]	Reutter and Herdendorf 1976

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluntnose minnow (cont'd)	Toronto, Ontario	1947	Lab A	Ad.					(20-Wi) 31.7[o] (25-Wi) 33.3[n]	Hart 1952
		Put-in-Bay - Ohio	1946	Lab A	Ad.					(20-Su) 32.7[o] (25-Su) 34[n]	
		Etobicoke Creek - Ontario	1945-46	Lab A	Ad.					(5) 26[n] (10) 28.3[n] (15) 30.6[o] (20) 31.7[p] (25) 33.3[r]	Hart 1947
		New R. - Virginia	1973	Field A	Ad. - juv.	20 -027.2[cc,kk]			31.7[m] 35[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A					35[yy] 27[m]		Stauffer et al. 1976
				Lab C				26.7[dd]	(12) 21 (15) 21 (18) 27 (21) 27 (24) 27 (27) 30		
		White R. - Indiana	1965-72	Field A	Ad.				31.1[yy]		Proffit and Benda 1971
		Potomac R. - Maryland	1980+	Lab C	1-3 yrs.			26.3[tt]	(6) 15[j] (12) none[xx] (18) 33[j] (24) 30[j] (30) 36[j] (36) 39[j]	(6) 31.9[t] (12) 27[t] (18) 33.1[t] (24) 33.1[t] (30) 32[t]	Stauffer et al. 1984
		Indian Cr.- Ohio	199	Lab A-2	Ad.?					(24) 37.9[ee]	Mundahl 1990
		Dicks Cr.- Ohio	1987-8	Lab A-2	Ad.					(11) 31.3[ee]	Hockett and Mundahl 1989
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 18.0-20.0[kk] (15) 19.9-21.5[kk] (18) 21.7-23.0[kk] (21) 23.5-24.6[kk] (24) 25.2-26.4[kk] (27) 26.7-28.8[kk] (30) 28.2-30.2[kk] (33)[aaa] (36)[aaa]		(12) 19.3[tt] (15) 20.9[tt] (18) 21.9[tt] (21) 23.2[tt] (24) 26.4[tt] (27) 27.9[tt] (30) 29.0[tt] (33)[aaa] (36)[aaa] 29.3[dd]	(12) 21[j] (15) 24[j] (18) 27[j] (21) 27[j] (24) 27[j] (27) 30[j] (30) 33[j] (33)[aaa] (36)[aaa]	(30) 32[xx]	Cherry et al. 1977
		New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) 13.9-17.3[kk] (9) 15.9-18.7[kk] (12) 17.9-20.1[kk] (15) 19.8-21.7[kk] (18) 21.5-23.4[kk] (21) 23.0-25.2[kk] (24) 24.5-27.2[kk] (27) 25.9-29.2[kk] (30)[aaa]		(6) 15.7[tt] (9) 17.2[tt] (12) 20.5[tt] (15) 20.4[tt] (18) 21.5[tt] (21) 22.8[tt] (24) 25.7[tt] (27) 28.9[tt] (30)[aaa]	(6) 20[j] (9) 21[j] (12) 23[j] (15) 25[j] (18) 26[j] (21) 25[j] (24) 30[j] (27) 31[j] (30)[aaa]		Cherry et al. 1975

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Eastern Blacknose dace (*Rhinicthys atratulus*)	Cazenovia Creek - New York	1976	Lab A	Ad.					(20) 28.8[r,qq],29.9[r,rr]	Terpin et al. 1976
		Toronto, Ontario	1945-46	Lab A	Ad.					(5) 26.5[o] (10) 28.8[o] (15) 29.6[o] (20-Wi) 30.4[o],29.3[q] (25-Wi) 30.8[o],29.5[q]	Hart 1952
		Don R. - Ontario	1945-46	Lab A	Ad.					(5) 26.5[n] (10) 28.8[n] (15) 29.6[p] (20) 29.3[r] (25) 29.3[r]	Hart 1947
		New R. - Virginia	1973	Field A	Ad. - juv.	23.3 - 27.2[cc,kk]			27.2[m] 33.9[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A	Ad. - juv.				33.9[yy] 27[m]		Stauffer et al. 1976
				Lab A-2						(15) 31.9[ee]	Kowalski et al. 1978
		Great Lakes region	?	?	?			24.6[dd]			Coker et al. 2001
		New R. - Virginia	?	Lab C	Juv.				(6) 24[j] (12) 24[j] (18) 24[j] (24) 27[j] (28) 34[j]		Cincotta and Stauffer 1984
	Longnose dace *(Rhinicthys cataractae*)	New R. - Virginia	1973-74	Field A					30[yy]		Stauffer et al. 1976
			1975+	Lab A-2	Ad.					(15) 31.4[ee]	Kowalski et al. 1978
	Longnose dace (cont'd)	Great Lakes region	?	?	?			20.6[dd]			Coker et al. 2001
	Northern Redbelly Dace *(Phoxinus eos)*	Ontario		Lab A						(6) 21.5[t] (10) 30[t] (15) 31[t] (20) 31.5[t] (25) 32.7[t] (20) 29[ee]	Tyler 1966
		Great Lakes region	?	?	?			25.3[dd]			Coker et al. 2001
		?	?	?	?			25.3[dd]			Stauffer et al. 1980
	Finescale Dace *(Phoxinus neogaeus)*	Ontario		Lab A						(9) 27[t] (15) 31[t] (22) 32.2[t] (25) 32.2t (20) 28.5[ee]	Tyler 1966

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Pearl Dace *(Margariscus margarita)*	Great Lakes region	?	?	?			16.2[dd]			Coker et al. 2001
		Juniata R. - Pennsylvania	1979	Lab C	Juv.			16[dd]		33[xx]	Stauffer et al. 1984
Fundulidae	Banded killifish (*Fundulus diaphanus*)	Porters Lake - Nova Scotia	1973	Lab E,G	Ad.			(5) 23-25[dd],14[jj] (15) 25[dd],12[jj] (25) 19[dd],14[jj] (30) 28[dd],23[jj]			Garside and Morrison 1977
		Brier Cr. - Oklahoma	198	Lab A Lab C	Ad.			27.3[tt]		(15) 36.8[ee]	Matthews 1981
		Denton Cr. - Texas	199	Lab A-2	Ad.					(30) 41.6[ee]	Rutledge and Beitinger 1989
		Great Lakes region	?	?	?			21[dd]			Coker et al. 2001
Anguillidae	American eel *(Anguilla rostrata)*	Great Lakes region	?	?	?			19[dd]			Coker et al. 2001
		Choptank R. - Maryland	1978	Lab C	Juv.			16.7[dd]		>24[ddd]	Barila and Stauffer 1980
		Choptank R. - Maryland	1978	Lab C	Juv.			17.4[dd]			Karlsson et al. 1984 review of Barila and Stauffer 1980
Moronidae	Striped bass *(Morone saxatilis)*	Hudson R. - New York	1977	Lab B, C	yoy		28.5[a] 26.9-30.3[ddd]	27[dd]			Kellog and Gift 1983
		Hudson R. - New York	1976-7	Lab A, B	yoy		25.1-29.6[a] 27.3[b]			(21) 31.8[q] (22) 33.5[r] (25) 33.2[q] (26) 33.0[yy]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab B	eggs		22.2[e] 26.3[q]				Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab E	Juv.			(7) 16[dd] (11.5) 29[dd] (24) 27.3[dd] (25) 28[dd] (26) 27[dd]			Ecological Analysts 1978
		Hatchery - Tennessee	1979	Lab C	Juv.			23.2-26.4[kk]			Coutant et al. 1984
		Hudson R. - New York	1976-7	Lab A	Juv.					(11.5) 29.1[q] (24) 32.3[p]	Ecological Analysts 1978
		Hatchery - Tennessee	1979	Lab C	Juv.		24[a] 33.5[ccc]				Cox and Coutant 1981
	White perch *(Morone americana)*	Hudson R. - New York	1977	Lab B, C	Juv.		28.5[a] 26.4-32.6[ddd]	30[dd]			Kellog and Gift 1983

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	White perch (cont'd.)	Hudson R. - New York	1976-7	Lab A, B	yoy		27.3-27.9[a] 27.3[b]			(15) 31.4[yy] (18) 35.6[yy] (19) 34.3[yy] (20) 34.0[yy] (21) 34.0[yy] (21.5) 35.3[yy] (22) 36.4[yy] (24) 36.1[yy] (25.0) 34.7[q] (25.5) 34.4[q] (27) 37.2[yy] (27.5) 37.0[yy]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab B	eggs		24.1[e] 27.0[vv]				Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab A	Ad.					(26) 32.4[q]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab E	yoy			(25) 32[dd] (26) 30.5[dd]			Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab E	Juv.			(5) 27.5[dd] (8) 26[dd] (8.5) 27.5[dd] (13) 25[dd] (20) 30[dd] (22.5) 29[dd] (23) 32[dd] (24) 29[dd] (25)32[dd] (26) 32[dd]			Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab E	Ad.			(15) 26[dd] (16) 26[dd] (20) 26[dd]			Ecological Analysts 1978
Ictaluridae	Channel catfish (*Ictalurs punctatus*)	Susquehanna R. - Pennsylvania	1973	Lab B	juv.		30[c]				Hocutt 1973
		Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 30-32kk	32[m]		Gammon 1973
		Orangeburg Hatchery - S. Carolina	1973	Lab A,C	yoy			(12) 17[dd] (16) 22[dd] (20) 22[dd] (24) 27.8[dd] (28) 26.3[dd] (32) 29.7[dd]		(12) 34.6[cc],36.2[gg] (16) 34.3[cc],36.6[gg] (20) 35.8[cc],37.1[gg] (24) 37.6[cc],38.4[gg] (28) 39.2[cc],40.4[gg] (32) 41.2[cc],42.3[gg]	Cheetham et al. 1976
		Georgia	1972	Lab B	yoy - Ad.	28 - 30[a]	28[a,b]				Andrews et al. 1972
		Muddy Run Pond - Pennsylvania	1975	Lab A,C	Ad.			(27.2) 31.1		(27.2) 35[p]	Peterson and Stutsky 1975
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 25.2[tt,dd] (Fa) 25.3[tt,dd]		(22.7) 36.5[t]	Reutter and Herdendorf 1974

