Center for Applied Bioassessment & Biocriteria
P.O. Box 21541
Columbus, OH 43221-0541

Temperature Criteria Options for the Lower Des Plaines River

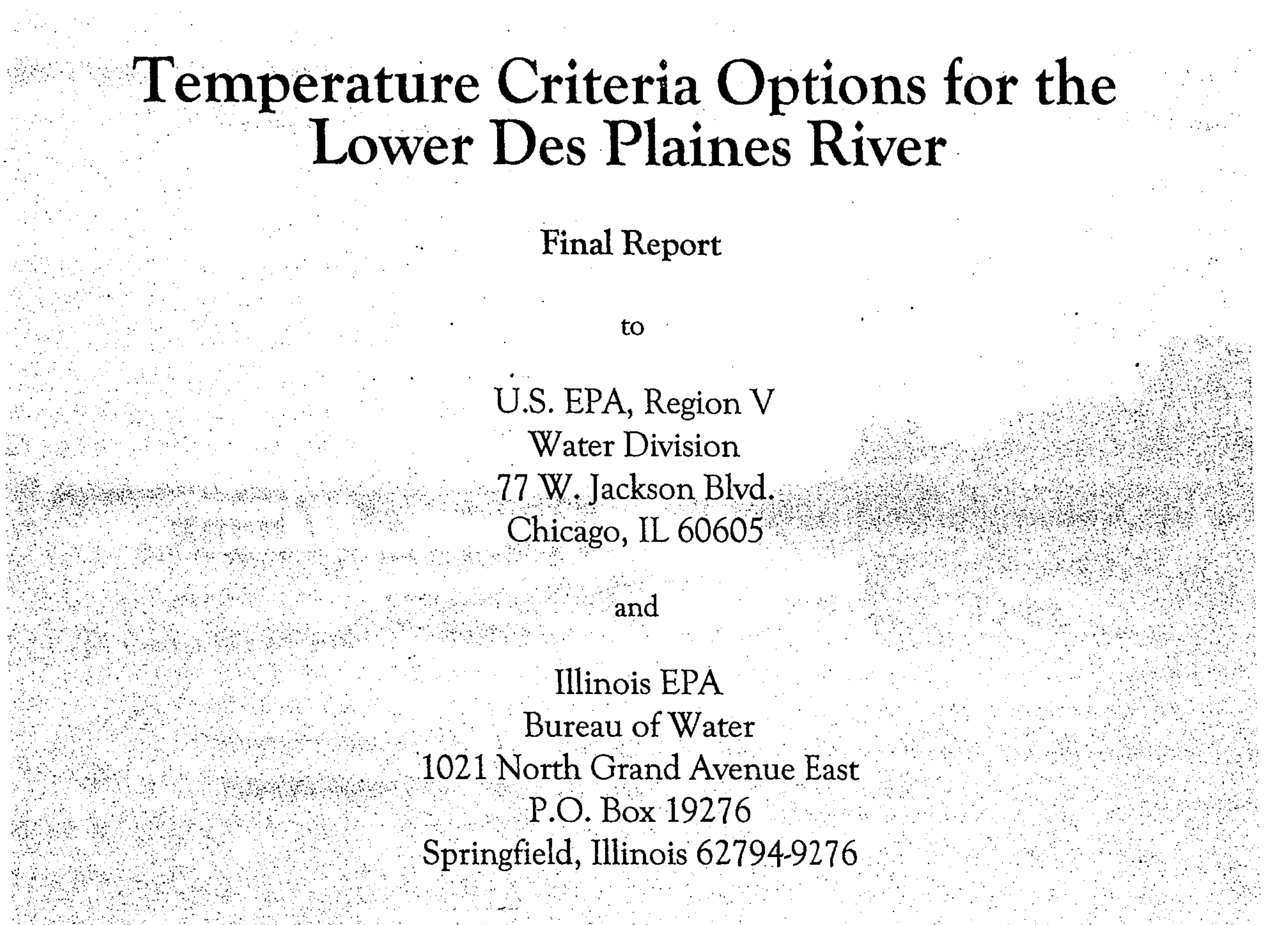
Final Report

to

U.S. EPA, Region V
Water Division
77 W. Jackson Blvd.
Chicago, IL 60605

and

Illinois EPA
Bureau of Water
1021 North Grand Avenue East
P.O. Box 19276
Springfield, Illinois 62794-9276



Des Plaines R. below Dresden Dam (Hey & Assoc. 2003)

November 23, 2005

Chris O. Yoder, Research Director
Midwest Biodiversity Institute
P.O. Box 215641
Columbus, OH 43221-0561

and

Edward T. Rankin, Senior Research Associate
Center for Applied Bioassessment and Biocriteria
P.O. Box 21541
Columbus, OH 43221-0541

Introduction

The Center for Applied Bioassessment and Biocriteria (CABB) was requested by U.S. EPA, Region V and the Illinois EPA to develop temperature criteria options for the Lower Des Plaines River in northeastern Illinois. The need to review and possibly revise the existing temperature criteria is a result of the recent use attainability analysis (UAA) conducted for the Brandon and Dresden navigation pools of the mainstem (Hey and Associates 2003).

CABB produced a draft report in June 2004 on temperature criteria options for three different use designation scenarios based on possible outcomes of the UAA process. Since that time, the methodology used to derive seasonal temperature criteria options (Ohio EPA 1978) was updated (MBI 2005), thus the June 2004 draft report is revised herein. The revised methodology emanates from that originally developed by Ohio EPA (1978) and later described by Yoder and Emery (2004). A project to review the temperature criteria for the Ohio River was the impetus for the revisions and included an examination of existing temperature criteria models and techniques, a review of state temperature criteria and methods, and an extensive update to the thermal tolerance database for freshwater fishes common to rivers and streams of the Great Lakes and Ohio River drainages. The new data and methodologies developed by this effort were used in this revision of the Lower Des Plaines temperature criteria options report.

Project Background

The Brandon and Dresden navigation pools of the Lower Des Plaines River were the subject of a use attainability analysis (UAA) conducted by Hey and Associates (2003). The purpose of the UAA was to evaluate the efficacy of the existing Secondary Contact/ Indigenous Aquatic Life use designation and the potential for upgrading to the General use designation or an intermediate designation that reflects the modified habitats of these navigation pools and impoundments. Regardless of the use designation decision that is ultimately made by Illinois EPA, the current temperature criteria for the Lower Des Plaines River could be changed. Thus, Illinois EPA is interested in developing options for temperature criteria that more closely reflect the potential biological assemblages that are representative of the possible designated use outcomes of the UAA process.

Project Purpose

The primary purpose of this report is to develop options for ambient temperature criteria for the Lower Des Plaines River within the objectives and the directives for this project. The temperature criteria options are the result of decisions and assumptions about the key input variables, the most important of which are the lists of representative aquatic species (RAS) and the statistical endpoints used to analyze the ambient temperature database. RAS lists varied by use designation option and the inclusion and exclusion of key fish species within each list. Ambient temperature data collected in the Lower Des Plaines R. and the Chicago Area Waterway System (CAWS) was analyzed and statistical thresholds were developed for later use in deriving non-summer season criteria. The results of a thermodynamic modeling study of the area (Holly and Bradley 1995) were also used to portray the ambient temperature regime. From these analyses and options, Illinois EPA should be able to derive a set of seasonal temperature criteria to apply to the Des Plaines R. and in consideration of the use designation decisions emanating from the UAA process.

It is not the purpose of this report to make specific use designation or temperature criteria determinations. Neither is it the purpose of this report to determine or allocate heat loads for specific sources based on the ambient temperature criteria options. The derivation of temperature criteria is a separate function apart from applying them to specific water pollution control issues such as NPDES permits or TMDLs. One of the most difficult issues in setting temperature criteria is the consideration of "normal" ambient thermal regimes and naturally occurring exceedences of fixed seasonal criteria. It is possible and perhaps likely that thermal thresholds for key RAS will be exceeded on occasion by natural background temperatures, thus raising the dilemma of criteria exceedences and their potential consequences. Such exceedences are of particular concern where they are frequent enough to result in the perception of an impaired designated use. However, as with other naturally occurring physical and chemical constituents, exceedences are inevitable and may not necessarily result in a biologically impaired use (Essig 1998). Conversely, setting criteria too high to avoid the regulatory inconveniences of such exceedences can also have potentially adverse biological consequences. These issues must be considered when deriving and applying temperature criteria.

Objectives, Approach, and Methods

The principal objective of this project is the development of seasonal temperature criteria options that are protective of the biological assemblages that are representative of the designated use options that may be considered for the Lower Des Plaines River. Using the same approach as the recently completed Ohio River methodology (MBI 2005), these were derived based on the representative fish assemblages for each designated use option. The methodology uses data from the thermal effects literature to create a thermal effects database for freshwater fish. This data is then used within a procedure that calculates four behavioral and physiological thresholds for a list of representative fish species termed RAS (Representative Aquatic Species) that are intended to represent the fish assemblage of a particular river or river segment. Ohio EPA used this approach in setting temperature criteria for inland waters and Lake Erie in the 1978 revisions to the Ohio water quality standards (WQS) and ORSANCO used it to adopt the current Ohio River temperature criteria in 1984. The temperature criteria derivation process was later incorporated within the Fish Temperature Modeling system that is part of the Ohio ECOS data management system originally developed and operated by Ohio EPA. The Fish Temperature Modeling system was initially developed as a mainframe routine, but was later converted to a relational database (FoxPro) as part of the Ohio ECOS data management system. MBI developed an update to this system as part of the Ohio River thermal criteria update (MBI 2005). It operates in an Excel format using Visual Basic – this system was used to develop the current set of temperature criteria options for the Lower Des Plaines R.

Comprehensive Literature Search and Compilation of Recent Fish Thermal-effects Data
The original Ohio EPA (1978) methodology used thermal effects data from 370+ literature sources that date before 1978. One of the major tasks of the ORSANCO sponsored study (MBI 2005) was to update the thermal effects database by obtaining new literature sources. A database search focused on keywords related to thermal effects on fish and other aquatic organisms. More than 500 titles and abstracts were screened for relevancy. In addition, other new literature sources not revealed by the database search were obtained via reviews of individual publications, major bibliographies, web links, and "word of mouth". In all, this effort produced more than 200 new and *useable* references that included specific thermal effects data for individual species or groups of fishes and invertebrates. An additional 200+ sources were reviewed, but deemed unsuitable for these purposes. An attempt was made to obtain thermal effects data for other assemblage groups such as bivalve mollusks, but there was very little if any usable information that could be found. The MBI (2005) compilation emphasized freshwater fishes of the Ohio River and Great Lakes drainages, but also included a compilation for selected macroinvertebrates.

Each new literature source was reviewed for relevancy, i.e., were the specific thermal tolerance endpoints used in the Fish Temperature Model readily available? Acceptable data were then entered into the master thermal effects database. The original literature source was examined for relevancy, originality, and completeness as much as was possible prior to accepting the data in the master database. The acceptance of "extrapolated" (i.e., without a direct review of the original publication) citations was done for some of the more comprehensive thermal effects compendia such as Brown (1974), Wismer and Christie (1987), Hokanson (1990), and Beitinger et al. (2000). A notation was made about the extrapolated citation of such references. We did find in some of these compendia a practice of citing an existing literature review as the source of the data in lieu of the original literature source. We avoided duplicating this practice and where it occurred we cited the original literature source.

Thermal Endpoints
The compilation originally produced by Ohio EPA (1978) relied mostly on the upper incipient lethal temperature (UILT) as the primary lethal endpoint. It is the principal basis for calculating the short and long term survival thresholds produced by the Fish Temperature Model. The UILT was the accepted lethal endpoint of that time (Brown 1974). The other widely available test endpoint, the critical thermal maximum (CTM), was thought to produce lethal temperatures that were too high to be protective in nature because the test organisms are not properly acclimated by the *rapid* increases in test temperatures. As such, the CTM endpoint occurs beyond the temperature at which the organism is irreparably harmed. A recently expressed concern with both of these commonly available lethal test methods is that the steady or regular increases in test temperature inherent to the methodologies do not reflect environmental reality. This concept is illustrated by Figure 1 (from Bevelheimer and Bennet 2000) in which the accumulation of thermal stress to an aquatic organism is dependent on seasonal acclimation, the severity and duration of periods of thermal exposure and stress, and the

duration of recovery periods, i.e., lower temperatures that are closer to physiological optima. However, few if any of the available *in situ* tests reflect this type of thermal exposure. Field derived thresholds (final preferenda and upper avoidance) may better represent these phenomena, but only if a complete range of thermal exposures was reasonably available in the study area.

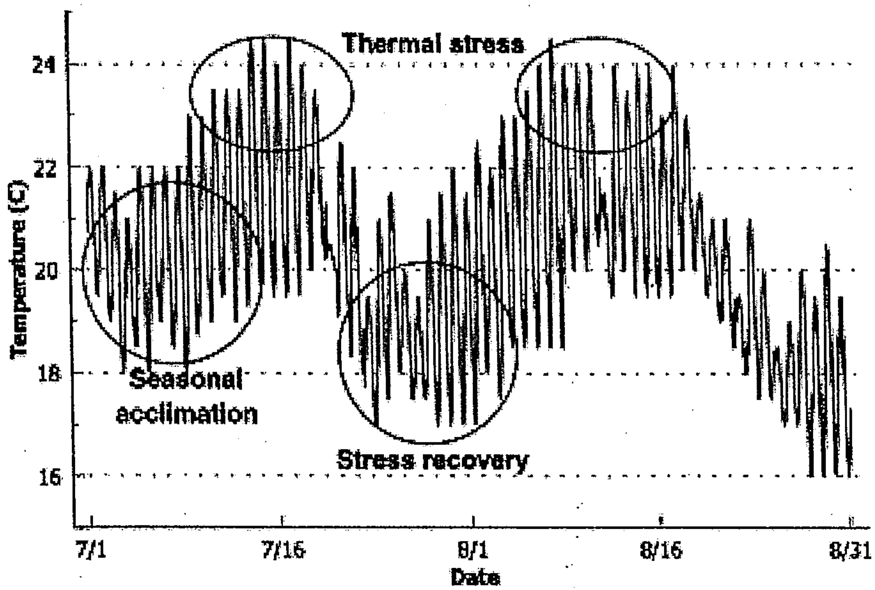


Figure 1. The important features of the thermal regime that is important in determining the effects of temperature on fish (after Bevelheimer and Bennet 2000).

While thermal resistance seems to increase with slowly increasing temperatures, does it represent reality in the environment where temperatures fluctuate upwards and downwards within a season? The few studies that have attempted to examine the effect of fluctuating test temperatures have produced conflicting results. Unfortunately, insufficient experimental data exists to support what might be viewed as "real time" temperature criteria in lieu of the current technology of fixed seasonal criteria. As one result, safety factors are commonly employed in interpreting thermal effects endpoints and in deriving temperature criteria. Early temperature criteria included a "5°F rise" provision presumably as a way to account for fluctuating ambient temperatures, but the scientific validity of this rule-of-thumb was questioned such that Ohio EPA and ORSANCO deleted it from their WQS.

The choice (or order of preference) of thermal endpoints was an important issue in the MBI (2005) update study. Clearly, different testing procedures can and do produce different thermal endpoints for the same species. The key technical issue with the traditional upper thermal tolerance testing procedures (CTM and UILT) is not the procedures themselves, but their disconnection with natural exposure regimes (see Figure

1). Selong et al. (2001) summarized the limitations of upper thermal endpoint data using these two methods:

> "However, their [CTM test results] relevance to the actual temperature tolerance of fishes is limited by the unnaturally rapid temperature changes, which preclude the normal acclimation that occurs in nature . . . However, as with the CTM method, the ILT method may have limitations when it comes to extrapolating test results to natural situations. A recent modification of the ILT method incorporates slower temperature change schedules (e.g., 1.0-1.5°C/d) to better mimic natural temperature changes and reduce (unnatural) thermal shock (Smith and Fausch 1997). However, another potential limitation of the ILT method still remains, as temperature tests are typically run for a short duration (<7 days; Elliott and Elliott 1995) and the effects of longer exposures are often unknown. (p. 1027)."

The authors tested the short-term and chronic effects of elevated temperature on bull trout using the acclimated chronic exposure (ACE) method, which is a modification of the CTM and ILT procedures. This method entails gradually adjusting water temperatures at environmentally realistic rates that allow fish to fully acclimate to changing conditions (e.g., 1.0-1.5°C/day). Hokanson and Koenst (1986) further described this "slow heating" method to define chronic thresholds. More recently Reash et al. (2000) derived upper thermal tolerance data for smallmouth and golden redhorse using this method. However, comparatively few studies based on this new method exist and it still does not address the phenomena portrayed by Figure 1. Some of the studies included in the MBI (2005) update were conducted under rising and falling ambient temperatures, but the results were mixed in terms of whether it determined the eventual thermal endpoints.

When upper thermal endpoints were available for more than one method the MBI (2005) study selected lethal endpoints based on the following (most preferred listed first):

1. "slow heating" method (e.g., a method analogous to ACE) that we term here the chronic thermal maximum (ChTM);
2. upper incipient lethal temperature (UILT) at acclimation temperatures of 25-30°C;
3. critical thermal maximum (CTM) based on the fast heating method (0.5-1.0°C/hr.) with appropriate adjustments (i.e., a 2°C safety factor) to account for the inherent over-estimation of lethality.

Very few slow heating (ChTM) method test results were found by MBI (2005) primarily because it is a new method that developed after the intensive thermal testing period of the 1970s. In fact, much of the newly obtained literature included the least preferred CTM based on the fast heating method. The papers that described the slow heating method agreed that slowly increasing test temperature followed by daily cooling was "probably the most environmentally realistic exposure regime", yet few if any studies were actually based on this technique. The practical impact to this and similar studies is a continued need to rely on the UILT and the use of safety factors for the conversion of CTM results.

Methodology

Four thermal input variables are used in the Fish Temperature Model to determine summer (June 16–September 15) average and daily maximum temperature criteria. However, in developing the baseline input variables, up to six thermal parameters were first considered by Ohio EPA (1978) and this was followed by MBI (2005). General concepts of thermal responsiveness (e.g., acclimation) were considered and are discussed in more detail in MBI (2005). Of the six thermal parameters that were inventoried for each fish species, the upper incipient lethal temperature (UILT), chronic thermal maximum (ChTM), 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 preferred basis for physiological response than did the fast heating method on which the CTM is based (Brown 1974).

Each of the six thermal parameters are defined as follows:

Upper Incipient Lethal Temperature – 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 – the temperature at which a test organism dies resulting from a slow and steady increase in temperature (<1.0-1.5°C/day); this newly developed endpoint is representative of the upper lethal temperature that can be tolerated indefinitely.

Critical Thermal Maximum – 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 – a sharply defined upper temperature at which an organism at a given acclimation temperature will avoid (Coutant 1977);

Growth – the Mean Weekly Average Temperature (MWAT) for growth (Brungs and Jones

1976). The MWAT can be calculated if a minimum of three of the six thermal parameters is available.

Data garnered from the comprehensive review of the thermal effects literature were characterized as one or more of the preceding thermal endpoints in the compilation of a master temperature effects database (MBI 2005).

Fish Temperature Model

The Fish Temperature Model uses four thermal input parameters that include: 1) the optimum or final preferendum; 2) the mean weekly average temperature (MWAT) for growth; 3) the upper avoidance temperature; and, 4) the upper lethal temperature at acclimation temperatures of 25-30°C. Thermal parameters compiled by MBI (2005) were used as the primary database for deriving the Lower Des Plaines R. temperature criteria options (see Appendix A). The four primary thermal parameters are stored by species and accessed by the model when a species is designated as an RAS for a particular designated use/RAS option. Different values can be substituted to determine the effect of thermal tolerance values on the resulting temperature criteria calculations. However, the substitute thermal endpoints must first meet the criteria for inclusion in the thermal effects database (MBI 2005).

Representative Aquatic Species (RAS)

The derivation of a given temperature criteria option is dependent on the development of a list of representative aquatic species (RAS), which is one of the primary input variables for the model. Because thermal effects data are not available for all species in an assemblage, the list of RAS constitute a *subset* of the potential assemblage being comprised of species that have sufficient thermal tolerance data from which temperature criteria can be derived. Thus an inherent assumption of this process is that all of the species not included as RAS will be protected by extension. This assumption is valid so long as there is adequate representation of thermally sensitive species. The recently completed update to the thermal database (MBI 2005) increased the representation of these species.

Species that are generally regarded as being highly to moderately tolerant to a variety of environmental impacts tend to be over-represented, which is a common occurrence in databases for most water quality parameters. Tolerant species are more accessible and more easily handled in laboratory tests, hence their predominance in these databases. In our compilation, these species were the most frequently studied and usually had data available for all six of the previously described thermal thresholds. Conversely, the data for species regarded as highly or moderately intolerant tended to be available for fewer thermal thresholds and were oftentimes based on field studies. As such, and until these species are tested more frequently, there remains a significant risk that the most sensitive groups of species will not be adequately protected. Our approach is simply a best attempt to represent the entirety of the potential assemblage and it is naturally limited by the extant thermal tolerance database. As such, the model output will propagate a degree of uncertainty, which can be considered in the eventual derivation *and* application of the temperature criteria.

In developing a list of representative fish species for a particular water body or segment, the following criteria for membership were used:

- species that represent the full range of response and sensitivity to environmental stressors;
- species that are commercially and/or recreationally important;
- species that are representative of the different trophic levels;
- rare, threatened, endangered, and special status species;
- species that are numerically abundant or prominent in the system;
- potential nuisance species; and,
- species that are indicative of the ecological and physiological requirements of representative species that lack thermal data.

The historical occurrence of fish species in a particular water body is an important consideration in the development of an RAS list, particularly in historically degraded waters. These criteria were followed in developing the RAS lists for the Lower Des Plaines River for each of the three designated use options that are under consideration via the UAA process. The resulting selections reflect the species membership expectations for the fish assemblage that would be expected to occur within each designated use option (Table 1). The General Use is expected to support a diverse, warmwater fish assemblage that is expected to occur in the least disturbed, free-flowing habitats of the Lower Des Plaines mainstem and similarly sized rivers in the region. The Modified Use option is intended to apply to physically modified riverine habitats characteristic of the areas that are inundated by artificial impoundment by low head dams. The Secondary Contact/Indigenous Aquatic Life use option is represented by an assemblage that is tolerant of the most extreme physical and hydrological modifications (gross habitat loss and simplification). As such, each designated use option ranging from General to Secondary Contact represents a progressive loss of the species that are incompatible with the increasing physical and hydrological modifications that are characteristic of each designated use option. Data compiled in Hey & Associates (2003) and Smith (1979) were the principal sources used to compile the RAS lists. The RAS lists have increased in terms of species membership since the 2004 draft of this report due primarily to the addition of thermal tolerance data for new species by MBI (2005). Based on the MBI study, thermal tolerance data for 35 new species in addition to the 62 species originally compiled by Ohio EPA (1978) was included. Hence the addition of new species has increased the number of RAS in this study.

Table 1. Representative fish species used to derive temperature criteria for the Lower Des Plaines River for three designated use options.

Species	Membership Rationale	General Use	Modified Use	Secondary Contact
Longnose gar (*Lepisosteus osseus*)	Historical[1]; 1994-2002[2]	X		
Skipjack herring (*Alosa chrysochloris*)	1994-2002	X		
Gizzard shad (*Dorosoma cepedianum*)	Historical; 1994-2002	X	X	X
Northern pike (*Esox lucius*)	Kankakee R.	X	X	
Bigmouth buffalo (*Ictiobus cyprinella*)	1994-2002	X	X	
Smallmouth buffalo (*I. niger*)	1994-2002	X		
Quillback (*Carpiodes cyprinus*)	1994-2002	X	X	
River carpsucker (*C. carpio*)	1994-2002	X		
Golden redhorse (*Moxostoma erythrurum*)	Historical; 1994-2002	X		
Golden redhorse (*Moxostoma erythrurum*)	Silver redhorse[3]; 1994-2002		X	
Smallmouth redhorse (*M. breviceps*)[4]	Historical; 1994-2002	X		
Northern hog sucker (*Hypentelium nigricans*)	Historical	X		
White sucker (*Catostomus commersonii*)	Historical	X	X	
Common carp (*Cyprinus carpio*)	Historical; 1994-2002	X	X	X
Golden shiner (*Notemigonus crysoleucas*)	Historical; 1994-2002	X	X	X
Creek chub (*Semotilus atromaculatus*)	Historical	X		
Emerald shiner (*Notropis atherinoides*)	Historical; 1994-2002	X	X	
Redfin shiner (*Lythrurus umbratilis*)	Historical	X		
Striped shiner (Luxilis chrysocephalus)	Historical; 1994-2002	X		
Spottail shiner (*Notropis hudsonius*)	1994-2002	X	X	
Spotfin shiner (*Cyprinella spiloptera*)	Historical; 1994-2002	X	X	
Bigmouth shiner (*Notropis dorsalis*)	Historical	X		
Sand shiner (*Notropis stramineus*)	Historical	X		
Fathead minnow (*Pimephales promelas*)	Historical	X	X	X
Bluntnose minnow (*Pimephales notatus*)	Historical; 1994-2002	X	X	X
Stoneroller (*Campostoma anomalum*)	Historical	X		
Channel catfish (*Ictalurus punctatus*)	1994-2002	X	X	
Yellow bullhead (*Ameirus natalis*)	Historical	X	X	
Black bullhead (*Ameirus melas*)	Historical	X	X	X
Flathead catfish (*Pylodictis olivaris*)	1994-2002	X	X	
Stonecat madtom (*Noturus flavus*)	Historical	X		
Blackstripe topminnow (*Fundulus notatus*)	1994-2002	X	X	
Brook silversides (*Labidesthes sicculus*)	1994-2002	X	X	
White bass (*Morone chrysops*)	Historical	X		
White crappie (*Pomoxis annularis*)	Historical; 1994-2002	X		

[1] Historical occurrence reported in Smith (1979).
[2] Species collected in the UAA study segment between 1994-2002.
[3] Silver redhorse retained in the modified use option - golden redhorse data used as a surrogate.
[4] Smallmouth redhorse used as surrogate for shorthead redhorse.

Table 1. continued.

Species	Membership Rationale	General Use	Modified Use	Secondary Contact
Black crappie (*P. nigromaculatus*)	Historical; 1994-2002	X	X	
Rock bass (*Ambloplites rupestris*)	Historical; 1994-2002	X	X	
Smallmouth bass (*Micropterus dolomieui*)	Historical; 1994-2002	X		
Largemouth bass (*M. salmoides*)	Historical; 1994-2002	X	X	X
Green sunfish (*Lepomis cyanellus*)	Historical; 1994-2002	X	X	X
Bluegill sunfish (*L. macrochirus*)	Historical; 1994-2002	X	X	
Orangespotted sunfish (*L. humilis*)	1994-2002	X		
Longear sunfish (*L. megalotis*)	1994-2002	X		
Pumpkinseed sunfish (*L. gibbosus*)	Historical; 1994-2002	X	X	
Walleye (*Sander vitreus*)	Kankakee	X	X	
Sauger (*Sander canadense*)	Kankakee	X		
Dusky darter (*Percina sciera*)	Blackside[5]; Hist.; '94-'02	X		
Johnny darter (*Etheostoma nigrum*)	Historical	X		
Fantail darter (*Etheostoma flabellare*)	Historical	X		
Freshwater drum (*Aplodonitus grunniens*)	Historical; 1994-2002	X	X	
Total RAS		49	27	8

Derivation of Seasonal Temperature Criteria Options

The principal objective of this project is the development of seasonal temperature criteria options for the range of possible outcomes of the UAA process. These include thermal requirements for:

1) a warmwater habitat assemblage that is consistent with the Illinois General Use;
2) an assemblage that reflects the habitat modified conditions of the impounded portions of the Lower Des Plaines River (Modified Use); and,
3) an assemblage that represents significantly limited conditions that approximate the Illinois Secondary Contact/Indigenous Aquatic Life use.

This does not presuppose the application of these designated use options via the UAA process, but rather represents options reflecting the range of restoration possibilities and limitations for the Lower Des Plaines River.

Summer Temperature Criteria

The summer months represent the most stressful period for fish in terms of exposure to high temperatures. However, this should not be construed as the only season in which

[5] Dusky darter used as a surrogate for blackside darter.

adverse effects can occur, thus other effects during the non-summer seasons are also considered in the derivation of seasonal criteria. For the purposes of temperature criteria development and application, the summer period is June 16 - September 15.

The Fish Temperature Model calculates average and daily maximum summer temperature criteria via an analytical process based on that originally developed by Bush et al. (1974). The calculation software of the model was recently revised and it produces these values using the database and thermal parameters compiled by MBI (2005). Temperature tolerance values for 97 fish species considered representative of the Ohio River and Great Lakes drainages are presently contained in the model's database. These values include the four primary thermal parameters described previously (optimum, mean weekly average for growth, upper avoidance, and upper incipient lethal temperatures). The model permits alternative thermal values to be substituted, thus the effect of species-specific differences on the derivation of summer season thresholds can be evaluated - these can be maintained as alternate databases. We did not attempt to make these types of substitutions as part pf the analyses contained herein.

The modeling procedure is simply one of listing each representative species under each thermal parameter adjacent to the whole Fahrenheit temperature when such is exceeded. The cumulative effect of increasing temperature is readily apparent as additional species thermal thresholds are exceeded. This process indicates where the various species occur (with respect to temperature) relative to each other and does not indicate exact thresholds or limits. The temperatures at which 100%, 90%, 75% and 50% of the representative species four primary thermal thresholds (optimum, growth, upper avoidance, and UILT) are exceeded are determined to show what proportion of the representative assemblage is protected at a given temperature. The long-term survival temperature is calculated from the short-term survival temperature (i.e., the UILT) as UILT - 2°C. The tolerance values in the existing model were initially used in the derivation of the summer average and maximum temperature criteria for the different designated use options being considered for the Lower Des Plaines River.

Derivation of Seasonal Temperature Criteria

The derivation of seasonal temperature criteria for each of the designated use options considered in this analysis included summer season average and maximum values based on the output of the Fish Temperature Model. Non-summer season criteria included consideration of species-specific spawning thresholds (MBI 2005) and consistency with the historical ambient temperature record, which in this case is based on analyses of long-term temperature monitoring data in the Lower Des Plaines R. and Chicago Area Waterway System (CAWS) upstream from the Brandon Pool and outside the direct influence of other sources of heat (Appendix B). In keeping with the guidance of Ohio EPA (1978) and MBI (2005), we adhered to the following in deriving the temperature criteria options:

Averages should be consistent with:

1) 100% long-term survival of all representative fish species;
2) growth of commercially or recreationally important fish species;
3) growth of at least 50% of the non-game fish species;
4) 100% long-term survival of all endangered fish species; and
5) the observed historical ambient temperature record.

Daily maxima should be consistent with:

1) 100% short-term survival of all representative fish species; and
2) the observed historical ambient temperature record.

Summer Average and Maximum Criteria

Summer average and maximum temperature criteria were calculated in accordance with the outputs of the Fish Temperature Model. These apply during the defined summer period of June 16 - September 15 as daily maxima and a *period* average. The rationale for a period average as opposed to a daily, weekly, or monthly average is in recognition of the realities of within season temperature variations and the thermal tolerances of fish. Neither is a "smooth" function as within season changes include naturally occurring temperatures that can approach or exceed thermal tolerances and which also fall well below these thresholds. It also includes the knowledge that fish can avoid or withstand occasional exceedences of short-term survival thresholds, provided that local refuges are available and/or the duration of the exceedences are sufficiently brief (see Figure 1). Meeting the long-term period average requires attenuating "cool down" periods where temperatures are well below the survival thresholds and closer to the physiological thresholds for growth and maintenance (see Figure 1).

The results of the Fish Temperature Model outputs for the three designated use options are portrayed in Tables 2 and 3 (summer season only) and Appendix A (primary model outputs). These were derived by using the RAS lists for each designated use option (Table 1) as the major input variables.

General Use

The original general use RAS list in the 2004 draft report included thirty (30) fish species. With the additional thermal data provided by MBI (2005), the general use RAS list now includes 49 fish species. We analyzed two subsets of the General Use RAS list - one adding yellow perch, walleye, and sauger and another removing stonecat madtom from the original RAS list. These changes were made to determine the sensitivity of adding and removing key RAS. The results are summarized in Table 2 and the long term and short term survival thresholds that protect 100% of the RAS represent summer average and maximum criteria options for the period June 16 – September 15. For the updated General Use RAS list a summer period average temperature of 27.0°C (80.6°F) and a daily maximum of 29.0°C (84.2°F) will protect for the long term survival of 100% of the RAS. The period average of 27.0°C exceeds the upper avoidance temperature of one RAS

Table 2. Fish temperature model outputs (°F[°C]) for four RAS variations of the Illinois General Aquatic Life use designation for the Lower Des Plaines River. The long-term and short-term survival temperatures represent summer season (June 16 – September 15) average and maxima.

Thermal Category	Proportion of Representative Fish Species			
	100%	90%	75%	50%
General Use Original RAS *(2004 draft)*				
Optimum	72.5 (22.5)	77.7 (25.4)	81.1 (27.3)	83.1 (28.4)
Growth (MWAT)	78.3 (25.7)	82.4 (28.0)	84.7 (29.3)	86.9 (30.5)
Avoidance (UAT)	83.3 (28.5)	85.1 (29.5)	87.3 (30.7)	88.9 (31.6)
Survival (Long-term)	85.1 (29.5)	86.9 (30.5)	88.5 (31.4)	91.2 (32.9)
Survival (Short-term)	88.7 (31.5)	90.5 (32.5)	92.1 (33.4)	94.8 (34.9)
General Use RAS 1 *(expanded list 2005)*				
Optimum	67.4 (19.7)	72.7 (22.6)	81.1 (27.3)	82.8 (28.2)
Growth (MWAT)	74.8 (23.8)	79.1 (26.2)	84.6 (29.2)	86.7 (30.4)
Avoidance (UAT)	78.3 (25.7)	84.7 (29.3)	87.3 (30.7)	88.9 (31.6)
Survival (Long-term)	80.6 (27.0)	86.9 (30.5)	88.7 (31.5)	90.9 (32.7)
Survival (Short-term)	84.2 (29.0)	90.5 (32.5)	92.3 (33.5)	94.5 (34.7)
General Use RAS 2 *(adds yellow perch, sauger, and walleye)*				
Optimum	67.4 (19.7)	72.7 (22.6)	78.3 (25.7)	82.6 (28.1)
Growth (MWAT)	74.8 (23.8)	78.8 (26.0)	82.8 (28.2)	86.5 (30.3)
Avoidance (UAT)	78.3 (25.7)	85.1 (29.5)	86.9 (30.5)	88.9 (31.6)
Survival (Long-term)	80.6 (27.0)	86.9 (30.5)	88.3 (31.3)	90.9 (32.7)
Survival (Short-term)	84.2 (29.0)	90.5 (32.5)	91.9 (33.3)	94.5 (34.7)
General Use RAS 3 *(removes stonecat madtom from RAS 2)*				
Optimum	67.4 (19.7)	72.9 (22.7)	78.8 (26.0)	82.6 (28.1)
Growth (MWAT)	75.4 (24.1)	79.2 (26.2)	82.9 (28.3)	86.5 (30.3)
Avoidance (UAT)	83.3 (28.5)	85.5 (29.7)	87.1 (30.6)	88.9 (31.6)
Survival (Long-term)	85.1 (29.5)	87.3 (30.7)	88.5 (31.4)	90.9 (32.7)
Survival (Short-term)	88.7 (31.5)	90.9 (32.7)	92.1 (33.4)	94.5 (34.7)

Table 3. Fish temperature model outputs (°F[°C]) for fish species representative of a modified use (two versions) and the Secondary Contact/Indigenous Aquatic Life use for the Lower Des Plaines River. The long-term and short-term survival temperatures represent summer season (June 16 – September 15) average and maxima.

Thermal Category	Proportion of Representative Fish Species 100%	90%	75%	50%
Modified Use RAS 1 *(includes golden redhorse)*				
Optimum	71.2 (21.8)	75.4 (24.1)	81.3 (27.4)	82.6 (28.1)
Growth (MWAT)	77.5 (25.3)	81.0 (27.2)	85.8 (29.9)	86.7 (30.4)
Avoidance (UAT)	83.7 (28.7)	84.9 (29.4)	87.1 (30.6)	88.9 (31.6)
Survival (Long-term)	85.1 (29.5)	86.5 (30.3)	89.1 (31.7)	91.4 (33.0)
Survival (Short-term)	88.7 (31.5)	90.1 (32.3)	92.7 (33.7)	95.0 (35.0)
Modified Use RAS 2 *(excludes golden redhorse)*				
Optimum	71.2 (21.8)	75.0 (23.9)	81.5 (27.5)	82.8 (28.2)
Growth (MWAT)	77.5 (25.3)	80.6 (27.0)	85.8 (29.9)	86.9 (30.5)
Avoidance (UAT)	83.7 (28.7)	85.6 (29.8)	87.4 (30.8)	89.1 (31.7)
Survival (Long-term)	85.1 (29.5)	86.5 (30.3)	89.8 (32.1)	91.4 (33.0)
Survival (Short-term)	88.7 (31.5)	90.1 (32.3)	93.4 (34.1)	95.0 (35.0)
Secondary Contact/Indigenous Aquatic Life				
Optimum	81.0 (27.2)	81.1 (27.3)	82.4 (28.0)	84.1 (29.0)
Growth (MWAT)	85.3 (29.6)	85.4 (29.7)	86.7 (30.4)	87.7 (31.0)
Avoidance (UAT)	87.8 (31.0)	87.8 (31.0)	88.0 (31.1)	91.9 (33.3)
Survival (Long-term)	88.3 (31.3)	88.6 (31.4)	90.5 (32.5)	93.0 (33.9)
Survival (Short-term)	91.9 (33.3)	92.2 (33.4)	94.2 (34.5)	96.6 (35.9)

(stonecat madtom) by 1.3°C. Thirteen (13) RAS are considered to be either commercially or recreationally important - the 27.0°C period average exceeds the growth temperature for one of these species (northern pike) by 1.7°C. No Illinois rare, threatened, or endangered species are among the species included in any of the RAS lists. The revised criteria based on the updated RAS list (compared to the 2004 original draft list) are 0.5°C lower. We also tested the influence of species additions by adding yellow perch, sauger, and walleye. While these species were not included by the review of historical distribution data and occurred in very low numbers in the 1994-2002 databases, each occurs in the Kankakee River or the CAWS and they could possibly occur in the Lower Des Plaines R. as water quality conditions improve in the future. The inclusion of these species did not change the model outputs, thus the aforementioned criteria should be protective of these species. However, the growth criteria of sauger and walleye are exceeded by the period average of 27.0°C by 0.1°C and 0.8°C, respectively. Stonecat madtom was the most thermally sensitive species in the updated RAS list. Removing this species changed the period average to 29.5°C and the daily maximum to 31.5°C. This option exceeded the UAT of fifteen (15) RAS and the growth criterion of four (4) recreational and commercially important species.

Modified Use

Twenty-seven (27) fish species are considered representative of the intent of a theorized Modified Use, which reflects the habitat modifications caused by impoundments formed by low head dams. The deletion of 22 species from the General use list reflects the biological consequences of the inundation of run and riffle habitats by the resulting impoundment. Two scenarios were developed for this designated use option; one including silver redhorse and the other excluding this species. Of the redhorse species that are potential inhabitants of the Lower Des Plaines River system, silver redhorse would likely tolerate impounded conditions. To calculate the temperature criteria, golden redhorse was used as an RAS surrogate since the thermal tolerance data are presently insufficient for silver redhorse (Ohio EPA 1978; MBI 2005). The results including silver redhorse are a period average temperature of 29.5°C and a daily maximum of 31.5°C to protect 100% of the modified habitat RAS during the summer period. The period average of 29.5°C exceeds the upper avoidance temperature for three RAS and the growth temperature for two of the recreationally important RAS. If silver redhorse are excluded, there is no effect on the period average or maximum. The same period average of 29.5°C exceeds the upper avoidance temperature for two species and the growth temperature for two of the recreationally important RAS. Fifteen (15) RAS are considered to be either commercially or recreationally important. No rare, threatened, or endangered species are among the RAS for this use option.

Secondary Contact/Indigenous Aquatic Life

Eight (8) species were selected as being representative of the intent of this designated use option. These species are regarded as highly tolerant to most forms of anthropogenic impacts including thermal enrichment. The results indicate that an average temperature of 30.4°C and a daily maximum of 32.4°C will protect 100% of the RAS during the summer period. The period average of 30.4°C does not exceed the upper avoidance temperature of any RAS or growth temperature of any recreationally or commercially important RAS for this designated use option.

Seasonal Temperature Criteria

Seasonal average and daily maximum temperature criteria for the General Use RAS 1 option are provided as an example of deriving and displaying a seasonal temperature criteria option (Table 4). The derivation of the summer period (June 16 – September 15) average and maximum criteria were just described. Non-summer season criteria are derived to maintain seasonal norms and cycles of increasing and decreasing temperatures. Important physiological functions such as gametogenesis, spawning, and growth should be assured since these are products of each species long term adaptation to natural climatic and regional influences of which temperature is one controlling factor. Thermal

Table 4. Seasonal average and daily maximum temperature criteria (°F) for the Illinois general aquatic life use RAS 1 option. Summer period temperatures from the Rt. 83 Cal Sag site appear in brackets and are based on the geometric mean and the 98th percentile values (Appendix B). Non-summer season temperatures in the CSSC at Rt. 83 are in parentheses for comparison to a thermally enriched segment.

Month- Dates	Average[6]	Maximum[7]	Basis for Criteria
January 1-31	38.4 (49.5)	46.6 (54.8)	Consistent with seasonal temperature measured at the Route 83 (Cal Sag) monitoring location.
February 1-28	41.7 (51.1)	51.7 (56.9)	
March 1-31	47.0 (54.8)	57.3 (62.4)	
April 1-15	54.0 (59.2)	59.9 (63.2)	Consistent with spawning criteria for all representative fish species in March, April, May, and June.
April 16-30	57.3 (58.8)	67.7 (65.0)	
May 1-15	63.7 (65.8)	71.6 (75.3)	
May 16-31	65.1 (68.4)	71.2 (74.0)	
June 1-15	69.8 (70.9)	77.8 (77.3)	
June 16-30	80.6 [74.8]	84.2 [79.8]	Average and maximum provide for short and long-term survival of 100% of representative fish species; one minor exceedence of ambient temp. at the Route 83 (Cal Sag) location.
July 1-31	80.6 [79.0]	84.2 [84.7]	
August 1-31	80.6 [78.4]	84.2 [83.8]	
September 1-15	80.6 [76.2]	84.2 [81.5]	
September 16-30	69.9 (74.4)	75.7 (81.0)	Consistent with seasonal temperature measured at the Route 83 (Cal Sag) monitoring location.
October 1-15	63.7 (69.8)	71.2 (76.0)	
October 16-31	59.8 (66.9)	68.0 (75.0)	
November 1-30	53.0 (61.3)	63.6 (70.7)	
December 1-31	43.4 (53.9)	56.9 (63.5)	

[6] Average temperature over the representative period - set at the geometric mean of the period of record based on the Rt. 83 Cal Sag site.

[7] Daily maximum temperature - set at the 98th percentile value of the period of record at the Rt. 83 Cal Sag site.

tolerance data for these physiological endpoints is comparatively limited being available for only a few RAS.

Seasonal ambient temperature data was analyzed from eight locations in the Lower Des Plaines River and the CAWS for the period 1998 through 2004 (Appendix B). Monthly and semi-monthly arithmetic mean, geometric mean, median, 98th, 95th, 90th, 75th, and 5th percentile values were calculated based on daily readings (Appendix B). Also included were the maximum temperatures that occurred once, twice, and three times in each period and the interquartile ranges of 1.5 and 2.5 times beyond the 75th percentile (non-parametric analogs of standard error and standard deviation, respectively). The monitoring location at Route 83 in the Cal Sag channel was used as a "background" location in Table 4. We used the geometric mean as the monthly and semi-monthly average and the 98th percentile as the daily maximum. Other statistical thresholds could be used to set the non-summer criteria. The 75th percentile was used previously as the average since this takes in account the occurrence of warmer temperatures during extreme condition years. None of the values in Table 5 exceeded the spawning criteria for any of the RAS options (MBI 2005) and all except one value in July were below the summer average (1.6-5.8°F) and maximum (0.4-4.4°F) tolerance values for the RAS options used in Table 4. The Route 83 location on the Chicago Sanitary and Ship Canal exhibited higher ambient temperatures, presumably the result of enrichment by thermal sources, thus reflecting higher seasonal temperatures that would exceed the thermal tolerances of the RAS. Other monitoring locations exhibited more pronounced effects of thermal enrichment, thus these were rejected as being representative of "background" ambient conditions. Table 5 provides a comparison of the different RAS and designated use options and with two different options for non-summer season ambient temperatures, the Cal Sag Rt. 83 location and the results of modeling by the Iowa Institute of Hydraulic Research (IIHR; Holly and Brady 1995). We interpreted monthly temperatures from their Figure 4-10 which provides estimates of maximum daily temperature distributions at the I-55 bridge with no thermal enrichment.

The determination of temperatures that are representative of ambient or "background" conditions for the upper Des Plaines River is complicated by the physically and thermally altered characteristics of the Upper Illinois Waterway System and the Chicago Area Waterway System. In addition to choosing a representative monitoring location to serve as a data source for determining this benchmark, the outputs of predictive modeling can also be used for this purpose. It is important to understand here that our primary purpose is to determine a representative background temperature, not to determine the acceptability of different thermal loading scenarios. The Holly and Brady (1995) thermal modeling studies included simulations of the upper Des Plaines River temperature in the absence of thermal enrichment by electric generating stations. Their study simulated summer season maximum temperatures at the I-55 bridge (the current upper boundary of the General Use designation) of 82-83°F *with no thermal sources, i.e.*, the conditions that could be expected in the absence of any thermal enrichment by electric generating station discharges (Figure

Table 5. Comparison of six temperature criteria options (average/maximum [°F]) for four variants of the Illinois general aquatic life use, a modified use, and the secondary contact use based on alternate RAS lists and two options for ambient temperature regimes in the Lower Des Plaines River.

Period	RAS 1 Option A[8]	RAS 1 Option B[9]	RAS 1 Option C[10]	RAS 1 Option D[11]	RAS 1 Option E[12]	RAS 1 Option F[13]
January 1-31	38.4/46.6	38.4/46.6	39.5/45.0	39.5/45.0	38.4/46.6	38.4/46.6
February 1-28	41.7/51.7	41.7/51.7	41.0/46.0	41.0/46.0	41.7/51.7	41.7/51.7
March 1-31	47.0/57.3	47.0/57.3	46.0/54.0	46.0/54.0	47.0/57.3	47.0/57.3
April 1-15	54.0/59.9	54.0/59.9	-	-	54.0/59.9	54.0/59.9
April 16-30	57.3/67.7	57.3/67.7	56.5/64.0	56.5/64.0	57.3/67.7	57.3/67.7
May 1-15	63.7/71.6	63.7/71.6	-	-	63.7/71.6	63.7/71.6
May 16-31	65.1/71.2	65.1/71.2	63.0/68.0	63.0/68.0	65.1/71.2	65.1/71.2
June 1-15	69.8/77.8	69.8/77.8	-	-	69.8/77.8	69.8/77.8
June 16-30	85.1/88.7	80.6/84.2	80.6/84.2	85.1/88.7	85.1/88.7	88.3/91.9
July 1-31	85.1/88.7	80.6/84.2	80.6/84.2	85.1/88.7	85.1/88.7	88.3/91.9
August 1-31	85.1/88.7	80.6/84.2	80.6/84.2	85.1/88.7	85.1/88.7	88.3/91.9
September 1-15	85.1/88.7	80.6/84.2	80.6/84.2	85.1/88.7	85.1/88.7	88.3/91.9
September 16-30	69.9/75.7	69.9/75.7	70.5/77.0	77/80.3	69.9/75.7	69.9/75.72
October 1-15	63.7/71.2	63.7/71.2	-	-	63.7/71.2	63.7/71.2
October 16-31	59.8/68.0	59.8/68.0	63.0/68.0	63.0/68.0	59.8/68.0	59.8/68.0
November 1-30	53.0/63.6	53.0/63.6	52.5/60.0	52.5/60.0	53.0/63.6	53.0/63.6
December 1-31	43.4/56.9	43.4/56.9	43.0/50.0	43.0/50.0	43.4/56.9	43.4/56.9

[8] General use original RAS (2004 draft report); Cal Sag Rt. 83 site as ambient.
[9] General use updated RAS (excludes yellow perch, sauger, walleye); Cal Sag Rt. 83 site as ambient
[10] General use updated RAS (includes yellow perch, sauger, walleye); Holly & Bradley modeling study used as ambient.
[11] General use updated RAS (excludes stonecat madtom); Holly & Bradley modeling study used as ambient.
[12] Modified use RAS (includes silver redhorse); Cal Sag Rt. 83 site as ambient.
[13] Secondary Contact/Indigenous Aquatic Life use RAS; Cal Sag Rt. 83 site as ambient.

4.10 in Holly and Brady 1995). The maximum 75th percentile values were 75-76°F, which is also consistent with our analysis of the Cal-Sag Rt. 83 temperature monitoring location. The non-summer season simulations were also consistent with the ambient values at this location, thus the temperature data should adequately represent the background or ambient conditions for this system. While the Upper Illinois Waterway System represents a complex mix of natural and human influenced hydrologic and thermal alterations, we are focused here primarily on the determination of representative background conditions as a baseline for evaluating the consequences of thermal alterations and the management of thermal loadings.

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 Service Corporation. 431 pp.

Brungs, W.A. and B.R. Jones. 1977. Temperature criteria for freshwater fish: protocol and procedures. U.S. EPA Ecological Research Series. EPA-600/3-77-061. 136 pp.

Coutant, C.C. 1975. Temperature selection by fish – a factor in power plant impact assessments, pp. 575-597. *in* Environmental Effects of Cooling Systems at Nuclear Power Plants. IAEA-SM-187/11.

Essig, D.A. 1998. The dilemma of applying uniform temperature criteria in a diverse environment: an issue analysis. Idaho Division of Environmental Quality, Water Quality Assessment and Standards Bureau, Boise, ID. 29 pp.

Fry, F.E.J. 1947. The effects of the environment on animal activity. University of Toronto Studies, Biol. Ser. 44: 91 pp.

Hey and Associates. 2003. Lower Des Plaines river use attainability analysis (draft). Prepared for Illinois Environmental Protection Agency. 8 chapters + appendices.

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. and W.M. Koenst. 1986. Revised estimates of growth requirements and lethal temperature limits of juvenile walleyes. Prog. Fish. Cult. 48:90-94.

Holly, F.M., Jr. and A.A. Bradley. 1995. The Upper Illinois Waterway study: summary report on thermo-dynamic modeling and analyses in the Upper Illinois River Waterway. Limited Distribution Repoprt No. 327, Iowa Inst. Hydraulic Res., Univ. of Iowa, Iowa City, IA. 112 pp.

Midwest Biodiversity Institute. 2005. 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.

Ohio Environmental Protection Agency. 1978. 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.

Reash, R.J., G.L. Seegert and W.L. Goodfellow. 2000. Experimentally-derived upper thermal tolerances for redhorse suckers: revised 316(a) variance conditions at two generating facilities in Ohio. *Environmental Science & Policy* 3: S191-S196.

Selong, J. H., T.E. McMahon, A. V. Zale, and F.T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. *Transactions of the American Fisheries Society* 130: 1026-1037.

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.

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. and E.B. Emery. 2004. Updating a temperature criteria methodology for the Ohio River mainstem, pp. 4-1 to 4-13. *in* Proceedings from the EPRI Workshop on 316(a) Issues: Technical and Regulatory Considerations: October 16-17, 2003, EPRI, Palo Alto CA, and American Electric Power Company, Columbus, OH: 2004. 1008476.

Appendix A

Lower Des Plaines River

Optimum, Growth, Upper Avoidance, and Upper Incipient Lethal Temperatures for Fish Species Representative of the Illinois General Use, a Modified Use, and the Secondary Contact/Indigenous Aquatic Life Use (21 tables)

Appendix Tables 1A-G

Appendix Tables 2A-G

Appendix Tables 3A-G

Appendix Table 1A. Thermal thresholds for original general use RAS list.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
10	004	Longnose Gar	32.5	34.3	34.5	37.8	Lepisosteus osseus
20	001	Skipjack Herring	27.3	29.6	30.7	34.3	Alosa chrysochloris
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
40	004	Smallmouth Buffalo	28.5	31.5	34.1	37.4	Ictiobus bubalus
40	005	Quillback Carpsucker	30.0	31.7	34.2	35.2	Carpiodes cyprinus
40	006	River Carpsucker	29.5	31.4	33.5	35.2	Carpiodes carpio carpio
40	010	Golden Redhorse	25.6	28.2	28.5	33.4	Moxostoma erythrurum
40	011	Smallmouth Redhorse	25.5	28.1	28.5	33.3	Moxostoma macrolepidotum
40	015	Northern Hog Sucker	27.3	29.2	31.6	33.0	Hypentelium nigricans
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
43	001	Common Carp	31.5	33.4	34.9	37.3	Cyprinus carpio
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
77	001	White Crappie	28.6	29.9	30.8	32.5	Pomoxis annularis
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
77	011	Longear Sunfish	24.1	28.0	31.8	35.9	Lepomis megalotis
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	004	Dusky Darter	22.5	26.0	29.6	32.9	Percina sciera sciera
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens

Appendix Table 2A. Thermal criteria results for orignal general use RAS list.

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	22.50	25.36	27.30	28.35
Growth	25.70	27.98	29.30	30.45
Avoidance (UAT)	28.50	29.51	30.70	31.60
Survival (LT)	29.50	30.49	31.40	32.85
Survival (ST)	31.50	32.49	33.40	34.85

Species Used **N =** 30

Common Name	Common Name	Common Name
Longnose Gar	Smallmouth Bass	
Skipjack Herring	Largemouth Bass	
Gizzard Shad	Green Sunfish	
Bigmouth Buffalo	Bluegill Sunfish	
Smallmouth Buffalo	Longear Sunfish	
Quillback Carpsucker	Pumpkinseed Sunfish	
River Carpsucker	Dusky Darter	
Golden Redhorse	Freshwater Drum	
Smallmouth Redhorse		
Northern Hog Sucker		
White Sucker		
Common Carp		
Golden Shiner		
Emerald Shiner		
Spottail Shiner		
Spotfin Shiner		
Bluntnose Minnow		
Channel Catfish		
Yellow Bullhead		
White Crappie		
Black Crappie		
Rock Bass		

Appendix Table 3A. Thermal tolerance rankings for orignal general use RAS list.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
22.5	72.5	Emerald Shiner [1]			
22.5	72.5	Dusky Darter [2]			
24.1	75.4	Longear Sunfish [3]			
25.5	77.9	Smallmouth Redhorse [4]			
25.6	78.1	Golden Redhorse [5]			
25.7	78.3		Emerald Shiner [1]		
26.0	78.8	White Sucker [6]			
26.0	78.8		Dusky Darter [2]		
27.3	81.1	Skipjack Herring [7]			
27.3	81.1	Northern Hog Sucker [8]			
27.3	81.1	Spottail Shiner [9]			
27.5	81.5	Bluntnose Minnow [10]			
27.6	81.7	Black Crappie [11]			
27.8	82.0		White Sucker [3]		
27.8	82.0	Golden Shiner [12]			
27.8	82.0	Green Sunfish [13]			
28.0	82.4		Longear Sunfish [4]		
28.1	82.6		Smallmouth Redhorse [5]		
28.1	82.6	Rock Bass [14]			
28.2	82.8		Golden Redhorse [6]		
28.3	82.9	Yellow Bullhead [15]			
28.4	83.1	Pumpkinseed Sunfish [16]			
28.5	83.3	Smallmouth Buffalo [17]			
28.5	83.3			Golden Redhorse [1]	
28.5	83.3			Smallmouth Redhorse [2]	
28.6	83.5	White Crappie [18]			
28.7	83.7			White Sucker [3]	
29.1	84.4		Bluntnose Minnow [7]		
29.1	84.4	Largemouth Bass [19]			
29.1	84.4	Freshwater Drum [20]			
29.2	84.6		Northern Hog Sucker [8]		
29.5	85.1	River Carpsucker [21]			

Appendix Table 3A. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
29.6	85.3		Skipjack Herring [9]		
29.6	85.3			Dusky Darter [4]	
29.7	85.5			Black Crappie [5]	
29.8	85.6			Emerald Shiner [6]	
29.8	85.6	Spotfin Shiner [22]			
29.9	85.8	Bigmouth Buffalo [23]			
29.9	85.8		Golden Shiner [10]		
29.9	85.8		White Crappie [11]		
30.0	86.0	Gizzard Shad [24]			
30.0	86.0	Quillback Carpsucker [25]			
30.0	86.0		Black Crappie [12]		
30.0	86.0	Smallmouth Bass [26]			
30.1	86.2		Spottail Shiner [13]		
30.3	86.5		Green Sunfish [14]		
30.4	86.7		Rock Bass [15]		
30.4	86.7	Bluegill Sunfish [27]			
30.5	86.9		Pumpkinseed Sunfish [16]		
30.5	86.9			Pumpkinseed Sunfish [7]	
30.5	86.9		Freshwater Drum [17]		
30.7	87.3			Skipjack Herring [8]	
30.7	87.3			Golden Shiner [9]	
30.8	87.4			White Crappie [10]	
30.9	87.6		Largemouth Bass [18]		
30.9	87.6			Green Sunfish [11]	
31.0	87.8		Yellow Bullhead [19]		
31.1	88.0	Channel Catfish [28]			
31.2	88.2			Freshwater Drum [12]	
31.3	88.3			Yellow Bullhead [13]	
31.4	88.5		River Carpsucker [20]		
31.4	88.5			Bluntnose Minnow [14]	
31.5	88.7		Smallmouth Buffalo [21]		
31.5	88.7				White Sucker [1]

Appendix Table 3A. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
31.5	88.7	Common Carp [29]			
31.6	88.9			Northern Hog Sucker [15]	
31.6	88.9		Smallmouth Bass [22]		
31.6	88.9			Largemouth Bass [16]	
31.7	89.1		Quillback Carpsucker [23]		
31.8	89.2			Longear Sunfish [17]	
31.9	89.4		Gizzard Shad [24]		
31.9	89.4		Spotfin Shiner [25]		
32.0	89.6			Smallmouth Bass [18]	
32.1	89.8		Bigmouth Buffalo [26]		
32.1	89.8				Emerald Shiner [2]
32.4	90.3				Bluntnose Minnow [3]
32.4	90.3		Bluegill Sunfish [27]		
32.5	90.5	Longnose Gar [30]			
32.5	90.5				White Crappie [4]
32.9	91.2				Dusky Darter [5]
33.0	91.4				Northern Hog Sucker [6]
33.0	91.4			Rock Bass [19]	
33.3	91.9			Bigmouth Buffalo [20]	
33.3	91.9				Smallmouth Redhorse [7]
33.4	92.1				Golden Redhorse [8]
33.4	92.1		Common Carp [28]		
33.4	92.1				Freshwater Drum [9]
33.5	92.3			River Carpsucker [21]	
33.5	92.3		Channel Catfish [29]		
33.7	92.7			Spotfin Shiner [22]	
33.8	92.8			Bluegill Sunfish [23]	
34.0	93.2			Gizzard Shad [24]	
34.0	93.2				Golden Shiner [10]
34.1	93.4			Smallmouth Buffalo [25]	
34.2	93.6			Quillback Carpsucker [26]	
34.3	93.7		Longnose Gar [30]		

Appendix Table 3A. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
34.3	93.7				Skipjack Herring [11]
34.5	94.1			Longnose Gar [27]	
34.5	94.1			Spottail Shiner [28]	
34.5	94.1				Largemouth Bass [12]
34.6	94.3				Pumpkinseed Sunfish [13]
34.7	94.5				Black Crappie [14]
34.7	94.5				Smallmouth Bass [15]
34.8	94.6			Channel Catfish [29]	
34.9	94.8			Common Carp [30]	
35.0	95.0				Rock Bass [16]
35.2	95.4				Quillback Carpsucker [17]
35.2	95.4				River Carpsucker [18]
35.3	95.5				Green Sunfish [19]
35.6	96.1				Spottail Shiner [20]
35.8	96.4				Gizzard Shad [21]
35.9	96.6				Longear Sunfish [22]
36.0	96.8				Spotfin Shiner [23]
36.4	97.5				Yellow Bullhead [24]
36.4	97.5				Bluegill Sunfish [25]
36.6	97.9				Bigmouth Buffalo [26]
37.3	99.1				Common Carp [27]
37.4	99.3				Smallmouth Buffalo [28]
37.8	100.0				Longnose Gar [29]
38.3	100.9				Channel Catfish [30]

Appendix Table 1B. Thermal thresholds for general use RAS alternate list 1.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
10	004	Longnose Gar	32.5	34.3	34.5	37.8	Lepisosteus osseus
20	001	Skipjack Herring	27.3	29.6	30.7	34.3	Alosa chrysochloris
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
37	003	Northern Pike	21.8	25.3	28.9	32.2	Esox lucius
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
40	004	Smallmouth Buffalo	28.5	31.5	34.1	37.4	Ictiobus bubalus
40	005	Quillback Carpsucker	30.0	31.7	34.2	35.2	Carpiodes cyprinus
40	006	River Carpsucker	29.5	31.4	33.5	35.2	Carpiodes carpio carpio
40	010	Golden Redhorse	25.6	28.2	28.5	33.4	Moxostoma erythrurum
40	011	Smallmouth Redhorse	25.5	28.1	28.5	33.3	Moxostoma macrolepidotum
40	015	Northern Hog Sucker	27.3	29.2	31.6	33.0	Hypentelium nigricans
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
43	001	Common Carp	31.5	33.4	34.9	37.3	Cyprinus carpio
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
43	013	Creek Chub	28.1	30.0	31.4	33.7	Semotilus atromaculatus
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides
43	023	Redfin Shiner	28.6	30.5	31.9	34.2	Lythrurus umbratilis
43	025	Striped Shiner	28.0	29.9	31.3	33.6	Luxilus chrysocephalus
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	033	Bigmouth Shiner	29.0	30.9	32.3	34.6	Notropis dorsalis
43	034	Sand Shiner	29.4	31.3	32.7	35.0	Notropis stramineus
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
43	044	Stoneroller	28.2	30.6	33.0	35.5	Campostoma anomalum
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
47	007	Flathead Catfish	31.1	33.4	34.7	38.0	Pylodictis olivaris
47	008	Stonecat Madtom	21.2	23.8	25.7	29.0	Noturus flavus
54	002	Blackstripe Topminnow	30.2	32.8	34.7	38.0	Fundulus notatus
70	001	Brook Silversides	25.0	28.3	31.7	35.0	Labidesthes sicculus

Appendix Table 1B. continued

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
74	001	White Bass	29.5	31.5	33.3	35.6	Morone chrysops
77	001	White Crappie	28.6	29.9	30.8	32.5	Pomoxis annularis
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
77	010	Orangespotted Sunfish	28.7	30.9	31.3	35.4	Lepomis humilis
77	011	Longear Sunfish	24.1	28.0	31.8	35.9	Lepomis megalotis
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	004	Dusky Darter	22.5	26.0	29.6	32.9	Percina sciera sciera
80	014	Johnny Darter	22.7	26.3	30.3	33.6	Etheostoma nigrum
80	024	Fantail Darter	19.7	24.1	30.6	32.8	Etheostoma flabellare
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens

Appendix Table 2B. Thermal criteria results for general use RAS alternate list 1.

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	19.70	22.62	27.30	28.20
Growth	23.80	26.18	29.15	30.40
Avoidance (UAT)	25.70	29.32	30.70	31.60
Survival (LT)	27.00	30.46	31.50	32.70
Survival (ST)	29.00	32.46	33.50	34.70

Species Used N = 47

Common Name	Common Name	Common Name
Longnose Gar	Fathead Minnow	Johnny Darter
Skipjack Herring	Bluntnose Minnow	Fantail Darter
Gizzard Shad	Stoneroller	Freshwater Drum
Northern Pike	Channel Catfish	
Bigmouth Buffalo	Yellow Bullhead	
Smallmouth Buffalo	Black Bullhead	
Quillback Carpsucker	Flathead Catfish	
River Carpsucker	Stonecat Madtom	
Golden Redhorse	Blackstripe Topminnow	
Smallmouth Redhorse	Brook Silversides	
Northern Hog Sucker	White Bass	
White Sucker	White Crappie	
Common Carp	Black Crappie	
Golden Shiner	Rock Bass	
Creek Chub	Smallmouth Bass	
Emerald Shiner	Largemouth Bass	
Redfin Shiner	Green Sunfish	
Striped Shiner	Bluegill Sunfish	
Spottail Shiner	Orangespotted Sunfish	
Spotfin Shiner	Longear Sunfish	
Bigmouth Shiner	Pumpkinseed Sunfish	
Sand Shiner	Dusky Darter	

Appendix Table 3B. Thermal tolerance rankings for general use RAS alternate list 1.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
19.7	67.5	Fantail Darter [1]			
21.2	70.2	Stonecat Madtom [2]			
21.8	71.2	Northern Pike [3]			
22.5	72.5	Emerald Shiner [4]			
22.5	72.5	Dusky Darter [5]			
22.7	72.9	Johnny Darter [6]			
23.8	74.8		Stonecat Madtom [1]		
24.1	75.4	Longear Sunfish [7]			
24.1	75.4		Fantail Darter [2]		
25.0	77.0	Brook Silversides [8]			
25.3	77.5		Northern Pike [3]		
25.5	77.9	Smallmouth Redhorse [9]			
25.6	78.1	Golden Redhorse [10]			
25.7	78.3		Emerald Shiner [4]		
25.7	78.3			Stonecat Madtom [1]	
26.0	78.8	White Sucker [11]			
26.0	78.8		Dusky Darter [5]		
26.3	79.3		Johnny Darter [6]		
27.3	81.1	Skipjack Herring [12]			
27.3	81.1	Northern Hog Sucker [13]			
27.3	81.1	Spottail Shiner [14]			
27.5	81.5	Bluntnose Minnow [15]			
27.6	81.7	Black Bullhead [16]			
27.6	81.7	Black Crappie [17]			
27.7	81.9	Fathead Minnow [18]			
27.8	82.0		White Sucker [7]		
27.8	82.0	Golden Shiner [19]			
27.8	82.0	Green Sunfish [20]			
28.0	82.4	Striped Shiner [21]			
28.0	82.4		Longear Sunfish [8]		
28.1	82.6		Smallmouth Redhorse [9]		
28.1	82.6	Creek Chub [22]			

Appendix Table 3B. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
28.1	82.6	Rock Bass [23]			
28.2	82.8		Golden Redhorse [10]		
28.2	82.8	Stoneroller [24]			
28.3	82.9	Yellow Bullhead [25]			
28.3	82.9		Brook Silversides [11]		
28.4	83.1	Pumpkinseed Sunfish [26]			
28.5	83.3	Smallmouth Buffalo [27]			
28.5	83.3			Golden Redhorse [2]	
28.5	83.3			Smallmouth Redhorse [3]	
28.6	83.5	Redfin Shiner [28]			
28.6	83.5	White Crappie [29]			
28.7	83.7			White Sucker [4]	
28.7	83.7	Orangespotted Sunfish [30]			
28.9	84.0			Northern Pike [5]	
29.0	84.2	Bigmouth Shiner [31]			
29.0	84.2				Stonecat Madtom [1]
29.1	84.4		Bluntnose Minnow [12]		
29.1	84.4	Largemouth Bass [32]			
29.1	84.4	Freshwater Drum [33]			
29.2	84.6		Northern Hog Sucker [13]		
29.4	84.9	Sand Shiner [34]			
29.5	85.1	River Carpsucker [35]			
29.5	85.1	White Bass [36]			
29.6	85.3		Skipjack Herring [14]		
29.6	85.3			Dusky Darter [6]	
29.7	85.5			Black Crappie [7]	
29.8	85.6			Emerald Shiner [8]	
29.8	85.6	Spotfin Shiner [37]			
29.9	85.8	Bigmouth Buffalo [38]			
29.9	85.8		Golden Shiner [15]		
29.9	85.8		Striped Shiner [16]		
29.9	85.8		White Crappie [17]		

Appendix Table 3B. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
30.0	86.0	Gizzard Shad [39]			
30.0	86.0	Quillback Carpsucker [40]			
30.0	86.0		Creek Chub [18]		
30.0	86.0		Fathead Minnow [19]		
30.0	86.0		Black Crappie [20]		
30.0	86.0	Smallmouth Bass [41]			
30.1	86.2		Spottail Shiner [21]		
30.2	86.4		Black Bullhead [22]		
30.2	86.4	Blackstripe Topminnow [42]			
30.3	86.5		Green Sunfish [23]		
30.3	86.5			Johnny Darter [9]	
30.4	86.7		Rock Bass [24]		
30.4	86.7	Bluegill Sunfish [43]			
30.5	86.9		Redfin Shiner [25]		
30.5	86.9		Pumpkinseed Sunfish [26]		
30.5	86.9			Pumpkinseed Sunfish [10]	
30.5	86.9		Freshwater Drum [27]		
30.6	87.1		Stoneroller [28]		
30.6	87.1			Fantail Darter [11]	
30.7	87.3			Skipjack Herring [12]	
30.7	87.3			Golden Shiner [13]	
30.8	87.4			White Crappie [14]	
30.9	87.6		Bigmouth Shiner [29]		
30.9	87.6		Largemouth Bass [30]		
30.9	87.6			Green Sunfish [15]	
30.9	87.6		Orangespotted Sunfish [31]		
31.0	87.8		Yellow Bullhead [32]		
31.1	88.0	Channel Catfish [44]			
31.1	88.0	Flathead Catfish [45]			
31.2	88.2			Freshwater Drum [16]	
31.3	88.3			Striped Shiner [17]	
31.3	88.3		Sand Shiner [33]		

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
31.3	88.3			Yellow Bullhead [18]	
31.3	88.3			Orangespotted Sunfish [19]	
31.4	88.5		River Carpsucker [34]		
31.4	88.5			Creek Chub [20]	
31.4	88.5			Bluntnose Minnow [21]	
31.5	88.7		Smallmouth Buffalo [35]		
31.5	88.7				White Sucker [2]
31.5	88.7	Common Carp [46]			
31.5	88.7			Fathead Minnow [22]	
31.5	88.7		White Bass [36]		
31.6	88.9			Northern Hog Sucker [23]	
31.6	88.9		Smallmouth Bass [37]		
31.6	88.9			Largemouth Bass [24]	
31.7	89.1		Quillback Carpsucker [38]		
31.7	89.1			Brook Silversides [25]	
31.8	89.2			Longear Sunfish [26]	
31.9	89.4		Gizzard Shad [39]		
31.9	89.4			Redfin Shiner [27]	
31.9	89.4		Spotfin Shiner [40]		
32.0	89.6			Smallmouth Bass [28]	
32.1	89.8		Bigmouth Buffalo [41]		
32.1	89.8				Emerald Shiner [3]
32.1	89.8			Black Bullhead [29]	
32.2	90.0				Northern Pike [4]
32.3	90.1			Bigmouth Shiner [30]	
32.4	90.3				Bluntnose Minnow [5]
32.4	90.3		Bluegill Sunfish [42]		
32.5	90.5	Longnose Gar [47]			
32.5	90.5				White Crappie [6]
32.7	90.9			Sand Shiner [31]	
32.8	91.0		Blackstripe Topminnow [43]		
32.8	91.0				Fantail Darter [7]

Appendix Table 3B. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
32.9	91.2				Dusky Darter [8]
33.0	91.4				Northern Hog Sucker [9]
33.0	91.4			Stoneroller [32]	
33.0	91.4			Rock Bass [33]	
33.3	91.9			Bigmouth Buffalo [34]	
33.3	91.9				Smallmouth Redhorse [10]
33.3	91.9			White Bass [35]	
33.4	92.1				Golden Redhorse [11]
33.4	92.1		Common Carp [44]		
33.4	92.1		Flathead Catfish [45]		
33.4	92.1				Freshwater Drum [12]
33.5	92.3			River Carpsucker [36]	
33.5	92.3		Channel Catfish [46]		
33.6	92.5				Striped Shiner [13]
33.6	92.5				Johnny Darter [14]
33.7	92.7				Creek Chub [15]
33.7	92.7			Spotfin Shiner [37]	
33.8	92.8			Bluegill Sunfish [38]	
34.0	93.2			Gizzard Shad [39]	
34.0	93.2				Golden Shiner [16]
34.1	93.4			Smallmouth Buffalo [40]	
34.2	93.6			Quillback Carpsucker [41]	
34.2	93.6				Redfin Shiner [17]
34.3	93.7		Longnose Gar [47]		
34.3	93.7				Skipjack Herring [18]
34.5	94.1			Longnose Gar [42]	
34.5	94.1			Spottail Shiner [43]	
34.5	94.1				Fathead Minnow [19]
34.5	94.1				Largemouth Bass [20]
34.6	94.3				Bigmouth Shiner [21]
34.6	94.3				Pumpkinseed Sunfish [22]
34.7	94.5			Flathead Catfish [44]	

Appendix Table 3B. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
34.7	94.5			Blackstripe Topminnow [45]	
34.7	94.5				Black Crappie [23]
34.7	94.5				Smallmouth Bass [24]
34.8	94.6			Channel Catfish [46]	
34.9	94.8			Common Carp [47]	
35.0	95.0				Sand Shiner [25]
35.0	95.0				Brook Silversides [26]
35.0	95.0				Rock Bass [27]
35.2	95.4				Quillback Carpsucker [28]
35.2	95.4				River Carpsucker [29]
35.3	95.5				Green Sunfish [30]
35.4	95.7				Black Bullhead [31]
35.4	95.7				Orangespotted Sunfish [32]
35.5	95.9				Stoneroller [33]
35.6	96.1				Spottail Shiner [34]
35.6	96.1				White Bass [35]
35.8	96.4				Gizzard Shad [36]
35.9	96.6				Longear Sunfish [37]
36.0	96.8				Spotfin Shiner [38]
36.4	97.5				Yellow Bullhead [39]
36.4	97.5				Bluegill Sunfish [40]
36.6	97.9				Bigmouth Buffalo [41]
37.3	99.1				Common Carp [42]
37.4	99.3				Smallmouth Buffalo [43]
37.8	100.0				Longnose Gar [44]
38.0	100.4				Flathead Catfish [45]
38.0	100.4				Blackstripe Topminnow [46]
38.3	100.9				Channel Catfish [47]

Appendix Table 1C. Thermal thresholds for general use RAS alternate list 2.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
10	004	Longnose Gar	32.5	34.3	34.5	37.8	Lepisosteus osseus
20	001	Skipjack Herring	27.3	29.6	30.7	34.3	Alosa chrysochloris
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
37	003	Northern Pike	21.8	25.3	28.9	32.2	Esox lucius
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
40	004	Smallmouth Buffalo	28.5	31.5	34.1	37.4	Ictiobus bubalus
40	005	Quillback Carpsucker	30.0	31.7	34.2	35.2	Carpiodes cyprinus
40	006	River Carpsucker	29.5	31.4	33.5	35.2	Carpiodes carpio carpio
40	010	Golden Redhorse	25.6	28.2	28.5	33.4	Moxostoma erythrurum
40	011	Smallmouth Redhorse	25.5	28.1	28.5	33.3	Moxostoma macrolepidotum
40	015	Northern Hog Sucker	27.3	29.2	31.6	33.0	Hypentelium nigricans
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
43	001	Common Carp	31.5	33.4	34.9	37.3	Cyprinus carpio
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
43	013	Creek Chub	28.1	30.0	31.4	33.7	Semotilus atromaculatus
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides
43	023	Redfin Shiner	28.6	30.5	31.9	34.2	Lythrurus umbratilis
43	025	Striped Shiner	28.0	29.9	31.3	33.6	Luxilus chrysocephalus
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	033	Bigmouth Shiner	29.0	30.9	32.3	34.6	Notropis dorsalis
43	034	Sand Shiner	29.4	31.3	32.7	35.0	Notropis stramineus
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
43	044	Stoneroller	28.2	30.6	33.0	35.5	Campostoma anomalum
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
47	007	Flathead Catfish	31.1	33.4	34.7	38.0	Pylodictis olivaris
47	008	Stonecat Madtom	21.2	23.8	25.7	29.0	Noturus flavus
54	002	Blackstripe Topminnow	30.2	32.8	34.7	38.0	Fundulus notatus
70	001	Brook Silversides	25.0	28.3	31.7	35.0	Labidesthes sicculus

Appendix Table 1C. continued

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
74	001	White Bass	29.5	31.5	33.3	35.6	Morone chrysops
77	001	White Crappie	28.6	29.9	30.8	32.5	Pomoxis annularis
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
77	010	Orangespotted Sunfish	28.7	30.9	31.3	35.4	Lepomis humilis
77	011	Longear Sunfish	24.1	28.0	31.8	35.9	Lepomis megalotis
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	001	Sauger	23.9	26.9	30.3	32.9	Stizostedion canadense
80	002	Walleye	22.8	26.2	30.0	32.9	Stizostedion vitreum
80	003	Yellow Perch	22.6	26.0	29.8	32.9	Perca flavescens
80	004	Dusky Darter	22.5	26.0	29.6	32.9	Percina sciera sciera
80	014	Johnny Darter	22.7	26.3	30.3	33.6	Etheostoma nigrum
80	024	Fantail Darter	19.7	24.1	30.6	32.8	Etheostoma flabellare
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens

Appendix Table 2C. Thermal criteria results for general use RAS alternate list 2.