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Channel catfish (cont'd)	W.L. Erie - Ohio	1973-74	Lab A	Ad.					(22.7) 38[t]	Reutter and Herdendorf 1976
		Put-in-Bay - Ohio	1946	Lab A	Ad. - juv.					(20) 32.7[o] (25) 33.5[o]	Hart 1952
		Welaka, Florida	1945-47	Lab A	Ad. - juv.					(15) 30.3[o] (20) 32.8[o] (25) 33.5[o]	
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad. - juv.	(Su)32-36[kk] (Fa)30-32[kk] (Wi) 9-14[kk]					Yoder and Gammon 1976a
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad. - juv.	(Su)31-34.5[m,kk]			35[m]		Yoder and Gammon 1976b
		New R. - Virginia	1973	Field A	Ad. - juv.	34.4 - 35[cc,kk]			35[m] 35[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Lab C	Ad. - juv.			33.8[dd]			Stauffer et al. 1975
		New R. - Virginia	1973-74	Field A Lab C	Ad. - juv. Ad. - juv.			33.9 - 35[cc] 33.8[dd]	35[yy]		Stauffer et al. 1976
		White R. - Indiana	1965-72	Field A	Ad.				37.8[yy]		Proffitt and Benda 1971
		Sonora, Mexico	1990+	Lab A-2	Juv.			(20) 27[dd],30[j] (23) 26.7[dd],29.7[j] (26) 27.3[dd],31.3[j] (29) 29[dd],34.5[j] (32) 30[dd],31[j]		(20) 34.5[ee], 35.0[gg] (23) 37.0[ee], 37.0[gg] (26) 39.0[ee], 39.0[gg] (29) 40.5[ee], 41.0[gg] (32) 41.5[ee], 42.5[gg]	Diaz and Buckle 1999
		New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) 16.2-19.6[kk] (9) 18.1-20.9[kk] (12) 19.9-22.3[kk] (15) 21.8-23.8[kk] (18) 23.4-25.3[kk] (21) 24.9-26.9[kk] (24) 26.4-28.8[kk] (27) 27.8-30.6[kk] (30) 29.1-32.6[kk]		(6) 18.9[tt] (9) 20.4[tt] (12) 19.9[tt] (15) 21.7[tt] (18) 22.9[tt] (21) 26.1[tt] (24) 29.4[tt] (27) 29.5[tt] (30) 30.5[tt]	(6) 25[j] (9) 26[j] (12) 29[j] (15) 30[j] (18) 30[j] (21) 32[j] (24) 33[j] (27) 34[j] (30) 35[j]		Cherry et al. 1975
		Fish Farm - Oklahoma	1995+	Lab A-2	Juv.					(20) 36.4[ee] (25) 38.7[ee] (30) 40.3[ee]	Currie et al. 1998
		Ottawa R. - Canada	1978	Review			34.3[bbb]				Christie 1979
				Lab A	Juv.					(34) 37.8[t]	Allen and Strawn 1968
				Field A	Ad.				33.9-34.4[j]		Churchill and Wojtalik 1969
		Great Lakes region	?	?	?			25.2[dd]			Coker et al. 2001
	White catfish *(Ameiurus catus)*	Hudson R. - New York	1977	Lab B, C	Juv.		29.6[a] 26.8-32.6[ddd]	30[dd]			Kellog and Gift 1983
		Hudson R. - New York	1976-7	Lab A, B	yoy		27.3-32.2[a] 29.6[b]			(7.5) 25.6[q] (16.5) 27.9[q] (22) 33.0[r]	Ecological Analysts 1978

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	White catfish (cont'd)	Hudson R. - New York	1976-7	Lab A	Ad.					(12.5) 27.9[q] (15) 30.9[q] (19) 32.8[q] (22) 30.9[q] (25) 33.7[q] (26) 34.7[q]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab C	Juv.			(2.5) 31[dd] (7) 28[dd] (10) 28[dd] (12) 25[dd] (20) 30[dd]			Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab C	Ad.			(8) 22[dd] (12) 22[dd] (13) 25[dd] (20) 30[dd] (22) 31[dd] (23) 30[dd] (25) 28[dd]			Ecological Analysts 1978
		Patuxent R. _ Maryland	1968	Lab A	Juv.					(20) 31.0[r]	Kendall and Schwartz 1968
		Patuxent R. _ Maryland	1968	Lab A	Ad.					(20) 29.2[r]	Kendall and Schwartz 1968
	Brown bullhead (*Ameiurus nebulosus*)	Delaware R. - Delaware	1971	Lab C	juv.			(26.1) 31.1	(25) 36.1		Meldrim and Gift 1971
		L. Opeongo - Ontario	1941	Lab A	juv.					(6) 28.9[n],28[ll] (13) 31[n],30[ll] (20) 33.4[n],32[ll] (26) 35.3[n],34[ll] (31.2)36.9[n],36[ll] (36) 37.5[n],37[ll]	Brett 1944
		Cedar Dell Pond - Massachusetts	1973-74	Lab C	juv.	(3.5) 11-16 (11) 15-26 (15.5) 17-22 (21) 21-26 (28) 26-28	(3.5) 12.5[m,s] (11) 18[m,s] (15.5)18.5[m,s] (21) 25[m,s] (28) 27.8[dd]				Richards and Ibara 1978
		Connecticut	1975	Lab C	Ad.			(7) 16[s] (16) 21[s] (24) 26[s] (32) 31[s] 29-31[dd]			Crawshaw 1975
		Hatchery - California	1974	Lab C	juv.		26[i]				Crawshaw & Hammel 1974
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 24.9[tt,dd] (Fa) 23.6[tt,dd] (Wi) 11.9[tt,dd] (Sp) 23.5[tt,dd]		(23.5) 37.1[t]	Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23) 37.8[t]	Reutter and Herdendorf 1976

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Brown bullhead (cont'd)	Algonquin Park, Ontario	1945-46	Lab A	Ad.					(10) 29[o] (20-Wi) 32.3[o] (30-Wi) 35.4[o]	Hart 1952
		Toronto, Ontario	1945-46	Lab A	Ad.					(10) 27.7[o] (15) 29[o]	
		Put-in-Bay - Ohio	1946	Lab A	Ad.					(20) 31.7[o] (25-Wi) 34.5[o]	
		Welaka, Florida	1945-47	LabA	Ad.					(20-Su) 32.7[o] (25-Su) 33.7[p],34.1[o] (30-Su) 34.7[p],35.6[o]	
		Ottawa R. - Canada	1978	Review			(Juv.) 32.3[bbb] (Ad.) 33.0[bbb]				Christie 1979
		Delaware R. - Pennsylvania		Lab A-2						(22.8) 37.3[ee]	Trembley 1960
		Delaware R. - Pennsylvania		Lab C				23.9 -32.2[kk]			Trembley 1960
		Huson River - New York	1976-7	Lab A	yoy			(24) 31[dd]		(24) 35.7[q] (25) 36.4[yy] (26) 36.5[yy]	Ecological Analysts 1978
		Great Lakes region	?	?	?			26[dd]			Coker et al. 2001
	Yellow bullhead (*Ameirus natalis*)	Pennsylvania	1977	Lab D	Ad. Juv. Ad. - juv.			(23) 27.9[k,tt],27.6[l,tt] (23) 20.6[k,tt],29.1[l,tt] (23) 28.4[tt]			Reynolds and Casterlin 1978b
		W.L. Erie -Ohio	1973-74	Lab C	Ad.			(Su) 28.3[tt,dd]		(19.7) 35[t]	Reutter and Herdendorf 1974
		W.L. Erie -Ohio	1973-74	Lab A	Ad.					(22.2) 36.4[t]	Reutter and Herdendorf 1976
		Great Lakes region	?	?	?			28.3[dd]			Coker et al. 2001
	Black bullhead *(Ameiurus melas)*	Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 35.7[p]	Cvancara et al. 1977
		British Columbia	1950+	Lab A	Juv.					(23) 35[t]	Black 1953
	Stonecat madtom (*Noturus flavus*)	W.L. Erie -Ohio	1973-74	Lab C	Ad.			(Fa) 25.1[tt,dd] (Wi) 5.5[tt,dd]		(1.6) 29[t]	Reutter and Herdendorf 1974, 1976
		W.L. Erie -Ohio	1973-74	Lab A	Ad.					(1.6) 29[t]	Reutter and Herdendorf 1976
	Atlantic tomcod *(Microgadus tomcod)*	Hudson R. - New York	1976-7	Lab A	yoy		10.9[b]			(2.5) 26.5[yy] (3) 26.6[yy] (3.5) 25.4[yy] (5) 25.3[yy] (7.5) 26.2[yy]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab B	eggs		2.0 and 3.4[e] 6.0-6.9[q]				Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab A	Juv.					(15) 24.5[q] (23.5) 26.4[q]	Ecological Analysts 1978

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Atlantic tomcod (cont'd)	Hudson R. - New York	1976-7	Lab A	Ad.					(1.5) 19.2[q] (3) 17.0[q]	Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab C	Juv.			(10) <4[dd] (24) 10[dd]			Ecological Analysts 1978
		Hudson R. - New York	1976-7	Lab C	Ad.			(2.5) <2[dd] (4) <2[dd] (5) <2[dd] (6) <4[dd] (8) <2[dd]			Ecological Analysts 1978
Gadidae	Burbot *(Lota lota)*	Ontario - lakes and streams		Field B	Ad.			15.6-18.3[cc]	23.3[cc]		Scott and Crossman 1973
		Maine - Moosehead L		Lab C	Juv.			21.2[dd]			Coutant 1977
		Great Lakes region	?	?	?			12.5[dd]			Coker et al. 2001
Centrarchidae	White crappie (*Pomoxis annularis*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 27 - 28.5[kk]	30.2[m]		Gammon 1973
		W.L. Erie -Ohio	1973-74	Lab C	Ad.			(Su) 19.4[tt,dd] (Fa) 10.4[tt,dd] (Wi) 19.8[tt,dd] (Sp) 18.3[tt,dd]			Reutter and Herdendorf 1974
		W.L. Erie -Ohio	1973-74	Lab A	Ad.					(24.4) 32.8[ee]	Reutter and Herdendorf 1976
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 26-31[kk] (Fa) 18-26[kk] (Wi) 5-8[kk]					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 29-30[m,kk]			31[m]		Yoder and Gammon 1976a
		White R. - Indiana	1965-72	Field A	Ad.				31.1[yy]		Proffit and Benda 1971
		Missouri lakes	199	Lab A-2	3 yrs.					(30) 32.0[t]	Walton and Noltie 1998
				Lab A	Juv.		25.1[a]			(29) 32.6[t]	Kleiner 1981
				Lab A	Juv./Ad.					(25.6) 32.8[j]	Peterson et al. 1974
		Oklahoma - reservoir		Field A	Ad.			23-29[kk]			Gebhart and Summerfelt 1975
	Black crappie (*Pomoxis nigromaculatus*)	L. Monona - Wisconsin	1970	Lab D	juv.				31.0m		Neill et al. 1972
		L. Monona - Wisconsin	1970	Field A	Ad. Ad. Ad. Ad.			27 - 28.2[i,k,m] 27.8 -29.8[i,l,m]	28.6[i,k,m] 29.9[i,l,m] 29[k,m] 30.2[l,m]		Neill and Magnuson 1974
				Lab D	juv. juv.			28 - 28.3[l,m] 25.9 - 29[k,m]	30[l,m] 29.4[k,m]		