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	19.70	22.59	25.70	28.10
Growth	23.80	26.00	28.23	30.25
Avoidance (UAT)	25.70	29.53	30.53	31.55
Survival (LT)	27.00	30.49	31.33	32.65
Survival (ST)	29.00	32.49	33.33	34.65

Species Used **N =** 50

Common Name	Common Name	Common Name
Longnose Gar	Fathead Minnow	Walleye
Skipjack Herring	Bluntnose Minnow	Yellow Perch
Gizzard Shad	Stoneroller	Dusky Darter
Northern Pike	Channel Catfish	Johnny Darter
Bigmouth Buffalo	Yellow Bullhead	Fantail Darter
Smallmouth Buffalo	Black Bullhead	Freshwater Drum
Quillback Carpsucker	Flathead Catfish	
River Carpsucker	Stonecat Madtom	
Golden Redhorse	Blackstripe Topminnow	
Smallmouth Redhorse	Brook Silversides	
Northern Hog Sucker	White Bass	
White Sucker	White Crappie	
Common Carp	Black Crappie	
Golden Shiner	Rock Bass	
Creek Chub	Smallmouth Bass	
Emerald Shiner	Largemouth Bass	
Redfin Shiner	Green Sunfish	
Striped Shiner	Bluegill Sunfish	
Spottail Shiner	Orangespotted Sunfish	
Spotfin Shiner	Longear Sunfish	
Bigmouth Shiner	Pumpkinseed Sunfish	
Sand Shiner	Sauger	

Appendix Table 3C. Thermal tolerance rankings for general use RAS alternate list 2.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
19.7	67.5	Fantail Darter [1]			
21.2	70.2	Stonecat Madtom [2]			
21.8	71.2	Northern Pike [3]			
22.5	72.5	Emerald Shiner [4]			
22.5	72.5	Dusky Darter [5]			
22.6	72.7	Yellow Perch [6]			
22.7	72.9	Johnny Darter [7]			
22.8	73.0	Walleye [8]			
23.8	74.8		Stonecat Madtom [1]		
23.9	75.0	Sauger [9]			
24.1	75.4	Longear Sunfish [10]			
24.1	75.4		Fantail Darter [2]		
25.0	77.0	Brook Silversides [11]			
25.3	77.5		Northern Pike [3]		
25.5	77.9	Smallmouth Redhorse [12]			
25.6	78.1	Golden Redhorse [13]			
25.7	78.3		Emerald Shiner [4]		
25.7	78.3			Stonecat Madtom [1]	
26.0	78.8	White Sucker [14]			
26.0	78.8		Yellow Perch [5]		
26.0	78.8		Dusky Darter [6]		
26.2	79.2		Walleye [7]		
26.3	79.3		Johnny Darter [8]		
26.9	80.4		Sauger [9]		
27.3	81.1	Skipjack Herring [15]			
27.3	81.1	Northern Hog Sucker [16]			
27.3	81.1	Spottail Shiner [17]			
27.5	81.5	Bluntnose Minnow [18]			
27.6	81.7	Black Bullhead [19]			
27.6	81.7	Black Crappie [20]			
27.7	81.9	Fathead Minnow [21]			
27.8	82.0		White Sucker [10]		

Appendix Table 3C. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
27.8	82.0	Golden Shiner [22]			
27.8	82.0	Green Sunfish [23]			
28.0	82.4	Striped Shiner [24]			
28.0	82.4		Longear Sunfish [11]		
28.1	82.6		Smallmouth Redhorse [12]		
28.1	82.6	Creek Chub [25]			
28.1	82.6	Rock Bass [26]			
28.2	82.8		Golden Redhorse [13]		
28.2	82.8	Stoneroller [27]			
28.3	82.9	Yellow Bullhead [28]			
28.3	82.9		Brook Silversides [14]		
28.4	83.1	Pumpkinseed Sunfish [29]			
28.5	83.3	Smallmouth Buffalo [30]			
28.5	83.3			Golden Redhorse [2]	
28.5	83.3			Smallmouth Redhorse [3]	
28.6	83.5	Redfin Shiner [31]			
28.6	83.5	White Crappie [32]			
28.7	83.7			White Sucker [4]	
28.7	83.7	Orangespotted Sunfish [33]			
28.9	84.0			Northern Pike [5]	
29.0	84.2	Bigmouth Shiner [34]			
29.0	84.2				Stonecat Madtom [1]
29.1	84.4		Bluntnose Minnow [15]		
29.1	84.4	Largemouth Bass [35]			
29.1	84.4	Freshwater Drum [36]			
29.2	84.6		Northern Hog Sucker [16]		
29.4	84.9	Sand Shiner [37]			
29.5	85.1	River Carpsucker [38]			
29.5	85.1	White Bass [39]			
29.6	85.3		Skipjack Herring [17]		
29.6	85.3			Dusky Darter [6]	
29.7	85.5			Black Crappie [7]	

Appendix Table 3C. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
29.8	85.6			Emerald Shiner [8]	
29.8	85.6	Spotfin Shiner [40]			
29.8	85.6			Yellow Perch [9]	
29.9	85.8	Bigmouth Buffalo [41]			
29.9	85.8		Golden Shiner [18]		
29.9	85.8		Striped Shiner [19]		
29.9	85.8		White Crappie [20]		
30.0	86.0	Gizzard Shad [42]			
30.0	86.0	Quillback Carpsucker [43]			
30.0	86.0		Creek Chub [21]		
30.0	86.0		Fathead Minnow [22]		
30.0	86.0		Black Crappie [23]		
30.0	86.0	Smallmouth Bass [44]			
30.0	86.0			Walleye [10]	
30.1	86.2		Spottail Shiner [24]		
30.2	86.4		Black Bullhead [25]		
30.2	86.4	Blackstripe Topminnow [45]			
30.3	86.5		Green Sunfish [26]		
30.3	86.5			Sauger [11]	
30.3	86.5			Johnny Darter [12]	
30.4	86.7		Rock Bass [27]		
30.4	86.7	Bluegill Sunfish [46]			
30.5	86.9		Redfin Shiner [28]		
30.5	86.9		Pumpkinseed Sunfish [29]		
30.5	86.9			Pumpkinseed Sunfish [13]	
30.5	86.9		Freshwater Drum [30]		
30.6	87.1		Stoneroller [31]		
30.6	87.1			Fantail Darter [14]	
30.7	87.3			Skipjack Herring [15]	
30.7	87.3			Golden Shiner [16]	
30.8	87.4			White Crappie [17]	
30.9	87.6		Bigmouth Shiner [32]		

Appendix Table 3C. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
30.9	87.6		Largemouth Bass [33]		
30.9	87.6			Green Sunfish [18]	
30.9	87.6		Orangespotted Sunfish [34]		
31.0	87.8		Yellow Bullhead [35]		
31.1	88.0	Channel Catfish [47]			
31.1	88.0	Flathead Catfish [48]			
31.2	88.2			Freshwater Drum [19]	
31.3	88.3			Striped Shiner [20]	
31.3	88.3		Sand Shiner [36]		
31.3	88.3			Yellow Bullhead [21]	
31.3	88.3			Orangespotted Sunfish [22]	
31.4	88.5		River Carpsucker [37]		
31.4	88.5			Creek Chub [23]	
31.4	88.5			Bluntnose Minnow [24]	
31.5	88.7		Smallmouth Buffalo [38]		
31.5	88.7				White Sucker [2]
31.5	88.7	Common Carp [49]			
31.5	88.7			Fathead Minnow [25]	
31.5	88.7		White Bass [39]		
31.6	88.9			Northern Hog Sucker [26]	
31.6	88.9		Smallmouth Bass [40]		
31.6	88.9			Largemouth Bass [27]	
31.7	89.1		Quillback Carpsucker [41]		
31.7	89.1			Brook Silversides [28]	
31.8	89.2			Longear Sunfish [29]	
31.9	89.4		Gizzard Shad [42]		
31.9	89.4			Redfin Shiner [30]	
31.9	89.4		Spotfin Shiner [43]		
32.0	89.6			Smallmouth Bass [31]	
32.1	89.8		Bigmouth Buffalo [44]		
32.1	89.8				Emerald Shiner [3]
32.1	89.8			Black Bullhead [32]	

Appendix Table 3C. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
32.2	90.0				Northern Pike [4]
32.3	90.1			Bigmouth Shiner [33]	
32.4	90.3				Bluntnose Minnow [5]
32.4	90.3		Bluegill Sunfish [45]		
32.5	90.5	Longnose Gar [50]			
32.5	90.5				White Crappie [6]
32.7	90.9			Sand Shiner [34]	
32.8	91.0		Blackstripe Topminnow [46]		
32.8	91.0				Fantail Darter [7]
32.9	91.2				Sauger [8]
32.9	91.2				Walleye [9]
32.9	91.2				Yellow Perch [10]
32.9	91.2				Dusky Darter [11]
33.0	91.4				Northern Hog Sucker [12]
33.0	91.4			Stoneroller [35]	
33.0	91.4			Rock Bass [36]	
33.3	91.9			Bigmouth Buffalo [37]	
33.3	91.9				Smallmouth Redhorse [13]
33.3	91.9			White Bass [38]	
33.4	92.1				Golden Redhorse [14]
33.4	92.1		Common Carp [47]		
33.4	92.1		Flathead Catfish [48]		
33.4	92.1				Freshwater Drum [15]
33.5	92.3			River Carpsucker [39]	
33.5	92.3		Channel Catfish [49]		
33.6	92.5				Striped Shiner [16]
33.6	92.5				Johnny Darter [17]
33.7	92.7				Creek Chub [18]
33.7	92.7			Spotfin Shiner [40]	
33.8	92.8			Bluegill Sunfish [41]	
34.0	93.2			Gizzard Shad [42]	
34.0	93.2				Golden Shiner [19]

Appendix Table 3C. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
34.1	93.4			Smallmouth Buffalo [43]	
34.2	93.6			Quillback Carpsucker [44]	
34.2	93.6				Redfin Shiner [20]
34.3	93.7		Longnose Gar [50]		
34.3	93.7				Skipjack Herring [21]
34.5	94.1			Longnose Gar [45]	
34.5	94.1			Spottail Shiner [46]	
34.5	94.1				Fathead Minnow [22]
34.5	94.1				Largemouth Bass [23]
34.6	94.3				Bigmouth Shiner [24]
34.6	94.3				Pumpkinseed Sunfish [25]
34.7	94.5			Flathead Catfish [47]	
34.7	94.5			Blackstripe Topminnow [48]	
34.7	94.5				Black Crappie [26]
34.7	94.5				Smallmouth Bass [27]
34.8	94.6			Channel Catfish [49]	
34.9	94.8			Common Carp [50]	
35.0	95.0				Sand Shiner [28]
35.0	95.0				Brook Silversides [29]
35.0	95.0				Rock Bass [30]
35.2	95.4				Quillback Carpsucker [31]
35.2	95.4				River Carpsucker [32]
35.3	95.5				Green Sunfish [33]
35.4	95.7				Black Bullhead [34]
35.4	95.7				Orangespotted Sunfish [35]
35.5	95.9				Stoneroller [36]
35.6	96.1				Spottail Shiner [37]
35.6	96.1				White Bass [38]
35.8	96.4				Gizzard Shad [39]
35.9	96.6				Longear Sunfish [40]
36.0	96.8				Spotfin Shiner [41]
36.4	97.5				Yellow Bullhead [42]

Appendix Table 3C. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
36.4	97.5				Bluegill Sunfish [43]
36.6	97.9				Bigmouth Buffalo [44]
37.3	99.1				Common Carp [45]
37.4	99.3				Smallmouth Buffalo [46]
37.8	100.0				Longnose Gar [47]
38.0	100.4				Flathead Catfish [48]
38.0	100.4				Blackstripe Topminnow [49]
38.3	100.9				Channel Catfish [50]

Appendix Table 1D Thermal thresholds for general use RAS alternate list 3.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
10	004	Longnose Gar	32.5	34.3	34.5	37.8	Lepisosteus osseus
20	001	Skipjack Herring	27.3	29.6	30.7	34.3	Alosa chrysochloris
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
37	003	Northern Pike	21.8	25.3	28.9	32.2	Esox lucius
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
40	004	Smallmouth Buffalo	28.5	31.5	34.1	37.4	Ictiobus bubalus
40	005	Quillback Carpsucker	30.0	31.7	34.2	35.2	Carpiodes cyprinus
40	006	River Carpsucker	29.5	31.4	33.5	35.2	Carpiodes carpio carpio
40	010	Golden Redhorse	25.6	28.2	28.5	33.4	Moxostoma erythrurum
40	011	Smallmouth Redhorse	25.5	28.1	28.5	33.3	Moxostoma macrolepidotum
40	015	Northern Hog Sucker	27.3	29.2	31.6	33.0	Hypentelium nigricans
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
43	001	Common Carp	31.5	33.4	34.9	37.3	Cyprinus carpio
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
43	013	Creek Chub	28.1	30.0	31.4	33.7	Semotilus atromaculatus
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides
43	023	Redfin Shiner	28.6	30.5	31.9	34.2	Lythrurus umbratilis
43	025	Striped Shiner	28.0	29.9	31.3	33.6	Luxilus chrysocephalus
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	033	Bigmouth Shiner	29.0	30.9	32.3	34.6	Notropis dorsalis
43	034	Sand Shiner	29.4	31.3	32.7	35.0	Notropis stramineus
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
43	044	Stoneroller	28.2	30.6	33.0	35.5	Campostoma anomalum
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
47	007	Flathead Catfish	31.1	33.4	34.7	38.0	Pylodictis olivaris
54	002	Blackstripe Topminnow	30.2	32.8	34.7	38.0	Fundulus notatus
70	001	Brook Silversides	25.0	28.3	31.7	35.0	Labidesthes sicculus
74	001	White Bass	29.5	31.5	33.3	35.6	Morone chrysops

Appendix Table 1D. continued

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
77	001	White Crappie	28.6	29.9	30.8	32.5	Pomoxis annularis
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
77	010	Orangespotted Sunfish	28.7	30.9	31.3	35.4	Lepomis humilis
77	011	Longear Sunfish	24.1	28.0	31.8	35.9	Lepomis megalotis
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	001	Sauger	23.9	26.9	30.3	32.9	Stizostedion canadense
80	002	Walleye	22.8	26.2	30.0	32.9	Stizostedion vitreum
80	003	Yellow Perch	22.6	26.0	29.8	32.9	Perca flavescens
80	004	Dusky Darter	22.5	26.0	29.6	32.9	Percina sciera sciera
80	014	Johnny Darter	22.7	26.3	30.3	33.6	Etheostoma nigrum
80	024	Fantail Darter	19.7	24.1	30.6	32.8	Etheostoma flabellare
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens

Appendix Table 2D. Thermal criteria results for general use RAS alternate list 3.

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	19.70	22.68	26.00	28.10
Growth	24.10	26.16	28.30	30.30
Avoidance (UAT)	28.50	29.68	30.60	31.60
Survival (LT)	29.50	30.74	31.40	32.70
Survival (ST)	31.50	32.74	33.40	34.70

Species Used **N =** 49

Common Name	Common Name	Common Name
Longnose Gar	Fathead Minnow	Yellow Perch
Skipjack Herring	Bluntnose Minnow	Dusky Darter
Gizzard Shad	Stoneroller	Johnny Darter
Northern Pike	Channel Catfish	Fantail Darter
Bigmouth Buffalo	Yellow Bullhead	Freshwater Drum
Smallmouth Buffalo	Black Bullhead	
Quillback Carpsucker	Flathead Catfish	
River Carpsucker	Blackstripe Topminnow	
Golden Redhorse	Brook Silversides	
Smallmouth Redhorse	White Bass	
Northern Hog Sucker	White Crappie	
White Sucker	Black Crappie	
Common Carp	Rock Bass	
Golden Shiner	Smallmouth Bass	
Creek Chub	Largemouth Bass	
Emerald Shiner	Green Sunfish	
Redfin Shiner	Bluegill Sunfish	
Striped Shiner	Orangespotted Sunfish	
Spottail Shiner	Longear Sunfish	
Spotfin Shiner	Pumpkinseed Sunfish	
Bigmouth Shiner	Sauger	
Sand Shiner	Walleye	

Appendix Table 3D. Thermal tolerance rankings for general use RAS alternate list 3.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
19.7	67.5	Fantail Darter [1]			
21.8	71.2	Northern Pike [2]			
22.5	72.5	Emerald Shiner [3]			
22.5	72.5	Dusky Darter [4]			
22.6	72.7	Yellow Perch [5]			
22.7	72.9	Johnny Darter [6]			
22.8	73.0	Walleye [7]			
23.9	75.0	Sauger [8]			
24.1	75.4	Longear Sunfish [9]			
24.1	75.4		Fantail Darter [1]		
25.0	77.0	Brook Silversides [10]			
25.3	77.5		Northern Pike [2]		
25.5	77.9	Smallmouth Redhorse [11]			
25.6	78.1	Golden Redhorse [12]			
25.7	78.3		Emerald Shiner [3]		
26.0	78.8	White Sucker [13]			
26.0	78.8		Yellow Perch [4]		
26.0	78.8		Dusky Darter [5]		
26.2	79.2		Walleye [6]		
26.3	79.3		Johnny Darter [7]		
26.9	80.4		Sauger [8]		
27.3	81.1	Skipjack Herring [14]			
27.3	81.1	Northern Hog Sucker [15]			
27.3	81.1	Spottail Shiner [16]			
27.5	81.5	Bluntnose Minnow [17]			
27.6	81.7	Black Bullhead [18]			
27.6	81.7	Black Crappie [19]			
27.7	81.9	Fathead Minnow [20]			
27.8	82.0		White Sucker [9]		
27.8	82.0	Golden Shiner [21]			
27.8	82.0	Green Sunfish [22]			
28.0	82.4	Striped Shiner [23]			

Appendix Table 3D. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
28.0	82.4		Longear Sunfish [10]		
28.1	82.6		Smallmouth Redhorse [11]		
28.1	82.6	Creek Chub [24]			
28.1	82.6	Rock Bass [25]			
28.2	82.8		Golden Redhorse [12]		
28.2	82.8	Stoneroller [26]			
28.3	82.9	Yellow Bullhead [27]			
28.3	82.9		Brook Silversides [13]		
28.4	83.1	Pumpkinseed Sunfish [28]			
28.5	83.3	Smallmouth Buffalo [29]			
28.5	83.3			Golden Redhorse [1]	
28.5	83.3			Smallmouth Redhorse [2]	
28.6	83.5	Redfin Shiner [30]			
28.6	83.5	White Crappie [31]			
28.7	83.7			White Sucker [3]	
28.7	83.7	Orangespotted Sunfish [32]			
28.9	84.0			Northern Pike [4]	
29.0	84.2	Bigmouth Shiner [33]			
29.1	84.4		Bluntnose Minnow [14]		
29.1	84.4	Largemouth Bass [34]			
29.1	84.4	Freshwater Drum [35]			
29.2	84.6		Northern Hog Sucker [15]		
29.4	84.9	Sand Shiner [36]			
29.5	85.1	River Carpsucker [37]			
29.5	85.1	White Bass [38]			
29.6	85.3		Skipjack Herring [16]		
29.6	85.3			Dusky Darter [5]	
29.7	85.5			Black Crappie [6]	
29.8	85.6			Emerald Shiner [7]	
29.8	85.6	Spotfin Shiner [39]			
29.8	85.6			Yellow Perch [8]	
29.9	85.8	Bigmouth Buffalo [40]			

Appendix Table 3D. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
29.9	85.8		Golden Shiner [17]		
29.9	85.8		Striped Shiner [18]		
29.9	85.8		White Crappie [19]		
30.0	86.0	Gizzard Shad [41]			
30.0	86.0	Quillback Carpsucker [42]			
30.0	86.0		Creek Chub [20]		
30.0	86.0		Fathead Minnow [21]		
30.0	86.0		Black Crappie [22]		
30.0	86.0	Smallmouth Bass [43]			
30.0	86.0			Walleye [9]	
30.1	86.2		Spottail Shiner [23]		
30.2	86.4		Black Bullhead [24]		
30.2	86.4	Blackstripe Topminnow [44]			
30.3	86.5		Green Sunfish [25]		
30.3	86.5			Sauger [10]	
30.3	86.5			Johnny Darter [11]	
30.4	86.7		Rock Bass [26]		
30.4	86.7	Bluegill Sunfish [45]			
30.5	86.9		Redfin Shiner [27]		
30.5	86.9		Pumpkinseed Sunfish [28]		
30.5	86.9			Pumpkinseed Sunfish [12]	
30.5	86.9		Freshwater Drum [29]		
30.6	87.1		Stoneroller [30]		
30.6	87.1			Fantail Darter [13]	
30.7	87.3			Skipjack Herring [14]	
30.7	87.3			Golden Shiner [15]	
30.8	87.4			White Crappie [16]	
30.9	87.6		Bigmouth Shiner [31]		
30.9	87.6		Largemouth Bass [32]		
30.9	87.6			Green Sunfish [17]	
30.9	87.6		Orangespotted Sunfish [33]		
31.0	87.8		Yellow Bullhead [34]		

Appendix Table 3D. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
31.1	88.0	Channel Catfish [46]			
31.1	88.0	Flathead Catfish [47]			
31.2	88.2			Freshwater Drum [18]	
31.3	88.3			Striped Shiner [19]	
31.3	88.3		Sand Shiner [35]		
31.3	88.3			Yellow Bullhead [20]	
31.3	88.3			Orangespotted Sunfish [21]	
31.4	88.5		River Carpsucker [36]		
31.4	88.5			Creek Chub [22]	
31.4	88.5			Bluntnose Minnow [23]	
31.5	88.7		Smallmouth Buffalo [37]		
31.5	88.7				White Sucker [1]
31.5	88.7	Common Carp [48]			
31.5	88.7			Fathead Minnow [24]	
31.5	88.7		White Bass [38]		
31.6	88.9			Northern Hog Sucker [25]	
31.6	88.9		Smallmouth Bass [39]		
31.6	88.9			Largemouth Bass [26]	
31.7	89.1		Quillback Carpsucker [40]		
31.7	89.1			Brook Silversides [27]	
31.8	89.2			Longear Sunfish [28]	
31.9	89.4		Gizzard Shad [41]		
31.9	89.4			Redfin Shiner [29]	
31.9	89.4		Spotfin Shiner [42]		
32.0	89.6			Smallmouth Bass [30]	
32.1	89.8		Bigmouth Buffalo [43]		
32.1	89.8				Emerald Shiner [2]
32.1	89.8			Black Bullhead [31]	
32.2	90.0				Northern Pike [3]
32.3	90.1			Bigmouth Shiner [32]	
32.4	90.3				Bluntnose Minnow [4]
32.4	90.3		Bluegill Sunfish [44]		

Appendix Table 3D. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
32.5	90.5	Longnose Gar [49]			
32.5	90.5				White Crappie [5]
32.7	90.9			Sand Shiner [33]	
32.8	91.0		Blackstripe Topminnow [45]		
32.8	91.0				Fantail Darter [6]
32.9	91.2				Sauger [7]
32.9	91.2				Walleye [8]
32.9	91.2				Yellow Perch [9]
32.9	91.2				Dusky Darter [10]
33.0	91.4				Northern Hog Sucker [11]
33.0	91.4			Stoneroller [34]	
33.0	91.4			Rock Bass [35]	
33.3	91.9			Bigmouth Buffalo [36]	
33.3	91.9				Smallmouth Redhorse [12]
33.3	91.9			White Bass [37]	
33.4	92.1				Golden Redhorse [13]
33.4	92.1		Common Carp [46]		
33.4	92.1		Flathead Catfish [47]		
33.4	92.1				Freshwater Drum [14]
33.5	92.3			River Carpsucker [38]	
33.5	92.3		Channel Catfish [48]		
33.6	92.5				Striped Shiner [15]
33.6	92.5				Johnny Darter [16]
33.7	92.7				Creek Chub [17]
33.7	92.7			Spotfin Shiner [39]	
33.8	92.8			Bluegill Sunfish [40]	
34.0	93.2			Gizzard Shad [41]	
34.0	93.2				Golden Shiner [18]
34.1	93.4			Smallmouth Buffalo [42]	
34.2	93.6			Quillback Carpsucker [43]	
34.2	93.6				Redfin Shiner [19]
34.3	93.7		Longnose Gar [49]		

Appendix Table 3D. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
34.3	93.7				Skipjack Herring [20]
34.5	94.1			Longnose Gar [44]	
34.5	94.1			Spottail Shiner [45]	
34.5	94.1				Fathead Minnow [21]
34.5	94.1				Largemouth Bass [22]
34.6	94.3				Bigmouth Shiner [23]
34.6	94.3				Pumpkinseed Sunfish [24]
34.7	94.5			Flathead Catfish [46]	
34.7	94.5			Blackstripe Topminnow [47]	
34.7	94.5				Black Crappie [25]
34.7	94.5				Smallmouth Bass [26]
34.8	94.6			Channel Catfish [48]	
34.9	94.8			Common Carp [49]	
35.0	95.0				Sand Shiner [27]
35.0	95.0				Brook Silversides [28]
35.0	95.0				Rock Bass [29]
35.2	95.4				Quillback Carpsucker [30]
35.2	95.4				River Carpsucker [31]
35.3	95.5				Green Sunfish [32]
35.4	95.7				Black Bullhead [33]
35.4	95.7				Orangespotted Sunfish [34]
35.5	95.9				Stoneroller [35]
35.6	96.1				Spottail Shiner [36]
35.6	96.1				White Bass [37]
35.8	96.4				Gizzard Shad [38]
35.9	96.6				Longear Sunfish [39]
36.0	96.8				Spotfin Shiner [40]
36.4	97.5				Yellow Bullhead [41]
36.4	97.5				Bluegill Sunfish [42]
36.6	97.9				Bigmouth Buffalo [43]
37.3	99.1				Common Carp [44]
37.4	99.3				Smallmouth Buffalo [45]

Appendix Table 3D. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
37.8	100.0				Longnose Gar [46]
38.0	100.4				Flathead Catfish [47]
38.0	100.4				Blackstripe Topminnow [48]
38.3	100.9				Channel Catfish [49]

Appendix Table 1E. Thermal thresholds for modified use RAS 1 list (includes golden redhorse).

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
37	003	Northern Pike	21.8	25.3	28.9	32.2	Esox lucius
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
40	010	Golden Redhorse	25.6	28.2	28.5	33.4	Moxostoma erythrurum
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
43	001	Common Carp	31.5	33.4	34.9	37.3	Cyprinus carpio
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
47	007	Flathead Catfish	31.1	33.4	34.7	38.0	Pylodictis olivaris
54	002	Blackstripe Topminnow	30.2	32.8	34.7	38.0	Fundulus notatus
70	001	Brook Silversides	25.0	28.3	31.7	35.0	Labidesthes sicculus
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	002	Walleye	22.8	26.2	30.0	32.9	Stizostedion vitreum
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens

Appendix Table 2E. Thermal criteria results for modified use RAS 1 list (includes golden redhorse).

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	21.80	24.12	27.40	28.10
Growth	25.30	27.16	29.50	30.40
Avoidance (UAT)	28.50	29.38	30.60	31.60
Survival (LT)	29.50	30.32	31.70	33.00
Survival (ST)	31.50	32.32	33.70	35.00

Species Used N = 27

Common Name	Common Name	Common Name
Gizzard Shad	Green Sunfish	
Northern Pike	Bluegill Sunfish	
Bigmouth Buffalo	Pumpkinseed Sunfish	
Golden Redhorse	Walleye	
White Sucker	Freshwater Drum	
Common Carp		
Golden Shiner		
Emerald Shiner		
Spottail Shiner		
Spotfin Shiner		
Fathead Minnow		
Bluntnose Minnow		
Channel Catfish		
Yellow Bullhead		
Black Bullhead		
Flathead Catfish		
Blackstripe Topminnow		
Brook Silversides		
Black Crappie		
Rock Bass		
Smallmouth Bass		
Largemouth Bass		

Appendix Table 3E. Thermal tolerance rankings for modified use RAS 1 list (includes golden redhorse).

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
21.8	71.2	Northern Pike [1]			
22.5	72.5	Emerald Shiner [2]			
22.8	73.0	Walleye [3]			
25.0	77.0	Brook Silversides [4]			
25.3	77.5		Northern Pike [1]		
25.6	78.1	Golden Redhorse [5]			
25.7	78.3		Emerald Shiner [2]		
26.0	78.8	White Sucker [6]			
26.2	79.2		Walleye [3]		
27.3	81.1	Spottail Shiner [7]			
27.5	81.5	Bluntnose Minnow [8]			
27.6	81.7	Black Bullhead [9]			
27.6	81.7	Black Crappie [10]			
27.7	81.9	Fathead Minnow [11]			
27.8	82.0		White Sucker [4]		
27.8	82.0	Golden Shiner [12]			
27.8	82.0	Green Sunfish [13]			
28.1	82.6	Rock Bass [14]			
28.2	82.8		Golden Redhorse [5]		
28.3	82.9	Yellow Bullhead [15]			
28.3	82.9		Brook Silversides [6]		
28.4	83.1	Pumpkinseed Sunfish [16]			
28.5	83.3			Golden Redhorse [1]	
28.7	83.7			White Sucker [2]	
28.9	84.0			Northern Pike [3]	
29.1	84.4		Bluntnose Minnow [7]		
29.1	84.4	Largemouth Bass [17]			
29.1	84.4	Freshwater Drum [18]			
29.7	85.5			Black Crappie [4]	
29.8	85.6			Emerald Shiner [5]	
29.8	85.6	Spotfin Shiner [19]			
29.9	85.8	Bigmouth Buffalo [20]			

Appendix Table 3E. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
29.9	85.8		Golden Shiner [8]		
30.0	86.0	Gizzard Shad [21]			
30.0	86.0		Fathead Minnow [9]		
30.0	86.0		Black Crappie [10]		
30.0	86.0	Smallmouth Bass [22]			
30.0	86.0			Walleye [6]	
30.1	86.2		Spottail Shiner [11]		
30.2	86.4		Black Bullhead [12]		
30.2	86.4	Blackstripe Topminnow [23]			
30.3	86.5		Green Sunfish [13]		
30.4	86.7		Rock Bass [14]		
30.4	86.7	Bluegill Sunfish [24]			
30.5	86.9		Pumpkinseed Sunfish [15]		
30.5	86.9			Pumpkinseed Sunfish [7]	
30.5	86.9		Freshwater Drum [16]		
30.7	87.3			Golden Shiner [8]	
30.9	87.6		Largemouth Bass [17]		
30.9	87.6			Green Sunfish [9]	
31.0	87.8		Yellow Bullhead [18]		
31.1	88.0	Channel Catfish [25]			
31.1	88.0	Flathead Catfish [26]			
31.2	88.2			Freshwater Drum [10]	
31.3	88.3			Yellow Bullhead [11]	
31.4	88.5			Bluntnose Minnow [12]	
31.5	88.7				White Sucker [1]
31.5	88.7	Common Carp [27]			
31.5	88.7			Fathead Minnow [13]	
31.6	88.9		Smallmouth Bass [19]		
31.6	88.9			Largemouth Bass [14]	
31.7	89.1			Brook Silversides [15]	
31.9	89.4		Gizzard Shad [20]		
31.9	89.4		Spotfin Shiner [21]		

Appendix Table 3E. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
32.0	89.6			Smallmouth Bass [16]	
32.1	89.8		Bigmouth Buffalo [22]		
32.1	89.8				Emerald Shiner [2]
32.1	89.8			Black Bullhead [17]	
32.2	90.0				Northern Pike [3]
32.4	90.3				Bluntnose Minnow [4]
32.4	90.3		Bluegill Sunfish [23]		
32.8	91.0		Blackstripe Topminnow [24]		
32.9	91.2				Walleye [5]
33.0	91.4			Rock Bass [18]	
33.3	91.9			Bigmouth Buffalo [19]	
33.4	92.1				Golden Redhorse [6]
33.4	92.1		Common Carp [25]		
33.4	92.1		Flathead Catfish [26]		
33.4	92.1				Freshwater Drum [7]
33.5	92.3		Channel Catfish [27]		
33.7	92.7			Spotfin Shiner [20]	
33.8	92.8			Bluegill Sunfish [21]	
34.0	93.2			Gizzard Shad [22]	
34.0	93.2				Golden Shiner [8]
34.5	94.1			Spottail Shiner [23]	
34.5	94.1				Fathead Minnow [9]
34.5	94.1				Largemouth Bass [10]
34.6	94.3				Pumpkinseed Sunfish [11]
34.7	94.5			Flathead Catfish [24]	
34.7	94.5			Blackstripe Topminnow [25]	
34.7	94.5				Black Crappie [12]
34.7	94.5				Smallmouth Bass [13]
34.8	94.6			Channel Catfish [26]	
34.9	94.8			Common Carp [27]	
35.0	95.0				Brook Silversides [14]
35.0	95.0				Rock Bass [15]

Appendix Table 3E. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
35.3	95.5				Green Sunfish [16]
35.4	95.7				Black Bullhead [17]
35.6	96.1				Spottail Shiner [18]
35.8	96.4				Gizzard Shad [19]
36.0	96.8				Spotfin Shiner [20]
36.4	97.5				Yellow Bullhead [21]
36.4	97.5				Bluegill Sunfish [22]
36.6	97.9				Bigmouth Buffalo [23]
37.3	99.1				Common Carp [24]
38.0	100.4				Flathead Catfish [25]
38.0	100.4				Blackstripe Topminnow [26]
38.3	100.9				Channel Catfish [27]

Appendix Table 1F. Thermal thresholds for modified use RAS 2 list (excludes golden redhorse).

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
37	003	Northern Pike	21.8	25.3	28.9	32.2	Esox lucius
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
43	001	Common Carp	31.5	33.4	34.9	37.3	Cyprinus carpio
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
47	007	Flathead Catfish	31.1	33.4	34.7	38.0	Pylodictis olivaris
54	002	Blackstripe Topminnow	30.2	32.8	34.7	38.0	Fundulus notatus
70	001	Brook Silversides	25.0	28.3	31.7	35.0	Labidesthes sicculus
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	002	Walleye	22.8	26.2	30.0	32.9	Stizostedion vitreum
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens

Appendix Table 2F. Thermal criteria results for modified use RAS 2 list (excludes golden redhorse).

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	21.80	23.90	27.53	28.20
Growth	25.30	27.00	29.93	30.45
Avoidance (UAT)	28.70	29.75	30.75	31.65
Survival (LT)	29.50	30.30	32.13	33.00
Survival (ST)	31.50	32.30	34.13	35.00

Species Used N = 26

Common Name	Common Name	Common Name
Gizzard Shad	Bluegill Sunfish	
Northern Pike	Pumpkinseed Sunfish	
Bigmouth Buffalo	Walleye	
White Sucker	Freshwater Drum	
Common Carp		
Golden Shiner		
Emerald Shiner		
Spottail Shiner		
Spotfin Shiner		
Fathead Minnow		
Bluntnose Minnow		
Channel Catfish		
Yellow Bullhead		
Black Bullhead		
Flathead Catfish		
Blackstripe Topminnow		
Brook Silversides		
Black Crappie		
Rock Bass		
Smallmouth Bass		
Largemouth Bass		
Green Sunfish		

Appendix Table 3F. Thermal tolerance rankings for modified use RAS 1 list (excludes golden redhorse).

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
21.8	71.2	Northern Pike [1]			
22.5	72.5	Emerald Shiner [2]			
22.8	73.0	Walleye [3]			
25.0	77.0	Brook Silversides [4]			
25.3	77.5		Northern Pike [1]		
25.7	78.3		Emerald Shiner [2]		
26.0	78.8	White Sucker [5]			
26.2	79.2		Walleye [3]		
27.3	81.1	Spottail Shiner [6]			
27.5	81.5	Bluntnose Minnow [7]			
27.6	81.7	Black Bullhead [8]			
27.6	81.7	Black Crappie [9]			
27.7	81.9	Fathead Minnow [10]			
27.8	82.0		White Sucker [4]		
27.8	82.0	Golden Shiner [11]			
27.8	82.0	Green Sunfish [12]			
28.1	82.6	Rock Bass [13]			
28.3	82.9	Yellow Bullhead [14]			
28.3	82.9		Brook Silversides [5]		
28.4	83.1	Pumpkinseed Sunfish [15]			
28.7	83.7			White Sucker [1]	
28.9	84.0			Northern Pike [2]	
29.1	84.4		Bluntnose Minnow [6]		
29.1	84.4	Largemouth Bass [16]			
29.1	84.4	Freshwater Drum [17]			
29.7	85.5			Black Crappie [3]	
29.8	85.6			Emerald Shiner [4]	
29.8	85.6	Spotfin Shiner [18]			
29.9	85.8	Bigmouth Buffalo [19]			
29.9	85.8		Golden Shiner [7]		
30.0	86.0	Gizzard Shad [20]			
30.0	86.0		Fathead Minnow [8]		

Appendix Table 3F. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
30.0	86.0		Black Crappie [9]		
30.0	86.0	Smallmouth Bass [21]			
30.0	86.0			Walleye [5]	
30.1	86.2		Spottail Shiner [10]		
30.2	86.4		Black Bullhead [11]		
30.2	86.4	Blackstripe Topminnow [22]			
30.3	86.5		Green Sunfish [12]		
30.4	86.7		Rock Bass [13]		
30.4	86.7	Bluegill Sunfish [23]			
30.5	86.9		Pumpkinseed Sunfish [14]		
30.5	86.9			Pumpkinseed Sunfish [6]	
30.5	86.9		Freshwater Drum [15]		
30.7	87.3			Golden Shiner [7]	
30.9	87.6		Largemouth Bass [16]		
30.9	87.6			Green Sunfish [8]	
31.0	87.8		Yellow Bullhead [17]		
31.1	88.0	Channel Catfish [24]			
31.1	88.0	Flathead Catfish [25]			
31.2	88.2			Freshwater Drum [9]	
31.3	88.3			Yellow Bullhead [10]	
31.4	88.5			Bluntnose Minnow [11]	
31.5	88.7				White Sucker [1]
31.5	88.7	Common Carp [26]			
31.5	88.7			Fathead Minnow [12]	
31.6	88.9		Smallmouth Bass [18]		
31.6	88.9			Largemouth Bass [13]	
31.7	89.1			Brook Silversides [14]	
31.9	89.4		Gizzard Shad [19]		
31.9	89.4		Spotfin Shiner [20]		
32.0	89.6			Smallmouth Bass [15]	
32.1	89.8		Bigmouth Buffalo [21]		
32.1	89.8				Emerald Shiner [2]

Appendix Table 3F. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
32.1	89.8			Black Bullhead [16]	
32.2	90.0				Northern Pike [3]
32.4	90.3				Bluntnose Minnow [4]
32.4	90.3		Bluegill Sunfish [22]		
32.8	91.0		Blackstripe Topminnow [23]		
32.9	91.2				Walleye [5]
33.0	91.4			Rock Bass [17]	
33.3	91.9			Bigmouth Buffalo [18]	
33.4	92.1		Common Carp [24]		
33.4	92.1		Flathead Catfish [25]		
33.4	92.1				Freshwater Drum [6]
33.5	92.3		Channel Catfish [26]		
33.7	92.7			Spotfin Shiner [19]	
33.8	92.8			Bluegill Sunfish [20]	
34.0	93.2			Gizzard Shad [21]	
34.0	93.2				Golden Shiner [7]
34.5	94.1			Spottail Shiner [22]	
34.5	94.1				Fathead Minnow [8]
34.5	94.1				Largemouth Bass [9]
34.6	94.3				Pumpkinseed Sunfish [10]
34.7	94.5			Flathead Catfish [23]	
34.7	94.5			Blackstripe Topminnow [24]	
34.7	94.5				Black Crappie [11]
34.7	94.5				Smallmouth Bass [12]
34.8	94.6			Channel Catfish [25]	
34.9	94.8			Common Carp [26]	
35.0	95.0				Brook Silversides [13]
35.0	95.0				Rock Bass [14]
35.3	95.5				Green Sunfish [15]
35.4	95.7				Black Bullhead [16]
35.6	96.1				Spottail Shiner [17]
35.8	96.4				Gizzard Shad [18]

Appendix Table 3F. continued

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
36.0	96.8				Spotfin Shiner [19]
36.4	97.5				Yellow Bullhead [20]
36.4	97.5				Bluegill Sunfish [21]
36.6	97.9				Bigmouth Buffalo [22]
37.3	99.1				Common Carp [23]
38.0	100.4				Flathead Catfish [24]
38.0	100.4				Blackstripe Topminnow [25]
38.3	100.9				Channel Catfish [26]

Appendix Table 1G. Thermal thresholds for secondary contact use RAS list.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
43	001	Common Carp	31.5	33.4	34.9	37.3	Cyprinus carpio
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus

Appendix Table 2G. Thermal criteria results for secondary contact use RAS list.

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	27.50	27.57	27.68	27.80
Growth	29.10	29.66	29.98	30.25
Avoidance (UAT)	30.70	30.84	31.28	31.55
Survival (LT)	30.40	31.52	32.38	32.90
Survival (ST)	32.40	33.52	34.38	34.90

Species Used N = 8

Common Name	Common Name	Common Name
Gizzard Shad		
Common Carp		
Golden Shiner		
Fathead Minnow		
Bluntnose Minnow		
Black Bullhead		
Largemouth Bass		
Green Sunfish		

Appendix Table 3G. Thermal tolerance rankings for secondary contact use RAS list.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
27.5	81.5	Bluntnose Minnow [1]			
27.6	81.7	Black Bullhead [2]			
27.7	81.9	Fathead Minnow [3]			
27.8	82.0	Golden Shiner [4]			
27.8	82.0	Green Sunfish [5]			
29.1	84.4		Bluntnose Minnow [1]		
29.1	84.4	Largemouth Bass [6]			
29.9	85.8		Golden Shiner [2]		
30.0	86.0	Gizzard Shad [7]			
30.0	86.0		Fathead Minnow [3]		
30.2	86.4		Black Bullhead [4]		
30.3	86.5		Green Sunfish [5]		
30.7	87.3			Golden Shiner [1]	
30.9	87.6		Largemouth Bass [6]		
30.9	87.6			Green Sunfish [2]	
31.4	88.5			Bluntnose Minnow [3]	
31.5	88.7	Common Carp [8]			
31.5	88.7			Fathead Minnow [4]	
31.6	88.9			Largemouth Bass [5]	
31.9	89.4		Gizzard Shad [7]		
32.1	89.8			Black Bullhead [6]	
32.4	90.3				Bluntnose Minnow [1]
33.4	92.1		Common Carp [8]		
34.0	93.2			Gizzard Shad [7]	
34.0	93.2				Golden Shiner [2]
34.5	94.1				Fathead Minnow [3]
34.5	94.1				Largemouth Bass [4]
34.9	94.8			Common Carp [8]	
35.3	95.5				Green Sunfish [5]
35.4	95.7				Black Bullhead [6]
35.8	96.4				Gizzard Shad [7]
37.3	99.1				Common Carp [8]

Appendix B

Ambient Temperature Regime, 1998-2004
Temperature Statistics at 8 Monitoring Locations in the Chicago Area Waterway System

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geometric Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
Location: Cicero Av															
Jan	Entire	119	56.3	55.9	54.0	70.6	69.3	68.2	68.3	68.1	67.2	62.7	45.5	80.3	92.1
	Early	55	56.3	55.8	58.1	69.3	68.1	68.0	68.6	68.0	66.7	62.2	45.3	80.3	92.4
	Late	64	56.4	55.9	52.7	70.6	68.2	68.1	68.7	68.1	67.3	63.4	46.1	82.0	94.4
Feb	Entire	109	59.2	59.0	59.0	70.9	69.8	69.6	69.7	68.6	66.9	63.4	50.7	75.4	83.4
	Early	60	59.3	59.0	59.0	70.9	69.8	69.6	70.1	69.6	68.4	63.3	50.1	75.0	82.8
	Late	49	59.1	58.9	59.0	68.3	67.3	66.2	67.8	66.3	65.4	63.4	51.0	75.5	83.6
Mar	Entire	120	62.4	62.1	61.9	76.8	75.4	75.0	75.0	74.2	72.3	65.7	53.6	78.3	86.7
	Early	58	60.9	60.6	59.5	74.9	74.3	74.0	74.5	73.3	72.1	65.2	53.4	79.5	89.0
	Late	62	63.8	63.6	63.3	76.8	75.4	75.0	75.8	74.6	73.0	66.5	54.2	75.4	81.3
Apr	Entire	114	64.7	64.3	64.6	81.5	79.8	79.1	79.3	77.9	74.9	67.9	53.4	78.7	85.9
	Early	56	64.5	64.3	63.9	81.5	78.2	75.7	79.5	75.6	73.6	66.4	56.7	73.3	77.9
	Late	58	64.8	64.3	65.8	79.8	79.1	79.1	79.3	78.8	76.7	70.0	51.9	90.1	104.0
May	Entire	119	74.0	73.7	73.7	88.7	85.9	85.6	85.6	83.9	82.7	80.1	62.7	97.0	108.0
	Early	55	72.3	72.0	71.7	85.4	83.0	82.8	84.0	82.8	80.7	77.8	61.9	92.9	103.0
	Late	64	75.4	75.1	75.1	88.7	85.9	85.6	86.5	85.3	83.3	81.4	64.1	99.1	111.0
Jun	Entire	106	80.9	80.6	81.5	94.2	92.8	92.4	92.6	91.9	90.2	87.0	68.7	105.0	117.0
	Early	60	78.8	78.6	78.9	91.9	91.4	89.2	91.6	89.0	88.1	84.4	68.7	102.0	114.0
	Late	46	83.6	83.3	85.6	94.2	92.8	92.4	93.6	92.5	92.0	89.3	68.6	106.0	118.0
Jul	Entire	117	88.6	88.5	88.4	98.3	98.0	97.8	97.8	96.4	95.4	91.2	81.3	99.3	105.0
	Early	59	86.8	86.7	87.8	91.7	91.6	91.6	91.6	91.6	90.9	89.0	80.6	96.4	101.0
	Late	58	90.5	90.4	89.8	98.3	98.0	97.8	98.1	97.7	96.4	94.4	84.1	104.0	111.0
Aug	Entire	151	88.9	88.8	89.1	101.0	99.7	98.8	97.9	95.0	94.2	91.6	82.4	99.7	105.0

08/17/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean[1]	Geo-metric Mean[1]	Median[1]	Maximum (Occurrence)[2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	71	90.6	90.5	89.8	101.0	99.7	98.8	99.8	97.0	95.0	93.4	84.9	101.0	106.0
	Late	80	87.4	87.3	88.0	94.5	93.9	93.8	93.9	93.2	92.3	90.6	81.2	100.0	106.0
Sep	Entire	145	83.7	83.4	83.8	96.4	96.4	95.3	94.9	94.0	91.9	90.0	71.2	107.0	119.0
	Early	75	88.2	88.0	89.6	96.4	96.4	95.3	96.4	94.3	94.0	91.2	78.4	98.3	103.0
	Late	70	78.9	78.7	79.2	91.9	91.2	91.0	91.3	90.7	88.0	82.8	68.1	95.6	104.0
Oct	Entire	140	73.4	72.9	73.8	90.0	89.9	89.7	89.3	86.8	84.3	79.2	58.7	97.1	109.0
	Early	75	73.2	72.8	75.2	87.3	86.6	85.3	86.6	84.6	83.1	79.0	59.5	98.8	112.0
	Late	65	73.6	73.1	72.3	90.0	89.9	89.7	89.9	88.7	86.2	79.7	57.9	96.9	108.0
Nov	Entire	146	65.7	65.3	65.6	83.4	82.1	82.1	80.0	75.4	74.4	72.0	54.0	91.7	105.0
	Early	71	67.6	67.1	68.5	83.4	82.1	82.1	82.2	76.8	75.2	72.7	55.0	86.6	95.8
	Late	75	63.9	63.5	63.6	77.2	74.8	74.5	74.8	74.4	73.5	70.1	53.2	87.3	98.7
Dec	Entire	155	60.2	59.9	59.7	75.0	74.9	74.7	73.7	70.9	69.2	64.6	51.5	78.0	87.0
	Early	75	61.9	61.5	60.0	75.0	74.9	74.7	74.9	72.9	71.0	67.2	52.5	83.7	94.8
	Late	80	58.6	58.3	59.5	68.8	68.6	67.9	68.5	67.3	65.0	62.3	50.5	75.2	83.8

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geo-metric Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
Location: Jefferson St.															
Jan	Entire	62	48.7	48.6	48.5	54.6	54.4	54.2	54.5	54.1	52.8	51.1	43.8	58.2	62.9
	Early	30	48.0	48.0	48.3	53.1	51.1	50.9	52.9	51.1	50.6	48.8	44.0	51.1	52.6
	Late	32	49.4	49.2	50.0	54.6	54.4	54.2	54.6	54.4	54.1	52.2	43.6	61.1	67.0
Feb	Entire	56	47.8	47.7	48.2	53.8	52.3	52.1	52.9	51.9	51.5	50.5	42.7	58.3	63.5
	Early	30	47.7	47.6	48.9	53.8	51.5	51.3	53.6	51.5	51.2	50.5	42.3	60.4	67.0
	Late	26	47.9	47.8	47.8	52.3	52.1	51.5	52.3	52.1	51.5	50.4	43.7	57.8	62.7
Mar	Entire	78	53.9	53.7	53.3	67.6	66.0	65.4	66.0	65.3	63.4	56.5	46.4	66.4	73.0
	Early	30	49.4	49.4	49.3	54.2	53.6	53.6	54.1	53.6	53.4	51.6	45.0	58.2	62.6
	Late	48	56.7	56.5	54.5	67.6	66.0	65.4	66.9	65.5	65.0	61.7	49.9	74.3	82.7
Apr	Entire	90	61.5	61.4	61.1	72.9	71.6	70.9	71.4	68.0	66.9	64.4	53.9	72.7	78.2
	Early	45	60.4	60.3	60.7	66.7	66.5	65.6	66.6	65.8	65.3	63.8	53.4	72.8	78.9
	Late	45	62.7	62.5	61.7	72.9	71.6	70.9	72.4	71.1	68.0	65.9	56.6	75.0	81.2
May	Entire	93	69.2	69.0	70.1	78.6	78.3	77.3	77.9	77.1	76.1	71.7	60.6	80.6	86.5
	Early	45	68.8	68.7	70.1	77.3	77.1	77.1	77.2	77.1	75.9	71.7	59.9	81.0	87.3
	Late	48	69.5	69.3	70.3	78.6	78.3	76.8	78.5	77.0	76.3	72.4	60.7	82.1	88.6
Jun	Entire	90	76.6	76.4	76.8	88.5	87.8	87.5	87.7	87.2	85.8	80.5	65.7	92.2	100.0
	Early	45	72.8	72.7	73.0	82.1	81.4	79.0	81.8	79.6	78.7	76.3	64.0	86.2	92.7
	Late	45	80.5	80.3	80.1	88.5	87.8	87.5	88.2	87.6	87.2	85.0	73.0	96.3	104.0
Jul	Entire	93	85.3	85.2	84.6	91.4	90.8	90.8	90.8	90.5	89.6	88.2	80.1	96.0	101.0
	Early	45	84.1	84.1	83.5	90.8	90.5	90.3	90.7	90.4	89.5	86.1	79.4	92.4	96.6
	Late	48	86.3	86.3	86.8	91.4	90.8	90.6	91.1	90.6	89.9	88.8	81.6	96.0	101.0
Aug	Entire	92	84.7	84.6	84.5	92.2	90.9	90.9	90.9	90.7	89.4	87.5	78.7	95.8	101.0

[1] Means/medians are means/medians of daily maximum values

08/17/2005

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geo-metric Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	45	86.6	86.6	86.3	92.2	90.9	90.9	91.7	90.9	90.7	89.2	81.4	96.8	102.0
	Late	47	82.9	82.8	82.7	88.9	88.0	87.8	88.5	87.8	87.3	85.3	78.3	92.2	96.8
Sep	Entire	85	79.3	79.0	80.7	90.5	89.6	88.8	89.4	88.6	87.6	84.6	68.0	101.0	111.0
	Early	40	84.0	83.9	84.1	90.5	89.6	88.8	90.2	89.2	88.7	86.3	74.8	91.9	95.7
	Late	45	75.1	74.9	75.2	86.5	86.4	84.8	86.5	85.2	83.2	79.9	67.2	94.8	105.0
Oct	Entire	93	68.6	68.3	69.4	83.6	81.1	80.4	80.8	78.3	76.6	73.0	57.8	86.8	96.0
	Early	45	70.2	70.0	70.3	83.6	81.1	80.4	82.6	80.6	77.4	73.4	62.2	85.4	93.4
	Late	48	67.1	66.8	68.6	78.8	77.2	76.6	78.1	76.7	75.6	72.9	55.4	89.9	101.0
Nov	Entire	90	60.4	60.2	61.2	72.1	71.7	70.6	71.4	67.0	65.0	63.2	52.3	71.6	77.2
	Early	45	62.7	62.6	62.6	72.1	71.7	70.6	71.9	70.9	67.0	64.3	56.2	70.0	73.7
	Late	45	58.1	57.9	59.2	64.1	63.4	63.3	63.8	63.3	63.2	61.6	51.9	73.9	82.1
Dec	Entire	81	49.8	49.5	50.7	62.2	60.4	60.3	60.4	59.4	57.3	53.3	39.2	63.1	69.7
	Early	35	52.8	52.6	52.2	62.2	60.4	60.3	61.8	60.4	59.7	55.4	46.9	63.5	68.9
	Late	46	47.6	47.3	48.5	57.8	55.9	55.7	57.0	55.7	54.3	51.6	38.1	65.4	74.6

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geometric Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
Location: Lockport															
Jan	Entire	118	51.1	51.0	50.5	59.6	59.4	59.2	59.2	58.2	55.7	53.5	46.1	61.0	66.0
	Early	60	51.0	50.9	51.1	58.6	55.8	55.5	56.6	55.5	54.2	53.3	46.9	60.7	65.6
	Late	58	51.2	51.0	50.2	59.6	59.4	59.2	59.5	59.1	57.9	54.4	44.4	63.3	69.2
Feb	Entire	113	52.6	52.5	53.0	62.3	60.9	59.7	60.0	58.3	56.3	54.7	46.9	61.4	65.8
	Early	60	51.6	51.5	51.9	57.3	56.8	56.3	57.0	56.3	55.3	54.2	46.5	62.0	67.2
	Late	53	53.7	53.6	53.9	62.3	60.9	59.7	61.5	59.6	58.4	55.1	46.9	60.1	63.5
Mar	Entire	124	57.4	57.2	57.3	72.5	70.5	68.4	68.4	67.4	65.0	61.4	49.3	73.3	81.2
	Early	60	55.0	54.8	53.8	65.2	65.0	64.3	65.1	64.2	63.3	58.3	48.2	69.3	76.6
	Late	64	59.7	59.5	58.6	72.5	70.5	68.4	70.9	68.1	67.3	63.1	53.6	74.1	81.4
Apr	Entire	114	62.7	62.6	63.2	74.7	74.5	71.2	71.9	69.6	68.6	66.2	55.2	76.9	84.0
	Early	54	62.4	62.3	62.0	70.5	69.7	69.4	70.0	69.2	68.0	64.9	55.6	73.3	78.9
	Late	60	63.0	62.8	63.6	74.7	74.5	71.2	74.6	70.8	69.0	67.1	54.8	81.2	90.7
May	Entire	124	70.3	70.1	70.7	81.9	81.0	79.0	79.0	78.0	77.3	74.2	61.3	86.1	94.0
	Early	60	68.7	68.5	69.4	79.0	78.0	77.9	78.3	77.7	76.8	72.8	59.0	85.3	93.7
	Late	64	71.7	71.6	72.3	81.9	81.0	78.8	81.2	78.7	77.8	75.1	63.5	85.3	92.2
Jun	Entire	103	76.8	76.7	77.0	89.2	88.4	88.0	88.2	86.3	83.0	79.4	68.6	88.9	95.3
	Early	60	75.1	74.9	75.6	84.0	83.4	82.7	83.6	82.1	80.3	78.7	67.3	88.9	95.7
	Late	43	79.3	79.2	78.5	89.2	88.4	88.0	88.9	88.1	86.6	82.9	70.7	92.2	98.4
Jul	Entire	81	84.9	84.9	84.8	89.7	89.5	89.4	89.5	89.2	88.5	86.3	81.5	90.8	93.7
	Early	45	83.9	83.9	83.6	88.7	88.0	86.5	88.4	86.9	86.2	85.0	81.4	88.6	91.1
	Late	36	86.2	86.2	86.3	89.7	89.5	89.4	89.7	89.5	89.3	87.8	82.1	92.4	95.4
Aug	Entire	129	85.1	85.0	84.9	93.4	93.0	92.5	92.5	91.2	89.8	87.3	80.0	94.3	98.9

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geometric Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	50	86.5	86.5	85.9	93.4	93.0	92.5	93.2	92.5	91.5	89.6	82.3	98.6	105.0
	Late	79	84.2	84.1	84.2	91.2	89.8	89.4	89.8	88.7	88.0	86.2	78.9	92.2	96.2
Sep	Entire	139	81.7	81.5	83.0	91.7	91.5	90.9	90.8	90.0	87.9	85.9	72.9	98.7	107.0
	Early	64	85.0	84.9	84.9	91.7	91.5	90.9	91.5	90.7	90.0	87.2	77.9	93.4	97.5
	Late	75	78.9	78.8	77.8	89.3	87.9	86.5	87.9	86.3	85.2	82.9	72.2	93.9	101.0
Oct	Entire	136	71.7	71.5	71.7	85.9	84.1	83.5	83.0	79.3	77.3	74.9	63.1	84.5	90.9
	Early	70	72.7	72.5	72.2	85.9	84.1	83.5	84.3	81.3	78.7	76.5	65.7	87.8	95.3
	Late	66	70.7	70.5	71.4	79.5	78.8	77.4	78.9	77.2	76.4	73.0	62.3	82.6	89.0
Nov	Entire	150	64.6	64.5	64.5	74.5	72.7	72.6	72.5	70.7	69.1	66.6	58.6	72.3	76.1
	Early	75	66.2	66.1	65.8	74.5	72.7	72.6	72.7	72.2	70.7	68.5	61.6	74.9	79.3
	Late	75	62.9	62.9	63.3	69.7	67.9	67.6	67.9	67.1	66.7	65.2	56.8	70.5	74.1
Dec	Entire	155	56.3	55.9	56.1	68.2	67.9	67.7	67.7	66.3	64.7	59.9	45.7	70.3	77.3
	Early	75	59.9	59.7	59.0	68.2	67.9	67.7	67.9	67.6	66.3	64.0	53.1	75.9	83.8
	Late	80	52.9	52.6	53.6	61.7	61.7	60.8	61.6	60.5	59.6	56.6	43.0	67.6	74.9

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geometric Mean [1]	Median [1]	[2]Maximum (Occurrence) Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
Location: River Mile 302															
Jan	Entire	124	46.8	46.7	46.1	52.2	51.9	51.7	51.7	51.2	51.0	49.3	42.8	56.1	60.6
	Early	60	46.6	46.5	46.3	51.9	51.7	51.5	51.8	51.4	51.0	49.1	42.2	56.2	60.9
	Late	64	47.0	46.9	46.1	52.2	51.3	51.3	51.5	51.2	50.9	49.4	43.8	55.7	59.9
Feb	Entire	113	48.6	48.5	48.9	56.4	56.0	54.5	54.9	53.3	51.4	50.1	43.7	55.5	59.1
	Early	60	48.0	48.0	48.2	53.0	51.6	51.6	52.0	51.5	51.1	49.9	43.6	55.1	58.5
	Late	53	49.2	49.1	49.4	56.4	56.0	54.5	56.2	54.5	53.5	50.4	43.8	54.1	56.6
Mar	Entire	124	52.0	51.8	51.5	60.6	60.6	60.2	60.2	59.1	57.8	55.3	45.3	64.2	70.1
	Early	60	50.2	50.0	49.2	60.6	60.2	59.1	60.3	58.4	56.9	53.5	42.1	61.6	67.0
	Late	64	53.6	53.5	52.9	60.6	60.0	59.8	60.1	59.4	58.8	56.2	49.7	63.4	68.3
Apr	Entire	114	58.3	58.2	58.5	67.7	67.5	66.2	66.5	64.6	62.3	60.5	52.6	67.7	72.5
	Early	60	57.3	57.2	57.5	61.9	61.6	61.3	61.7	61.2	60.8	59.6	52.1	65.6	69.6
	Late	54	59.3	59.2	59.5	67.7	67.5	66.2	67.6	65.9	64.7	61.6	53.4	70.5	76.4
May	Entire	111	65.6	65.4	66.2	75.4	73.5	73.0	73.1	72.6	71.5	68.8	55.3	78.3	84.6
	Early	55	65.0	64.9	65.2	75.4	73.5	72.3	74.3	72.2	70.3	68.3	58.3	77.7	84.1
	Late	56	66.1	65.9	66.6	73.0	72.7	72.6	72.8	72.6	72.0	69.7	53.3	78.7	84.8
Jun	Entire	114	73.7	73.6	73.8	81.1	80.9	80.8	80.8	79.5	78.5	76.4	67.2	84.4	89.7
	Early	54	71.8	71.7	72.1	77.8	77.7	77.5	77.7	77.3	76.2	74.2	66.1	81.0	85.5
	Late	60	75.5	75.4	76.0	81.1	80.9	80.8	81.0	80.8	79.5	78.3	70.0	87.0	92.8
Jul	Entire	86	79.6	79.6	79.7	84.2	84.2	83.7	84.1	83.3	82.5	80.9	76.0	85.3	88.2
	Early	47	78.6	78.6	78.7	81.6	81.3	81.0	81.5	81.0	80.9	80.4	75.6	85.2	88.4
	Late	39	80.8	80.8	80.6	84.2	84.2	83.7	84.2	84.0	83.4	82.4	77.7	86.6	89.4
Aug	Entire	100	80.7	80.6	80.6	88.0	87.1	86.2	86.7	85.1	83.8	82.5	76.5	87.8	91.4

08/17/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geo-metric Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	45	82.1	82.0	81.8	88.0	87.1	86.2	87.6	86.4	85.4	83.5	78.7	88.4	91.7
	Late	55	79.6	79.5	79.9	82.9	82.8	82.8	82.8	82.8	82.5	80.7	76.3	84.6	87.1
Sep	Entire	150	76.3	76.2	76.9	83.9	83.9	83.8	83.7	82.2	80.9	79.6	68.0	88.5	94.4
	Early	75	79.0	79.0	79.3	83.9	83.9	83.8	83.9	83.3	82.2	80.5	74.5	85.6	89.0
	Late	75	73.6	73.5	74.1	79.9	79.6	79.2	79.6	79.1	78.5	76.2	67.4	83.2	88.0
Oct	Entire	155	66.6	66.5	66.3	76.2	75.9	75.0	74.8	73.4	71.4	69.6	60.4	78.3	84.1
	Early	75	68.2	68.1	68.8	76.2	75.9	75.0	75.9	74.6	73.6	70.1	62.6	77.3	82.1
	Late	80	65.1	65.0	65.1	72.7	72.5	71.3	72.4	70.7	70.1	67.5	59.8	75.7	81.1
Nov	Entire	138	59.0	58.9	59.2	68.5	68.5	67.8	67.7	66.3	63.3	61.1	52.3	67.4	71.6
	Early	75	60.9	60.8	60.4	68.5	68.5	67.8	68.5	67.2	65.8	62.0	57.5	66.6	69.6
	Late	63	56.7	56.6	56.8	63.6	63.6	63.3	63.6	63.2	61.2	59.2	51.8	66.7	71.7
Dec	Entire	148	51.5	51.3	51.2	62.4	62.1	61.6	61.4	59.3	57.7	55.4	43.6	66.0	73.1
	Early	68	54.5	54.4	54.9	62.4	62.1	61.6	62.1	61.2	59.4	57.2	48.5	66.3	72.4
	Late	80	49.0	48.9	48.7	55.7	55.6	55.6	55.6	55.4	54.8	51.7	42.4	59.6	64.8

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geometric Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
						Location: Romeoville									
Jan	Entire	124	45.5	45.4	44.6	50.0	50.0	50.0	50.0	50.0	50.0	48.2	41.0	56.3	61.7
	Early	60	45.2	45.1	44.6	50.0	50.0	50.0	50.0	50.0	50.0	48.2	41.0	56.3	61.7
	Late	64	45.8	45.7	44.6	50.0	50.0	50.0	50.0	50.0	50.0	48.2	42.8	53.6	57.2
Feb	Entire	113	47.6	47.6	48.2	55.4	55.4	55.4	55.4	51.5	50.0	50.0	42.8	55.4	59.0
	Early	60	47.0	46.9	46.4	50.0	50.0	50.0	50.0	50.0	50.0	48.2	42.8	52.3	55.0
	Late	53	48.4	48.3	48.2	55.4	55.4	55.4	55.4	55.1	52.2	50.0	43.1	55.4	59.0
Mar	Entire	124	51.5	51.3	50.9	69.8	60.8	59.0	59.0	59.0	57.2	54.5	46.4	64.0	70.3
	Early	60	49.8	49.6	48.2	59.0	59.0	57.2	59.0	57.2	57.2	52.7	44.6	62.2	68.5
	Late	64	53.0	52.9	51.8	69.8	60.8	59.0	62.8	59.0	59.0	55.4	50.0	63.5	68.9
Apr	Entire	120	57.7	57.5	57.2	68.0	66.2	66.2	66.2	64.4	62.6	60.8	51.8	68.9	74.3
	Early	60	56.7	56.6	57.2	68.0	66.2	64.4	66.7	62.6	60.8	59.0	51.8	67.1	72.5
	Late	60	58.6	58.5	59.0	66.2	66.2	64.4	66.2	64.4	64.4	60.8	53.6	68.9	74.3
May	Entire	124	65.8	65.7	66.2	73.4	73.4	73.4	73.4	71.6	70.0	68.0	59.0	76.1	81.5
	Early	60	64.9	64.7	65.3	73.4	73.4	71.6	73.4	71.6	69.8	68.0	57.2	76.1	81.5
	Late	64	66.7	66.5	66.2	73.4	73.4	73.4	73.4	72.1	71.6	69.8	59.0	77.9	83.3
Jun	Entire	120	72.6	72.4	73.4	82.4	80.6	80.6	80.6	79.7	78.8	75.2	62.6	83.3	88.7
	Early	60	69.9	69.8	71.6	77.0	77.0	77.0	77.0	76.1	75.2	73.4	62.6	84.2	91.4
	Late	60	75.3	75.2	75.2	82.4	80.6	80.6	81.1	80.6	79.7	77.0	69.8	85.1	90.5
Jul	Entire	124	79.9	79.9	80.6	84.2	84.2	84.2	84.2	84.2	82.4	80.6	77.0	83.3	85.1
	Early	60	78.9	78.9	78.8	82.4	82.4	82.4	82.4	81.5	80.6	80.6	75.2	86.0	89.6
	Late	64	80.9	80.9	80.6	84.2	84.2	84.2	84.2	84.2	84.2	82.4	78.3	87.8	91.4
Aug	Entire	150	80.1	80.1	80.6	86.0	86.0	86.0	86.0	84.2	82.4	80.6	77.0	83.3	85.1

08/17/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geometric Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	70	80.8	80.8	80.6	86.0	86.0	86.0	86.0	86.0	84.2	82.4	77.0	87.8	91.4
	Late	80	79.4	79.4	78.8	86.0	84.2	82.4	84.0	82.4	82.4	80.6	77.0	83.3	85.1
Sep	Entire	146	76.6	76.5	77.0	84.2	82.4	82.4	82.4	82.4	80.6	78.8	69.4	86.9	92.3
	Early	75	78.9	78.9	78.8	84.2	82.4	82.4	82.4	82.4	82.4	80.6	73.9	86.0	89.6
	Late	71	74.1	74.1	73.4	80.6	80.6	80.6	80.6	80.5	78.8	77.0	68.0	85.1	90.5
Oct	Entire	140	66.0	65.9	66.2	75.2	75.2	73.4	73.4	73.4	71.6	69.8	60.8	80.6	87.8
	Early	66	68.1	68.0	68.0	75.2	75.2	73.4	75.2	73.4	73.4	69.8	62.6	77.9	83.3
	Late	74	64.2	64.1	64.4	71.6	71.6	69.8	71.6	69.8	68.2	66.2	59.0	74.3	79.7
Nov	Entire	143	58.2	58.1	59.0	68.0	68.0	68.0	67.4	66.2	62.6	60.8	51.8	68.9	74.3
	Early	68	60.5	60.5	60.8	68.0	68.0	68.0	68.0	66.4	66.2	60.8	57.0	63.5	65.3
	Late	75	56.1	56.0	57.2	62.6	62.6	62.6	62.6	62.2	59.0	58.6	50.0	66.0	70.9
Dec	Entire	149	50.5	50.2	50.0	64.4	62.6	62.6	61.7	59.0	57.2	54.1	41.0	65.5	73.2
	Early	75	52.9	52.6	53.6	64.4	62.6	62.6	62.6	60.8	59.0	57.2	44.6	70.7	79.7
	Late	74	48.1	47.9	48.2	55.4	55.4	55.4	55.4	55.0	53.6	51.8	41.0	62.6	69.8

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geo-metric Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
Location: Route 83 (CalSag)															
Jan	Entire	123	38.6	38.4	39.2	48.7	48.0	46.5	46.6	45.0	43.8	41.5	32.3	51.7	58.6
	Early	60	38.1	37.8	38.2	48.7	46.5	45.8	47.2	45.8	44.8	42.4	32.3	56.5	65.9
	Late	63	39.1	38.9	39.5	48.0	44.6	44.3	45.4	44.1	42.7	41.5	33.2	47.6	51.7
Feb	Entire	109	41.8	41.7	41.7	52.2	51.7	51.7	51.7	47.5	45.9	43.3	37.1	49.1	52.9
	Early	60	41.1	41.0	41.4	47.4	47.3	47.1	47.3	47.0	44.7	42.8	36.9	48.2	51.9
	Late	49	42.7	42.6	42.0	52.2	51.7	51.7	52.0	51.7	48.2	44.3	38.5	50.0	53.7
Mar	Entire	122	47.2	47.0	46.8	57.7	57.3	57.3	57.3	55.5	54.4	50.5	40.4	60.9	67.8
	Early	58	45.5	45.2	43.6	57.3	57.3	55.4	57.3	55.2	53.4	50.6	39.6	63.8	72.6
	Late	64	48.9	48.7	48.5	57.7	57.1	56.5	57.2	55.9	54.8	50.3	44.0	57.1	61.7
Apr	Entire	120	55.8	55.7	55.7	69.3	67.0	66.1	66.2	62.9	61.8	58.6	47.2	66.1	71.1
	Early	60	54.2	54.0	55.3	61.4	59.3	59.0	59.9	59.0	58.9	57.9	46.5	68.1	74.9
	Late	60	57.5	57.3	56.0	69.3	67.0	66.1	67.7	65.7	62.9	61.1	51.4	70.8	77.2
May	Entire	124	64.6	64.4	65.5	71.7	71.7	71.5	71.5	70.7	69.3	67.4	56.7	75.8	81.4
	Early	60	63.9	63.7	65.0	71.7	71.5	69.4	71.6	69.3	68.1	67.1	55.7	75.8	81.7
	Late	64	65.2	65.1	66.2	71.7	71.1	71.1	71.2	70.9	70.4	68.4	57.2	77.7	84.0
Jun	Entire	120	72.4	72.3	72.9	80.8	79.4	79.2	79.2	78.9	78.2	75.7	61.6	84.2	89.8
	Early	60	69.9	69.8	70.4	78.5	77.5	77.2	77.8	76.8	75.5	72.9	60.4	80.4	85.4
	Late	60	74.9	74.8	74.6	80.8	79.4	79.2	79.8	79.1	78.9	77.5	70.7	84.5	89.2
Jul	Entire	106	79.1	79.0	78.7	86.9	84.8	84.7	84.7	84.2	82.2	80.5	75.4	85.0	88.0
	Early	58	78.6	78.6	78.2	82.2	82.1	81.9	82.1	81.9	81.7	80.3	75.0	84.8	87.8
	Late	48	79.7	79.6	79.3	86.9	84.8	84.7	85.9	84.7	84.5	81.1	75.6	86.1	89.4
Aug	Entire	144	78.4	78.4	78.3	84.9	84.1	84.0	83.8	82.7	82.0	79.9	75.1	85.0	88.4

08/17/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geo-metric Mean [1]	Median [1]	[2]Maximum (Occurrence)			Percentile					Outlier Cutoff	
						Single	Twice	Three	98th	95th	90th	75th	5th	75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	64	79.7	79.7	79.4	84.9	84.1	84.0	84.3	83.6	83.1	81.9	75.9	87.8	91.7
	Late	80	77.3	77.3	77.4	80.8	80.4	80.4	80.4	80.1	79.6	78.6	75.0	82.5	85.2
Sep	Entire	144	73.0	72.8	73.6	83.1	81.3	80.9	80.8	79.0	78.0	76.4	64.5	86.6	93.4
	Early	69	76.2	76.2	76.4	83.1	81.3	80.9	81.5	80.6	79.1	77.9	71.1	82.4	85.5
	Late	75	70.0	69.9	69.7	76.2	75.7	75.4	75.7	75.3	74.5	72.5	64.1	78.7	82.8
Oct	Entire	155	61.8	61.7	61.8	71.8	71.2	71.0	70.9	69.2	66.6	64.7	54.4	73.1	78.8
	Early	75	63.8	63.7	64.3	71.8	71.2	71.0	71.2	70.9	69.0	65.6	57.7	71.8	76.0
	Late	80	60.0	59.8	60.1	69.6	68.1	67.3	68.0	67.0	64.6	63.0	52.3	71.4	77.1
Nov	Entire	144	53.2	53.0	53.6	64.8	63.9	63.7	63.6	60.9	58.6	56.1	44.3	63.9	69.1
	Early	69	55.4	55.3	54.8	64.8	63.9	63.7	64.0	63.5	60.6	57.5	50.6	64.7	69.5
	Late	75	51.2	50.9	51.7	62.5	59.4	58.8	59.4	57.2	56.2	54.6	41.0	64.2	70.6
Dec	Entire	142	44.0	43.4	44.3	57.9	57.4	57.0	56.9	54.7	52.3	49.6	32.7	66.4	77.6
	Early	65	48.2	47.8	49.6	57.9	57.4	57.0	57.5	56.8	55.0	51.9	37.5	63.3	70.9
	Late	77	40.4	40.1	39.8	52.1	51.8	49.9	51.7	48.7	47.6	44.7	32.3	57.9	66.6

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geo-metric Mean [1]	Median [1]	[2] Maximum (Occurrence)			Percentile					Outlier Cutoff	
						Single	Twice	Three	98th	95th	90th	75th	5th	75th+ 1.5*IQR	75th+ 2.5*IQR
Location: Route 83 (CSSC)															
Jan	Entire	124	49.6	49.5	49.3	55.0	55.0	54.8	54.8	54.5	54.1	52.5	44.1	60.2	65.4
	Early	60	49.8	49.7	49.9	55.0	55.0	54.8	55.0	54.8	54.1	52.5	44.9	60.5	65.9
	Late	64	49.4	49.3	49.1	54.6	54.6	54.5	54.6	54.4	54.1	52.5	42.0	60.0	65.0
Feb	Entire	113	51.2	51.1	51.7	58.6	57.4	56.8	56.9	56.2	54.8	53.0	45.2	58.0	61.3
	Early	60	50.7	50.6	51.0	56.5	56.2	55.0	56.3	54.9	54.7	53.1	43.0	59.2	63.2
	Late	53	51.8	51.7	51.9	58.6	57.4	56.8	57.9	56.8	56.1	52.7	46.9	55.3	57.1
Mar	Entire	113	55.0	54.8	54.1	77.3	62.5	62.4	62.4	61.4	60.5	57.2	50.2	64.3	69.0
	Early	50	54.2	54.0	52.7	77.3	62.4	62.1	69.9	62.1	60.5	56.7	49.2	65.7	71.7
	Late	63	55.6	55.6	54.7	62.5	61.5	61.4	61.7	61.4	60.5	57.5	51.9	64.1	68.5
Apr	Entire	98	59.0	59.0	58.9	65.2	64.8	64.7	64.8	63.7	62.9	61.3	54.2	68.4	73.1
	Early	48	59.2	59.2	59.1	63.5	62.8	62.6	63.2	62.6	62.2	60.8	55.1	65.4	68.4
	Late	50	58.9	58.8	58.1	65.2	64.8	64.7	65.0	64.7	63.6	62.1	53.9	71.7	78.1
May	Entire	91	67.1	67.0	67.8	75.6	75.0	74.0	74.7	73.4	72.8	69.7	59.4	77.6	83.0
	Early	49	66.0	65.8	67.4	75.6	75.0	73.4	75.3	73.5	70.9	69.2	58.2	79.1	85.8
	Late	42	68.5	68.4	68.7	74.0	73.9	73.3	74.0	73.5	73.1	71.4	63.5	79.8	85.4
Jun	Entire	94	73.8	73.6	73.9	83.5	83.1	81.5	82.5	80.6	79.7	76.8	65.2	85.5	91.3
	Early	40	71.0	70.9	71.2	77.4	76.9	76.2	77.3	76.6	75.8	74.2	64.6	84.0	90.5
	Late	54	75.8	75.7	76.3	83.5	83.1	81.5	83.3	81.4	80.5	79.0	69.1	88.0	94.0
Jul	Entire	117	80.7	80.7	80.7	87.3	86.5	86.1	86.2	85.7	85.1	82.5	76.1	87.8	91.3
	Early	53	78.8	78.8	79.0	81.6	81.5	81.5	81.5	81.4	81.0	80.1	75.3	83.4	85.5
	Late	64	82.3	82.3	81.9	87.3	86.5	86.1	86.7	86.0	85.6	84.1	79.0	89.1	92.4
Aug	Entire	110	81.7	81.7	81.6	88.9	88.3	87.5	87.7	86.1	85.3	82.9	78.2	87.9	91.2

08/17/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

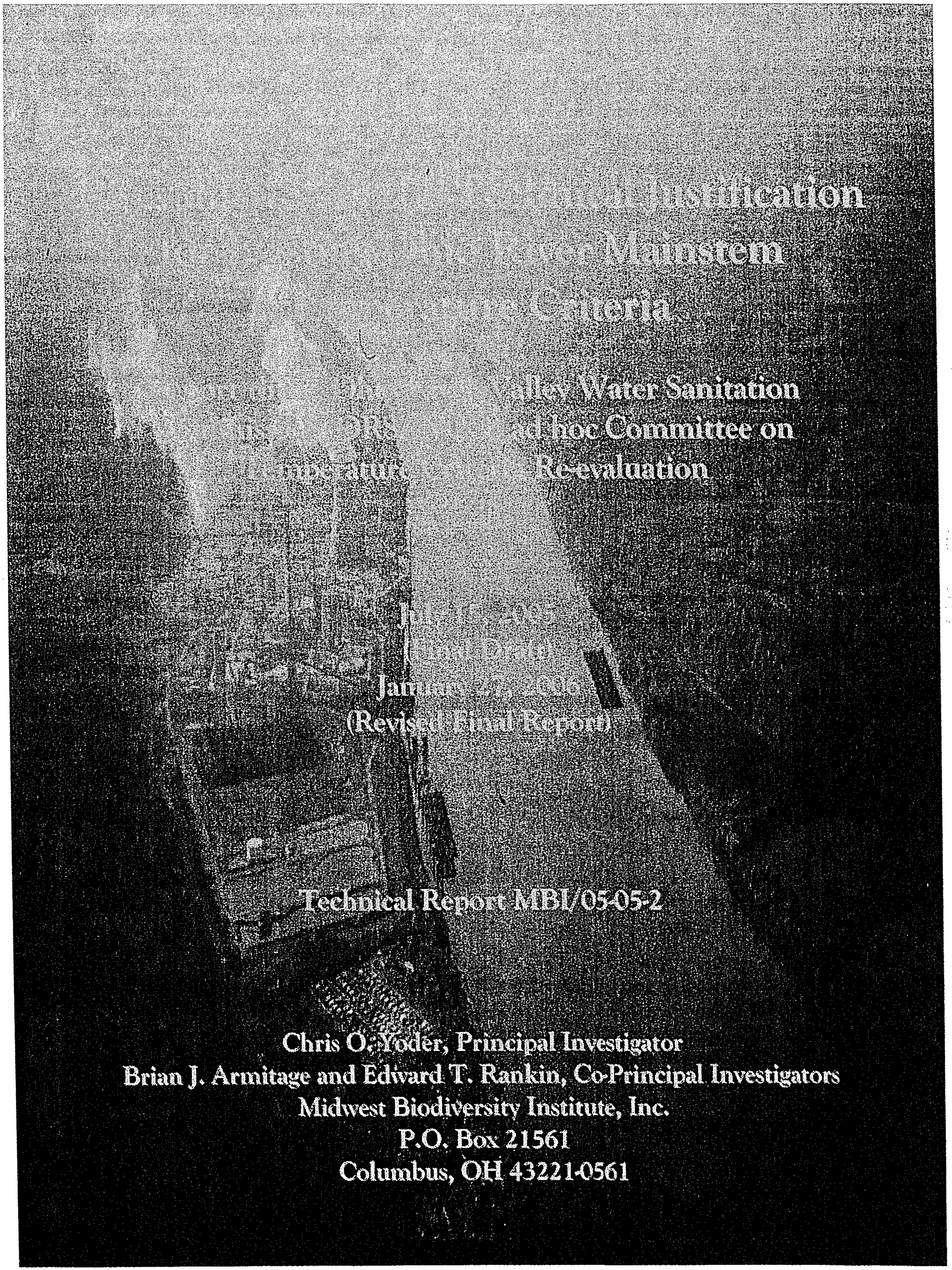
Appendix Table 2. Monthly and bi-monthly ambient temperature statistics for the Des Plaines river system at selected sites. Data collected from 1998 to 2004.