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Black crappie (cont'd.)	W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 21.7[tt,dd] (Fa) 22.2[tt,dd] (Wi) 20.5[tt,dd] (Sp) 21[tt,dd]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23.8) 34.9[t]	Reutter and Herdendorf 1976
		? - Pennsylvania	1977	Lab D	Ad.			24[s]			Reynolds and Casterlin 1977
		Illinois - Hatchery	1990+	Lab A Lab A-2	yoy/Juv.					(24) 33.8, 35.1, 31.5[o,t] (24) 38,39,35[ee] (30) 38.5,39,38[ee] (32) 39,40,39[ee]	Baker and Heidinger 1996
		Ottawa R. - Canada	1978	Review			27.6[bbb]				Christie 1979
		Minnesota	1980	Lab A,C			22-25[a]			(29) 32.5[j]	Hokanson and Kleiner 1981
				Lab A-1						(7.2) 28.9[ee]	Trembley 1961
		Great Lakes region	?	?	?			10.5[dd]			Coker et al. 2001
	Rockbass (*Ambloplites rupestris*)	L. Monona - Wisconsin	1970	Lab D	juv.				29.4m		Neill et al. 1972
		L. Monona - Wisconsin	1970	Field A	Ad.			26.8 - 28.3[i,k,m]	28.3[i,k,m]		Neill and Magnuson 1974
					Ad.			27.1 -27.8[i,l,m]	28[i,l,m]		
					Ad.				30.2[k,m]		
					Ad.				31.5[l,m]		
				Lab D	juv.			27.2 - 28.6[l,m]	29[l,m]		
					juv.			27.1 - 29[k,m]	29.3[k,m]		
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 18.7[tt,dd] (Fa) 22.8[tt,dd] (Wi) 21.6[tt,dd] (Sp) 20.5[tt,dd]		(14.6) 31.2[t]	Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23.5) 36[t]	Reutter and Herdendorf 1976
		New R. - Virginia	1973-74	Lab A	Ad. - juv.			30.2[dd]	35[yy] (18) 27 (21) 27 (24) 30 (27) 33 (30) 33		Stauffer et al. 1976

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Rockbass (cont'd)	New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) - (15) - (18) 21.3-26.3[kk] (21) 23.2-27.2[kk] (24) 25.1-28.2[kk] (27) 26.6-29.4[kk] (30) 27.9-31.0[kk] (33) 28.9-32.8[kk] (36) 29.8-34.8[kk]		(12) - (15) - (18) 23.2[tt] (21) 24.0[tt] (24) 28.4[tt] (27) 28.4[tt] (30) 29.7[tt] (33) 32.2[tt] (36) 30.4[tt] [illegible][dd]	(12) - (15) - (18) 27[j] (21) 27[j] (24) 30[j] (27) 33[j] (30) 33[j] (33) 36[j] (36) 37[j]	(36) 36[xx]	Cherry et al. 1977
		Ottawa R. - Canada	1978	Review			26.4[bbb]				Christie 1979
		Great Lakes region	?	?	?			21.7[dd]			Coker et al. 2001
	Largemouth bass (*Micropterus salmoides*)	L. Monona - Wisconsin	1970	Lab D	juv.				30.8[m]		Neill et al. 1972
		L. Monona - Wisconsin	1970	Field A	juv.			29.3 - 30.9[i,l,m]	31.4[i,k,m]		Neill and Magnuson 1974
					Juv.				32[l,m]		
					Ad.			26.4 -29.1[i,k,m]	28.8[i,k,m]		
					Ad.			29.3 - 32[i,l,m]	32.2[i,l,m]		
				Lab D	Ad.				30.8[k,m]		
					Ad.				33.3[l,m]		
					juv.			28.6 - 29.5[l,m]			
					juv.			27.2 - 30.6[k,m]	30.6[l,m]		
									31[k,m]		
		Delaware R. - Delaware	1971	Lab C	juv.				(25)30.6-32.8		Meldrim and Gift 1971
		Susquehanna R. - Pennsylvania	1973	Lab B	juv.		30[c]				Hocutt 1973
		Cornell Hatchery - New York	1966	Lab B	eggs	(17.2)12.8-23.9[e] (18.9)12.8-23.9[e] (21.1)15.6-26.7[e] (21.1)12.8-23.9[e]	(17.2)15.6[e,m] (18.9)18.3[e,m] (21.1)18.3[e,m] (21.1)23.9[e,m]				Kelley 1968
		Pond C(SREL) - S. Carolina	1973	Field A	Ad.				30[cc]		Siler and Clugston 1975
		Oak Ridge Nat'l Lab - Tennessee	1975	Lab B	eggs	15 - 25[g]					Coutant 1975a
					yoy		27[a] 25 - 30[ss]				
		Reservoir - E. Tennessee			Ad.			27[cc,dd]			
		Pennsylvania	1976	Lab D	juv. - Ad.			30.2[i,tt]			Reynolds et al. 1976
		Pennsylvania	1976	Lab D,G	juv.			30.1[tt] 32.2[tt,uu]			Reynolds et al. 1976
		Hatchery - Texas	1961	Lab B	yoy	27.5 - 30[a]	27.5[a]				Strawn 1961
		Pennsylvania	1977	Lab D	juv. (?)			26[l,m],30[k,m]			Reynolds 1977a
		W.L. Erie	1973-74	Lab A	Ad.					(0.7) 12[t]	Reutter and Herdendorf 1976

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Largemouth bass (cont'd)	Put-in-Bay - Ohio	1945-47	Lab A	Ad. - juv.					(20) 32.5[o] (25) 34.5[o] (30) 36.4[o] (30) 36.4[o] (20) 31.8[o] (25) 32.7[o] (30) 33.7[o]	Hart 1952
		Knoxville, Tenn.	1945-47	Lab A	Ad. - juv.						
		Welaka, Florida	1945-47	Lab A	Ad. - juv.						
		Par Pond - S. Carolina	1973	Lab A	juv.					(20) 36.7[ee] (28) 40.1[ee]	Smith 1975
		Lake Mendota - Wisconsin	1927	Lab A	juv.					(23) 32.2[zz]	Hathaway 1927
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 24-31[kk] (Fa) 18-21[kk]					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su) 29-30.5[m,kk]			33[m]		Yoder and Gammon 1976a
		Hatchery - Virginia	198	Lab C	Juv.			(12) 19.6[dd] (24) 27.3[dd]	(12) 24[j] (24) 33[j]	(12) 36[xx]	Cherry et al. 1982
		Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 35.6[p]	Cvancara et al. 1977
		Pond C(SREL) - S. Carolina	1979-82	Field A	Ad.	(Su) 26.1-32.5 (Su) 20.0-30.4 (Fa) 20.4-32.5 (Sp) 24.4-31.3					Block et al. 1984
		Fish Farm - Oklahoma	1995+	Lab A-2	Juv.					(20) 35.4[ee] (25) 36.7[ee] (30) 38.5[ee]	Currie et al. 1998
		Ottawa R. - Canada	1978	Review			(Juv.) 31.3[bbb] (Ad.) 31.1[bbb]				Christie 1979
		New R. - Virginia	?	Lab C	Juv.				(6) 27[j] (12) 30[j] (18) 33[j] (24) 36[j] (30) 36[j] (36) 39[j]		Cincotta and Stauffer 1984
	Northern Largemouth Bass *(Micropterus salmoides salmoides)*	Minnesota/Wisconsin	1976	Lab A, B	gamete embryo fry yoy Juv.		32[b] 34.8[v] 33.4[bbb]			fry (20) 31.2[o] fry (24) 32.4[o] fry (27) 33.0[o] fry (30) 31.7[o] fry (20) 33.7[r] (early emryo) 29.5[o] (late embryo) 32.3[o]	McCormick and Wegner 1981
		Bone L. - Wisconsin	1978	Lab A-2	Juv.					(8) 29.2[ee] (16) 33.6[ee] (24) 36.5[ee] (32) 40.9[ee] (32) 37.3[ww]	Fields et al. 1987
		Great Lakes region	?	?	?			30.2[dd]			Coker et al. 2001

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Smallmouth bass (*Micropterus dolomieui*)	St. Croix R. - Minnesota	1970-71	Lab A,B	juv.	26 - 29[a]	26[a]		29[vv]		Horning and Pearson 1973
		L. Erie - Ohio	1971	Lab C	yoy Ad.	(Su) 29-31[s] (Fa) 26-30[s] (Wi) 24-28[s] (Sp) 22-28[s] (Su) 30-31[s] (Fa) 21-27[s] (Wi) 13-26[s] (Sp) 18-26[s]		(Su) 30[m,s] (Fa) 28.8[m,s] (Wi) 25[m,s] (Sp) 24.5[m,s] (Su) 30.8[m,s] (Fa) 25[m,s] (Wi) 25.7[m,s] (Sp) 17.7[m,s]	(Su) 33[m] (Fa) 31[m] (Wi) 27.8[m] (Sp) 27.5[m] (Su) 33[m] (Fa) 29[m] (Wi) 27.8[m] (Sp) 25.8[m]		Barans and Tubb 1973
		Pennsylvania	1977	Lab D	juv. (?)			29[l,m],31[k,m]			Reynolds 1977a
		Tennessee R. - Alabama	1972-73	Field A	Ad. - juv.				35.1[yy]		Wrenn 1976
		W.L. Erie - Ohio	1973-74	Lab C	yoy			(Fa) 26.6[tt,dd]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23.3) 36.3[t]	Reutter and Herdendorf 1976
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.				31[m]		Yoder and Gammon 1976a
		New R. - Virginia	1973	Field A	Ad. - juv.				35[yy] 27.2[m]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Lab C	Ad. - juv.			(17.7) 25.8[aaa] (21.1) 27.1[aaa] (23.9) 28.2[aaa] (27.2) 29.5[aaa] (30) 30.5[aaa] (32.8) 31.6[aaa] 28.3[dd]			Stauffer et al. 1975
		New R. - Virginia	1973-74	Field A Lab C	Ad. - juv. Ad. - juv.				35[yy] (18) 27 (21) 30 (24) 33 (27) 33 (30) 33 (33) 36		Stauffer et al. 1976
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) - (15) 19.5-21.7[kk] (18) 21.7-26.6[kk] (21) 23.7-27.5[kk] (24) 25.4-28.8[kk] (27) 26.7-30.6[kk] (30) 27.7-32.6[kk] (33) 28.5-34.8[kk] (36)[aaa]		(12) - (15) 20.2[tt] (18) 25.5[tt] (21) 25.8[tt] (24) 28.2[tt] (27) 29.7[tt] (30) 30.9[tt] (33) 29.4[tt] (36)[aaa] 31.5[dd]	(12) - (15) - (18) 27[j] (21) 30[j] (24) 33[j] (27) 33[j] (30) 33[j] (33) 35[j] (36)[aaa]	(33) 35[xx]	Cherry et al. 1977

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Smallmouth bass (cont'd)	New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) -[kk] (9) -[kk] (12) -[kk] (15) 18.5-23.7[kk] (18) 21.4-25.3[kk] (21) 24.2-27.2[kk] (24) 26.5-29.5[kk] (27) 28.3-32.2[kk] (30) 29.9-31.9[kk]		(6) -[tt] (9) -[tt] (12) -[tt] (15) 20.2[tt] (18) 22.9[tt] (21) 26.5[tt] (24) 29.8[tt] (27) 30.1[tt] (30) 31.3[tt]	(6) -[j] (9) -[j] (12) -[j] (15) 26[j] (18) 27[j] (21) 30[j] (24) 31[j] (27) 31[j] (30) 33[j]		Cherry et al. 1975
		Hatchery - Alabama	1977-8	Lab C	yoy/Juv.		32-33[bbb]			35[ccc]	Wrenn 1980
		Ottawa R. - Canada	1978	Review			24.7[bbb]				Christie 1979
		Great Lakes region	?	?	?			30.3[dd]			Coker et al. 2001
	Bluegill *(Lepomis macrochirus)*	Private Pond-S.C. (ambient T)	1970, 1972	Lab A-2	juv.					(25) 37.3[gg],37.8[ee] (30) 39.4[gg],40[ee] (35) 41.9[gg],43.4[ee]	Holland et al. 1974
		Par Pond (Hot) - S.C. (30-40C, Su)	1970, 1972	Lab A-2	juv.					(25) 37.6[gg],38.5[ee] (30) 39.1[gg],40.2[ee] (35) 42.4[gg],43.9[ee]	
		Par Pond (Cold)) - S.C. (near ambient)	1970, 1972	Lab A-2	juv.					(25) 37[gg],37.7[ee] (30) 39[gg],40.6[ee] (35) 42.4[gg],43.9[ee]	
		Pond C - S.C. (30-50C, year-round)	1970, 1972	Lab A-2	juv.					(25) 39.1[gg],41.2[ee] (30) 40.9[gg],42.2[ee] (35) 42.8[gg],44.2[ee]	
		Brier Cr. - Oklahoma	198	Lab A-2 Lab C	Ad.					(15) 36.8[ee]	Matthews 1981
		Hatchery - Tennessee	1969	Lab A	juv.					(5[KLm]25)6.5[hh],2.5[ii] (5[KLm]30)1.9[hh],0.8[ii] (5[KLm]30)3.9[hh],1.8[ii] (30)36[r]	Speakman and Krenbel 1972
		Canals, Hatchery, L. Apopka, Fla. (Cu and Cd in test water exceeded "safe" limits).	1971	Lab A Lab B	egg egg juv.	18 - 36[e]	22.2 - 23.9[e]			(26) 33.8[q] (12.1) 27.5[q] (19) 33[q] (26) 36.1[q] (32.9) 37.3[q]	Banner and Van Arman 1973
		Lake Mills Hatchery-Wisc.	1977	Lab B	juv.	28.34[a]	30.1[a]				Lemke 1977
		Pennsylvania	1976	Lab D,G	Ad.			30.5[tt] 33.2[tt,uu]			Reynolds et al. 1976
		L. Monona - Wisconsin	1975	Lab D	juv. - Ad.			31.2[tt]			Beitinger & Magnuson 1975

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluegill (cont'd)	L. Monona - Wisconsin	1974	Lab D	juv. - Ad.			(21) 31.3[tt] (31) 31.2[tt] (36.1) 33.1[tt]	(21) 33.1 (31) 33.1 (36.1) 33.1		Beitinger 1976
		Muddy Run Pond-Pennsylvania	1975	Lab A,C	Ad.			(27.2) 27.2[dd]	(27.2) 35	(27.2) 35.6[p]	Peterson & Shutsky 1975
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Wi) 27.4[tt,dd]			Reutter and Herdendorf 1974
		L. Monona - Wisconsin	1970	Lab D	juv.				31.8m		Neill et al. 1972
		L. Monona - Wisconsin	1970	Field A	juv.			27.1 - 29.1[i,k,m]	29.3[i,k,m]		Neill and Magnuson 1974
					juv.			28.8 - 31.2[i,l,m]	31.3[i,l,m]		
					juv.				30[k,m]		
					juv.				32.2[l,m]		
					Ad.			27.8 - 28.9[i,k,m]	30.2[i,k,m]		
					Ad.			29.6 - 32.7[i,l,m]	32.8[i,l,m]		
					Ad.				30.5[k,m]		
					Ad.				33[l,m]		
				Lab D	juv.			29.6 - 31.2[l,m]	32[l,m]		
					juv.			29.3 - 31.4[k,m]	32.5[k,m]		
		L. Texoma - Oklahoma	1971	Lab C	y.			(16) 22.5[tt] (21) 23.4[tt] (26) 28.2[tt]			Hill et al. 1975
		Conowingo Pond - Pennsylvania	1972	Lab A,C	Ad. - juv.			(13) 24.6[s] (27) 30.7[s]	(1) 22[ww],27.6 (13)28[ww],30.3 (27)35[ww],33.5	(1) 23.3[q],23.5[t] (13) 29.3[q],30[t] (27) 35.8[q],36[t]	Peterson and Shutsky 1976
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(22.8) 38.3[t]	Reutter and Herdendorf 1976
		Welaka, Florida	1945-47	Lab A	Ad.					(15) 30.7[o] (20) 31.5[o] (30) 33.8[o]	Hart 1952
		L. Mendota - Wisconsin	1927	Lab A	juv.					(23) 34zz	Hathaway 1927
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad. - juv.	(Su) 22-34[kk] (Fa) 14-24[kk] (Wi) 5-8[kk]					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad. - juv.	(Su) 27-32[m,kk]			34[m]		Yoder and Gammon 1976a
		White R. - Indiana	1965-72	Field A	Ad.				33.6yy		Proffitt and Benda 1971
		New R. - Virginia	1973-74	Field A	Ad. - juv.				35[yy]		Stauffer et al. 1976
				Lab C	Ad. - juv.				(12) 24 (15) 27 (18) 30 (21) 30 (24) 33 (27) 33 (30) 33 (33) 36		
		Hatchery - Virginia	198	Lab C	Juv.			(12) 23.9[dd] (24) 28.2[dd]	(12) 24[j] (24) 33[j]	(12) 36[ww]	Cherry et al. 1982

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluegill (cont'd)	Texas, Oklahoma, Mississippi	200	Lab A-2	Ad.?					(10) 33.4-34.8[ee] (20) 37.1-37.3[ee] (30) 41.2[ee]	Dent and Lutterschmidt 2003
		Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 28.5[p]	Cvancara et al. 1977
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 23.2-25.7[kk] (15) 24.5-26.5[kk] (18) 25.7-27.4[kk] (21) 26.8-28.3[kk] (24) 27.8-29.2[kk] (27) 28.9-30.3[kk] (30) 29.8-31.5[kk] (33) 30.6-32.7[kk] (36) 31.4-33.9[kk]		(12) 24.1[tt] (15) 25.2[tt] (18) 26.8[tt] (21) 27.8[tt] (24) 28.2[tt] (27) 30.0[tt] (30) 32.4[tt] (33) 30.9[tt] (36) 31.8[tt] 32.1[dd]	(12) 24[j] (15) 27[j] (18) 30[j] (21) 30[j] (24) 33[j] (27) 36[j] (30) 36[j] (33) 39[j] (36) 38[j]	(36) 36[xx]	Cherry et al. 1977
		New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(12) 17.3-22.3[kk] (15) 19.5-23.6[kk] (18) 21.6-25.0[kk] (21) 23.7-26.5[kk] (24) 25.5-28.2[kk] (27) 27.2-30.1[kk] (30) 28.7-32.1[kk] (33) 30.1-34.2[kk] (36) 31.5-36.4[kk]		(12) 18.7[tt] (15) 19.6[tt] (18) 23.9[tt] (21) 25.9[tt] (24) 29.2[tt] (27) 30.1[tt] (30) 31.2[tt] (33) 31.4[tt] (36) 31.7[tt]	(12) 22[j] (15) 23[j] (18) 25[j] (21) 26[j] (24) 31[j] (27) 33[j] (30) 33[j] (33) 34[j] (36) 35[j]		Cherry et al. 1975
		Oklahoma streams	1995+	Lab A-2	Ad./juv.					(10) 32.6[ee] (Su) (10) 30[ee] (Wi)	Schaefer et al. 1999
		Great Lakes region	?	?	?			30.9[dd]			Coker et al. 2001
	Green Sunfish *(Lepomis cyanellus*)	Ponds - Oklahoma	1965	Lab C	juv.			(4) 10.6 (10) 15.2 (22) 26.8 (30) 26.8 27.3[dd]			Jones and Irwin 1965
		Ponds - Wisconsin	1975	Lab D	juv.	26-30[m]		28.2[s]	30.3[j] 30.4[j,k] 29.7[j,l]		Beitinger et al. 1975
		Lake Texoma - Oklahoma	1971	Lab C	y.			(16) 18.9tt (21) 25.5[tt] (26) 26[tt]			Hill et al. 1975
		White R. - Indiana	1965-72	Field A	Ad.				36.1[yy]		Proffit and Benda 1971
		Brier Cr. - Oklahoma	198	Lab A Lab C	Ad.			30.8[tt]		(15) 36.5[ee]	Matthews 1981

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Green sunfish (cont'd)	New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) 14.7-18.8[kk] (9) 17.0-20.5[kk] (12) 19.3-22.1[kk] (15) 21.5-23.9[kk] (18) 23.5-25.8[kk] (21) 25.4-27.8[kk] (24) 27.2-30.0[kk] (27) 28.8-32.3[kk] (30) 30 5 34 6[kk]		(6) 16.9[tt] (9) 18.2[tt] (12) 21.1[tt] (15) 20.7[tt] (18) 25.2[tt] (21) 28.1[tt] (24) 30.4[tt] (27) 30.7[tt] (30) 30 6[tt]	(6) 20[j] (9) 21[j] (12) 24[j] (15) 25[j] (18) 29[j] (21) 31[j] (24) 33[j] (27) 33[j] (30) 33[j]		Cherry et al. 1975
				Lab A-2						(20) 35.8[ee]	Carrier and Beitinger 1988
				Lab A-2						(26) 37.9[ee]	Smale and Rabeni 1995
				Lab A-2						(10) 34.2[ee]	Lutterschmidt and Hutchinson 1977
				Lab A	Juv./Ad.					(30) 35.4[p]	Boswell 1967
				Lab B	Juv./Ad.		30				Jude 1973
		Great Lakes region	?	?	?			30.6[dd]			Coker et al. 2001
	Pumpkinseed sunfish (*Lepomis gibbosus*)	L. Monona - Wisconsin	1970	Field A	Ad. Ad. Ad. Ad.			27 - 29.1[i,k,m] 28.5 - 32[i,l,m]	30.4[i,k,m] 32.2[i,l,m] 30.5[k,m] 33[l,m]		Neill and Magnuson 1974
		L. Amikeus, L. Opeongo,Ontario	1941	Lab A	juv.					(25-26) 34.5[n],33[ll]	Brett 1944
		Laboratory - Massachusetts	1976	Lab A	juv.					32 - 39[ee]	Power and Todd 1976
		Lake-on-the-Mountain-Ontario	1966-67	Lab B	juv.		30[a],25[b]				Pessah and Powles 1974
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 27.7[tt,dd] (Sp) 24.2[tt,dd]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A Lab C	Ad.			(Sp) 23.8[tt,dd]		(23.1) 37.5[t]	Reutter and Herdendorf 1976
		L. Mendota - Wisconsin	1927	Lab A	juv.					(23) 34[zz]	Hathaway 1927
		? - Pennsylvania	1977	Lab D	Ad.			26[s]			Reynolds & Casterlin 1977
				Lab A-2						(10) 30.1[ee] (20) 35.1[ee]	Becker and Galloway 1979
		Hudson R. - New York	1976-7	Lab A, B	yoy			(2.5) 28[dd]			Ecological Analysts 1978
		Great Lakes region	?	?	?			26[dd]			Coker et al. 2001
		New R. - Virginia	?	Lab C	Juv.				(6) 30[xx] (12) 33[xx] (18) 33[j] (24) 36[j] (30) 36[j] (36) 39[j]		Cincotta and Stauffer 1984
	Redbreast sunfish (*Lepomis auritus*)	Hudson R. - New York	1976-7	Lab A, B	yoy			(2.5) 27[dd]			Ecological Analysts 1978

Appendix Table A-1.