Month	Period	Samples	Mean [1]	Geometric Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	64	82.7	82.7	82.3	88.9	88.3	87.5	88.4	87.2	85.9	84.6	79.2	89.6	93.0
	Late	46	80.3	80.3	80.1	85.0	83.8	82.8	84.5	83.0	82.4	81.6	77.3	85.2	87.6
Sep	Entire	145	77.3	77.1	77.8	85.0	84.9	84.9	84.9	83.8	82.4	80.7	69.1	90.2	96.5
	Early	70	80.3	80.2	80.5	85.0	84.9	84.9	84.9	84.8	83.8	82.1	76.4	87.5	91.1
	Late	75	74.5	74.4	74.5	82.2	81.0	80.8	81.0	80.7	79.6	77.0	68.6	84.5	89.6
Oct	Entire	130	68.2	68.1	67.8	76.5	75.7	75.1	75.1	75.0	73.6	71.4	62.1	80.3	86.2
	Early	55	69.9	69.8	69.7	76.5	75.7	75.1	76.0	75.1	74.8	72.4	64.3	79.5	84.2
	Late	75	67.0	66.9	66.9	75.1	75.0	75.0	75.0	73.5	72.4	69.6	61.6	78.0	83.6
Nov	Entire	143	61.4	61.3	61.0	71.0	71.0	70.7	70.7	67.9	65.7	63.3	55.9	69.0	72.9
	Early	68	63.3	63.2	62.3	71.0	71.0	70.7	71.0	70.6	68.1	64.7	59.8	70.3	74.0
	Late	75	59.6	59.6	59.4	67.7	66.3	66.2	66.3	65.8	63.4	61.0	55.0	65.8	69.0
Dec	Entire	149	54.1	53.9	52.9	65.6	64.9	64.0	63.5	62.6	60.8	58.3	46.9	70.0	77.8
	Early	75	56.5	56.4	56.5	65.6	64.9	64.0	64.9	63.0	62.6	60.2	49.7	71.7	79.4
	Late	74	51.6	51.5	50.8	59.3	59.1	58.8	59.1	58.6	57.9	54.5	46.0	62.6	68.0

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

ATTACHMENT
3



... Justification ... Mainstem ... Criteria

... Valley Water Sanitation ... ad hoc Committee on Temperature ... Re-evaluation

July ... 2005
(Final Draft)
January 27, 2006
(Revised Final Report)

Technical Report MBI/05-05-2

Chris O. Yoder, Principal Investigator
Brian J. Armitage and Edward T. Rankin, Co-Principal Investigators
Midwest Biodiversity Institute, Inc.
P.O. Box 21561
Columbus, OH 43221-0561

Re-evaluation of the Technical Justification for Existing Ohio River Mainstem Temperature Criteria

Chris O. Yoder, Principal Investigator
Brian J. Armitage and Edward T. Rankin, Co-Principal Investigators
Midwest Biodiversity Institute, Inc.
P.O. Box 21561
Columbus, OH 43221-0561

Project Summary and Conclusions

A major project was undertaken beginning in 2004 to evaluate the methodology and underlying data on which the existing Ohio River temperature criteria are based. The criteria are based on data and methods originally developed by Ohio EPA (1978a), which was used to derive river and basin specific temperature criteria for Ohio rivers, streams, and the open and shoreline waters of Lake Erie. These were adopted by Ohio EPA in the 1978 revisions to the Ohio water quality standards. ORSANCO used the results that Ohio EPA calculated for the Ohio River mainstem in revisions to the ORSANCO temperature criteria in 1984. The Ohio EPA methodology uses data from the thermal effects literature to create a thermal effects database for freshwater fish. This data is then used within a procedure that calculates four behavioral and physiological thresholds for a list of representative fish species that are intended to represent the fish assemblage of a particular river or river segment.

Re-evaluation Process

The issue of re-evaluating the Ohio River temperature criteria has been discussed since the early 1990s. Draft re-calculations based on a partial update to the thermal effects database compiled by Ohio EPA (1978a) were initially attempted by Ohio EPA (at ORSANCO's request) in 1995. In 2003, ORSANCO issued a request for proposals (RFP) to complete a comprehensive evaluation and update of the thermal effects database and the original methodology developed by Ohio EPA (1978a). An Ad Hoc committee of ORSANCO members including state and federal agencies, the electric power industry, and academia was assembled to review progress and provide feedback. The Midwest Biodiversity Institute (MBI) was selected as the contractor for the project, which was completed in two major phases. Phase I entailed the compilation of thermal effects data for fish and other aquatic taxa, as available, to determine if sufficient new information was available to warrant making revisions to the Ohio River mainstem temperature criteria. New information consisted of that not included in the original Ohio EPA (1978a) compilation, which was limited to data from studies conducted prior to 1977. Phase I also included a review of existing state and federal temperature standards, "common methodologies" for deriving temperature criteria, and an analysis of the ambient temperature regime of the Ohio River mainstem based on recently available data. The work plan stipulated that if sufficient new data and/or methodologies were found, the Ad Hoc committee would recommend proceeding to phase II. This would entail the derivation of draft Ohio River mainstem temperature criteria options and the modernization of the Ohio EPA Fish Temperature Modeling programs.

Phase I Summary

A comprehensive review of the thermal effects literature was undertaken as a major activity within phase I. The review consisted of conducting a literature search using the Chemical Abstracts service and other means including compilations accomplished by other researchers, internet searches, and "word of mouth". After screening more than 500 titles and abstracts, we accessed and reviewed more than 200 individual references in addition to several major compendia. In all, data for 125 temperate climate freshwater fish species, 2 subspecies, 5 hybrids, and 28 macroinvertebrate taxa were compiled (Appendix Table Z.1). Our review of individual studies included classifying the types of experimental laboratory tests and/or field studies, which are categorized in the key to Appendix Table Z.1. This is important because of the diversity of differing types of experimental designs and thermal endpoints determined by each. Standardization of experimental endpoints is possible to only a general degree and an acceptance of some variability between different studies is required to effectively use the database. So called "grey literature" was admitted provided the citation could be validated, either by direct examination of the original study or cited "as is" by one of the major compendia noted above. We endeavored to accept studies that provided details concerning the study design, methods, and analyses. However, within the time and funding constraints of this review, it was necessary to accept most studies at "face value" as reported by the individual study or literature compendium. 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 relevant literature sources that exist. Instead, we see this as an ongoing process that captures some of the older missing references and updates the database with newly published information. Upon reviewing the results of phase I in 2004, the Ad Hoc committee recommended proceeding with phase II in 2005.

Phase II Summary: Draft Re-evaluation of Ohio River Temperature Criteria

As part of the recommendation to proceed with the re-examination of the current temperature criteria, the Ad Hoc committee also approved using an updated version of the Ohio EPA Fish Temperature Modeling system. This system requires the derivation of a list of representative fish species (RAS) and the selection of four thermal input variables for each RAS; a physiological optimum temperature, a calculated Maximum Weekly Average for Growth (MWAT; Brungs and Jones 1976), an upper avoidance temperature (UAT), and an Upper Incipient Lethal Temperature (UILT) or its equivalent. All four endpoints were available from the literature for only a few commonly tested species. However, for most species only one, two, or three of these variables were available. Ohio EPA (1978a) developed an extrapolation procedure for determining missing values since the Fish Temperature Model requires all four input variables to function. The extrapolations are based on family level relationships between the seven major thermal variables that were compiled in Appendix Table Z.1. The next step is to assign the four baseline thermal input variables to all species that are expected to occur in a common region or area, some of which would be used as RAS for determining draft temperature criteria options for the Ohio River mainstem (Appendix Table Z.3). Temperature criteria options that emanate from the Fish Temperature Modeling system are the result of

RAS selections and the thermal endpoints selected for each RAS. Thus decisions made about each can potentially affect the outcome of the process.

Criteria for RAS used by Ohio EPA (1978a) are consistent with the definition in the Ohio Water Quality Standards and the Ohio EPA 316 guidelines (Ohio EPA 1978b). We generally followed these principles with some modification and modernization of the language and criteria as follows:

- species that represent the full range of response and sensitivity to environmental stressors;
- species that are commercially and/or recreationally important;
- species that are representative of the different trophic levels;
- rare, threatened, endangered, and special status species;
- species that are numerically abundant or prominent in the system;
- potential nuisance species; and,
- species that are indicative of the ecological and physiological requirements of representative species that lack thermal data.

A subgroup of the Ad Hoc committee developed lists of representative Ohio River fish by group consensus after examining the ORSANCO fish assemblage database and other pertinent historical references. This effort produced one list that we term here "all possible RAS" in that it was inclusive of all species that have been found to occur in the mainstem. Another list termed here as "mainstem restricted" RAS included "mainstem dependent" fish species. The original list of RAS used by Ohio EPA (1978a) was also used as an example output.

The Fish Temperature Model produces period average and daily maximum summer temperature criteria options using an analytical process similar to that first developed by Bush et al. (1974). In addition to varying the list of RAS, the model permits alternative thermal tolerance values to be substituted for any of the four principle thermal variables and these can be maintained as alternate databases to be used for computing the effect of any species-specific differences on the derivation of the summer season criteria options. The tolerance values that we retrieved from the database were used here to derive summer average and daily maxima criteria options for three segments of the Ohio River mainstem. The temperatures at which 100%, 90%, 75% and 50% of different lists of representative fish species are then calculated for the four thermal thresholds to show what proportion of the representative assemblage is protected at a given temperature. The following guidelines were established to guide the process for deriving summer average and maximum temperature criteria options:

The period average* should be consistent with:

- 100% long-term survival of all representative fish species;
- growth of commercially or recreationally important fish species;
- growth of at least 50% of the non-game fish species;
- 100% long-term survival of all state and federally listed fish species; and
- the observed historical ambient temperature record.

* - averaging period is June 16 – September 15.

Daily maxima should be consistent with:

- 100% short-term survival of all representative fish species; and
- the observed historical ambient temperature record.

The average applies over the *entire summer period*, which is defined as occurring between June 16 and September 15. This value should be compared to ambient averages over the same temporal period to determine compatibility with the observed ambient temperature regime. Non-summer season temperature criteria options were derived primarily from the historical temperature record and in consideration of other species-dependent criteria such as spawning periods. The results of the full derivation process for different RAS lists show the influence of this variable on the resulting criteria options. Differences in summer average and maximum criteria were on the order of 9°F for the upper lethal threshold between the two RAS lists that were tested. While we did not extensively test the use of alternate thermal endpoints for individual species, this is an additional variable that can be evaluated in the eventual derivation process. We recommend that sensitivity analyses be developed based on variations of the RAS and thermal endpoint variables as part of a formal temperature criteria derivation process.

Species that are generally regarded as being highly to moderately tolerant to a variety of environmental impacts tend to be over-represented in these databases, which is common to databases for many water quality parameters. In our study, these species were the most commonly studied and frequently had data available for all six thermal parameters. The data that existed for species regarded as highly or moderately intolerant tended to be available for fewer parameters, were based on field studies, or were non-existent. As such, and until these species are adequately tested, there remains a significant risk that the most sensitive groups of species will not be adequately protected. This approach is simply a best attempt to represent the entirety of the assemblage and it is limited by the extant thermal tolerance databases. As such, the model output will propagate a degree of uncertainty, which can be considered in the eventual derivation *and* application of the temperature criteria.

Outstanding Issues

Consideration of several issues involving the development and use of the temperature criteria were not directly addressed by this study, but were raised by the initial results. They represent critical issues that need to be resolved as a practical matter of accepting the credibility of the resulting temperature criteria derivation methods and processes detailed by this study. Issues exist with the selection of RAS for the different mainstem segments, the acceptability of specific practices used to select and determine the required thermal input variables, some of individual studies on which the thermal endpoints were based, and reconciliation of Fish Temperature Model outputs with the ambient temperature regime.

Because RAS lists are primarily determined from historical presence/absence data, questions remain about the "representativeness" of lists that are all inclusive versus approaches that restrict the RAS to what are thought to be "mainstem dependent" species. Our current knowledge of species distribution and abundance is largely from shoreline electrofishing and lock chamber studies. Studies using multiple gear types are from geographically isolated sites. Emerging techniques that could be used to improve the understanding of species distribution and abundances may well prove useful in determining the true representativeness and inclusion of certain species as RAS. In addition, emerging processes such as EPA's biological condition gradient (Davies and Jackson 2006) may improve the rationale for developing the RAS lists that are a key input variable in deriving temperature criteria.

The methodology used to develop the draft temperature criteria options that are reported herein included the use of various data sources and methodologies that were compiled, developed, and explained in phase I and accepted by the Ad Hoc committee. This included the use of field derived preference and upper avoidance thresholds and the extrapolation procedure used by Ohio EPA (1978a). Field derived values were accepted into the database provided the sampling design included the opportunity for species to have access to a wide range of temperatures including those that would exceed known thermal tolerance endpoints of the most tolerant species. These types of studies were largely conducted in the 1960s and 1970s in the direct influence of large thermal discharges. An important argument for including these studies is that they include the behavioral responses of adult fish, which fills an important gap left by most laboratory studies that test only juvenile or younger life stages. It is well known in the thermal effects literature that juvenile and younger life stages are thermally more tolerant than adults.

The missing data extrapolation procedure was developed to ensure that the four primary input variables required by the Ohio EPA Fish Temperature Model were populated so that the model could function. It is a reality of the thermal effects database that most species do not have experimentally derived endpoints for all four endpoints used in the model. Ohio EPA (1978a) examined the efficacy of this approach by graphically depicting the distribution of thermal thresholds based on literature and extrapolated values to ensure that the trend in tolerance values occurred within general ranges of warm water to cold water thermal responses and tolerances of the species with sufficient data. That information is reproduced in the discussion of phase II.5 and assists in determining if extrapolated values meet the test of making "biological sense" and are in keeping with the observed relationship between the thermal thresholds.

The compilation of literature based values for 125 fish species and other aquatic taxa that occur in the general region of the Ohio River basin necessarily includes a wide variety of different types of laboratory and field studies. Some species are more thoroughly tested than others and these tend to be the more thermally and environmentally tolerant species that are widely distributed and more amenable to laboratory rearing and handling. This is true not only of temperature, but of most pollutant testing that forms much of the basis for other water quality criteria. Because of this potential bias towards a select group of more tolerant species, there has been a desire to include other less commonly tested and probably more sensitive species and such was the case with this study. This fulfills an important goal of having as wide a representation of environmental tolerances and taxonomic inclusion as is possible in the thermal effects database. It is also in keeping with the currently accepted definitions of the concept of representative aquatic species and the recently developed concepts in the EPA biological condition gradient.

Finally, it is important to understand here that temperature criteria are intended for application across multiple management issues, which include land use effects, flow effects, TMDLs, climate change, and other issues in addition to the more familiar regulation of point source discharges of heat. Some state WQS contain specific provisions for the discharge of heated wastewater while others do not. Some state standards implied an almost exclusive emphasis on the control of heated wastewater, but we have seen where issues such as the TMDL process can expose weaknesses in such a narrow focus on specific management issues. We suggest here that WQS and the attendant criteria should be focused first on the holistic protection of designated uses and secondly the implementation for specific regulatory programs. The Ad Hoc committee recognized this issue and spent time developing a better understanding of key implementation issues. While this recognizes the inherent dichotomy between criteria development and criteria applications, it also exposes the need for better linkages between standards setting and water quality management than presently exists in most states and the current ORSANCO standards. General and vaguely defined designated uses and narrative "catch-all phrases" are of little value to management programs unless they can be translated more effectively to management applications and restoration goals.

Introduction and Project Description

An Ad Hoc Work Group for the Re-evaluation of Ohio River Temperature Criteria was tasked by the Commission in July 2003 to re-evaluate the technical justification for the temperature criteria in the ORSANCO Pollution Control Standards. Requests for proposals were accepted and the Midwest Biodiversity Institute was chosen to complete the requirements outlined in a detailed work plan that was approved by the Ad Hoc Work Group.

The work plan called for the project to be completed in two phases. Phase I included:

1) documentation of the existing methodology used to derive the existing Ohio River temperature criteria;
2) a compilation and description of common methodologies used or being developed by others to establish temperature criteria;
3) a review of the existing technical literature primarily concerning thermal effects on fishes; and,
4) documentation of the ambient temperature regime in the Ohio River mainstem.

Phase II called for:

1) a *draft* re-evaluation of the Ohio River temperature criteria; and,
2) modernization of the software programming that was used to establish the current criteria.

This report includes the results of all activities conducted in phase I and *draft* criteria recalculations called for in phase II.

Each phase is described as follows:

Phase I.1. *Describe and evaluate the methodology used to develop the current ORSANCO temperature criteria.*
The methodology and temperature criteria calculation program that was designed and developed by Ohio EPA (1978a) were used to develop the current temperature criteria for the mainstem of the Ohio River. The information and data used by Ohio EPA was reviewed and evaluated during the course of this investigation. The detailed methodology and thermal effects summaries that were compiled by Ohio EPA presently exists in hard copy (no electronic archive is available). It includes complex tables, data summaries, literature citations (approximately 500 sources), and temperature criteria derivations for the Ohio River mainstem, major inland rivers, smaller streams, and Lake Erie including the open lake, hypolimnetic region, river mouths, and harbor areas. A description of the Ohio EPA methodology as it pertains to the Ohio River mainstem was developed as phase I of this project and was published as part of the Electric Power Research Institute (EPRI) *Workshop on 316(a) Issues: Technical and Regulatory Considerations* held October 16-17, 2003 in Columbus, Ohio (Yoder and Emery 2004) and is included here as Appendix A.

***Phase I.2**: Description and evaluation of the "common methodologies" used by others to establish thermal criteria.*

The principal methods by which temperature criteria have been or are being developed were compiled via a standard literature search, web searches, and word of mouth. Some new approaches have emerged since the development of the 1984 ORSANCO criteria and these are summarized and described. In terms of similarly focused efforts to derive temperature criteria and thermal discharge limitations only one other project (by the state of Wisconsin) has been undertaken. A general introduction of the Wisconsin process and methodology was also published via the 2004 EPRI workshop proceedings. The state of Illinois is also engaged in temperature criteria development for a use attainability analysis of the lower Des Plaines River, but they are using the same methodology upon which the current ORSANCO criteria are based. Other methodologies that involve the determination of thermal effects and/or the revision of temperature criteria were also found and these are likewise described. Finally, a compendium of temperature criteria for the states was developed to provide insights as to the origins of the criteria and their relationship to the newer methodologies described and developed by this project.

***Phase I.3**: Comprehensive literature search and compilation of the most recent fish thermal-effects data.*

The thermal effects database on which the existing Ohio River temperature criteria are based dates from before 1978. Hence one of the major tasks of this project was an update of the thermal effects database primarily for fish. A compilation of new literature was accomplished by computer searches (primary published literature), from individual literature sources, and personal contacts within the thermal effects research "community", the power industry, and regulatory agencies (unpublished reports and "grey" literature) was accomplished to provide an up-to-date compilation of thermal effects data for freshwater fish species known to be native to, or resident in the Ohio River basin. New or updated information for various fish species was tabulated in a manner similar to the compilation originally used by Ohio EPA so as to ensure consistency of terminology and endpoints. However, changes in how the endpoints are defined and derived were included as part of the update. The original compilation by Ohio EPA included all relevant behavioral and physiological endpoints including various behavioral preferenda (i.e., preferred, avoidance) and physiological thresholds (i.e., spawning, growth, incipient lethal, critical thermal maxima). These provide the raw data for supporting the Fish Temperature Model program. We used the Chemical Abstracts literature search service to scan for relevant thermal literature in addition to contacting various practitioners and researchers for information about unpublished reports and studies. The result was a compilation of more than 100 new literature sources for Ohio River basin fish species.

***Phase I.4**: Documentation of Ambient Ohio River Conditions.*

Using data generated primarily by ORSANCO and the U.S. Army Corps of Engineers, spatial and temporal trends in recent ambient temperatures were examined from multiple locations along the length of the mainstem. Emphasis was placed on characterizing longitudinal and seasonal variations in ambient water temperatures from Pittsburgh, Pennsylvania to Cairo, Illinois. Normal seasonal variations during the non-summer months are an important consideration for evaluating the temperature criteria outside of the critical summer period, thus this analysis is critical to establishing non-summer season criteria. Various duration values for monthly and semi-monthly periods for the period of record covered by these databases were derived.

Phase II.5: Draft re-evaluation of Ohio River thermal criteria.
Based on the products provided via phase I, objectives 1-4 the ORSANCO workgroup decided that there was sufficient new information to warrant a re-evaluation of the existing temperature criteria. As such, draft options for revised Ohio River mainstem temperature criteria were developed. This task consisted of conducting analyses of different scenarios based on combinations of changes in representative fish species and segmentation of the mainstem (upper, middle, and lower). The same basic methodology developed by Ohio EPA (1978a) and more recently described by Yoder and Emery (2004) was used for these analyses.

Phase II.6: Rewrite the software used to derive potential thermal endpoints.
The task of re-writing the Fish Temperature Model software originally developed by Ohio EPA to calculate summer season temperature thresholds for selected representative fish species was undertaken as phase II.6. The original Ohio EPA programs were written in FoxPro which is no longer supported by the manufacturer and is not widely available to potential users. We developed programming in an Excel format that employs Visual Basic to accomplish the necessary calculations. The routine for developing and maintaining the species master data files and the program reports and outputs are the same as the original Ohio EPA Fish Temperature Model. Requirements for using the software are an ability to run Excel and to enable the macros associated with the programming. A user's manual is provided in Appendix C.

This new programming offers the capacity to quickly determine the end result of different RAS and species-specific thermal endpoint variations. As such it is an essential tool for the eventual development and derivation of temperature criteria for a particular waterbody and/or subsets of waterbodies. In the case of the Ohio River mainstem this tool proved useful in determining the effect of different combinations of mainstem segments, RAS lists, and species-specific thermal endpoints. Some of these are presented as examples in the section of the report concerning phase II.5.

Phase I.1. Describe and evaluate the methodology used to develop the current ORSANCO temperature criteria

The technical justification for the temperature criteria in the ORSANCO Pollution Control Standards is based on the methodology originally developed by Ohio EPA (1978a) for calculating seasonal average and daily maximum temperature criteria. The original methodology was more recently described in a paper by Yoder and Emery (2004) that is appended to this report (Appendix A). The Ohio EPA methodology used data from the thermal effects literature to create a thermal effects database for freshwater fish. This data was then used within a procedure that calculates four behavioral and physiological thresholds for a list of representative fish species that are intended to represent the fish assemblage of a particular river or river segment. Ohio EPA used this approach in setting temperature criteria for inland rivers and streams and Lake Erie in the 1978 revisions to the Ohio water quality standards (WQS). The temperature criteria derivation process was later incorporated within the Fish Temperature Modeling system that is part of the Ohio ECOS data management system developed and operated by Ohio EPA. The Fish Temperature Modeling system was originally developed as a mainframe routine, but was later converted to FoxPro as part of the Ohio ECOS data management system. MBI developed an update to this system as part of phase II.6 of this project.

Much of the literature upon which the thermal effects data is based dates from before 1978 with some sources dating to the 1940s and 1950s. Because the literature database exceeds 30-40 years of age and newer sources have since become available, concerns have been expressed about the applicability of the existing Ohio River temperature criteria. The incorporation of more recent information via the compilation of new literature and studies is seen as necessary to determine the relevancy and appropriateness of the current temperature criteria. Other considerations, including the use of new thermal thresholds (e.g., chronic thermal maxima) were also raised.

The primary input variables to the Fish Temperature Model are four thermal parameters for each representative fish species; a physiological optimum temperature, a maximum weekly average temperature for growth, an upper avoidance temperature, and an upper lethal temperature. These were derived from an extensive literature review and were assigned to each Ohio River basin fish species for which sufficient thermal data could be found. When multiple values were available for a particular species, the most ecologically and geographically relevant data was used or an average of multiple values was derived from geographically relevant areas.

Phase I.2: Description and Evaluation of Common Methodologies Used by Others to Establish Thermal Criteria

The principal methods by which temperature criteria are calculated or being developed by other entities including states, U.S. EPA, and other resource management agencies were reviewed. Some of these approaches have emerged since the development of the original Ohio EPA methodology (upon which the current ORSANCO criteria are based). These were reviewed for their potential value and applicability to this project. Another aspect of this task was to determine how states have established their currently applicable temperature criteria.

Review of U.S. EPA and State Temperature Criteria

U.S. EPA published a digest of water quality criteria consisting of excerpts from state standards including temperature (U.S. EPA 1988). This document also summarized the guidelines published in Quality Criteria for Water (U.S. EPA 1986) which is widely known as the "Gold Book". This is based on one of the common methodologies (see phase I.3) available for deriving temperature criteria (Brungs and Jones 1977). The principal numeric and applicable narrative provisions for states in the conterminous U.S. are summarized in Table 1. While some of this information may be dated, it reflects the techniques employed during the same period from which the current ORSANCO criteria were derived.

Status of State Temperature Criteria

The majority of states have relatively simple temperature criteria that include a permissible rise over ambient and either single or seasonal maximum temperatures. These are usually differentiated for warmwater and coldwater fishery uses when the latter is also relevant. Most state temperature criteria follow verbatim the National Academy of Sciences/Engineering (NAS/NAE 1973) "blue book" on water quality criteria. Some states further differentiate various subclasses of warmwater and coldwater fisheries or habitats, with corresponding allowances for temperature rises, exceedences, and maxima. States bordering major rivers such as the Mississippi and Missouri specify monthly maximum and averages specific to defined segments or the entire mainstem. Fewer states yet specify river basin or river specific criteria within their state. Only one state, Ohio, substantially followed the guidance developed by U.S. EPA (Brungs and Jones 1977) for temperature end points other than protection against lethal conditions (Ohio EPA 1978a). In addition, Ohio employs the concept of representative aquatic species, which represents the entire fish assemblage, a concept pioneered in the Ohio River temperature criteria developed by the FWPCA (1969). This is in contrast to most other methods that focus on selected game or commercial species.

The majority of states have not revised or updated their temperature criteria since the publication of the "blue book" (NAS/NAE 1973), thus most retain what are now regarded by some as outdated concepts. An example is the concept of an allowable rise in temperature above ambient, such as the "5°F rise" that remains in most state WQS. Brown (1974) first raised the issue that this criterion had little if any biological justification – it was quite simply a "rule-of-thumb". In a memo from Charles C. Coutant to Stanley I. Auerbach, Oak Ridge National Laboratory, in response to a question posed by ORSANCO, Coutant concluded that the 5°F rise had no biological justification and should be dropped. This explains its absence from the current ORSANCO temperature criteria and from Ohio's WQS. These are two of the few states or entities that modernized their temperature criteria in the post "blue book" period. Coutant favored what ORSANCO adopted in 1984, fixed temperature values based on multiple tolerance endpoints for representative fish species that are seasonally varied to reflect normal ambient temperature changes.

Multipurposed Roles of Temperature Criteria

It is important to understand here that temperature criteria are intended for application across

Table 1. Summary of key attributes and elements of state temperature criteria compiled from U.S. EPA (1988). Provisions for inland fresh waters (excluding Great Lakes and estuarine waters) of the conterminous U.S. and the District of Columbia are included. All values apply outside of permitted mixing zones.

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Alabama	Specifics listed under Public Water Supply (other uses conform to PWS with some exceptions)	5°F	90°F (except specific waters) 86°F (smallmouth bass, sauger, walleye)	No hypolimnetic discharges, Seasonal variation maintained, no blockages; specific 316[a] variance
Arizona	General Aquatic Life	3°C	None	None
	General Coldwater Fishery	1°C	None	None
Arkansas	None specified	5°F	Ecoregion specific (not listed)	Mid-depth or >3' in lakes and reservoirs
California	Cold interstate waters	None	No ETW (elevated temp. waste)	Excluding irrigation return water > natural temp.
	Warm interstate waters	5°F	90°F (July-Sept.; other months have different maxima)	Specific waters have different requirements; CWRB can designate biologically significant areas
	Cold intrastate waters	5°F	None	No alteration of natural without a demonstration
	Warm intrastate waters	5°F	None	(same as above)

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Colorado	Aquatic Life Class I (Cold water)	3°C	20°C	None
	Aquatic Life Class II (Warm water)	3°C	30°C	None
	Aquatic Life Class III	Case-by-case	Case-by-case	None
Connecticut	Class AA	No rise allowed	None	Allow demonstration for cold water spawn./growth
	Class A	(same)	(same)	(same)
	Class B	4°F	85°F	No increase except where It will not exceed maximum rise or summer limitations
	Class C	(same)	(same)	(same)
Delaware	General Streams	5°F	85°F	Unless exceeded by natural No max. > 85°F due to thermal discharges
	Coldwater Fishery	5°F	75°F	(no exceptions)
Florida	General Freshwaters	5°F	90°F (Northern FL) 92°F (Peninsular FL)	Numerous narrative prohibitions and exceptions
Georgia	Specifics listed under Drinking	5°F	90°F	None
	Primary trout/smallmouth bass waters	1.5°F	None	None
	Secondary trout waters	2°F	None	None

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Idaho	Warmwater biota Cold water biota	2°C 1°C	29°C average/33°C maximum 19°C average/22°C maximum	No interference with designnated uses; normal daily and seasonal cycles maintained
Illinois	General Aquatic Life Secondary Contact	5°F	90°F (April – November) 100°F instantaneous max. 93°F <95% of time	Numerous provisions for the discharge of heat; >90°F by 3°F one percent of time
Indiana	Warm water fish Cold water fish	5°F 5°F	90°F (June - September) 65°F	Normal daily and seasonal fluxes, no adverse impacts
Iowa	Class B – interior streams Cold water fisheries Lakes, reservoirs Missouri River Mississippi River	3°C, 1°C/hr. 2°C, 1°C/hr. 2°C, 1°C/hr. 3°C, 1°C/hr. 3°C, 1°C/hr.	32°C 20°C 32°C 32°C 29°C (zone II) 30°C (zone III)	None Exceedence <1%/mo., <2°C (same)
Kansas	Surface waters	5°F 3°F epiliminion	90°F	No changes beyond natural
Kentucky	Warmwater Aquatic Habitat Cold water Aquatic Habitat	None None	89°F (July - August) None	Normal daily, seasonal fluxes No increase >natural

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Louisiana	Fresh Waters – streams/rivers	5°F	90°F	No heat added >maximum
	Lakes, reservoirs	3°F	90°F	
Maine	Freshwater Thermal Discharges	5°F	84°F 68°F (trout, salmon waters)	None
Maryland	Class I Waters – Aquatic Life	None	> of 90°F or Ambient	No thermal barriers
	Class II Waters	(same)	(same)	
	Class III Waters – Trout Reproduction	None	> of 68°F or Ambient	No thermal barrier
	Class IV Waters – Recreational Trout	None	> of 75°F or Ambient	No thermal barrier
Massachusetts	Class A, B, C	4°F	83°F warmwater 68°F coldwater	None
Michigan	Rivers. Streams, impoundments			
	- Coldwater Fish	2°F	68°F (June – August)	Natural daily, seasonal fluxes,
	- Warmwater Fish	5°F	83°F (July) Northern Mich. 85°F (July – Aug.) South Mich. 85°F (June – Sept.) St. Josephs R.	Exceedence criteria specified
	Non-trout Migratory Rivers	5°F	None	No interference w/migration

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Minnesota	Fisheries/Recreation - Class A	0°F	None	No increase above natural
	- Class B	5°F (Rivers) 3°F (Lakes)	86°F	
	- Class C	5°F (Rivers) 3°F (Lakes)	90°F	
Mississippi	All surface waters	5°F	90°F 86°F (Tennessee R.)	Normal daily, seasonal flux
Missouri	Classified waters	5°F	90°F	Site-specific exceptions
	Coldwater Fishery	2°F	68°F	
	Lakes	0°F		
	Mississippi R.	None	88°F (Zones 1A, 1B) 89°F (Zone 2)	1% exceedence allowed in zones 1A, 2; 5% in 1B; no exceedence >3°F allowed.
Montana	Class A-1	1°F	67°F	Exceedence above background specified depending on temp. range; allowable increases and decreases of 2°F/hr. specified
	Class B-1	1°F	67°F	
	Class B-2	1°F	67°F	
	Class B-3, C-3	3°F	80°F 82°F/85°F (Yellowstone R.)	
	Class C-1, C-2	1°F	67°F	
	Class E	0°F	No increase above natural	

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Nebraska	Warmwater Aquatic Life	5°F	90°F	Special studies allowed
		4°F	85°F (Missouri R. - S.D. line to Sioux City, IA)	
	Coldwater Aquatic Life	5°F	72°F	
Nevada	Class A	0°C	20°C	Specific criteria designated for control points
	Class B	0°C	20°C (trout waters) 24°C (non-trout waters)	
	Class C	3°C	20°C (trout waters) 34°C (non-trout waters)	
New Hampshire	Class A	0°F	No artificial rise allowed	
	Class B, C	0°F	No artificial rise, except that allowed on case-by-case basis	
New Jersey	Streams: FW2-TP	1°F	None, except no deviation >1°F	
	FW2-TM	2°F	68°F	
	FW2-NT	5°F	82°F (smallmouth bass, yellow perch waters) 86°F (other non-trout waters)	
	All SE	1.5°F (June - Aug.) 4°F (Sept. - May)	85°FF	
New Mexico	General Standards - Streams	5°F	90°F	Natural exceedences are not deemed violations
	Coldwater Fishery	5°F	68°F	

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
New York	Non-trout Waters	5°F	90°F	Natural seasonal fluxes maintained
	Trout Waters	2°F	68°F	
North Carolina	Surface Waters – Mtn., Upper Pied.	2.8°C	29°C	
	- Low Pied., Coastal Plain	2.8°C	32°C	
	- Trout waters	0.5°C	20°C	
North Dakota	Class I Streams	5°F	85°F	
Ohio	General Ohio R. Basin Streams	None	82/85°F (June 16 – Sept. 15)	Period avg./max. by month; Non-summer month based on normal seasonal cycles based on historic record at ambient sites
	General Lake Erie Basin Streams	None	82/85°F (June 16 – Sept. 15)	
	Lower Great Miami R.	None	85/89°F (June 16 – Sept. 15)	
	Scioto R.	None	83/87°F (June 16 – Sept. 15)	
	Hocking R.	None	83/87°F (June 16 – Sept. 15)	
	Muskingum R.	None	85/89°F (June 16 – Sept. 15)	
	Maumee R.	None	85/89°F (June 16 – Sept. 15)	
	Mahoning R.	None	85/89°F (June 16 – Sept. 15)	
	Cuyahoga R.	None	84/88°F (June 16 – Sept. 15)	
	Ohio R.	None	84/89°F (July – Aug.)	
	Exceptional Warmwater, Coldwater	None	No change >natural	
	Nuisance Prevention	None	94/98°F (30 day avg./maximum)	

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Oklahoma	Primary, Secondary Warmwater Fishery	5°F	Critical temperature	94°F max. in Arkansas R.
	Smallmouth bass streams	5°F	84°F	
	Trout streams	5°F	68°F	
Oregon	Columbia River	2°F	68°F	Varied increase depending on ambient (0.5-2°F); narrative provisions for exceedence durations
	Columbia R. tribs.	2°F	58°F	
	Mid-Coast Basin	2°F	64°F	
	Umpqa Basin	2°F	68°F	
	Willamette Basin	2°F	70°F	
	Sandy Basin	2°F	68°F	
	Deschutes Basin	2°F	68°F	
	Powder Basin	2°F	68°F	
	Goose/Summer Lakes Basin	2°F	70°F	
	Klamath Basin	2°F	68°F (trout and salmon waters) 72°F (non-trout and salmon waters)	
Pennsylvania	Temp 1	0°F (<58°F) 5°F (>58°F)		2°F rise/hour maximum when permitted
	Temp 2	0°F (>87°F) 5°F (<87°F)		
	Temp 3	0°F (>74°F; Feb. 15 – July 31) 5°F (<74°F; Feb. 15 – July 31) 0°F (>87°F; Aug. 1 – Feb. 15) 5°F (<87°F; Aug. 1 – Feb. 15)		

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Penna. (cont'd)	Temp. 4	None	90°F (June – September)	
Rhode Island	Class A	0°F	No exceedences of natural	
	Class B	4°F	83°F	Site-specific provisions that
	Class C	Not specified	No adverse effect on growth	do not result in impairment
	Class D	Most sensitive water use	90°F	
South Carolina	Class A, B	5°F	90°F	316[a] provisions
	Class SA, SB, SC	4°F (fall, winter, spring)	Exceedence above natural <4°F	
		1.5°F (summer)	Exceedences above natural <1.5°F	Exceptions for demonstration
	Class A, B – Trout	None	No exceedences from natural	that use will be maintained
South Dakota	Coldwater Permanent Fish	4°F	65°F	Exceptions granted if for non-impairment of use
	Coldwater Marginal	4°F	75°F	
	Warmwater Permanent	4°F	80°F	
	Warmwater Semi-permanent	5°F	90°F	
	Warmwater Marginal	5°F	90°F	
Tennessee	Fish/Aquatic Life	3°C	30.5°C	Maximum change <2°C/hr.
	Trout Waters		20°C	No abnormal changes
Texas	Freshwater streams	5°F (fall – spring) 1.5°F (summer)		

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Utah	Aquatic Life - Class 3A	2°C	20°C	
	- Class 3B, 3C	4°C	27°C	
Vermont	General	No adverse impact	None specified	Exceptions may be granted by demonstration of no adverse impacts
	Coldwater Fish Habitat	1-5°F (varies with ambient)		
	Warmwater Fish Habitat	1-5°F (varies with ambient)		
Virginia	Class III non-tidal	3°C	32°C	More stringent temp. can be imposed; max. hourly change <2°C, except Class VI <0.5°C; provisions for site-specific criteria and short-term exposure
	Class IV	3°C	31°C	
	Class V (put-and-take trout waters)	3°C	21°C	
	Class VI (natural trout waters)	3°C	20°C	
	Class VII (swamp water)	3°C	= Classes I-VI as appropriate	
Washington	Class AA (extraordinary)	t=23/[T+5] 0.3°C (>16°C)	16°C	
	Class A (excellent)	t=28/[T+7] 0.3°C (>18°C)	18°C	
	Class B (good)	t=34/[T+9] 0.3°C (>21°C)	21°C	
	Class C (fair)	t=20/[T+2] 0.3°C (>24°C)	24°C	
West Virginia	Warmwater	5°F	87°F (May – November); 73°F (December – April)	

Table 1. (continued)

State	Designated Uses Structure/Description	Amount of Increase >Ambient	Summer Season Average/Maximum	Other Requirements
Wisconsin	Fish and Aquatic Life Mississippi River	5°F 5°F	89°F 84°F (June – August)	Natural daily, seasonal fluxes maintained; provisions for review of thermal discharges
Wyoming	Class I, II, III Coldwater Fisheries effluents Warmwater Fisheries effluents Coldwater Fisheries Warmwater Fisheries	0°F 2°F 4°F	No changes from ambient No change >2°F No change >4°F 78°F 90°F	No exceedences permitted; no changes over salmonid spawning beds; 316[a] demonstration provision
Dist. of Columbia	Class B, C	2.8°C	32.2°C	

multiple management issues, which includes land use effects, flow effects, TMDLs, climate change, and other issues in addition to the more common regulation of discharges of heat. Some state WQS contained specific provisions for the discharge of heated wastewater while others did not. Some state standards implied an almost exclusive emphasis on the control of heated wastewater, but we have seen where issues such as the TMDL process can expose weaknesses in a too narrow focus on single management issues. We suggest here that WQS and the attendant criteria should be focused first on the holistic protection of designated uses and secondly the implementation for specific regulatory programs. The Ad Hoc committee recognized this issue and spent time developing a better understanding of key implementation issues. While this recognizes the inherent dichotomy between criteria development and criteria applications, it also exposes the need for better linkages between standards setting and water quality management than presently exists in most states and the current ORSANCO standards. General and vaguely defined designated uses and narrative "catch-all phrases" are of little value to management programs unless they can be translated more effectively to management applications and restoration goals.

Common Methods for Deriving Temperature Criteria

The commonly available methods used or being developed by others to derive and establish temperature criteria were compiled through the literature search and the general knowledge of such practices gained during the past 30 years. We included sources that offered an approach or methodology for deriving temperature criteria that are protective of aquatic life and the inherent requirements for survival, reproduction, and growth. We did not include major compendia of thermal effects data as a common method unless these also included a methodology for deriving temperature criteria.

Five methodologies were considered sufficient to include here as common methods. These include the current U.S. EPA guidance (Brungs and Jones 1977) which is referenced in the 1986 U.S. EPA Quality Criteria for Water ("Gold Book"), guidance produced by the U.S. Fish & Wildlife Service in 1991 (Armour 1991), a field-based information system for estimating fish temperature tolerances (Eaton et al. 1995), the development of temperature criteria for the Pacific Northwest (U.S. EPA 2001), and an in progress effort by the state of Wisconsin to develop revised temperature criteria and thermal implementation guidelines (Wenholz 2003).

U.S. EPA Temperature Criteria for Freshwater Fish: Protocol and Procedures

This guidance was produced as part of the development and refinement of water quality criteria by the U.S. EPA, Office of Research and Development that occurred for many parameters and substances in the 1970s. It was intended as a guide for the derivation of temperature criteria for freshwater fish based on the philosophy and protocol presented earlier by the NAS/NAE (1973), but updating that effort with the rapidly expanding knowledge of thermal effects that was generated in the intervening time period. According to this volume, one of the earliest published procedures for deriving temperature criteria was by ORSANCO in 1956 and a subsequent modification in 1967. This was followed by the FWPCA (1968) effort known as the "green book" which recommended the 5°F rise provision that appears in many state WQS today. It also recommended temperatures that were compatible with the well-being of various fish species focusing on survival, growth, spawning, and embryonic development. The EPA guidance (Brungs and Jones 1977) defined various lethal and sublethal endpoints and thresholds and incorporated these into a systematic temperature criteria derivation process. The procedure derives maximum weekly average temperatures (MWAT) for growth, reproduction, and winter survival. The guidance further describes the derivation of short-term maxima during the spawning season. MWAT formulas and example calculations for 34 freshwater fish species are provided in Appendix Table Z.3. Ohio EPA (1978a) used the MWAT for growth as one of several thermal thresholds for deriving river specific seasonal temperature criteria. As such, it is included in the current Ohio River criteria.

The strength of this methodology is an adherence to a consistent formula and an ability to incorporate new species, as new information is made available. A weakness is a comparative lack of emphasis on other behavioral and physiological effects such as avoidance and long term effects of approaching and exceeding lethal thresholds in the derivation of temperature criteria.

Guidance for Evaluating and Recommending Temperature Regimes to Protect Fish

This method was designed primarily to address instream flow and related issues and specifically focused on salmonids of the Pacific Northwest. However, it describes a methodology that could be applied to warmwater fish and for a variety of management issues with the common concern of seeking protective strategies for fish. Hence it is relevant to the task of compiling common methodologies for deriving temperature criteria. Armour (1991) provides an extensive compilation of basic thermal endpoints of concern for fish, all of which were incorporated in the Ohio EPA (1978a) methodology (an exception is the lower incipient lethal temperature). Besides providing a concise primer on thermal requirements, three options are described for developing temperature regimes for fish; 1) experimental temperature tolerance results, 2) suitability of temperatures for key life stages, and 3) predicted responses of a population to temperature. Each option includes specific calculations using input variables based on literature references for various lethal and sub-lethal thresholds for targeted fish species. Option 1 is essentially the same procedure described by Brungs and Jones (1977) for growth and short-term survival. Option 2 focuses on the temperature requirement for various life stages and is dependent on obtaining thermal effects thresholds for each from the literature. Critical functions such as post-spawning emergence, embryonic development, and growth of young-of-year and juvenile fish are addressed. Option 3 involves the construction of temperature envelopes for individual fish species. This process focuses on many of the same endpoints as option 2 and is a method used to compare species requirements with simulated temperatures under different management scenarios, a common practice in instream flow management applications.

This technique, while well conceived and described, does not provide much in the way of a new or improved approach over that used to derive the current ORSANCO temperature criteria. It might prove a very useful technique for predicting impacts at a specific site, but seems comparatively laborious for developing temperature criteria protective of an entire fish assemblage. One other weakness of this is the frequent reference to an unpublished report by Hokanson and Beisinger, which was not included in the references.

Field Information-Based System for Estimating Fish Temperature Tolerances

This method involves the matching of fish species occurrences in the field with the ambient temperature regime to which their presence corresponds. The method is superficially similar to some of the early thermal discharge studies from which field based thresholds for preference and avoidance were derived. This paper describes the Fish Temperature Database Matching System (FTDMS), which was used here to estimate a maximum weekly mean temperature tolerance for common fish species across the U.S. The authors (Eaton et al. 1995) acknowledge that the maximum mean weekly temperatures derived from this approach were lower than laboratory determined lethal temperatures, but were similar to temperature requirements obtained form laboratory data through EPA interpolation procedures (i.e., Brungs and Jones 1977). This approach is promoted as a cost-effective method for generating a wide range of temperature tolerance information for a large number (100s) of fish species.

Eaton et al. (1995) acknowledged that the FTDMS method produces estimates that are consistently lower than laboratory derived lethal values. Also, it seems that it produces temperatures that are lower than field-derived thresholds where a wide range of temperatures including higher than ambient maximums were included in the study design. The method may produce information that is more useful for deriving field preference or avoidance temperatures, which are critical values that are frequently not available for many fish species. It could include more species in calculation procedures that use a representative species and/or assemblage approach.

Scientific Issues Relating to Temperature Criteria for Salmon, Trout, and Char Native to the Pacific Northwest

One of the most recent efforts to re-evaluate temperature criteria occurred in the Pacific Northwest and focused primarily on salmonids. This was prompted by a convergence of Clean Water Act, Endangered Species Act, and native people's management issues regarding salmonids and their management. The alteration of natural thermal regimes is a critical issue for the management of salmonids in the Pacific Northwest. These alterations occur as the result of land use impacts (logging, grazing), flow alterations (dams, diversions, irrigation), and exploitation (commercial and subsistence harvest). The intent of this project is to serve as a basis for the adoption of revised temperature criteria by the states. This could potentially change the criteria in Table 1 for the states of Alaska, Idaho, Oregon, and Washington. While the focus of this effort is entirely on salmonids, it offers some excellent analyses of several issues that are in common with this project, thus it is a valuable conceptual reference. It also offers a unique perspective on some of the dilemmas in deriving temperature criteria that are inherently different from those for other water quality parameters. This report promises to be a valuable asset to this project.

Development of Thermal WQS and Point Source Implementation Rules in Wisconsin

The state of Wisconsin is presently engaged in a process to revise the temperature criteria in the Wisconsin WQS and the development of implementation procedures for point sources of heated wastewater (Wenholz 2003). Wisconsin is the only state that we know of that is engaged in a statewide revision process. Illinois is interested in revising the temperature criteria for the lower Des Plaines River and they are using the Ohio EPA (1978a) methodology. This effort also recognizes the broader role of WQS as being applicable to point sources, nonpoint sources, flow alterations such as dams, and TMDLs.

Wisconsin anticipates that the temperature criteria will be derived as a daily maxima based on acute concerns and a 7-day average to account for sub-lethal effects. The acute endpoints include upper incipient lethal temperatures and the sublethal endpoints include growth, spawning, and gametogenesis considerations. Ambient background temperatures will also be considered and include more than 2200 data points. In many regards, this process is similar to that used to develop the current ORSANCO criteria. More specific information regarding temperature values and data points will be forthcoming and can be incorporated as necessary in phase II. We have already exchanged our literature search information with the Wisconsin project.

Phase I.3: Comprehensive literature search and compilation of the most recent fish thermal-effects data

All of the 370+ literature sources upon which the current Ohio River temperature criteria are based date to before 1978. Hence one of the major tasks of this study was to update the thermal effects database by obtaining new literature sources since that time. We used a database search from Chemical Abstracts by focusing on keywords related to thermal effects on fish and other aquatic organisms. More than 500 titles and abstracts were then screened for relevancy to this project. In addition, we obtained new literature sources via our review of these publications, bibliographies provided by work group members, web links, and "word of mouth". In all, this effort produced more than 200 new and *useable* references that included specific thermal effects data for individual or groups of fishes and invertebrates. An additional 200+ sources were reviewed, but deemed unsuitable for the purposes of our study. We attempted to obtain thermal effects data for other groups such as bivalve mollusks, but there was very little if any relevant information that could be found. Hence, this effort focuses solely on fishes.

Each potential new literature source was reviewed for relevancy, i.e., were specific thermal tolerance endpoints described as part of phase I.1 readily available. Acceptable data were then recorded in the master thermal effects database (Appendix Table Z.1). We attempted as much as possible to examine the original literature source prior to accepting the data in the master database. However, we accepted indirect citations within some of the more comprehensive compendia such as Brown (1974), Wismer and Christie (1987), Hokanson (1990), and Beitinger et al. (2000). A notation was made about where the original citation was made for such references. We did find in some of these and other compendia a practice of citing specific literature reviews as the source in lieu of the original literature source. We tried to avoid duplicating this practice and where it occurred we cited the original literature source. 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 relevant literature sources that exist.

Instead, we see this as an ongoing process that captures some of the older missing references and updates the database with newly published information.

We also requested that members of the ORSANCO Ad Hoc working group provide any field data that would have been suitable for deriving field-based final preference and/or upper avoidance temperatures, especially for species that are either not included in Appendix Z.1 or which have single values. In the interim we have concluded that these data should be analyzed and published in a report format where the study design, field methods, and field conditions can be clearly stated and included as part of the conclusions. While such an effort could add to and/or change some of the thermal thresholds in Appendix Z.1, we believe these data should qualify as published studies (grey literature is acceptable) prior to their fuller use. We recommend that these types of studies be pursued in the near future.

In our review of the preceding thermal effects compendia, priority was given to finding data for new species, for endpoints that were lacking for individual species, and filling gaps in geographical coverage. We also included data for species that may not occur in the Ohio River mainstem, but which do occur in the greater Ohio River basin and which may qualify as representative aquatic species (RAS) for temperature criteria derivation purposes. The result of this review process is Appendix Table Z.1 that serves as the thermal effects database for the calculations of the draft temperature criteria options in phase II.5.

Phase I.4: Documentation of Ambient Ohio River Temperatures

This task involved accessing and analyzing long term records of ambient water temperature in the Ohio River mainstem. There are two primary purposes: 1) documentation of spatial and temporal patterns in water temperature, and 2) analyzing the statistical properties of the database over the past 20-25 years for use in setting non-summer season temperature criteria. The database on which the current temperature criteria are based in part span the time period including the 1960s and early 1970s. This data largely consisted of continuously recorded data at monitoring locations throughout the mainstem, but the network was largely abandoned in the late 1970s and early 1980s. What effectively replaced it is a network of grab sampling locations operated largely by the U.S. Army Corps of Engineers at the locks and dams. Hence, the analyses presented here are based on that more recent database.

Database

Temperature data was obtained from the U.S. Army Corp of Engineers (U.S. ACE) at 16 sampling locations along the length of the Ohio River, most located at locks and dams. Data was downloaded from the U.S. ACE web site[1] and converted to FoxPRO files for further manipulation. The data collection period ranged from 1995-2003 with some variation among sites. Obvious errors were removed. This data set is useful because it provides a consistently collected set of temperature data collected along the length of the mainstem with at least daily and more frequent readings. For some statistics we divided the river into three reaches, an upper reach (Pittsburg to Greenup), middle reach (Greenup to Louisville), and lower reach (Louisville to Cairo). Additional data was obtained from Cynergy Corp. at the Markland Dam hydroelectric facility (1994-2003) and from American Electric Power at the Ohio Falls hydroelectric facility (1999-2003) and from selected electrofishing sites (1981-2003) near power plants. Daily temperature profiles over the period of record for each station that was analyzed are summarized in Appendix A. This includes summarized statistics for monthly and bimonthly periods by monitoring location for the U.S. ACE dataset. We attempted to access data from other sources such as USGS, but the

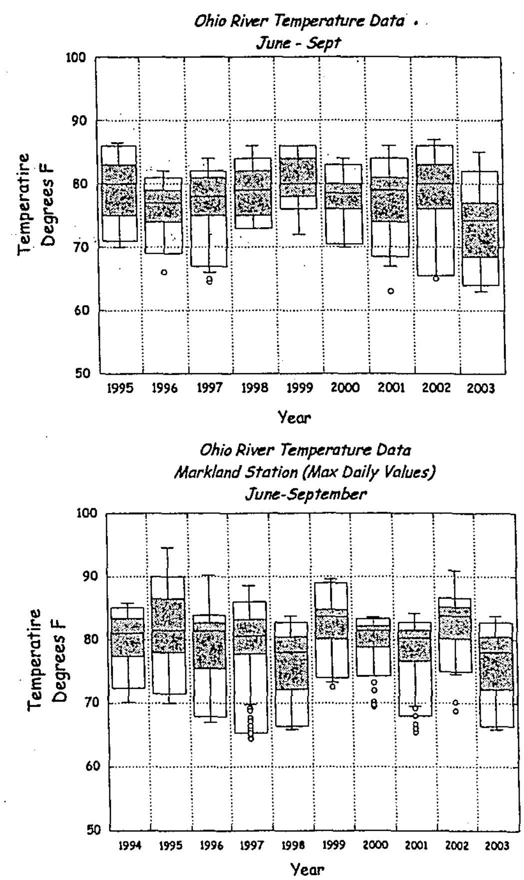


Figure 1. Box and whisker plot of median monthly summer temperatures by year for sixteen stations in the Ohio river from 1996 to 2003 (top) and for the Markland Pool (bottom).

[1] http://www.lrdwc.usace.army.mil/NavData/

continuous monitors that provided the dataset for the original assessment of Ohio River ambient temperature conditions (Ohio EPA 1978a) have long since been discontinued.

Yearly Observations
The warmest summer season of record occurred in 1999 for the data that we analyzed (Figure 1); 1995 and 2001 were the next warmest summers. Water temperatures during the summer of 1999 were consistently warm, whereas there was more variability in the next warmest years.

Longitudinal Trends in Temperature
Daily maximum and mean temperatures were plotted by river mile (Pittsburgh at RM 0 to RM 983 at Cairo, Illinois) to reveal longitudinal trends in ambient temperature in the mainstem. Downstream reaches were warmer than upstream reaches during the summer months, but only slightly so as is illustrated by the low slopes in the regression equations (Figure 2). Temperatures were more variable in the upper reach of the river as is illustrated by the box and whisker plots by month (Figure 3, left) or bi-monthly for the summer period (Figure 3, right).

Criteria and Ambient Temperatures
The Ohio EPA (1978a) temperature criteria were derived from fish temperature tolerances *and* ambient temperature conditions; hence it was and is important to have representative data about the latter. Table 2 summarizes various statistics for ambient temperatures for the upper, middle, and lower reaches (respectively) for all years combined for the U.S. ACE database. Data for individual sites and years is summarized in Appendix A. The values in this table differed somewhat from those reported in Yoder and Emery (2004). The data used by Yoder and Emery was from the 1960s and 1970s and the temperature regimes may have been different during that time period because of potentially different climatic and anthropogenic influences. The data used in generating those values were based on continuous data with means based on daily maximums and maximum values based on the highest observed values during the period or record and those occurring more than three times in a single year and ten times during the period or record (10 years). The data we used was based on daily or, at most, data collected two or three times daily, except for the Markland and Ohio Falls data which is comprised of multiple readings each day. The absolute maximum values are reported in Tables 2-4 as well as maximum values with outliers removed that did not occur more than two or three times during the period of record in these data sets (U.S. ACE, 1995-2003; Markland, 1994-2003; Ohio Falls, 1999-2003).

Data collected at intervals of approximately 30 minutes from the ORSANCO AMI monitoring location at RM 462.4 was also examined. The daily variation in results on several warm days and from several cooler days during 2003 was assessed. The maximum daily variation in this data was 3-3.5°F with cooler temperatures at night and early morning and the warmest temperatures in the mid to late afternoon (Figure 4). Most of the U.S.

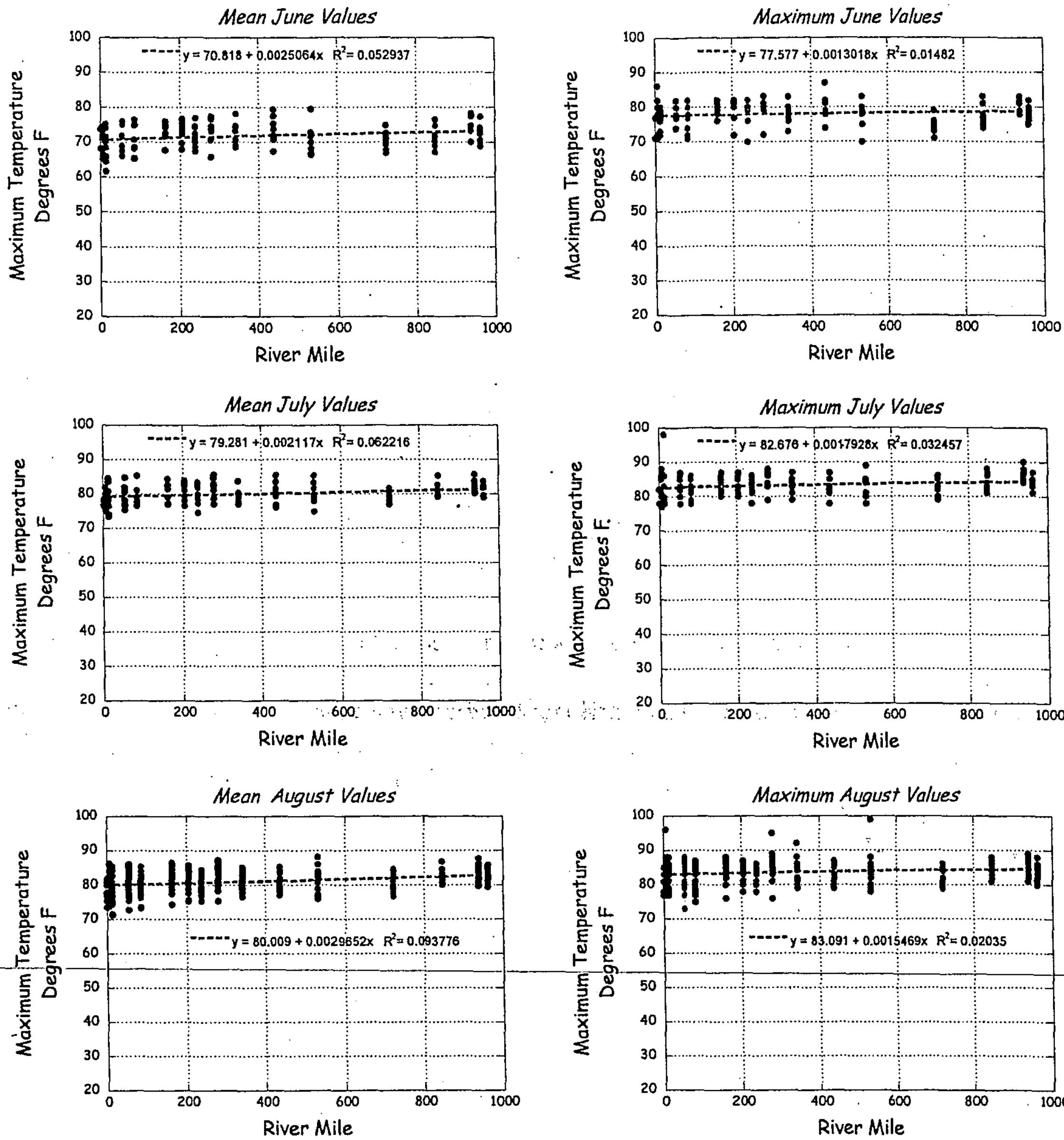


Figure 2. Plots of mean (left) and maximum(right) temperatures (°F) by river mile for the Ohio Rive for June (top), July (middle) and August (Bottom). Data from the ACOE stations collected from 1995-2003.

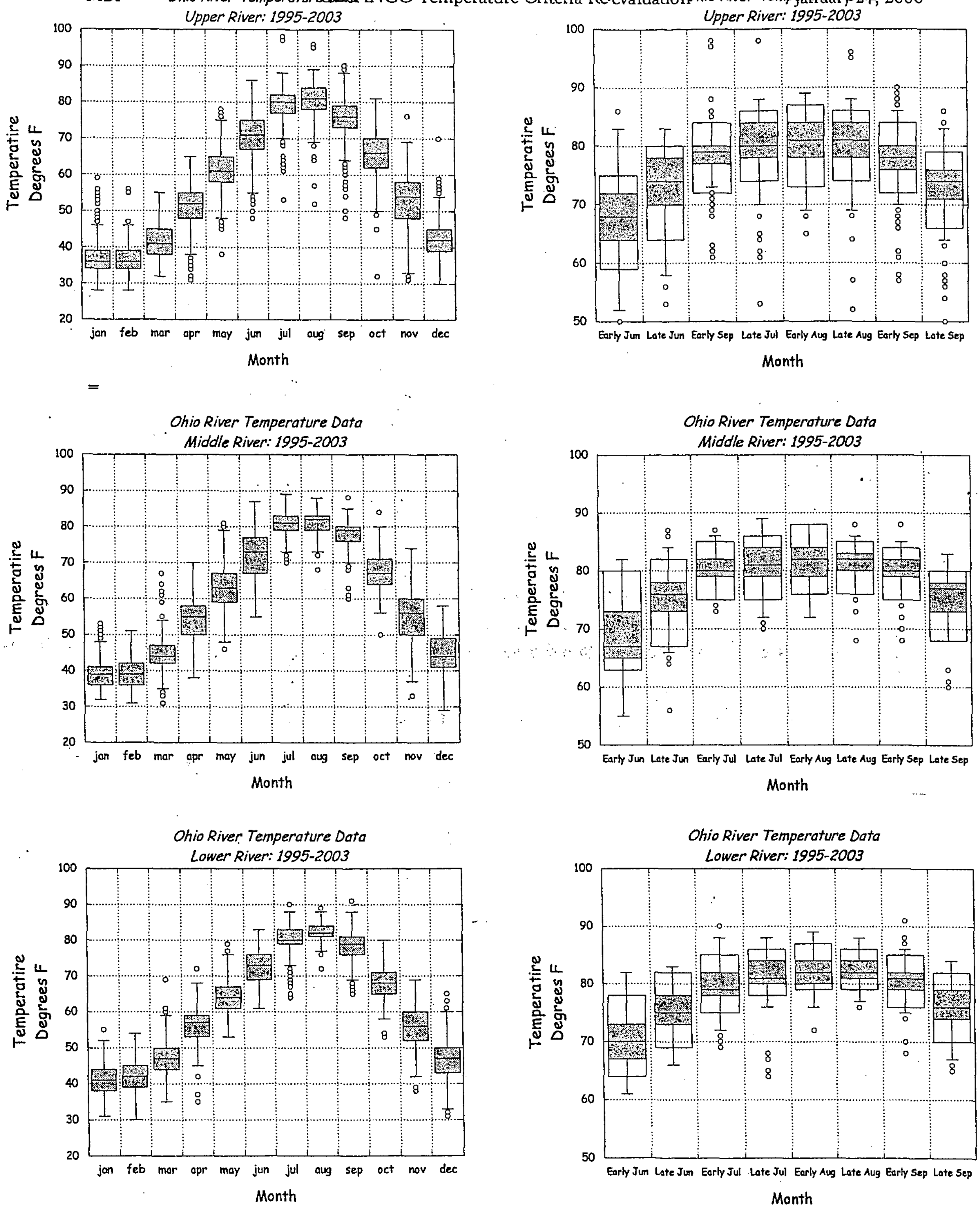


Figure 3. Box and whisker plots of monthly (left) and bi-monthly summer (right) temperatures (°F) for the Ohio Rive for the upper reach (top), middle reach (middle) and lower reach (Bottom). Data from the ACOE stations collected from 1995-2003.

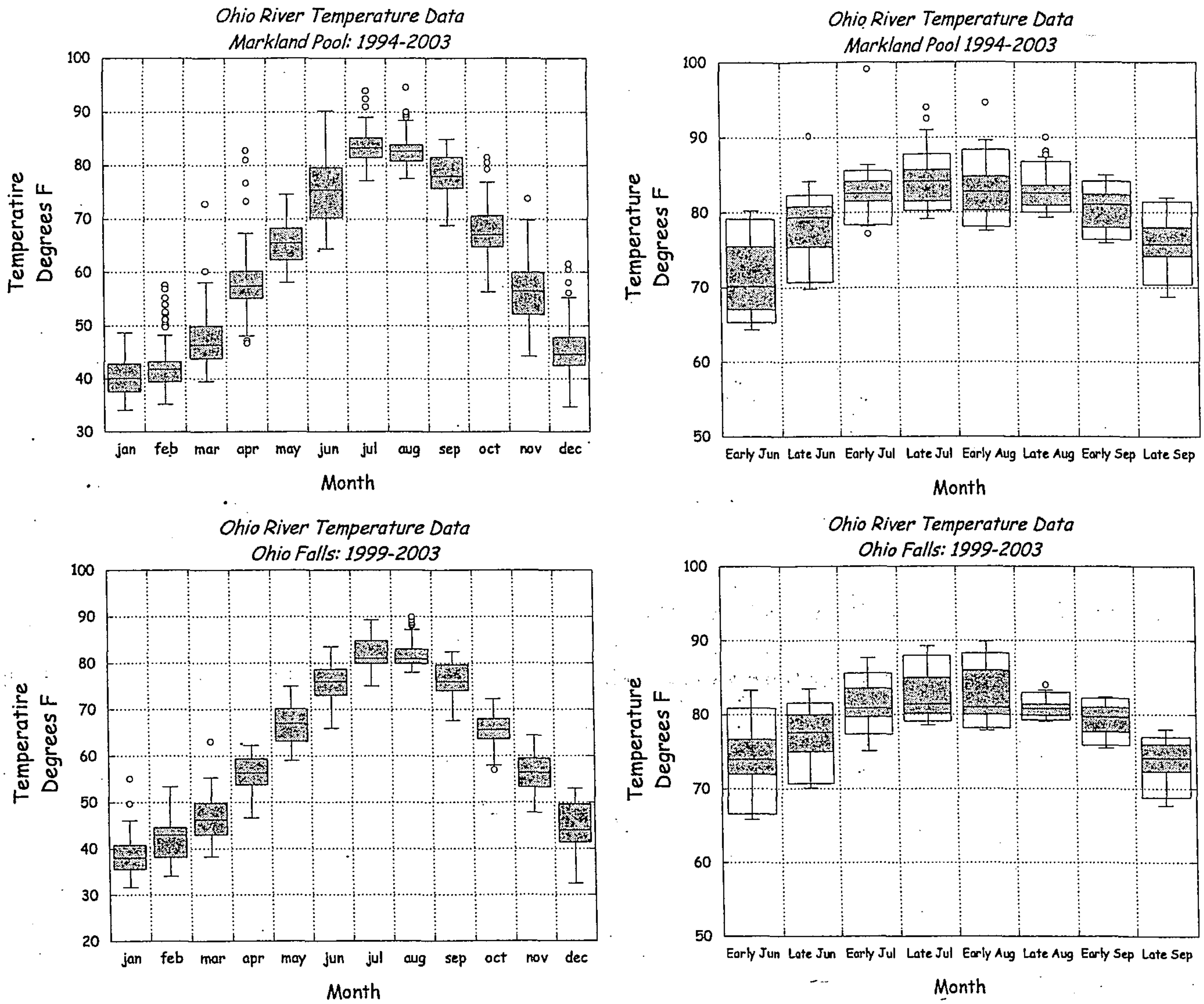


Figure 4. Box and whisker plots of monthly (left) and bi-monthly summer (right) temperatures (degrees F) measured in the Ohio River at the Markland Pool (1994-2003. top) and the Ohio Falls (1999-2003, bottom) hydroelectric facilities.

Table 2. Monthly and bi-monthly ambient temperature statistics for the Ohio River by reach. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
					Location:	Lower								
Jan	Entire	1132	40.2	40.0	55.1	51.0	50.0	49.0	47.0	46.0	43.0	33.0	52.0	58.0
	Early	538	40.9	41.0	55.1	50.0	50.0	49.0	48.0	46.0	44.0	33.0	53.0	59.0
	Late	594	39.6	40.0	55.0	50.0	49.0	47.0	46.0	45.0	42.0	33.7	50.3	55.8
Feb	Entire	1058	41.5	42.0	54.0	53.4	53.0	51.0	48.0	47.0	45.0	34.0	55.5	62.5
	Early	552	40.3	40.0	53.0	52.0	51.0	50.0	47.4	46.0	44.0	33.0	55.7	63.5
	Late	506	42.8	43.0	54.0	53.4	53.0	52.0	49.0	48.0	46.0	35.0	55.0	61.0
Mar	Entire	1058	47.0	47.0	63.1	59.0	59.0	56.0	55.0	53.8	50.0	39.0	59.0	65.0
	Early	499	44.8	44.0	56.0	56.0	56.0	55.5	53.4	50.0	48.0	38.0	57.0	63.0
	Late	559	48.9	49.0	63.1	59.0	59.0	58.0	55.0	54.0	52.0	42.0	61.0	67.0
Apr	Entire	1041	56.0	56.0	68.0	68.0	68.0	65.0	62.1	61.4	59.0	48.0	68.0	74.0
	Early	507	53.2	53.0	64.0	62.0	62.0	61.0	59.0	59.0	56.0	47.0	64.0	69.3
	Late	534	58.6	59.0	68.0	68.0	68.0	66.0	65.0	62.0	60.7	54.0	67.8	72.5
May	Entire	1169	64.9	65.0	79.0	76.0	75.0	74.0	72.8	71.0	68.0	58.0	77.0	83.0
	Early	567	62.9	62.6	75.0	74.0	74.0	71.0	69.2	68.0	66.0	57.0	74.9	80.8
	Late	602	66.8	66.0	79.0	76.0	75.0	75.0	73.0	72.0	70.0	61.0	79.0	85.0
Jun	Entire	1120	73.0	73.0	83.5	83.0	83.0	82.0	81.0	79.6	76.9	65.0	87.3	94.2
	Early	557	70.7	70.0	83.3	80.0	80.0	80.0	78.0	76.2	74.0	65.0	84.5	91.5
	Late	563	75.4	75.0	83.5	83.0	83.0	82.0	82.0	80.9	78.0	69.0	85.5	90.5
Jul	Entire	1173	81.0	81.0	90.0	88.0	88.0	87.0	86.0	85.0	83.0	76.0	89.0	93.0
	Early	573	80.1	80.0	90.0	88.0	87.0	86.0	85.0	84.1	82.0	75.0	88.0	92.0
	Late	600	81.9	82.0	89.3	88.0	88.0	87.0	87.0	86.0	84.0	78.0	90.0	94.0

04/14/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Table 2. Monthly and bi-monthly ambient temperature statistics for the Ohio River by reach. Data collected from 1995 to 2003.

					[2]Maximum (Occurrence)			Percentile					Outlier Cutoff	
Month	Period	Samples	Mean [1]	Median [1]	Single	Twice	Three	98th	95th	90th	75th	5th	75th+ 1.5*IQR	75th+ 2.5*IQR
Aug	Entire	1022	82.4	82.0	89.9	88.0	88.0	88.0	87.0	86.0	84.0	79.0	89.6	93.3
	Early	521	82.5	82.0	89.9	88.0	88.0	88.0	87.0	86.0	85.0	78.7	92.5	97.5
	Late	501	82.2	82.0	88.0	88.0	88.0	88.0	86.0	85.0	84.0	79.0	88.7	91.8
Sep	Entire	1017	78.3	79.0	88.0	86.0	86.0	85.0	84.0	83.0	81.0	71.0	88.5	93.5
	Early	517	80.5	81.0	88.0	86.0	86.0	86.0	84.0	84.0	82.0	76.0	86.5	89.5
	Late	500	76.0	76.0	84.0	82.0	82.0	82.0	82.0	81.0	78.0	70.0	85.2	90.0
Oct	Entire	994	67.5	68.0	80.0	80.0	80.0	78.0	75.8	73.0	70.0	60.8	77.5	82.5
	Early	473	70.3	69.0	80.0	80.0	80.0	79.0	78.0	76.0	73.0	65.0	80.5	85.5
	Late	521	65.0	65.0	74.0	73.0	73.0	72.0	71.0	69.0	68.0	59.4	77.0	83.0
Nov	Entire	1005	56.5	56.0	69.0	69.0	69.0	67.0	65.0	63.0	60.0	49.0	70.5	77.5
	Early	490	59.7	59.0	69.0	69.0	69.0	68.0	67.0	65.0	62.0	54.0	69.5	74.5
	Late	515	53.4	53.0	65.0	64.0	63.0	62.2	61.0	59.0	56.0	46.0	65.0	71.0
Dec	Entire	1097	46.6	46.0	65.0	60.0	59.0	57.0	56.0	54.0	50.0	39.1	60.5	67.5
	Early	542	48.7	49.0	61.0	60.0	59.0	57.7	57.0	55.0	52.0	42.0	62.5	69.5
	Late	555	44.6	44.0	65.0	56.0	56.0	55.0	53.0	51.0	48.0	37.5	57.6	63.9
					Location:	Middle								
Jan	Entire	790	39.3	39.8	53.0	51.0	51.0	47.7	44.9	44.0	42.0	33.0	49.5	54.5
	Early	384	40.1	40.0	53.0	51.0	51.0	50.8	45.9	44.3	42.9	33.0	51.2	56.7
	Late	406	38.5	38.5	48.7	48.0	46.0	46.0	44.0	43.0	40.9	33.0	46.8	50.7
Feb	Entire	722	40.1	40.0	57.6	50.0	49.0	49.0	46.0	44.0	42.7	34.0	49.9	54.7
	Early	369	39.0	38.6	48.2	44.0	44.0	45.2	44.0	43.9	42.0	34.0	51.0	57.0

04/14/2005

[1]Means/medians are means/medians of daily maximum values

[2]Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Table 2. Monthly and bi-monthly ambient temperature statistics for the Ohio River by reach. Data collected from 1995 to 2003.