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
Percidae	Yellow perch *(Perca flavescens*)	Park L. - Minnesota	1973	Lab B	yoy		28[a]			(28) 32-34[q] 32[nn]	McCormick 1976
		?	?	Lab B	gonadal egg	3.9 - 18.6[d]	4 - 6[h](winter) 8 - 11[d]				Jones et al. (ms)
		Little Cut Foot Sioux L. - Minnesota	1971	Lab B	egg(constantT) egg(neural keel) egg (rising T) larvae		10.1 - 18.2[e] 13.1 - 22.1[e] 24.3[e](upper)	13.1 - 18.2			Hokanson and Kleiner 1974
		L. Monona - Wisconsin	1970	Lab D	juv.				27.4[m]		Neill et al. 1972
		L. Monona - Wisconsin	1970	Field A	juv. juv.			26.7 - 28.3[i,l,m]	28.9[i,l,m] 32.2[l,m]		Neill and Magnuson 1974
				Lab D	juv. juv.			23.7 - 24.2[l,m] 21.2 - 23.7[k,m]	26.3[l,m] 25[k,m]		
		Delaware R. - Delaware	1971	Lab C	juv.			(18) 23.3 (25) 22.3	(25) 33.4-34		Meldrim and Gift 1971
		L. Amikeus, L. Opeongo,Ontario	1941	Lab A	juv.					(25-26) 30.9[n],29[ll]	Brett 1944
		Hatchery - Wisconsin	1976	Lab B	yoy		22[a,ff]				Huh et al. 1976
		Clear L., Ontario	1976	Lab E	larvae			(20) 21.5[s],22.8[tt] (23) 24.5[s],24[tt] (25) 22.5[s],22.6[tt]			Ross et al. 1977
		W.L. Erie - Ohio	1971	Lab C	yoy	(Su) 28-29[s] (Fa) 24-31[s] (Wi) 11-15[s]		(Su) 29[m,s] (Fa) 25[m,s] (Wi) 13[m,s]	(Su) 31[m] (Fa) 30.7[m] (Wi) 20.2[m]		Barans and Tubb 1973
					Ad.	(Sp) 17-25[s] (Su) 23-26[s] (Fa) 13-21[s] (Wi) 12-16[s] (Sp) 10-14[s]		(Sp) 24[m,s] (Su) 25[m,s] (Fa) 17[m,s] (Wi) 15[m,s] (Sp) 10[m,s]	(Sp) 27.5[m] (Su) 30[m] (Fa) 29[m] (Wi) 18.5[m] (Sp) 19.8[m]		
		Grand R., L. St. Clair - Ontario	1971	Lab E	yoy juv. Ad.			(24) 23[s],23.3[tt] (24) 24[s],23.3[tt] (24) 20[s],20.1[tt]			McCauley and Read 1973
		L. St. Clair - Ontario	1974	Lab C	Ad.			(Wi) 25[dd] (Sp) 21[dd] (Su) 17[dd]			McCauley 1977
		L. St. Clair - Ontario	1975	Lab C	Ad.			(Wi) 30[dd] (Sp) 21.1[dd] (Su) 18[dd]			
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 20.9[tt,dd] (Fa) 19.9[tt,dd] (Wi) 14.1[tt,dd]		(23) 33.5[t]	Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A						(22) 35[t]	Reutter and Herdendorf 1976
		Toronto, Ontario	1945-46	Lab A	Ad. - juv.					(25-Wi) 29.7[o]	Hart 1952
		Put-in-Bay - Ohio	1946	Lab A	Ad. - juv.					(25-Su) 32.3[o]	
		L. Mendota - Wisconsin	1927	Lab A	juv.					(23) 29.6[zz]	Hathaway 1927

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Yellow perch (cont'd.)	Chippewa Cr. - Ontario	1945-46	Lab A	juv.					(5) 21.3[n] (10) 25[n] (15) 27.7[n] (25) 29.7[q]	Hart 1947
		Hatchery - Virginia	1974+	Lab C[bb]	Juv.	(12) - (15) 18.5-19.9[kk] (18) 19.8-20.7[kk] (21) 20.8-21.8[kk] (24) 21.6-28.0[kk] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa]		(12) - (15) 19.2[tt] (18) 20.4[tt] (21) 21.1[tt] (24) 22.4[tt] (27)[aaa] (30)[aaa] (33)[aaa] (36)[aaa] 22.2[dd]	(12) - (15) 21[j] (18) 27[j] (21) 27[j] (24) 29[j] (27) - (30) - (33) - (36) -	(24) 26[xx]	Cherry et al. 1977
		Ottawa R. - Canada	1978	Review			24.0[bbb]				Christie 1979
		Hudson River - New York	1976-7	Lab A	yoy					(15) 30.0[yy] (15) 32.5[yy]	Ecological Analysts 1978
		Great Lakes region	?	?	?			21.4[dd]			Coker et al. 2001
	Walleye (*Sander vitreus*)	L. Cutfoot Sioux L., Upper Red L. - Minnesota	1971, 1972	Lab A Lab B	egg egg larvae juv. (small) juv. (large) juv.		6 - 12[f] 9 - 15[g] 15 - 21[e] 25[a] 22[a]			(8) 27[q],26[ll] (10.1) 28.6[q],28[ll] (12.1) 29[q],28[ll] (13.9) 29.5[q],28.6[ll] (16) 30.6[q],30[ll] (18.2) 30.5[q],30[ll] (20.2) 30.5[q],30[ll] (22.1) 30.5[q],30[ll] (24) 31.5[q],30.8[ll]	Smith and Koenst 1975; Koenst and Smith 1976
		Canada ?	?	?	juv.		20[a]				Kelso 1972
		? Oklahoma	?	Field B	Ad.	26-27					Eley et al. 1967
		? Wisconsin	?	Lab B	egg		17.8 - 19.4[e]				Anonymous 1967
		Hatchery - Wisconsin	1976	Lab B	yoy		22[a,ff]				Huh et al. 1976
		Tennessee R. - Alabama	1972-73	Field A	Ad. - juv.				30[cc]		Wrenn 1976
		W.L. Erie - Ohio	1972-73	Lab A-2	Ad.					(23.3) 34.4[ee]	Reutter and Herdendorf 1976
		Hatchery - Wisconsin	1968	Lab B	egg		16.7 - 19.4[e]				Steucla 1968

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Walleye (cont'd.)	Hatchery - Minnesota	1978	Lab A-1	juv.		22-26[a]			(22.1) 33.0[ww] (26.0) 34.1[ww] (28.0) 34.1[ww] (25.8) 31.6[t]	Hokanson and Koenst 1986
		Iowa and Mississippi - hatchery	1990+	Lab A-2	Juv.					(23) 34.8-35.0[ee]	Peterson 1993
		Ottawa R. - Canada	1978	Review			25.0[bbb]				Christie 1979
		Great Lakes region	?	?	?			22[dd]			Coker et al. 2001
	Johnny darter *(Etheostoma nigrum)*	Harker's Run - Ohio	198	Lab A-2 Lab C	Ad.	18.9-28.2 (Su) 17.6-26.8 (Wi)		22.9[tt] (Su) 22.0[tt] (Wi)			Ingersoll and Claussen 1984
		?	1975+	Lab A-2	Ad.					(5) 30.7[ee] (15) 31.4[ee]	Kowalski et al. 1978
		Missouri streams		Lab A-2						(26) 36.4[ee]	Smale and Rabeni 1995
		Colorado streams	1995+	Lab A-2	Ad.					(20) 34.0[ee] (30) 37.4[ee]	Smith and Fausch 1997
				Lab A-2						(20) 33.0[ee]	Lydy and Wissing 1988
	Tesselated darter *(Etheostoma olmsteadi)*	Great Lakes region	?	?	?			22.8[dd]			Coker et al. 2001
Gasterosteidae	Brook Stickleback *(Culeae inconstans)*	L. Amikeus, L. Opeongo-Ontario	1941	Lab A	Ad.					(25-26) 30.6[n],29[ll]	Brett 1944
		Great Lakes region	?	?	?			21.3[dd]			Coker et al. 2001
	Three-spine Stickleback *(Gasterosteus aculeatus)*									(19) 25.8[t]	Houston 1982
								16[dd]			Garside et al. 1977
	Nine-spine Stickleback *(Pungitius pungitius)*	Great Lakes region	?	?	?			12.5[dd]			Coker et al. 2001
Cottidae	Mottled sculpin *(Cottus bairdi)*	Sweetwater Cr. - Georgia	1995+	Lab A-2	Ad.					(10) 29.6[ee] (15) 30.4[ee] (20) 32.0[ee] (25) 33.8[ee]	Walsh et al. 1997
		?	1975+	Lab A-2	Ad.					(15) 30.9[ee]	Kowalski 1978
		Great Lakes region	?	?	?			16.6[dd]			Coker et al. 2001
	Slimy sculpin *(Cottus cognatus)*	Great Lakes region	?	?	?			11.5[dd]			Coker et al. 2001

Family	Species	Location	Year	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Slimy sculpin (cont'd.)	L. Michigan	1975	Lab A	Ad.			(5) 9[dd] (15) 12[dd] 10[dd]	(5) 15.2[j] (15) 21.5[j]	(5) 18.5[t] (10) 22.5[t] (15) 23.5[t] (20) 26.5[t] (5) 22.7[ee] (10) 24.8[ee] (15) 26.3[ee] (20) 29.4[ee]	Otto and Rice 1977

Appendix Table A-1 References

Alabaster, J. S. and A. L. Downing. 1966. A field and laboratory investigation on the effect of heated effluents on fish. Fish. Invest. London Ser. I, no. 6: 1-42.

Alabaster, J. S. and R. L. Welcome. 1962. Effect of concentration of dissolved oxygen on survival of trout and roach in lethal temperatures. Nature 194: 107.

Allen, K. O. and K. Strawn. 1968. Heat tolerance of channel catfish, *Ictalurus punctatus* (Rafinesque). Proc. 21st Ann. Conf. S.E. Assoc. Game and Fish Comm. (1967) 21: 299-411.

Alpaugh, W. C. 1972. High lethal temperatures of golden shiner *Notemigonus crysoleucas.* Copeia 1972, no. 1: 185.

Andrews, J. W. L. H. Knight and T. Murai. 1972. Temperature requirements for high density rearing of channel catfish from fingerling to market size. Prog. Fish-Cult. 34, no. 4: 240-241.

Baker, S. C. and R. C Heidinger. 1996. Upper lethal temperature tolerance of fingerling black crappie. *Journal of Fish Biology* 48: 1123-29.

Banner, A. and J. A. VanArman. 1973. Thermal effects on eggs, larvae and juveniles of bluegill sunfish, EPA-R3-73-041. U.S. EPA Ecol. Res. Ser.

Barans, C. L. and R. A. Tubb. 1973. Temperatures selected seasonally by four fishes from western Lake Erie. J. Fish. Res. Bd. Can. 30, no. 1: 1697-703.

Barila, T.Y. and J.R. Stauffer. 1980. Temperature and behavioral responses of the American eel, *Anguilla rostrata* (LeSueur), from Maryland. Hydrobiologia 74: 49-51.

Battle, H. I. 1940. The embryology and larval development of the goldfish *(Carassius auritus*, L.) from Lake Erie. Ohio J. Sci. 40, no. 2: 82-93.

Becker, C. Dale and Robert G. Genoway. 1979. Evaluation of the critical thermal maximum for determining thermal tolerance of freshwater fish. *Env. Biol. Fish.* 4, no. 3: 245-56.

Beitinger T.L. 1976. Behavioral thermoregulation by bluegill exposed to various rates of temperature change. pp. 176-179, In G.W. Esch and R.W. McFarlane [eds.] Thermal Ecology II (ERDA Symposium Series) "CONF-750425".

Beitinger, T.L., W.A. Bennett, and R.W. McCauley. 2000. Temperature tolerances of North American freshwater fishes exposed to dynamic changes in temperature. Env. Biology Fishes 58: 237-275.

Beitinger, T. L. and J. J. Magnuson. 1975. Influence of social rank and size on thermoselection behavior of bluegill *(Lepomis macrochirus).* J. Fish. Res. Bd. Can. 32: 2133-36.

Beitinger, T. L J. J. Magnuson W. H. Neill and W. R. Shaffer. 1975. Behavioral thermoregulation and activity patterns in the green sunfish, *Lepomis cyanellus.* Animal Behavior 23: 222-29.

Beltz, J.R., J.E. Johnson, D.L. Cohen, and F.B. Pratt. 1974. An annotated bibliography of the effects of temperature on fish with special reference to the freshwater and anadromous species of New England. Res. Bull. No. 605. Mass. Agr. Exp. Sta., U. Mass, Amherst, MA. 97 pp. (cited from Wismer and Christie 1987)

Bishai, H. M. 1960. Upper lethal temperatures for larval salmonids. J. Cons. Perma. Int. Explor. Mer. 25, no. 2: 129-33.

Black, E. C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. J. Fish. Res. Bd. Can. 10, no. 4: 196-210.

Block, Claire J. James R. Spotila Edward A. Standora and J. Whitfield Gibbons. 1984. Behavioral thermoregulation of largemouth bass, *Micropterus salmoides,* and bluegill, *Lepomis macrochirus*, in a nuclear reactor cooling reservoir. *Env. Biology of Fishes* 11, no. 1: 41-52.

Boswell, T.O. 1967. The effects of water hardness on the upper lethal temperature of the green sunfish *(Lepomis cyanellus).* M.Sc. thesis, New Mexico State University, University Park, NM. 31 pp.

Brandt, S.B., J.J. Magnuson, and L.B. Crowder. 1980. Thermal habitat partitioning by fishes in Lake Michigan. Can. J. Fish. Aq. Sci. 37: 1557-1564.

Brett, J. R. 1944. Some lethal relations of Algonquin Park fishes. Publ. Ont. Fish Res. Lab 63: 1-49.

———. 1952. Temperature tolerance in young Pacific salmon Genus *Oncorhynchus.* J. Fish. Res. Bd. Can. 9, no. 6: 265-323.

Brown, H. W. 1974. Handbook of the effects of temperature on some North American fishes. American Electric Power Serv. Corp. (Dec. 1974) : 431 pp.
[with supplements May 1975; March 1976].

Brungs, W. A. and B. R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures, EPA-600/3-77-061. U.S. EPA Ecological Research Series.

Campbell, J. S. and H. R. MacCrimmon. 1970. Biology of the emerald shiner *Notropis atherinoides* Rafinesque in Lake Simcoe, Canada. J. Fish. Biol. 2, no. 3: 259-73.

Carrier, R. and T.L. Beitinger. 1988. Resistance of temperature tolerance ability of green sunfish to cadmium exposure. Bull. Environ. Contam. Toxicol. 40: 475-480.

Cheetham, J. L. C. T. Garten Jr. C. L. King and M. H. Smith. 1976. Temperature tolerance of immature channel catfish *(Ictalurus punctatus).* Copeia 1976, no. 3: 609-12.

Cherry, D. S. K. L. Dickson and J. Cairns Jr. 1977. Preferred, avoided, and lethal temperatures of fish during rising temperature conditions. J. Fish. Res. Bd. Can. 34: 239-46.

———. 1975. Temperatures selected and avoided by fish at various acclimation temperatures. J. Fish. Res. Bd. Can. 32: 485-91.

———. 1974. The use of a mobile laboratory to study temperature response of fish, Manuscript of paper presented at the 29thPurdue Industrial Conference, May 7-9, 1974. 23 pp.

Cherry, D.S., S.R. Larrick, J.D. Giattina, J. Cairns Jr., and J. VanHassel. 1982. Influence of temperature selection upon the chlorine avoidance of cold-water and warm-water fishes. Can. J. Fish. Aq. Sci. 39: 162-173.

Christie, A. E. 1979. The calculation of temperature guidelines to protect fish resident in the Ottawa River, Report No. 79382. Environmental Studies and Assessments Department.

Churchill, M.A. and T.A. Wojtalik. 1969. Effects of heated discharges: the TVA experience. Nucl. News 12: 80-86.

Cincotta, D.A. and J.R. Stauffer. 1984. Temperature preference and avoidance studies of six North American freshwater fish species. Hydrobiologia 109: 173-177.

Coker, G. A., C. B. Portt, and C. K. Minns. 2001. Morphological and ecological characteristics of Canadian freshwater fishes. Canadian Manuscript Report of Fisheries Aquatic Sciences 2554.

Colby, P. J. and L. T. Brooke. 1970. Survival and development of lake herring *(Coregonus artedii)* eggs at various incubation temperatures. pp. 417-428, In C.C. Lindsey and C.S. Woods [eds.]. Biology of Coregonids. Winnipeg, Man.: Univ. Manitoba Press.

Coutant, C. C., 1977. Compilation of temperature preference data. J. Fish. Res. Bd. Can. 34, no. 5: 739-45.

———. 1975a. Responses of bass to natural and artificial temperature regimes. pp. 272-285, In R.H. Stroud and H. Clepper [eds.]. National Symposium on the Biology and Management of the Centrarchid Basses. Washington, D.C.: Sport Fishing Institute.

Coutant, C. C., K. L. Zachman, D. K. Cox, and B. L. Pearman. 1984. Temperature selection by juvenile striped bass in laboratory and filed. Trans. Amer. Fish. Soc. 113: 666-71.

Cox, D. K. and C. C. Coutant. 1981. Growth dynamics of juvenile striped bass as functions of temperature and ration. Trans. Am. Fish. Soc. 110: 226-238.

Crawshaw, L. I. 1975. Attainment of the final thermal preferendum in brown bullheads acclimated to different temperatures. Comp. Biochem. Physiol. A, no. 52: 171-73. [**19**]

Crawshaw, L. and I. Hammel. 1974. Behavioral regulation of internal temperature in the brown bullhead, *Ictalurus nebulosus.* Comp. Biochem. Physiol. A, no. 47 (1): 51-60.

Currie, Rebecca J Wayne A. Bennett and Thomas L. Beitinger. 1998. Critical thermal minima and maxima of three freshwater game-fish spices acclimated to consent temperature. *Env. Biology of Fishes* 51: 187-200.

Cvancara, V. A. S. F. Stieber and B. Cvancara. 1977. Summer temperature tolerance of selected species of Mississippi River acclimated young of the year fishes. Comp. Biochem. Physiol. 56A: 81-85.

Dendy, J. S. 1948. Predicting depth distribution of fish in three TVA storage type reservoirs. Trans. Am. Fish. Soc. 75: 65-71.

Dent, L. and W.I. Lutterschmidt. 2003. Comparative thermal physiology of two sympatric sunfishes (Centrarchidae: Perciformes) with a discussion of microhabitat utilization. J. Thermal Biol. 28: 67-74.

Diaz, F. and L. F. Buckle. 1999. Effect of the critical thermal maximum on the preferred temperatures of *Ictalurus punctatus* exposed to constant and fluctuating temperatures. *J. Thermal Biology* 24: 155-60.

Ecological Analysts. 1978. Hudson River thermal effects studies for representative species. Final Report to Central Hudson Gas & Electric Corp., Consolidated Edison Co. of New York, Inc., Orange and Rockland Utilities, Inc. Middleton, NY.

Edsall, T. A. 1970. The effect of temperature on the rate of development and survival of alewife eggs and larvae. Trans. Am. Fish. Soc. 2: 376-380.

Edsall, T. A. and D. V. Rottiers. 1976. Temperature tolerance of young-of-the-year lake whitefish, Coregonus clupeaformis. J. Fish. Res. Bd. Can. 33: 177-80.

Edsall, T. A. and P. A. Colby. 1970. Temperature tolerance of young-of-the-year cisco, *Coregonus artedii.* Trans. Am. Fish. Soc. 99, no. 3: 526-31.

Elliott, J.M. and J. A. Elliott. 1995. The effect of the rate of temperature increase on the critical thermal maximum for parr of Atlantic salmon and brown trout. J. Fish Biology 47: 917-919.

Ellis, C.J. 1984. Predicted survival of selected fish species released via fish pump to untempered water at Nanticoke TGS. Rept. No. 84355. Env. Stud. Assess. Dept. 44 pp.

(cited from Wismer and Christie 1987)

Farmer, G.J., F.W.H. Beamish, and F.L. Lett. 1977. Influence of water temperature in the growth rate of the landlocked sea lamprey *(Petromyzon marinus)* and the associated rate of host mortality. J. Fish. Res. Bd. Can. 34: 1373-1378.

Ferguson, R. G. 1958. The preferred temperature of fish and their midsummer distribution in temperature lakes and streams. J. Fish. Res. Bd. Can. 15, no. 4: 607-24.

Fry, F. E. J. and M. B. Gibson. 1953. Lethal temperature experiments with speckled trout x lake trout hybrids. J. Hered. 44, no. 2: 56-57.

Gammon, J. R. 1973. The effect of thermal inputs on the populations of fish and macroinvertebrates in the Wabash River, Tech. Rep. No. 32. Purdue University Water Resources Res. Center.

Garside, E. T. and G. C. Morrison. 1977. Thermal preferences of mummichog, *Fundulus heteroclitus* L., and banded killifish, *F. diaphanus* (Le Sueur), (Cyprinodontidae) in relation to thermal acclimation and salinity. Can. J. Zool. 55: 1190-1194.

Garside, E. T., D.G. Heinze, and S.E. Barbour. 1977. Thermal preference in relation to salinity in three-spined stickleback, *Gasterosteus aculeatus* L., with an interpretation of its significance. Can. J. Zool. 55: 590-594.

Garside, E. T. and J. S. Tait. 1958. Preferred temperature of rainbow trout and its unusual relationship to acclimation temperature. Can. J. Zool. 36: 565-67.

Gebhart, G.E. and R.C. Summerfelt. 1975. Factors affecting the vertical distribution of white crappie (Pomoxis annularis) in two Oklahoma reservoirs. Proc. Ann. Conf. SE Game Fish Comm. 28: 355-366.