					[2]Maximum (Occurrence)			Percentile					Outlier Cutoff	
Month	Period	Samples	Mean [1]	Median [1]	Single	Twice	Three	98th	95th	90th	75th	5th	75th+ 1.5*IQR	75th+ 2.5*IQR
	Late	353	41.3	41.2	57.6	50.0	49.0	51.6	48.2	45.2	43.0	35.0	49.0	53.0
Mar	Entire	734	45.8	45.0	72.8	58.1	57.7	57.6	53.4	52.0	48.8	40.0	58.1	64.3
	Early	359	43.6	43.0	58.1	51.0	50.0	52.0	50.0	48.7	46.0	39.0	53.5	58.5
	Late	375	47.9	47.0	72.8	58.1	57.6	58.1	56.3	53.0	51.0	42.0	60.0	66.0
Apr	Entire	700	55.5	56.0	82.8	81.0	67.3	65.0	63.0	61.6	59.0	46.9	69.5	76.5
	Early	349	52.6	52.0	81.0	76.7	63.0	63.5	61.0	58.9	55.9	43.0	65.9	72.6
	Late	351	58.3	58.3	82.8	67.3	65.6	65.6	64.0	62.4	60.8	52.0	68.0	72.8
May	Entire	822	64.5	64.0	81.0	77.0	77.0	75.0	73.1	71.8	67.8	57.0	78.3	85.3
	Early	395	62.6	62.0	74.0	72.0	71.0	71.7	70.0	68.2	66.0	56.0	75.0	81.0
	Late	427	66.2	65.6	81.0	77.0	77.0	77.0	74.6	73.0	70.0	59.0	80.5	87.5
Jun	Entire	725	73.3	74.0	90.2	86.0	83.0	82.7	81.7	80.4	78.0	65.0	93.0	**.*
	Early	365	70.1	69.0	82.0	82.0	82.0	81.2	79.2	77.8	74.0	63.0	86.0	94.0
	Late	360	76.5	77.4	90.2	86.0	83.0	84.0	82.3	81.4	80.0	68.0	89.0	95.0
Jul	Entire	732	81.6	81.5	94.0	89.0	88.0	88.0	86.5	85.7	84.0	75.0	90.0	94.0
	Early	342	81.2	81.0	87.0	87.0	86.0	86.0	85.3	85.0	83.5	75.0	90.3	94.8
	Late	390	82.0	82.0	94.0	89.0	88.0	88.3	87.6	86.1	85.0	75.0	92.5	97.5
Aug	Entire	746	82.0	82.0	94.6	88.2	88.0	88.0	86.8	85.6	84.0	77.0	90.0	94.0
	Early	365	82.1	82.4	94.6	88.0	88.0	88.2	88.0	86.0	84.5	77.0	91.4	96.0
	Late	381	81.9	82.0	90.0	86.8	86.0	86.8	85.0	84.5	83.5	77.0	88.8	92.3
Sep	Entire	746	78.0	78.9	88.0	85.0	84.0	84.0	83.4	82.7	80.8	70.1	88.0	92.8
	Early	375	80.2	80.0	88.0	85.0	84.0	84.4	84.0	83.4	82.0	75.0	86.5	89.5

04/14/2005

[1]Means/medians are means/medians of daily maximum values

[2]Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Table 2. Monthly and bi-monthly ambient temperature statistics for the Ohio River by reach. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Late	371	75.8	76.0	83.0	83.0	83.0	82.0	81.0	80.0	78.2	69.0	84.6	89.0
Oct	Entire	776	67.8	67.4	84.0	80.0	80.0	78.0	75.2	74.0	71.0	60.0	81.1	87.8
	Early	385	70.6	70.6	84.0	80.0	80.0	79.6	77.0	75.0	73.0	64.0	80.5	85.5
	Late	391	65.0	65.0	79.3	75.0	71.0	72.3	70.6	69.9	67.0	60.0	73.8	78.3
Nov	Entire	730	55.8	56.0	74.0	71.0	68.0	67.0	64.0	62.4	60.0	47.0	73.4	82.3
	Early	370	59.3	59.0	74.0	71.0	68.0	69.8	66.2	64.0	62.0	52.0	71.0	77.0
	Late	360	52.3	52.0	73.8	62.0	60.8	61.2	59.3	58.0	56.0	46.0	66.5	73.5
Dec	Entire	730	45.3	44.1	61.6	57.0	57.0	55.9	54.0	53.0	48.4	39.0	58.0	64.4
	Early	356	47.3	45.9	61.6	57.0	57.0	57.0	55.0	54.0	51.3	41.0	62.1	69.4
	Late	374	43.3	42.5	54.0	54.0	54.0	53.0	51.0	50.0	45.6	37.7	53.4	58.6
					Location: Upper									
Jan	Entire	2295	37.2	37.0	59.0	54.0	49.0	45.0	43.0	42.0	40.0	32.0	49.0	55.0
	Early	1109	38.0	38.0	59.0	54.0	49.0	46.0	44.0	43.0	40.0	32.0	47.5	52.5
	Late	1186	36.4	36.0	48.0	45.0	45.0	44.0	42.0	41.0	39.0	32.0	46.5	51.5
Feb	Entire	2097	37.6	37.0	48.0	48.0	47.0	45.0	44.0	42.0	40.0	33.0	47.5	52.5
	Early	1080	36.8	36.0	48.0	45.0	45.0	43.0	43.0	42.0	39.0	32.0	46.5	51.5
	Late	1017	38.5	38.0	48.0	47.0	46.0	45.0	44.0	43.0	41.0	33.0	50.0	56.0
Mar	Entire	2091	42.8	42.0	58.0	57.0	56.0	53.0	51.0	49.0	46.0	35.0	55.0	61.0
	Early	996	41.1	41.0	56.0	56.0	56.0	49.0	48.0	47.0	44.0	34.0	53.0	59.0
	Late	1095	44.4	44.0	58.0	57.0	55.0	54.0	52.0	50.0	48.0	37.0	58.5	65.5
Apr	Entire	2052	52.4	53.0	65.0	64.0	64.0	62.0	60.0	59.0	56.0	43.0	66.5	73.5

04/14/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Table 2. Monthly and bi-monthly ambient temperature statistics for the Ohio River by reach. Data collected from 1995 to 2003.

Month	Period	Samples	Mean[1]	Median[1]	Maximum (Occurrence)[2] Single	Twice	Three	Percentile 98th	95th	90th	75th	5th	Outlier Cutoff 75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	976	50.1	50.0	63.0	63.0	61.0	60.0	57.0	56.0	54.0	42.0	64.5	71.5
	Late	1076	54.5	55.0	65.0	64.0	64.0	62.0	61.0	60.0	57.0	47.0	66.0	72.0
May	Entire	2257	62.4	62.0	78.0	75.0	75.0	72.0	71.0	69.0	66.0	55.0	76.5	83.5
	Early	1063	60.3	60.0	78.0	71.0	70.0	70.0	68.0	66.0	64.0	53.0	73.0	79.0
	Late	1194	64.2	64.0	77.0	75.0	75.0	73.0	72.0	71.0	68.0	56.0	78.5	85.5
Jun	Entire	2135	71.7	72.0	86.0	83.0	83.0	81.0	80.0	78.0	76.0	63.0	88.0	96.0
	Early	1050	68.8	69.0	86.0	80.0	80.0	78.0	76.0	75.0	73.0	62.0	85.0	93.0
	Late	1085	74.5	75.0	83.0	83.0	83.0	82.0	80.0	80.0	78.0	67.0	88.5	95.5
Jul	Entire	2194	79.9	80.0	88.0	88.0	87.0	86.0	85.8	85.0	82.8	74.0	90.0	94.8
	Early	1059	79.0	79.0	88.0	86.0	86.0	86.0	84.0	83.0	81.0	73.0	87.0	91.0
	Late	1135	80.8	81.0	88.0	87.0	87.0	86.0	86.0	85.0	84.0	75.0	93.0	99.0
Aug	Entire	2099	81.1	81.0	92.0	88.0	88.0	87.0	86.0	86.0	84.0	74.0	91.5	96.5
	Early	1076	81.2	82.0	92.0	88.0	88.0	87.0	87.0	86.0	84.0	73.0	91.5	96.5
	Late	1023	81.1	81.0	88.0	88.0	88.0	87.0	86.0	85.2	84.0	75.0	91.5	96.5
Sep	Entire	2181	76.8	77.0	90.0	88.0	86.0	85.0	83.0	82.0	80.0	69.0	89.0	95.0
	Early	1110	79.1	80.0	90.0	88.0	86.0	85.0	84.0	83.0	81.0	73.0	87.0	91.0
	Late	1071	74.4	75.0	86.0	84.0	84.0	81.0	80.0	79.0	77.0	67.0	84.5	89.5
Oct	Entire	2309	66.5	67.0	81.0	80.0	78.0	77.0	75.0	74.0	70.0	58.0	80.5	87.5
	Early	1149	69.6	70.0	81.0	80.0	78.0	77.0	77.0	75.0	73.0	62.0	82.0	88.0
	Late	1160	63.5	64.0	74.0	74.0	74.0	71.0	69.0	68.0	67.0	57.0	77.5	84.5
Nov	Entire	2239	53.6	54.0	76.0	66.0	65.0	64.0	63.0	61.0	58.0	43.0	71.5	80.5

04/14/2005

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Table 2. Monthly and bi-monthly ambient temperature statistics for the Ohio River by reach. Data collected from 1995 to 2003.

					[2] Maximum (Occurrence)			Percentile					Outlier Cutoff	
Month	Period	Samples	Mean [1]	Median [1]	Single	Twice	Three	98th	95th	90th	75th	5th	75th+ 1.5*IQR	75th+ 2.5*IQR
	Early	1119	57.1	58.0	76.0	66.0	65.0	65.0	63.0	62.0	60.0	50.0	69.0	75.0
	Late	1120	50.1	50.0	65.0	63.0	63.0	60.0	58.0	56.5	54.0	42.0	66.0	74.0
Dec	Entire	2208	43.4	42.0	62.0	59.0	57.0	56.0	55.0	53.0	47.0	35.0	59.0	67.0
	Early	1099	45.3	44.0	62.0	57.0	57.0	56.0	55.0	54.0	50.0	37.0	65.0	75.0
	Late	1109	41.5	41.0	59.0	57.0	57.0	55.0	51.1	50.0	44.3	34.0	55.1	62.4

[1] Means/medians are means/medians of daily maximum values

04/14/2005

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

ACE data was based on readings taken in the morning and afternoon thus reflecting "typical" maximum temperatures even without more frequent measurements, especially with a more conservative method of eliminating outliers.

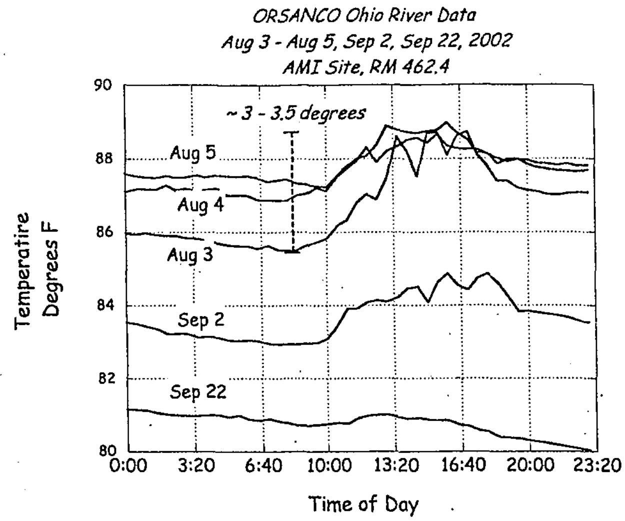


Figure 5. Ambient water temperature data taken at thirty minute intervals at RM 462.4 from four dates during 2002

Period of Record and Trends in Ambient Ohio River Temperatures

The period from 1995 to 2003 should be representative of recent ambient conditions in the Ohio River. As can be seen in the average annual air temperatures in Ohio over the past 110 years (Figure 6), the 1960s and 1970s were generally cooler, on average and more variable with a higher frequency of warmer temperatures in the 1980s and 1990s.

The existing Ohio River temperature criteria were partially derived from data on ambient water temperatures from the 1960s and 70s. We compared the ambient data summarized by ORSANCO (1983) from the period 1962-1978 (see Table 5) with the data we obtained from the 1995-2003 U.S. ACE stations, and the Markland and Ohio Falls sites. Monthly or bimonthly averages (and medians for the Markland and Ohio Falls sites) from these two time periods were plotted for stations from each time period that were close to one another (Figure 7). These monthly or bimonthly averages were clearly higher during the 1962-1978 period compared to the 1995 - 2003 time period even through average air temperatures during this period were lower. Table 3 summarizes the long-term monthly averages and maximum temperature values for 8 stations on the Ohio River monitored during the 1980s and 1990s.

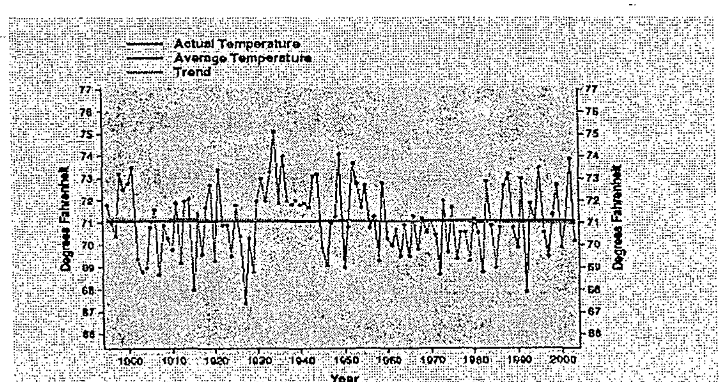


Figure 6. Trend in average summer air temperatures in Ohio from 1895-2003. Data from USGS.

Table 4. Maximum hourly and monthly temperatures in the Ohio River, 1962-1978, compiled by ORSANCO.

	Statistic			Mar		Apr		May		Jun							
Location		Jan	Feb	1-15	16-31	1-15	16-30	1-15	16-31	1-15	16-0	Jul	Aug	Sep	Oct	Nov	Dec
South Heights, MP 15.2, 1963-1978	Max. Hr	46.8	46.8	51.2	54.3	60.8	67.0	75.8	79.2	84.4	83.4	87.4	85.8	84.4	74.3	65.9	52.9
	Mp. Avg.	41.2	39.8	46.5	47.8	55.7	63.4	65.6	72.7	75.8	80.4	82.3	82.4	79.3	69.2	57.8	43.5
Stratton-E.Liv'pl, MP 53.8-40.2, 1962-1978	Max. Hr	48.7	47.5	54.0	54.5	62.0	67.7	74.7	80.2	80.5	86.2	88.0	88.4	85.8	77.0	71.3	52.5
	Mp. Avg.	43.7	42.1	49.1	48.4	54.8	63.1	69.5	75.4	78.8	82.2	84.9	83.6	79.7	69.8	59.1	45.4
Huntington, MP 306.9, 1962-1978	Max. Hr	48.4	49.1	56.4	57.7	61.0	66.5	76.2	81.9	81.7	85.8	88.2	88.3	85.6	77.8	67.1	53.8
	Mp. Avg.'	43.9	47.6	50.2	50.4	57.6	63.3	69.0	75.7	79.5	80.7	84.1	83.1	82.8	71.4	58.2	46.3
Cincinnati, MP 462.8, 1962-1978	Max. Hr	47.8	46.4	53.4	55.5	57.3	64.5	71.1	77.7	80.0	83.7	88.1	87.8	86.4'	78.9	70.0	57.5
	Mp. Avg.'	43.8	43.0	49.5	50.1	55.4	61.3	65.8	73.3	76.7	79.1	83.6	85.5	80.9	72.6	59.6	45.9
Noth Bend, MP 490.0, 1965-1978	Max. Hr	49.0	49.0	54.0	55.7	59.6	64.7	72.7	77.8	84.7	85.5	88.1	87.6	85.1	77.9	67.0	56.9
	Mp. Avg.'	43.1	43.1	50.0	50.2	55.1	61.4	67.4	73.5	80.1	81.5	84.4	83.9	81.2	71.4	58.7	48.1
Louisville, MP 600.6, 1962-1978	Max. Hr	49.0	48.0	55.1	59.2	65.5	66.0	73.2	80.8	81.7	85.9	88.2	87.5	86.3	77.9	69.1	53.4
	Mp. Avg.'	42.8	44.1	52.4	52.2	60.0	63.1	66.9	77.5	78.8	81.0	85.0	83.2	80.1	71.4	60.0	49.5
Cane Run-West Pt, MP 616.8-625.9, 1965-1978	Max. Hr	47.9	47.9	56.0	56.0	62.2	66.0	71.7	80.0	80.7	85.7	90.1	89.4	86.8	79.0	71.4	53.5
	Mp. Avg.'	45.5	43.5	50.7	51.5	58.1	62.6	66.5	72.4	76.8	80.8	85.3	84.3	81.4	72.7	59.6	47.7
Evansville, MP 791.5, 1969-1978	Max. Hr	48.9	50.1	54.4	55.7	60.9	68.3	73.0	79.5	81.8	87.4	89.7	87.3	86.3	77.7	69.8	52.7
	Mp. Avg.'	44.5	45.0	50.8	51.7	55.4	63.8	67.2	74.6	77.8	81.1	84.8	83.6	80.5	70.9	59.7	46.9
Ohio EPA Standards	Max	50	50	56	59	64	69	73	80	85	87	89	89	87/86	82/77	72	57
	Avg	45	45	51	54	58	64	68	75	80	83	84	84	82/82	77/72	67	52

Exceedences of Existing Temperature Criteria

We compared exceedences of the existing Ohio River temperature criteria with the ambient data collected from 1995-2003. For the recent data (U.S. ACE sites, Markland and Ohio Falls sites) we compared monthly averages to the average criteria and counted exceedences of the daily maximum criteria (Tables 6-8). Exceedences greater than 2°F was considered major, less than that were considered as minor. For the recent U.S. ACE data, major excursions were infrequent, with only 8 exceedences of average monthly temperatures at 15 locations from 1995 to 2003. Exceedences of daily maximum criteria were more frequent, but were less than 0.5% of samples for all exceedences and less than 0.2% for major exceedences. In addition, most of the major excursions occurred during December-February with only a small percentage during the critical summer months. The patterns were not very different among all of the datasets. For the purposes of evaluating the Fish Temperature Modeling outputs based on the new and updated thermal effects literature and various possible lists of representative fish species, we suggest using the statistics in Table 2 to evaluate the risk of exceedences due to "natural conditions".

Table 5. Summary of temperature criteria exceedecnes for the Ohio River by month and period. Data collected from 1995 to 2003.

Month	Period	No. Stations X Periods	Monthly Avg Exceedences: Number	Percent	[a] Major (#/%)	Samples	Daily Maximum Exceedences: Number	Percent	[a] Major (#/%)
Jan	Entire	124.0	4	3.23	0/ 0.00	6268	28	0.45	9/ 0.14
Feb	Entire	125.0	6	4.80	2/ 1.60	5662	29	0.51	8/ 0.14
Mar	Early	113.0	1	0.88	1/ 0.88	2646	1	0.04	1/ 0.04
	Late	118.0	5	4.24	1/ 0.85	2962	11	0.37	5/ 0.17
Apr	Early	110.0	5	4.55	1/ 0.91	2626	2	0.08	1/ 0.04
	Late	118.0	1	0.85	0/ 0.00	2778	2	0.07	2/ 0.07
May	Early	122.0	0	0.00	0/ 0.00	2896	10	0.35	1/ 0.03
	Late	129.0	1	0.78	0/ 0.00	3140	1	0.03	0/ 0.00
Jun	Early	119.0	0	0.00	0/ 0.00	2777	1	0.04	0/ 0.00
	Late	120.0	0	0.00	0/ 0.00	2852	0	0.00	0/ 0.00
Jul	Entire	125.0	9	7.20	0/ 0.00	5594	6	0.11	5/ 0.09
Aug	Entire	111.0	24	21.62	2/ 1.80	5093	4	0.08	4/ 0.08
Sep	Early	123.0	2	1.63	0/ 0.00	2748	2	0.07	0/ 0.00
	Late	118.0	1	0.85	0/ 0.00	2656	0	0.00	0/ 0.00
Oct	Early	124.0	1	0.81	0/ 0.00	2807	0	0.00	0/ 0.00
	Late	119.0	0	0.00	0/ 0.00	2865	0	0.00	0/ 0.00
Nov	Entire	127.0	0	0.00	0/ 0.00	5527	3	0.05	2/ 0.04
Dec	Entire	125.0	8	6.40	1/ 0.80	5748	26	0.45	12/ 0.21
	Totals:	Sum:	68		8		126		2.7
		Average:	3	3.21	.44 0.38		7	0.14	.15 0.05

01/30/2004

[a] Major excursions are greater than 2 degrees F greater than the criteria.

Table 6. Summary of temperature criteria exceedences for the Markland Pool of the Ohio River by month and period. Data collected from 1994 to 2003.

Month	Period	No. Stations X Periods	Monthly Avg Exceedences: Number	Percent	[a] Major (#/%)	Samples	Daily Maximum Exceedences: Number	Percent	[a] Major (#/%)
Jan	Entire	9.0	0		0/ 0.00	6590	0		0/ 0.00
Feb	Entire	9.0	1	11.11	0/ 0.00	5544	131	2.36	83/ 1.49
Mar	Early	9.0	0		0/ 0.00	3072	16		1/ 0.03
	Late	9.0	1	11.11	0/ 0.00	3288	3	0.09	1/ 0.03
Apr	Early	9.0	0		0/ 0.00	3047	15		13/ 0.42
	Late	9.0	0		0/ 0.00	3192	22		22/ 0.68
May	Early	10.0	1	10.00	0/ 0.00	3119	3	0.09	0/ 0.00
	Late		0		0/ 0.00	3648	0		0/ 0.00
Jun	Early		0		0/ 0.00	3384	0		0/ 0.00
	Late		0		0/ 0.00	3456	1		1/ 0.02
Jul	Entire	10.0	2	20.00	0/ 0.00	6121	4	0.06	2/ 0.03
Aug	Entire	10.0	3	30.00	0/ 0.00	6984	26	0.37	1/ 0.01
Sep	Early		0		0/ 0.00	3336	0		0/ 0.00
	Late		0		0/ 0.00	3504	0		0/ 0.00
Oct	Early		0		0/ 0.00	3456	0		0/ 0.00
	Late		0		0/ 0.00	3672	1		1/ 0.02
Nov	Entire		0		0/ 0.00	6768	1		0/ 0.00
Dec	Entire		0		0/ 0.00	7128	21		15/ 0.21
	Totals:	Sum:	8		0		244		140
		Average:	0	4.56	.00 0.00		13	0.28	7.8 0.16

[a] Major excursions are greater than 2 degrees F greater than the criteria.

Table 7. Summary of temperature criteria exceedences for the Ohio Falls of the Ohio River by month and period. Data collected from 1999 to 2003.

Month	Period	No. Stations X Periods	Monthly Avg Exceedences: Number	Percent	[a] Major (#/%)	Samples	Daily Maximum Exceedences: Number	Percent	[a] Major (#/%)
Jan	Entire	5.0	0	0.00	0/ 0.00	151	1	0.66	1/ 0.66
Feb	Entire	5.0	1	20.00	0/ 0.00	141	3	2.12	2/ 1.41
Mar	Early	5.0	0	0.00	0/ 0.00	74	0	0.00	0/ 0.00
	Late	5.0	0	0.00	0/ 0.00	80	1	1.25	1/ 1.25
Apr	Early	5.0	0	0.00	0/ 0.00	71	0	0.00	0/ 0.00
	Late	5.0	0	0.00	0/ 0.00	75	0	0.00	0/ 0.00
May	Early	5.0	0	0.00	0/ 0.00	73	0	0.00	0/ 0.00
	Late	5.0	0	0.00	0/ 0.00	80	0	0.00	0/ 0.00
Jun	Early	5.0	0	0.00	0/ 0.00	75	0	0.00	0/ 0.00
	Late	5.0	0	0.00	0/ 0.00	75	0	0.00	0/ 0.00
Jul	Entire	5.0	2	40.00	0/ 0.00	154	1	0.64	0/ 0.00
Aug	Entire	4.0	0	0.00	0/ 0.00	155	2	1.29	0/ 0.00
Sep	Early	4.0	0	0.00	0/ 0.00	75	0	0.00	0/ 0.00
	Late	4.0	0	0.00	0/ 0.00	75	0	0.00	0/ 0.00
Oct	Early	4.0	0	0.00	0/ 0.00	75	0	0.00	0/ 0.00
	Late	4.0	0	0.00	0/ 0.00	80	0	0.00	0/ 0.00
Nov	Entire	4.0	0	0.00	0/ 0.00	149	0	0.00	0/ 0.00
Dec	Entire	5.0	0	0.00	0/ 0.00	155	0	0.00	0/ 0.00
	Totals:	Sum:	3		0		8		4
		Average:	0	3.33	.00 0.00		0	0.33	.22 0.18

03/22/2004

[a] Major excursions are greater than 2 degrees F greater than the criteria.

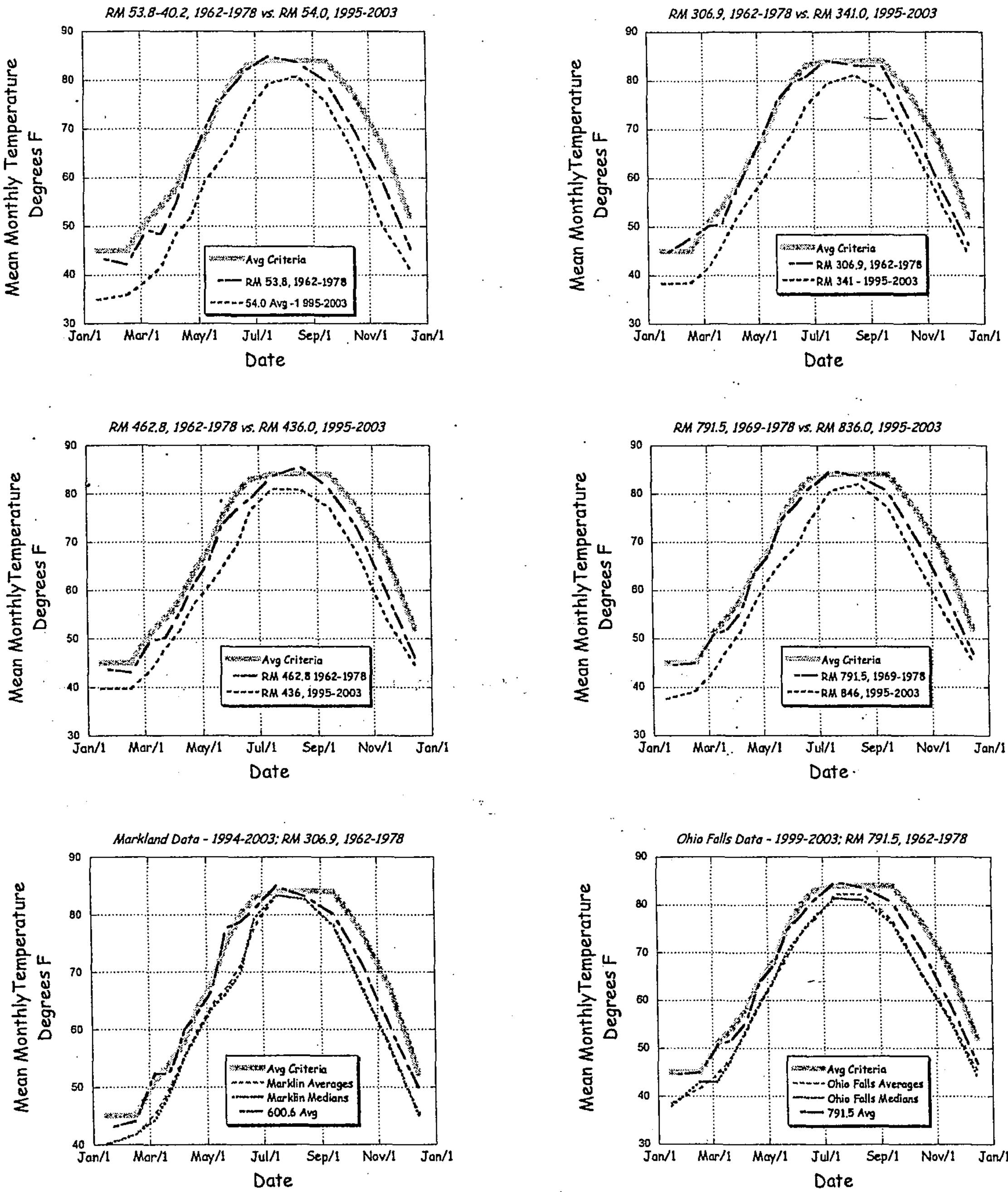


Figure 7. Monthly average temperature data for the Ohio River for selected stations from 1962-1978(blue broken line) and from 1995-2003 (green dahsed line) for panels 1-4. Green lines on medians and means from Panel 5 respesents data from the Markland Pool from 1994 to 2003 and panel siz from the Ohio Falls from 1999-2003. Yellow line represents monthly average Ohio River temperature criteria.

Phase II.5: Draft re-evaluation of Ohio River thermal criteria

Based on the results of the initial literature review, the Ad Hoc committee recommended proceeding with a draft re-evaluation of the existing Ohio River mainstem temperature criteria. It was also agreed that the general method of Ohio EPA (1978a) and later described by Yoder and Emery (2004) was valid for this purpose. The thermal effects data originating in Appendix Table Z.1 and the representative fish species (RAS) selected for a particular reach or segment are the two principal input variables of the current methodology. How these are determined potentially influences the outcomes of the temperature criteria derivation process. We developed example temperature criteria for three major segments of the Ohio River mainstem; 1) an upper reach from Pittsburgh to Greenup dam, a middle reach from Greenup to The Falls at Louisville, and a lower reach from Louisville to the mouth based on two lists of representative fish species. A list of "all possible RAS" was developed by members the Ad Hoc committee by consensus and a list of "mainstem restricted" species was developed as a subset of the larger list. We also derived summer season thresholds for the original list of representative species used to derive the current temperature criteria as another comparison.

Methodology

Review of the Literature

A comprehensive review of the literature was undertaken to supplement the thermal database that was originally compiled by Ohio EPA (1978a). The original compilation of literature that serves as the basis for the current Ohio River temperature criteria was accomplished over two years and occurred at the height of studies on thermal effects, specifically 316[a] demonstrations. This included a good mix of laboratory and field studies, some of which were coordinated in their scope and conduct. Some of these studies lingered into the early 1980s, thus some literature of that time period was not used by Ohio EPA (1978a). Other than the early compilations of temperature effects data accomplished by Brown (1974) and Brungs and Jones (1977), few compilations as comprehensive as these were available.

Several comprehensive compendia were 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, we 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 (Appendix Table Z.1). Our review of individual studies included classifying the methods and types of experimental tests and/or field studies. These are categorized in the key to Appendix Table Z.1. So called "grey literature" 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 that detailed the study design, methods, and analyses was required to accept thermal effects data into Appendix Table Z.1. Overall, our literature search produced a significant, but incomplete overlap with the major compendia. Our review alone added previously unknown literature sources for several fish species. A summary by species appears in Table 9.

Appropriate Thermal Endpoints

The compilation produced by Ohio EPA (1978a) relied mostly on upper incipient lethal temperature (UILT) as a lethal endpoint and for calculating the short and long term survival thresholds. This was the accepted thermal endpoint of that time (Brown 1974). The other available endpoint, the critical thermal maximum (CTM), was thought to produce lethal endpoints that were too high to be protective in nature because the test organisms were not properly acclimated by the rapid increase in test temperature. There is also the long standing concern that steady or consistent increases in test temperature do not reflect reality. The concept is amply illustrated by Figure 8 from Bevelheimer and Bennet (2000) in which the accumulation of thermal stress to an organism is dependent on seasonal acclimation, the extent and severity of periods of thermal stress and exposure, and the occurrence and duration of recovery periods, i.e., lower temperatures that are closer to physiological optima.

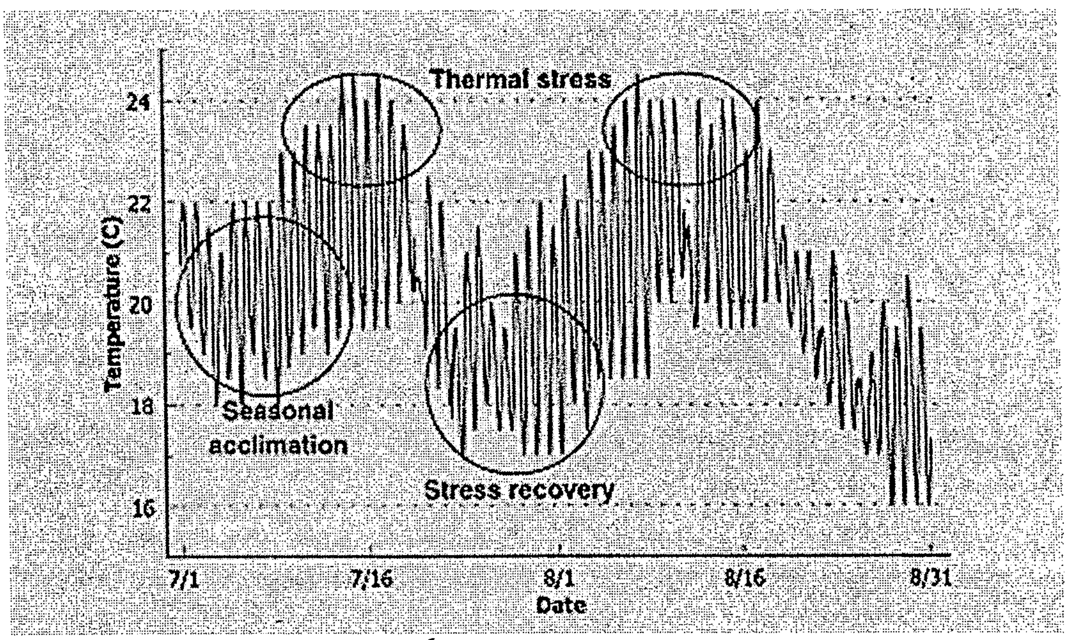


Figure 8. The important features of the thermal regime that is important in determining the effects of temperature on fish (after Bevelheimer and Bennet 2000).

While thermal resistance seems to increase with slowly increasing temperatures, does it represent reality in the environment where temperatures change 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 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. As a result, safety factors are frequently employed in interpreting thermal effects endpoints and in deriving temperature criteria.

The choice (or order of preference) of thermal endpoints was an important issue in this re-evaluation study. Clearly, different testing procedures produce different thermal endpoints.

Table 9. Compilation of thermal effects data available for Ohio River mainstem species comparing the availability of data for the current ORSANCO temperature criteria and new information compiled via a literature search (excluding Salmonids). Number under Appendix Table Z.1 heading indicates the number of data sources for each species.

Species	Original Sources	Appendix Table Z.1	New Literature	Preliminary Ohio R. RAS[2]
Silver lamprey	-	1	1	U,M,L
No. brook lamprey	-	1	1	U,M
Amer. brook lamprey	-	1	1	U,M
Paddlefish	-	1	1	U,M,L
Shortnose gar	2	2	-	U,M,L
Longnose gar	4	6	2	U,M,L
Bowfin	-	1	1	U,M,L
Goldeye	1	1	-	U,M,L
Mooneye	1	1	1	U,M,L
American eel	-	1	1	U,M,L
Skipjack herring	3	4	1	U,M,L
Gizzard shad	7	9	2	U,M,L
Central mudminnow	-	2	2	-
Grass pickerel	1	1	-	-
Northern pike	4	9	5	M,L
Muskellunge	2	3	1	U,M
N. pike x Muskellunge	-	2	2	-
Bigmouth buffalo	1	2	1	U,M,L
Smallmouth buffalo	3	4	1	U,M,L
Quillback carpsucker	3	6	3	U,M,L
River carpsucker	3	5	2	U,M,L
Highfin carpsucker	1	1	-	U,M,L
Golden redhorse	2	3	1	U,M,L
Smallmouth redhorse	1	2	1	U,M,L
Robust redhorse[3]	-	1	1	U,M,L
Hog sucker	3	5	2	U,M
White sucker	15	16	1	U,M
Spotted sucker	2	3	1	U,M,L
Common carp	12	12	-	U,M,L
Goldfish	6	10	4	U,M,L
Carp x Goldfish	-	1	-	-
Grass Carp	-	1	1	U,M,L
Bighead carp	-	1	1	M,L
Grass x Bighead Carp	-	1	1	-

[2] U - upper mainstem; M - middle mainstem; L - lower mainstem
[3] Does not occur in Ohio R. basin; function as a substitution RAS for river redhorse.

Table 9. continued.

Species	Original Sources	Appendix Table Z.1	New Literature	Preliminary Ohio R. RAS
Golden shiner	6	6	-	U,M,L
W. Blacknose dace	2	6	4	U
Longnose dace	1	2	1	U
River chub	-	1	1	
Hornyhead chub	-	1	1	
Creek chub	5	5	-	
Bigeye chub	-	1	1	
Emerald shiner	6	11	5	U,M,L
Silver shiner	1	2	1	M
Scarlet shiner	-	1	1	M
Redfin shiner	-	2	2	
Rosyface shiner	1	8	7	
Mimic shiner	-	1	1	U,M,L
Sand shiner	-	4	4	U,M
Striped shiner	1	5	4	U,M
Common shiner	1	6	5	
Spottail shiner	6	8	2	U,M
Spotfin shiner	3	9	6	U,M,L
Silverjaw minnow	1	2	1	M,L
Suckermouth minnow	-	1	1	M,L
Fathead minnow	5	9	4	U,M,L
Bluntnose minnow	6	12	6	U,M,L
Bullhead minnow	-	1	1	U,M,L
Central stoneroller	2	11	9	U,M
Blue catfish	-	1	1	U,M,L
Channel catfish	13	20	7	U,M,L
Yellow bullhead	2	3	1	U,M,L
Brown bullhead	8	11	3	U,M,L
Black bullhead	-	2	2	U,M,L
Flathead catfish	4	5	1	U,M,L
Tadpole madtom	-	1	1	M,L
Stonecat madtom	1	2	1	U,M
Brook silversides	-	2	2	U,M,L
Bl'kstripe topminnow	-	-	1	U,M,L
Banded killifish	-	1	1	
Mosquitofish	3	3	-	M,L
Striped bass	-	2	2	U,M,L
White bass	7	9	2	U,M,L
White x striped bass	-	1	1	U,M,L

Table 9. continued.