Greene, K.E., J.L. Zimmerman, R.W. Laney, and J.C. Thomas-Blate. 2009. Atlantic Coast Diadromous Fish Habitat: A Review of Utilization, Threats, Recommendations for Conservation, and Research Needs. Atlantic States Marine Fisheries Commission, Habitat Management Series #9, Washington, D.C.

Hart, J. S. 1952. Geographical variations of some physiological and morphological characters in certain freshwater fishes, University Toronto Stud., Biol. Ser. No. 60, Publ. Ontario Fish. Res. Lab. No 72: 79 pp.

———. 1947. Lethal temperature relations of certain fish in the Toronto region. Trans. Roy. Soc. Can. 41, no. III: 57-71.

Heist, B.G. and W.A. Swenson. 1983. Distribution and abundance of rainbow smelt in western Lake Superior as determined from acoustic sampling. J. Great Lakes Research 9(3): 343-353.

Hill, L.G., G.D. Schnell, and J. Pigg. 1975. Thermal acclimation and temperature selection in sunfishes (Lepomis, Centrarchidae). The Southwestern Naturalist 20 (2): 177-184.

Hockett, C.T. and N.D. Mundahl. 1989. Effects of black spot disease on thermal tolerances and condition factors of three cyprinid fishes. J. Freshwater Ecol. 5(1): 67-72.

Hocutt, C. H. 1973. Swimming performance of three warmwater fishes exposed to a rapid temperature change. Chesapeake Sci. 14, no. 1: 11-16.

Hokanson, Kenneth E. F. and Walter M. Koenst. 1986. Revised estimates of growth requirements and lethal temperature limits of juvenile walleyes. Prog. Fish-Cult. 48: 90-94.

Hokanson, K. E. F., C.F. Kliener, and T.W. Thorsland. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, *Salmo gairdneri.* J. Fish. Res. Bd. Can. 34: 639-648.

Hokanson, K. E. F. and C. F. Kleiner. 1981. Effects of constant and diel fluctuations in temperature on growth and survival of black crappie, Unpublished data, National Water Quality Laboratory. [cited in Brungs and Jones 1977].

———. 1974. Effects of constant and rising temperatures on survival and developmental rate of embryo and larval yellow perch, *Perca flavescens* (Mitchill). pp. 437-438, In J.H.S. Blaxter [ed.]. The Early Life History of Fish. Heidelberg: Springer-Verlag.

Hokanson, K. E. F. J. H. McCormick and B. R. Jones. 1973a. Temperature requirements for embryos and larvae of the northern pike, *Esox lucius* (Linnaeus). Trans. Am. Fish. Soc. 102, no. 1: 89-100.

Holland, W. E. M. H. Smith J. W. Gibbons and D. H. Brown. 1974. Thermal tolerances of fish from a reservoir receiving heated effluent from a nuclear reactor. Physiol. Zool. 47: 110-118.

Horak, O. L. and H. A. Tanner. 1964. The use of vertical gill nets in studying fish depth distribution, Horsetooth Reservoir, Colorado. Trans. Am. Fish. Soc. 93: 137-45.

Horning, W. B. and R. E. Pearson. 1973. Temperature requirements for juvenile smallmouth bass (Micropterus dolomieui) - growth and lower lethal temperatures. J. Fish. Res. Bd. Can. 30: 1226-30.

Horoszewica, L. 1973. Lethal and "disturbing" temperatures in some fish species from lakes with normal and artificially elevated temperatures. J. Fish. Biol. 5: 165-81.

Horton, D. B., and D. W. Bridges. 1973. A study to predict the effects of thermal additions in the Bay River and Neuse River area of North Carolina. U.S. Department of the Interior Office of Water Research and Technology Report No. OWRT-004-NC, Washington, D.C.

Houston, A.H. 1982. Thermal effects upon fishes. Rept. NRCC No. 18566. National research Council of Canada. Assoc. Comm. Sci. Crit. Env. Qual. 200 pp.

Huh, H. T. H. E. Calbert and D. A. Stuiber. 1976. Effects of temperature and light on growth of yellow perch and walleye using formulated feed. Trans. Am. Fish. Soc. 105, no. 2: 254-58.

Ingersoll, Christopher G. and Dennis L. Claussen. 1984. Temperature selection and critical thermal maxima of the fantail darter, *Etheostoma flabellare*, and johnny darter, *E. nigrum*, related to habitat and season. *Environ. Biology of Fishes* 11, no. 2: 131-38.

Javaid, M. Y. and J. M. Anderson. 1967b. Influence of starvation on selected temperature of some salmonids. J. Fish. Res. Bd. Can. 24, no. 7: 1515-19.

Jinks, S.M., G.J. Lauer, and M.E. Loftus. 1981. Advances in techniques for assessment of ichthyoplankton entrainment survival, pp. 92-110. in L.D. Jensen (ed.), Issues Associated with Impact Assessment. Proc. 5th Natl. Workshop on Entrainment and Impingement, San Francisco. Ecological Analysts, Inc. and Electric Power Research Institute. 307 pp.

Jobling, M. 1981. Temperature tolerance and the final preferendum – rapid methods for the assessment of optimum growth temperatures. J. Fish Biol. 19: 439-455.

Johnson, F. H. 1961. Walleye egg survival during incubation on several types of bottom in Lake Winnibigoshish, Minnesota. Trans. Am. Fish. Soc. 90, no. 3: 312-22.

Jones, B. R. K. E. F. Hokanson and J. H. McCormick. (manuscript in preparation). Temperature requirements of maturation and spawning of yellow perch, *Perca flavescens* (Mitchill). [cited in McCormick (1976) and Brown (1974)].

Jones, T. C. and W. H. Irwin. 1965. Temperature preferences by two species of fish and the influence of temperature on fish distribution. Proc. 26th Ann. Conf. S.E. Assoc. Game and Fish Comm. 1962, pp. 323-33.

Jude, D.J. 1973. Sublethal effects of ammonia and cadmium on growth of green sunfish. Ph.D. thesis, Michigan State University, E. Lansing, MI. 193 pp.

Karlsson, L., G. Ekbohm, G. Steinholtz. 1984. Comments on a study of the thermal behavior of the American eel *(Anguilla rostrata)* and some statistical suggestions for temperature preference studies. Hydrobiologia 109: 75-78.

Kaya, C. M. 1977. Reproductive biology of rainbow and brown trout in a geothermally heated stream: the Firehole River of Yellowstone National Park. Trans. Am. Fish. Soc. 106, no. 4: 354-61.

Kendall, A.W. and F.J. Schwartz. 1968. Lethal temperature and salinity tolerances of the white catfish, *Ictalurus catus,* from the Patuxent River, Maryland. Chesapeake Science 9(2):

103-108.

Kleiner, C.F. 1981. Effects of temperature on growth and survival of the white crappie. U.S. EPA, Env. Res. Lab, Duluth, MN. Unpublished data (cited from Hokanson 1990).

Koenst, W. M. and L. L. Smith Jr. 1976. Thermal requirements of the early life history stages of walleye, *Stizostedion vitreum vitreum,* and sauger, *Stizostedion canadense.* J. Fish. Res. Bd. Can. 33: 1130-1138.

Kowalski, K.T., J.P. Schubauer, C.L. Scott, and J.R. Spotilla. 1978. Interspecific and seasonal differences in the temperature tolerance of stream fish. J. Thermal Biol. 3: 105-108.

Lee, R.M. and J.N. Rinne. 1980. Critical thermal maxima of five trout species in the southwestern United States. Trans. Am. Fish. Soc. 109(6): 632-635.

Lemke, A.E. 1977. Optimum temperature for growth of juvenile bluegills. The Prog. Fish-Culturist 39(2): 55-57.

Lillelund, V. K. 1966. Versuche zur Erbrutung der Eier vom Hecht, Esox lucius L., in Abhangigkiet von Temperatur und Licht. Arch. Fischereiwiss 17: 95-113.

Lutterschmidt, W.I. and V.H. Hutchinson. 1997. The critical thermal maximum: data to support the onset of muscle spasm as the definitive end point. Can. J. Zool. 75: 1553-1560.

Lydy, M.J. and T.E. Wissing. 1988. Effect of sublethal concentrations of copper on the critical thermal maximum (CTmax) of the fantail *(Etheostoma flabellare)* and Johnny *(E. nigrum)* darters. Aquat. Toxicol. 12: 311-322.

Marcy, B. C., Jr., P.M. Jacobson, and R.L. Nankee. 1972. Observations on the reactions of young American shad to a heated effluent. Trans. Am. Fish. Soc. 4: 740-743.

Matthews, W. J. 1981. Physicochemical tolerance and selectivity of stream fishes as related to their geographic ranges and local distributions. Pages 111-120 *In*, W.J. Matthews and D.C. Heins [eds.], Community and Evolutionary Ecology of Stream Fishes. Norman, OK: University of Oklahoma Press.

McCauley, R.W. 1981. Laboratory studies on direct and acute lethal effects of temperature on alewife *(Alosa pseudoharengus)* and rainbow smelt *(Osmerus mordax)* collected at Pickering GS, pp. H1-H27. *in* A.E. Christie (ed.) Biological Investigations to Improve Once-Through Cooling System Designs for the Great Lakes. Rept. No. 81481. Env. Stud. Assess. Dept., Design Dev. Div., Ontario Hydro, Toronto, Ontario.

_____. 1980. Wilfrid Laurier University, Waterloo, Ontario. Unpublished data (cited in Hokanson 1990).

_____. 1977. Laboratory methods for determining temperature preference. J. Fish. Res. Bd.

Can. 34, no. 5: 749-52.

_____. 1963. Lethal temperatures of the developmental stages of the sea lamprey, *Petromyzon marinus* L. J. Fish. Res. Bd. Can. 20: 483-490.

McCauley, R.W. and F.P. Binkowski. 1982. Thermal tolerance of the alewife. *Trans. Amer. Fish. Soc.* 111: 389-91.

McCauley, R. W. and J. S. Tait. 1970. Preferred temperature of yearling lake trout, Salvelinus namaycush. J. Fish. Res. Bd. Can. 27: 1729-33.

McCauley, R. W. and L. A. A. Read. 1973. Temperature selection by juvenile and adult yellow perch *(Perca flavescens)* acclimated to 24C. J. Fish. Res. Bd. Can. 30: 1253-55.

McCauley, R. W. and W. L. Pond. 1971. Temperature selection of rainbow trout *(Salmo gairdneri)* in vertical and horizontal gradients. J. Fish. Res. Bd. Can. 28: 1801-4.

McCormick, J. H. 1976. Temperature effects on young yellow perch, *Perca flavescens* (Mitchill), U.S. EPA Ecological Research Series, EPA-600/3-057.

McCormick, J. H. and J. A. Wegner. 1981. Responses of largemouth bass from different latitudes to elevated water temperatures. *Trans. Amer. Fish. Soc.* 110: 417-29.

McCormick, J. H. and C. F. Kleiner. 1976. Growth and survival of young-of-the-year emerald shiners *(Notropis atherinoides)* at different temperatures. J. Fish. Res. Bd. Can. 33: 839-42.

McCormick, J. H. B. R. Jones and K. E. F. Hokanson. 1977. White sucker *(Catostomus commersoni)* embryo development and early growth and survival at different temperatures. J. Fish. Res. Bd. Can. 34, no. 7: 1019-25.

McCormick, J.H., K.E.F. Hokanson, and B.R. Jones. 1972. Effects of temperature on growth and survival of young brook trout, *Salvelinus fontinalis.* J. Fish. Res. Bd. Can. 29: 1107-1112.

McCormick, J. H. B. R. Jones and R. F. Syrett. 1971. Temperature requirements for growth and survival of larval ciscos *(Coregonus artedii).* J. Fish. Res. Bd. Can. 28: 924-27.

Meldrim, J. W. and J. J. Gift. 1971. Temperature preference, avoidance and shock experiments with estuarine fishes. Ichthyological Assoc. Bull. 7 : 75 pp.

Meuwis, A. and M. Heuts. 1957. Temperature dependence of breathing rate in carp. Biol. Bull. 112, no. 1: 97-107.

Moss, S.A. 1970. The responses of young American shad to rapid temperature changes. Trans. Am. Fish. Soc. 2: 381-384.

Muncy, R. J. 1962. Life history of the yellow perch, *Perca flavescens,* in estuarine waters of Severn River, a tributary of Chesapeake Bay, Maryland. Chesapeake Sci. 3, no. 3: 143-59.

Mundahl, Neal D. 1990. Heat depth of fish in shrinking stream ponds. Am. Midl. Nat. 123: 40-46.

Neill, W. H. and J. J. Magnuson. 1974. Distributional ecology and behavioral thermoregulation of fishes in relation to heated effluent from a power plan at Lake Monona, Wisconsin. Trans. Am. Fish. Soc. 103, no. 4: 664-710.

Neill, W. H. J. J. Magnuson and G. G. Chipman. 1972. Behavioral thermoregulation by fishes: a new experimental approach. Science 176: 1443-45.

Otto, R. G. M. A. Kitchell and J. O. Rice. 1976. Lethal and preferred temperatures of the Alewife *(Alosa pseudoharengus)* in Lake Michigan. Trans. Am. Fish. Soc. 105, no. 1: 96-106. [**2**]

Otto, R. G. and J. O. Rice. 1977. Response of the freshwater sculpin *(Cottus cognatus gracilis)* to temperature. Trans. Am. Fish. Soc. 106: 89-94.

Peterson, M. S. 1993. Thermal tolerance of Iowa and Mississippi populations of juvenile walleye, *Stizostedion vitreum*. *Copeia* 3: 890-894.

Peterson, S. E. and R. M. Schutsky. 1976. Some relationships of upper thermal tolerances to preference and avoidance responses of the bluegill. pp. 148-153, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposium Series) "CONF 750425".

———. 1975. Temperature tolerance studies on freshwater fishes. (Unpublished manuscript) Presented at Northeast Fish and Wildlife Conference, New Haven, Ct., Feb. 23-26, 1975.

Pitt, T. K. E. T. Garside and R. L. Hepburn. 1956. Temperature selection of the carp (Cyprinus carpio). Can. J. Zool. 34: 555-57. [**7**]

Potter, I. C. and F. W. H. Beamisk. 1975. Lethal temperatures in four ammocoetes of four species of lampreys. Acta Zool. 56: 85-91.

Power, M. E. and J. H. Todd. 1976. Effects of increasing temperature on social behaviour in territorial groups of pumpkinseed sunfish, *Lepomis gibbosus.* Environ. Poll. 10, no. 3: 217-23.

Proffitt, M. A. and R. S. Benda, and M. A. Proffitt. 1971. Growth and movement of fishes, and distribution of invertebrates, related to a heated discharge into the White River at Petersburg, Indiana. Ind. University Water Res. Research Cen. Rep. Invest. 5 : 94 pp.

Pyron, M. and T.L. Beitinger. 1993. Temperature tolerance after spawning in female and male fathead minnows, *Pimephales promelas*. The Texas J. Sci. 45(4): 319-323.

Rawson, D. S. 1956. Life history and ecology of the walleye *Stizostedion vitreum,* in Lac La Rouge, Saskatchewan. Trans. Am. Fish. Soc. 86: 15-37.

Reutter, J. M. and C. E. Herdendorf. 1974. Laboratory estimates of the seasonal final temperature preferenda of some Lake Erie fish. Proc. 17th Great Lakes Res 1974: 59-67.

Reutter, J. M. and C. E. Herdendorf. 1975. Laboratory estimates of fish response to the heated discharge from the Davis-Besse reactor, Lake Erie, Ohio. CLEAR Tech. Rep. 31 : 54 pp.

———. 1976. Thermal discharge from a nuclear power plant: predicted effects on Lake Erie Fish. Ohio J. Sci. 76, no. 1: 39-45.

Raney, W. W. 1977c. Fever and antipyresis in the bluegill sunfish, *Lepomis macrochirus.* Comp. Biochem. Physiol C.

———. 1977a. Fish orientation behavior: an electronic device for studying simultaneous responses to two variables. J. Fish. Res. Bd. Can. 34: 300-304. [**16**]

———. 1977d. Temperature as a proximate factor in orientation behavior. J. Fish. Res. Bd. Can. 34: 734-39.

———. 1977b. Thermal equilibrium rates n relation to heartbeat and ventilatory frequencies in largemouth blackbass, *Micropterus salmoides.* Comp. Biochem. Physiol. A56: 195-201.

Richards, F.P. and R.M. Ibara. 1978. the preferred temperatures of the brown bullhead, Ictalurus nebulosus, with references to its selection of a nuclear power plant discharge canal. Trans. Am. Fish. Soc. 107(2): 288-294.

Rutledge, C.J. and T.L. Beitinger. 1989. The effects of dissolved oxygen and aquatic surface respiration on the critical thermal maxima of three intermittent-stream fishes. Env. Biol. Fishes 24(2): 137-143.

Schaefer, J.F., W.I. Lutterschmidt, and L.G. Hill. 1999. Physiological performance and stream microhabitat use by the centrarchids *Lepomis megalotis* and *Lepomis macrochirus.* Env. Biol. Fishes 54: 303-312.

Scott, D. P. 1964. Thermal resistance of pike *(Esox lucius L.),* muskellunge *(E. masquinongy)* Mitchill, and their F hybrids. J. Fish. Res. Bd. Can. 21, no. 5: 1043-49.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184: 966 pp.

Siler, J. R. and J. P. Clugston. 1975. Largemouth bass under conditions of extreme thermal stress. pp. 333-343, In R.H. Stroud and H. Clepper [eds.]. Black Bass Biology and Management. Nat. Symp. Biol. Mgmt. Centrarchid Basses, Sport Fish. Inst., Washington, D.C.

Smale, M.A. and C.F. Rabeni. 1995. Hypoxia and hyperthermia tolerances of headwater stream fishes. Trans. Am. Fish. Soc. 124: 698-710.

Smith, M.H. and K.D. Fausch. 1997. Thermal tolerance and vegetation preference of Arkansas darter and johnny darter for Colorado plains streams. Trans. Am. Fish. Soc. 126: 676-686.

Smith, L. L. and W. M. Koenst. 1975. Temperature effects on the eggs and fry of percoid fishes, Ecological Research Ser., EPA-660/3-75-017. U.S. EPA, Corvallis, Oregon, 99 pp.

Speakman, J. N. and P. A. Krenkel. 1972. Quantification of the effects of rate of temperature change on aquatic biota. Wat. Res. 6: 1283-90.

Spigarelli, S. A. 1975. Behavioral responses of Lake Michigan fishes to a nuclear power plant discharge. pp. 479-498, In Environmental Effects of Cooling Systems at Nuclear Power Stations, Int. Atomic Energy Agency (IAEA), Vienna.

Stauffer, J. R., D.R. Lipsi, and C.H. Hocutt. 1984. The preferred temperatures of three *Semotilus* species. Arch. Hydrobiol. 101(4): 595-600.

Stauffer, J. R. K. L. Dickson A. G. Heath G. W. Lane and J. Cairns Jr. 1975. Body temperature change of bluegill sunfish subjected to thermal shock. Prog. Fish-Cult. 37, no. 2: 90-92.

Stauffer, J. R. K. L. Dickson and J. Cairns Jr. 1974. A field evaluation of the effects of heated discharges on fish distribution. Water Res. Bull. 10, no. 5: 860-876.

Stauffer, J. R. K. L. Dickson J. Carins Jr. and D. S. Cherry. 1976. The potential and realized influences of temperature on the distribution of fishes in the New River, Glen Lyn, Virginia. Wild. Monogr. 50: 4-40.

Strawn, K. 1961. Growth of largemouth bass fry at various temperatures . Trans. Am. Fish. Soc. 90, no. 3: 334-35.

Talmadge, S.S. and C.C. Coutant. 1979. Thermal effects. J. Water Poll. Contr. Fed. 51: 1517-1554.

Tatarko, K. I. 1966. Sensitivity of pond carp to elevated temperature at different periods of embryonic development. Gidrobiol. Zh. 4, no. 6: 34-43. [cited in Brown (1974)].

Terpin, K. M. J. R. Spotila and R. R. Koons. 1976. Effect of photoperiod on the temperature tolerance of the blacknose dace, *Rhinichthys atratulus.* Biochem. Physiol. 53A: 241-44. [**xxx**]

Trembley, F. J. 1960. Research project on the effects of condenser discharge water on aquatic life, Progress Rept. 1956-59. Inst. Research, Lehigh University, Bethlehem, PA. 164 pp.

Tyler, A.V. 1966. Some lethal temperature relations of two minnows of the genus *Chrosomus.* Can. J. Zool. 44: 349-364.

Ulvestad, D.A. and J.H. Zar. 1977. Preferred temperature of the common shiner, *Notropis cornutus,* in relation to age, size, season, and nutritional state. Ohio J. Sci. 77(4): 170-173.

Wallace, C. R. 1973. Effects of temperature on developing meristic structures of smallmouth bass, Micropterus dolomieui Lacepede. Trans. Am. Fish. Soc. 102, no. 1: 142-44.

Walsh, S. J. D. C. Haney and C. M. Timmerman. 1997. Variation in thermal tolerance and routine metabolism among spring and stream-dwelling freshwater sculpins (Teleostei: Cottidae) of the southeastern United States. *Ecol. Fresh. Fish* 6: 84-94.

Walton, D.A. and D.B. Noltie. 1998. Effects of elevated ambient temperature on white crappie *(Pomoxis annularis)* feeding and growth. Trans. Missouri Acad. Sci. 32: 1-11.

Wismer, D.A. and A.E. Christie. 1987. Temperature relationships of Great Lakes fishes: a data compilation. Great Lakes Fishery Commission Special Publication 87-3. 165 pp.

Wrenn, W. B. 1980. Effects of elevated temperature on growth and survival of smallmouth bass. *Trans. Amer. Fish. Soc.* 109: 617-25.

Wrenn, W. B. 1976. Temperature preference and movement of fish in relation to a long heated discharge channel. pp. 191-194, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425".

Yoder, C. O. and J. R. Gammon. 1976a. Spatial temporal distributions and abundance of fishes in the Middle Ohio River, 1976 Rept. to Dayton Power and Light Co., DePauw University. Greencastle, Ind.

_____. 1976b. Seasonal distribution and abundance of Ohio River fishes at the J.M. Stuart electric generating station. pp. 284-296, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425".