Species	Original Sources	Appendix Table Z.1	New Literature	Preliminary Ohio R. RAS
White crappie	6	10	4	U,M,L
Black crappie	6	9	3	U,M,L
Rock bass	7	7	-	U,M,L
Smallmouth bass	13	13	-	U,M,L
Spotted bass	6	7	1	U,M,L
Largemouth bass	18	22	4	U,M,L
Green sunfish	5	11	6	U,M,L
Bluegill	17	27	10	U,M,L
Longear sunfish	3	8	.5	U,M,L
Pumpkinseed sunfish	6	9	3	U,M,L
Redear sunfish	-	2	2	M,L
Orangespotted sunfish	-	4	4	U,M,L
Sauger	6	10	4	U,M,L
Walleye	7	12	5	U,M,L
Yellow perch	14	19	5	U
E. sand darter	-	1	1	U,M,L
Dusky darter	1	1	1	U,M,L
Logperch	-	1	1	U,M,L
Johnny darter	-	5	5	U,M,L
Greenside darter	1	4	3	U,M
Rainbow darter	-	3	3	U,M
Orangethroat darter	2	6	4	M
Fantail darter	2	8	6	M
Freshwater drum	6	6	-	U,M,L
Total Species (93) [4 hybrids]	288 [62 species]	505 [97 species]	217 [97 species]	**79U, 90M, 62L**

The key technical issue with the traditional upper thermal tolerance testing methods (CTM and UILT) is not the procedure itself, but a lack of correspondence to natural exposure conditions (see Figure 8). Selong et al. (2001) summarized the limitations of upper thermal endpoint data using these two methods:

> "However, their [CTM test results] relevance to the actual temperature tolerance of fishes is limited by the unnaturally rapid temperature changes, which preclude the normal acclimation that occurs in nature...However, as the CTM method, the ILT method may have limitations when it comes to extrapolating test results to natural situations. A recent modification of the ILT method incorporates slower

temperature change schedules (1.5C°/d) to better mimic natural temperature changes and reduce thermal shock (Smith and Fausch 1997). However, another potential limitation of the ILT method still remains, as temperature tests are typically run for a short duration (<7 d; Elliott and Elliott 1995) and the effects of longer exposures are often unknown. (p. 1027)."

The authors tested the short-term and chronic effects of elevated temperature on bull trout using the acclimated chronic exposure (ACE) method, which is a hybrid of the traditional CTM and ILT procedures. This method entails gradually adjusting water temperatures at environmentally realistic rates that allow fish to fully acclimate to changing conditions (e.g., 1°C/d). In tests with shorthead (now smallmouth redhorse) and golden redhorse, (Reash et al. 2000), an upper lethal temperature was derived using a heating rate very similar to the ACE method (1°C increase/d). Hokanson and Koenst (1986) further described this "slow heating" method to define chronic thresholds. There appears to be latent consensus that the CTM and UILT testing methods are less representative of natural daily and seasonal temperature patterns, although this is in conflict with much of the baseline literature concerning the UILT. When upper thermal endpoints were available for more than one method, we selected lethal endpoints in the following order (most preferred listed first):

1. "slow heating" method (e.g., a method analogous to ACE) that we term here the chronic thermal maximum (ChTM);
2. ultimate upper incipient lethal temperature (UUILT) at acclimation temperatures of 25-30°C;
3. critical thermal maximum (CTM) based on the fast heating method of 0.5-1.0°C/hr. with appropriate adjustments to account for the inherent over-estimation of lethality.

Unfortunately, very few slow heating (ChTM) method test results were found in our literature search. In fact, much of the new literature included the least preferred CTM based on the faster heating method. The papers that described the slow heating method agreed that slowly increasing test temperature followed by daily cooling would be "probably the most environmentally realistic exposure regime". However, the availability of test results using this approach are practically non-existent. The practical impact to our study is a continued need to rely on the UILT and the use of safety factors for the conversion of CTM results.

Thermal Endpoints

Four thermal input variables are used in the Fish Temperature Model to determine the summer (June 16–September 15) average and daily maximum temperature criteria. However, in developing these baseline input variables, six thermal parameters were first considered by Ohio EPA (1978a). General concepts of thermal responsiveness (e.g., acclimation) were considered and are discussed in more detail elsewhere (Brown 1974). Of the six thermal parameters that were inventoried for each fish species, 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 does the faster heating method on which the CTM is based (Brown 1974). Each of the thermal thresholds are defined as follows:

Upper Incipient Lethal Temperature – 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 – 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 Z.3.

Critical Thermal Maximum – 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 – a sharply defined upper temperature at which an organism at a given acclimation temperature will avoid (Coutant 1977);

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

Data garnered from a 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 Z.1). This compilation included all data used by Ohio EPA (1978a) and new references available since.

Compilation of Temperature Effects Data

Appendix Table Z.1 serves as the "raw data" for the temperature criteria derivation methodology. The Fish Temperature Model requires four input parameters, an optimum or final preferendum, the mean weekly average temperature for growth (after Brungs and Jones 1977), the upper avoidance temperature, and an upper lethal temperature. The values used in the model were retrieved from Appendix Table Z.3, which were in turn derived from Appendix Table Z.1. Where multiple values were available for selected species, the respective endpoints were developed by considering regional relevance, acclimation temperature (applies to lab studies), and other factors peculiar to the individual studies. In the case of lethal temperatures, data for acclimation temperatures of 25-30°C were preferred and included either upper incipient lethal (UILT) temperatures or the newer chronic thermal maximum (ChTM) advocated by Hokanson and Koenst (1984) and others since the inception of the original temperature criteria. In some cases, critical thermal maximum (CTM) data was the only available and the conversion factors in Appendix Table Z.2 or a default conversion to a value more representative of the two former endpoints was used (e.g., UILT = CTM - 2°C). An exception was when the CTM value was available only for lower acclimation temperatures (≤15°C) and only if no other data was available, in which case no such adjustments were made.

Thermal Input Variables

The Fish Temperature Model requires four thermal input parameters that include: 1) the optimum or final preferendum; 2) the mean weekly average temperature (MWAT) for growth; 3) the upper avoidance temperature; and, 4) the upper lethal temperature at acclimation temperatures of 25-30°C. Thermal parameters compiled in Appendix Table Z.1 were used as the primary database for the model. Ohio EPA (1978a) estimated missing parameters by calculating relationships between the six thermal parameters that were compiled for each species – at least three of the six parameters had to be available for a species before this procedure was used. Estimates of missing thermal parameters included calculation of the differences between:

1) optimum and UAT;
2) optimum and UILT or ChTM;
3) optimum and critical thermal maximum (CTM);
4) UAT and UILT/ChTM;
5) UAT and CTM; and,
6) UILT/ChTM and CTM

Conversion factors are summarized in Appendix Table Z.2. Extrapolations for missing values were then made in a stepwise procedure as follows:

- based on the species family or subfamily relationships (e.g., longnose gar, Lepisosteidae, "deep bodied" Catostomidae, "round-bodied" Catostomidae); or
- based on the next closest family if information for a parameter did not exist within the species family; or,
- based on the average of all families as a last choice.

Finally, the extrapolated thermal parameter had to make "biological sense", *i.e.*, it had to be "in line" with derived 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 (1978a) four the four basic input temperature thresholds including extrapolated values is graphically depicted in Figure 9. This figure depicts the relationships of thermal tolerance values between groupings of species ranging from highly tolerant to sensitive warmwater to cold water and can be used, in part, to evaluate the biological reality of extrapolated values.

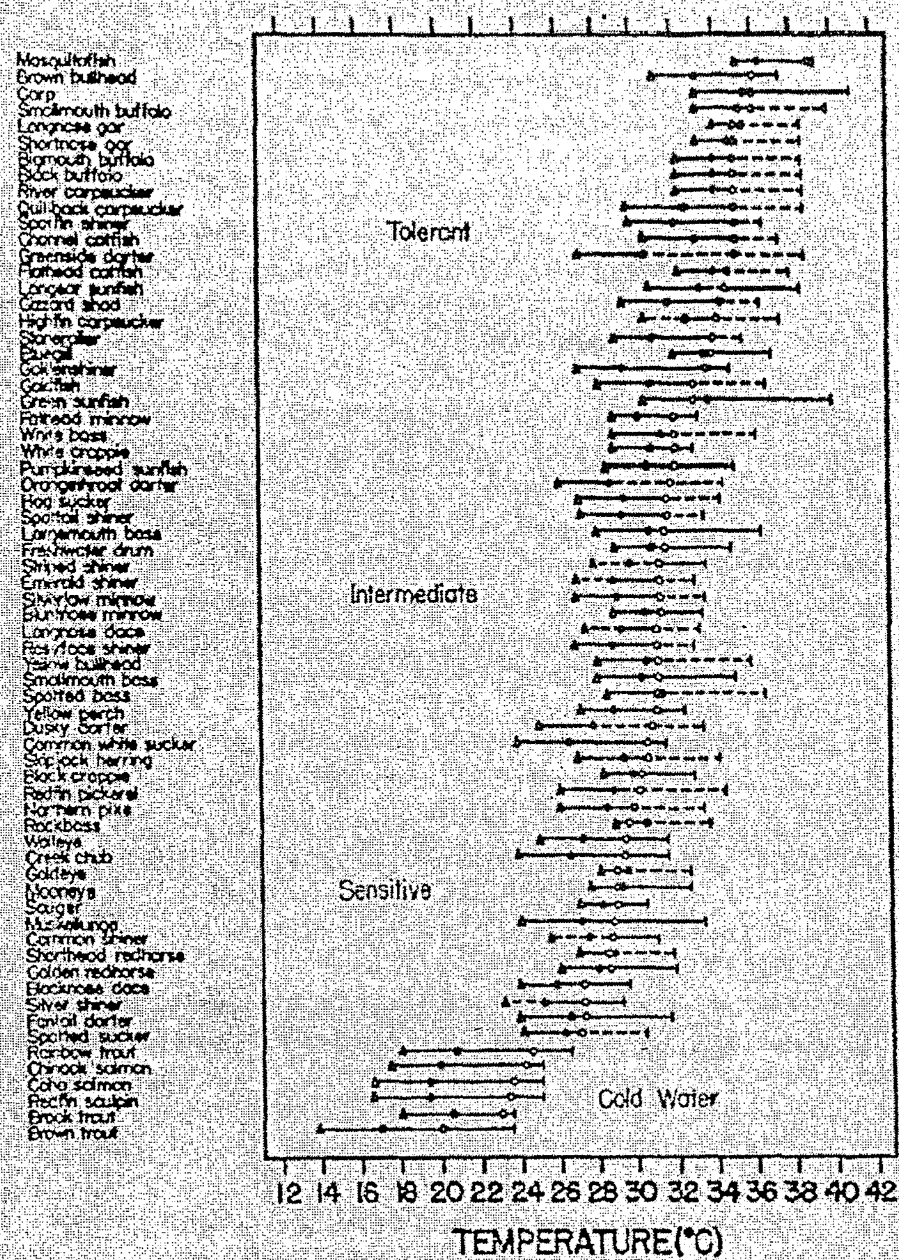


Figure C-1: Comparison of behavioral and physiological temperature criteria for 67 principal Ohio River - Lake Erie basin species based on Table C-2 (▲ - optimum, ◆ - growth, ○ - upper avoidance, ➜ - UILT, - - - estimated).

Figure 9. Reproduction of Figure C-1 from Ohio EPA (1978a). Species were ranked by their upper avoidance temperature determined by Ohio EPA.

The four primary thermal parameters are stored by species and accessed by the model when a species is designated as an RAS. Different RAS lists can be used by simply adding and removing species. Different thermal tolerance values can also be substituted to determine the impacts on the resulting summer season temperature thresholds.

Representative Fish Species for RAS

The derivation of temperature criteria is also dependent on the development of a list of representative fish species termed RAS (representative aquatic species), which is one of the two primary input variables for the model. Because thermal effects data are not available for all species in an assemblage, the list of representative species constitutes a *subset* of the assemblage that have sufficient thermal tolerance data from which temperature criteria can be derived. Thus an inherent assumption of this process is that all of the species not included in the database and the RAS will be protected by extension.

Species that are generally regarded as being highly to moderately tolerant to a variety of environmental impacts tend to be over-represented in these databases, which is common to databases for many water quality parameters. In our study, these species were the most commonly studied and frequently had data available for all six thermal parameters. The data that existed for species regarded as highly or moderately intolerant tended to be available for fewer parameters, were based on field studies, or were non-existent. As such, and until these species are adequately tested, there remains a significant risk that the most sensitive groups of species will not be adequately protected. This approach is simply a best attempt to represent the entirety of the assemblage and it is limited by the extant thermal tolerance databases. As such, the model output will propagate a degree of uncertainty, which can be considered in the eventual derivation *and* application of the temperature criteria.

In developing a list of representative fish species for a particular water body or segment, the following criteria for membership were used:

- species that represent the full range of response and sensitivity to environmental stressors;
- species that are commercially and/or recreationally important;
- species that are representative of the different trophic levels;
- rare, threatened, endangered, and special status species;
- species that are numerically abundant or prominent in the system;
- potential nuisance species; and,
- species that are indicative of the ecological and physiological requirements of representative species that lack thermal data.

The historical occurrence of fish species in a particular water body is an additional consideration in the development of the RAS list.

A subgroup of the Ad Hoc committee developed a list of representative Ohio River fish by consensus after examining the ORSANCO fish assemblage database and other pertinent historical references. This effort produced a list that we term here "all possible RAS" in that it tends to be inclusive of all species that have been found to occur in the mainstem. We also developed a list termed "mainstem restricted" that reflects an attempt to only include "mainstem dependent" fish species. This process illustrates one of the difficulties with the RAS approach, which species to include and which to exclude. By using two lists, the effect of RAS membership can be seen in the Fish Temperature Modeling results. We also included the original and much smaller list of RAS used by Ohio EPA (1978a) in the derivation of the current Ohio River temperature criteria. The various RAS lists for the upper, middle, and lower Ohio River mainstem appear in Table 10.

Temperature Criteria Derivation Process

Summer average and daily maximum summer temperature criteria were determined via an analytical process similar to that developed by Bush et al. (1974). Temperature tolerance values for 125 freshwater fish species are presently compiled in the database (Appendix Table Z.1). These values include the four primary thermal parameters described previously; optimum, mean weekly average for growth, upper avoidance, and upper incipient lethal temperatures. The model permits alternative values to be substituted and these can be maintained as alternate databases to be used for computing the effect of any species-specific differences on the derivation of summer season thresholds. The tolerance values in the database were used in the derivation of the summer average and maxima for three segments of the Ohio River mainstem. The procedure is simply one of listing each representative species under each thermal parameter adjacent to the whole Fahrenheit temperature when it is exceeded. The cumulative effect of increasing temperature is readily apparent as each species thermal criteria are exceeded. This process indicates where the various species occur (with respect to increasing temperature) relative to each other and does not indicate exact thresholds or limits. The temperatures at which 100%, 90%, 75% and 50% of the representative fish species for the four thermal thresholds are then derived to show what proportion of the representative assemblage is protected at a given temperature. The long-term survival temperature is calculated from the short-term survival (i.e., the UILT or ChTM) as UILT/ChTM minus 2°C. The following guidelines are used to derive summer average and maximum temperature criteria.

Averages should be consistent with:

- 100% long-term survival of all representative fish species;
- growth of commercially or recreationally important fish species;
- growth of at least 50% of the non-game fish species;
- 100% long-term survival of all state and federally listed fish species; and
- the observed historical ambient temperature record.

Daily maxima should be consistent with:

- 100% short-term survival of all representative fish species; and
- the observed historical ambient temperature record.

Non-summer season temperature criteria were derived primarily from the historical temperature record and considering other species-dependent criteria such as spawning periods. The rationale is that the chronic and acute thresholds that are important during

Table 10. Lists of representative fish species including "all possible RAS" and "mainstem restricted" RAS with data availability.

Species	Data Available	All Possible RAS	Mainstem RAS	Substitute RAS	Comment
AMERICAN BROOK LAMPREY	X	U			INCIDENTAL STREAM TRANSIENT
CHESTNUT LAMPREY		ML		SILVER LAMPREY	
OHIO LAMPREY		M		SILVER LAMPREY	
SILVER LAMPREY	X	UML	UML		
LAKE STURGEON		UML			
SHOVELNOSE STURGEON		UML			
PADDLEFISH	X	UML	UML		
LONGNOSE GAR	X	UML	UML		
SHORTNOSE GAR	X	ML	UML		
SPOTTED GAR	X	L			
ALLIGATOR GAR		ML			
BOWFIN	X	ML			
GOLDEYE	X	UML	UML		
MOONEYE	X	UML	UML		
AMERICAN EEL	X	UML			
ALEWIFE	X	UM			NON-INDIGENOUS INTRODUCED
GIZZARD SHAD	X	UML	UML		
SKIPJACK HERRING	X	UML	UML		
THREADFIN SHAD		ML			
MUSKELLUNGE	X	UML			
TIGER MUSKIE	X	U			
NORTHERN PIKE	X	U			
GRASS PICKEREL		ML			
BIGMOUTH BUFFALO	X	UML	UML		
BLACK BUFFALO		UML		SM. BUFFALO	
BLACK REDHORSE		UM		SM. REDHORSE	
BLUE SUCKER	X	UML			
GOLDEN REDHORSE	X	UML	UML		
HIGHFIN CARPSUCKER	X	UML	UML		
NORTHERN HOG SUCKER	X	UM	UM		
QUILLBACK CARPSUCKER	X	UML	UML		
RIVER CARPSUCKER	X	UML	UML		
RIVER REDHORSE		UM	UML	ROBUST REDHORSE	
SILVER REDHORSE		UML		GOLDEN REDHORSE	
SMALLMOUTH BUFFALO	X	UML	UML		
SMALLMOUTH REDHORSE	X	UML	UML		
SPOTTED SUCKER	X	UML	UML		
WHITE SUCKER	X	UM	UM		
LAKE CHUBSUCKER		L			
CREEK CHUBSUCKER		L			
COMMON CARP		UML	UML		EXCLUDED AS ALIEN
GOLDFISH		UML	UML		EXCLUDED AS ALIEN
GRASS CARP		UML	ML		EXCLUDED AS ALIEN
BIGHEAD CARP		UML	ML		EXCLUDED AS ALIEN
SILVER CARP		ML			EXCLUDED AS ALIEN
STONEROLLER	X	UM	UM		
RED SHINER		L			INVASIVE NON-INDIGENOUS
SPOTFIN SHINER	X	UML	UML		
STEELCOLOR SHINER		UML		SPOTFIN SHINER	

Table 10. (continued)

STREAMLINE CHUB		UM			INCIDENTAL STREAM TRANSIENT
MISS. SILVERY MINNOW		L		STONEROLLER	
BIGEYE CHUB	X	UML			
COMMON SHINER	X	UM			
STRIPED SHINER	X	UM	UM		
SCARLET SHINER		M			INCIDENTAL STREAM TRANSIENT
SILVER CHUB		UML			
SPECKLED CHUB		UML		BIGEYE CHUB	
RIVER CHUB	X	U			MUSSEL HOST
GOLDEN SHINER	X	UML	UML		
EMERALD SHINER	X	UML	UML		
RIVER SHINER		UML		SAND SHINER	
BIGEYE SHINER	X	UML			INCIDENTAL STREAM TRANSIENT
GHOST SHINER		UML		MIMIC SHINER	
SILVERJAW MINNOW		UM			INCIDENTAL STREAM TRANSIENT
SPOTTAIL SHINER	X	U	UM		
SAND SHINER	X	UML	UM		
SILVER SHINER	X	UM			
SILVERBAND SHINER		L		SPOTFIN SHINER	
ROSYFACE SHINER	X	UML			MUSSEL HOST
MIMIC SHINER	X	UML	UML		
CHANNEL SHINER		UML		MIMIC SHINER	
PUGNOSE MINNOW		L			INCIDENTAL STREAM TRANSIENT
SUCKERMOUTH MINNOW		M			
FATHEAD MINNOW	X	UM	UML		
BLUNTNOSE MINNOW	X	UML	UML		
BULLHEAD MINNOW	X	UML	UML		
WESTERN BLACKNOSE DACE		U			INCIDENTAL STREAM TRANSIENT
LONGNOSE DACE		U			INCIDENTAL STREAM TRANSIENT
CREEK CHUB		UML			INCIDENTAL STREAM TRANSIENT
PIRATE PERCH		L			
TROUT-PERCH		UM			
BROOK SILVERSIDE	X	UML	UML		
INLAND SILVERSIDE		ML		BROOK SILVERSIDE	
BANDED KILLIFISH	X	U			
BLACKSTRIPE TOPMINNOW	X	UL	UML		MUSSEL HOST
WESTERN MOSQUITOFISH	X	L	M		
BLACK BULLHEAD	X	UML	UML		
BLUE CATFISH	X	UML			
BRINDLED MADTOM		UML			INCIDENTAL STREAM TRANSIENT
BROWN BULLHEAD	X	UML	UML		
CHANNEL CATFISH	X	UML	UML		
FLATHEAD CATFISH	X	UML	UML		
FRECKLED MADTOM		L		TADPOLE MADTOM	
MOUNTAIN MADTOM		UML		STONECAT MADTOM	
STONECAT	X	UML			
TADPOLE MADTOM	X	ML	UML		
WHITE CATFISH	X	UML			NON-INDIGENOUS INVASIVE
YELLOW BULLHEAD	X	UML	UML		
NORTHERN MADTOM		L		STONECAT MADTOM	

Table 10. (continued)

HYBRID STRIPER	X	UML			
STRIPED BASS	X	UML	UML		
WHITE BASS	X	UML	UML		
WHITE PERCH		U			NON-INDIGENOUS INVASIVE
YELLOW BASS		ML		WHITE BASS	
BLACK CRAPPIE	X	UML	UML		
BLUEGILL	X	UML	UML		
GREEN SUNFISH	X	UML	UML		
LARGEMOUTH BASS	X	UML	UML		
LONGEAR SUNFISH	X	UML	UML		
ORANGESPOTTED SUNFISH	X	UML	UML		
PUMPKINSEED	X	UML	UML		
REDEAR SUNFISH	X	UML			INTRODUCED MANAGED
ROCK BASS	X	UML	UML		
SMALLMOUTH BASS	X	UML	UML		
SPOTTED BASS	X	UML	UML		
WARMOUTH	X	UML	UML		
WHITE CRAPPIE	X	UML	UML		
BANDED DARTER		UM		GREENSIDE DARTER	MUSSEL HOST
BLACKSIDE DARTER		UML		LOGPERCH	MUSSEL HOST
BLUEBREAST DARTER		U		RAINBOW DARTER	
BLUNTNOSE DARTER		L		JOHNNY DARTER	
CHANNEL DARTER		UML		LOGPERCH	
DUSKY DARTER	X	UML	UML		
EASTERN SAND DARTER	X	UM			
FANTAIL DARTER	X	UM			
GREENSIDE DARTER	X	UML	UM		
JOHNNY DARTER	X	UM			
LOGPERCH	X	UML			
MUD DARTER		L		RAINBOW DARTER	
ORANGETHROAT DARTER		U			INCIDENTAL STREAM TRANSIENT
RAINBOW DARTER	X	UML	UM		
RIVER DARTER		UML		DUSKY DARTER	
SAUGER	X	UML	UML		
SAUGEYE		UML		SAUGER	
SLENDERHEAD DARTER		UML		LOGPERCH	
VARIEGATE DARTER		UM			
WALLEYE	X	UML	UML		
YELLOW PERCH	X	UM	U		
FRESHWATER DRUM	X	UML	UML		
MOTTLED SCULPIN		U			INCIDENTAL STREAM TRANSIENT

Table 9. (continued)

the warm weather months are not approached or exceeded during this time period and that maintaining seasonal cycles is most important. Thus basing criteria on the maintenance of *historically representative* norms should be protective.

Derivation of Draft Ohio River Temperature Criteria Options

The derivation of draft seasonal temperature criteria options for the Ohio River mainstem included summer average and daily maximum values based on the output of the Fish Temperature Model, consideration of the historical ambient temperature record (phase I.4), and two different lists of RAS for three segments of the mainstem (Table 10). The thermal endpoints in Appendix Table Z.3 were then used as the thermal database in the Fish Temperature Model.

Purpose and Scope of Temperature Criteria

Temperature is defined as a pollutant in the Clean Water Act and as such can be regulated via state WQS. Temperature is usually included as one of the baseline parameters in all state WQS and is almost always depicted as single values. While temperature criteria are usually identified with the control of heat discharges, they also must serve a multitude of purposes associated with the application of WQS, for both well known and poorly appreciated purposes. Lately that has included TMDLs and the role of temperature as a co-variate of other important pollutants (e.g., ammonia) and stressors (e.g., urbanization) and as a primary pollutant. Changes in temperature regimes of flowing waters has recently been seen as an issue in urban watersheds and as a regional issue in global climate change (Eaton et al. 1995). Thus temperature criteria must also be developed with these other purposes in mind.

Temperature criteria must fulfill a broad role as defining the seasonal thermal regime that is needed to allow the restoration and maintenance of aquatic life designated uses, other designated uses, and associated processes in the aquatic environment. They need to protect against both short and long term changes, adverse fluctuations, and at multiple spatial scales. While the discharge of heat by electric generating stations and industrial processes that employ once-through cooling water processes has been the principal focus and use of temperature criteria and their resulting implications, other issues such as nonpoint sources and habitat modifications are emerging.

Summer Average and Maximum Criteria

Summer average and maximum criteria options were calculated in accordance with the outputs of the Fish Temperature Model (Table 11). These apply during the defined

Table 11. Fish temperature model outputs (°F[°C]) for two lists of RAS for the upper, middle, and lower Ohio River mainstem and the original list of RAS used by Ohio EPA (1978a).

Thermal Category	Proportion of Representative Fish Species 100%	90%	75%	50%
***Upper Mainstem** (all possible RAS 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 RAS)*				
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 RAS 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 RAS)*				
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 RAS 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 RAS)*				
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]

Table 11. continued

Thermal Category	Proportion of Representative Fish Species 100%	90%	75%	50%
Ohio River Mainstem (Original RAS)				
Optimum	71.1 [21.7]	73.6 [23.1]	78.1 [25.6]	84.4 [29.1]
Growth (MWAT)	77.4 [25.2]	79.2 [26.2]	82.8 [28.2]	88.5 [31.4]
Avoidance (UAT)	83.3 [28.5]	83.7 [28.7]	86.5 [30.3]	89.6 [32.0]
Survival (Long-term)	86.2 [30.1]	86.9 [30.5]	88.5 [31.4]	91.8 [33.2]
Survival (Short-term)	89.8 [32.1]	90.5 [32.5]	92.1 [33.4]	95.4 [35.2]

summer period of June 16- September 15 as daily maxima and a *period* average. The rationale for the period average as opposed to a daily or weekly average is in recognition of the realities of day-to-day and week-to-week variations in ambient temperature and the thermal requirements of fish. Neither is a "smooth" function with fish being able to avoid short- term exceedences of the long-term survival thresholds, but also being subject to seasonal acclimation, thermal stress, and recovery periods (Bevelheimer and Bennett 2000). A long-term period average should assure the occurrence of the necessary seasonal acclimation and stress recovery periods when temperatures are well below extreme survival and avoidance thresholds and closer to the equally important physiological thresholds for growth and maintenance.

Seasonal Average and Daily Maximum Criteria Derivation
The results of the Fish Temperature Model outputs for the three Ohio River mainstem segments appear in Table 11 (as summer season average and maximum criteria). The outputs of the Fish Temperature Model appear in Appendix B and can be used to examine the position of specific RAS in the model. The derivation of example seasonal temperature criteria includes using the results in Table 11 for the summer period (June 16-September 15) and seasonal temperature information for the remaining months developed from the analyses accomplished in phase I.4 (see Table 2). Table 11 includes the results of criteria derived from two RAS lists and the original RAS list used by Ohio EPA (1978a). These were derived in accordance with the criteria established by Ohio EPA (1978a) and Yoder and Emery (2004) that were described in the previous section. The temperature analyses in phase I.4 were used to determine the historical seasonal average and daily maximum temperatures. Daily maximum temperatures were initially determined by examining the period of record and selecting the 95th percentile value for each distinct period (month or bi-month). However, additional candidate duration values in Table 2 could be selected. Average temperatures were set at the upper quartile (75th percentile) for each time period to account for warmer years. An example of the results of this process appears in Tables 12 and 13.

Example temperature criteria were calculated for the upper, middle, and lower mainstem based on two different RAS lists. One list included *all possible RAS* by the consensus of the Ad Hoc work group based on the occurrence of a species in the mainstem. A second list included what are termed here as *mainstem restricted RAS* based both on occurrence and the known ecology

Table 12. An example of seasonal average and daily maximum temperature criteria (°F) for the upper Ohio River mainstem based on all possible RAS.

Month- Dates	Average[4]	Maximum[5]	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	75.2 [75.0]	78.8 [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 RAS; average exceeds UAT for 3 RAS; average meets long-term survival of listed RAS.
July 1-31	75.2 [80.0]	78.8 [87.0]	
August 1-31	75.2 [81.0]	78.8 [83.0]	
September 1-15	75.2 [80.0]	78.8 [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	

[4] 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.

[5] 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.

Table 13. An example of seasonal average and daily maximum temperature criteria (°F) for the upper Ohio River mainstem based on mainstem restricted RAS.

Month- Dates	Average[6]	Maximum[7]	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 RAS; average exceeds UAT for 3 RAS; average meets long-term survival of listed RAS.
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	

6 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.

7 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.

of that species. Both lists required the application of expert judgment in deciding which species to include or exclude from either list. The influence of each can be seen in the comparisons within the same segment (Tables 11 and 12). Between segments comparisons can include the influence of natural longitudinal changes in the RAS, particularly in the lower mainstem. Differences in summer average and maximum criteria were on the order of 9°F for the upper lethal threshold between the two RAS lists. These represent the aggregate effect of RAS selection and ambient temperature analyses. Table 14 contains a comparison of the outputs from all of the RAS by river segment model outputs with the original ORSANCO RAS used by Ohio EPA (1978a), which shows the effect of the new thermal data for the original RAS. Additional combinations of variations in RAS and different thermal endpoints for key species are possible and can be used as a way to develop sensitivity analyses for a particular river or river segment.

Table 14. Comparison of existing ORSANCO RAS temperature criteria (°F) with six alternative sets of possible criteria for the upper, middle, and lower Ohio River mainstem based on two sets each of RAS.

Period	Existing RAS[8]	Upper RAS 1[9]	Upper RAS 2[10]	Middle RAS 1	Middle RAS 2	Lower RAS 1	Lower RAS 2
January 1-31	45/50	37/43	37/43	39/44	39/44	40/47.5	40/47.5
February 1-28	45/50	37/44	37/43	39/44	39/44	42/48	42/48
March 1-31	51/56	42/51	42/51	45/52	45/52	47/55	47/55
April 1-15	58/64	50/57	50/57	51/61	51/61	53/59	53/59
April 16-30	64/69	55/61	55/61	57.5/63	57.5/63	59/65	59/65
May 1-15	75/80	60/68	60/68	61/70	61/70	62/69	62/69
May 16-31	80/85	64/72	64/72	64/75.7	64/75.7	66/73	66/73
June 1-15	80/85	69/76	69/76	68/80	68/80	70/78	70/78
June 16-30	86.2/89.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8
July 1-31	86.2/89.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8
August 1-31	86.2/89.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8
September 1-15	86.2/89.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8	75.2/78.8	84.2/87.8
September 16-30	82/86	75/80	75/80	77/80.3	77/80.3	76/82	76/82
October 1-15	77/82	70/77	70/77	71/76	71/76	70/78	70/78
October 16-31	72/77	64/70	64/70	65/70.1	65/70.1	65/72	65/72
November 1-30	67/72	54/63	54/63	56/65	56/65	56/66	56/66
December 1-31	52/57	42/55	42/55	44/54.4	44/54.4	46/56	46/56

[8] Original RAS used by Ohio EPA (1978a); recalculated with new data.
[9] RAS 1 - all possible RAS included.
[10] RAS 2 - mainstem restricted RAS.

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. [100]

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. [57]

Alderice, D. F. 1976. Some concepts and descriptions of physiological tolerance: rate-temperature curves of poikilotherms as transects of response surfaces. J. Fish. Res. Bd. Can. 33: 299-307. [xxx]

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. [37]

Allison, D. and H. Hothem. 1975. An evaluation of the status of the fisheries and the status of other selected wild animals in the Maumee River basin, Ohio, Ohio Dept. Nat. Res. Div. Wildl. Dist. 2, Findlay, Ohio. [xxx]

Alpaugh, W. C. 1972. High lethal temperatures of golden shiner *Notemigonus crysoleucas*. Copeia 1972, no. 1: 185. [264]

Altman, P. A. and D. S. Dittmer eds. 1966. Environmental biology. 694 pp. Bethesda, Md.: Fed. Am. Soc. Exp. Biol. [cited in Brown 1974]. [266]

American Electric Power Service Corporation. 1977. Commentary on proposed revisions to Ohio water quality standards, American Electric Power Serv. Corp. Env. Eng. Div., Canton, Ohio. [xxx]

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. [xxx]

Armour, Carl L. 1993. Evaluation Temperature Regimes for Protection of Smallmouth Bass. *U.S. Dept. of the Interior, Resource Publication 191*. 27 pp.

Armstrong, P. B. 1962. Stages in the development of Ictalurus nebulosus, Syracuse Univ. Press, Syracuse, N.Y. [203]

Bacon, E. J. Jr. W. H. Neill Jr. and R. V Kilambi. 1967. Temperature selection and heat resistance of the mosquitofish, Gambusia affinis. Proc. Ann. Conf. S.E. Assoc. Game Fish Comm. 21: 411-16. [23]

Badenhuizen, T. 1969. Effect of incubation temperature on mortality of embryos of largemouth bass Micropterus salmoides Lacepede, M.S. Thesis. Cornell Univ., Ithica, N.Y. [cited in Brown (1974)]. [272]

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

Bailey, M. M. 1964. Age, growth, maturity, and sex composition of the American smelt, Osmerus mordax (Mitchill), of western Lake Superior. Trans. Am. Fish. Soc. 93, no. 3: 382-95.

Bailey, R. M. 1955. Differential mortality from high temperture in a mixed population of fishes in southern Michigan. Ecology 36: 526-28. [259]

——. 1938. The fishes of the Merrimack watershed, pp. 149-185, In Biological survey of the Merrimack watershed, N.H. Fish Game Dept. Surv. Rep. 3. [208]

Baldwin, N. S. 1948. The speckled trout of Redrock Lake. Sylva 4, no. 4: 25-31. [107]

Balon, K. 1975. Reproductive guilds of fishes: a proposal and definition. J. Fish. Res. Bd. Can. 32: 821-64. [141]

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. [275]

Barans, C. L. and R. A. Tubb. 1973. Tempertures selected seasonally by four fishes from western Lake Erie. J. Fish. Res. Bd. Can. 30, no. 1: 1697-703. [6]

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. [175]

Battle, H. I and W. M. Sprules. 1960. A description of the semi-bouyant eggs and early development stages of the goldeye, Hiodon alosiodes (Rafinesque). J. Fish. Res. Brd. Can. 17, no. 2: 245-66. [142]

Becker, G. C. 1976. Inland fishes of the Lake Michigan drainage basin In Environmental status of the Lake Michigan Region. Env. Con. Tech. Earth Sci. ANL/ES-40, Vol. 17, 237 pp.Argonne Nat'l Lab, Argonne, Ill. [253]

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.

Behmer, D. 1965. Spawning periodicity of the river carpsucker, Carpiodes carpio. Iowa Acad. Sci. 72: 253-62. [162]

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". [88]

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. [xxx]

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. [21]

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)

Bennett, D. H. and J. W. Gibbons. 1972. Food of largemouth bass (Microptera salmoides) from a South Carolina reservoir receiving heated effluent . Trans. Am. Fish. Soc. 101: 650. [328]

——. 1975. Reproductive cycles of Largemouth bass (Micropterus Salmoides) in a cooling reservoir. Trans. Am. Fish. Soc. 104, no. 1: 77-82. [1]

Bettoli, P.W., W.H. Neill, and S.W. Kelch. 1985. Temperature preference and heat resistance of grass carp, *Ctenopharyngodon idella* (Valenciennes), bighead carp, *Hypophthalmichthys nobilis* (Gray), and their F_1 hybrid. J. Fish. Biol. 27: 239-247.

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

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. Fish. Bull. U.S. Fish Wildl. Serv. 74, no. 53: 577 pp. [209]

Bishai, H. M. 1960. Upper lethal temperatures for larval salmonids. J. Cons. Perma. Int. Explor. Mer. 25, no. 2: 129-33. [58]

Black, E. C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. J. Fish. Res. Bd. Can. 10, no. 4: 196-210. [50]

Black, J. D. 1945. Natural hisory of the northern mimic shiner, Notropis volucellus volucellus. Cope. Invest. Ind. Lakes Streams 2, no. 18: 449-46. [195]

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.

Bodola, A. 1966. Life history of the gizzard shad, Dorosoma cepedianum (Le Sueur), in western Lake Erie. U.S. Fish Wildl. Serv. Fish. Bull. 65, no. 2: 391-425. [144]

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.

Bower, S. 1897. The propagation of small mouth black bass. Trans. Amer. Fish. Soc. 25: 127-36. [220]

Bowman, M. L. 1970. Life history of the black redhorse, Moxostoma duguesnei (Le Sueur), in Missouri. Trans. Am. Fish. Soc. 99, no. 3: 546-59. [165]

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.

Breder, C. M. Jr. and D. E. Rosen. 1966. Modes of Reproduction in Fishes. 941 pp. Garden City, N.Y.: The Natural Hist. Press. [139]

Brett, J. R. 1944. Some lethal relations of Algonquin Park fishes. Publ. Ont. Fish Res. Lab 63: 1-49. [128]

——. 1956. Some principles in the thermal requirements of fishes . Quart. Rev. Biol. 31: 75-87. [257]

——. 1969. Temperature and fish - Resume. Chesapeake Sci. 10, no. 3,4: 275-76. [xxx]

——. 1964. "Temperature. animals. fishes. pp. 515-560, In O. Kinne [ed.]. The Effects of Temperature and Salinity on Marine and Brackish Water Animals." Oceanogr. Mar. Biol. Ann. Rev., 2. [xxx]

——. 1952. Temperature tolerance in young Pacific salmon Genus Oncorhynchus. J. Fish. Res. Bd. Can. 9, no. 6: 265-323. [45]

——. 1960. Thermal requirements of fish - three decades of study, 1940-1970. pp. 110-117, In Biol. Prob. Water Poll., Tech. Rep. No. W60-3, Robt. A. Taft San. Eng. Cen., Cincinnati, Ohio. [xxx]

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]. [30]

Brungs, W. A. 1971. Chronic effects of constant elevated temperature on the fathead minnow (Pimephales promelas). Trans. Am. Fish. Soc. 100, no. 4: 659-64. [3]

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. [96]

Bryan, J. E. and Kato D. A. 1975. Spawning of the lake white fish, Coregonus clupeaformis, and round white fish, Prosopium cylindraceum, in Aishihik Lake and East Aishihik River, Yukon Territory. J. Fish. Res. Bd. Can. 32: 283. [325]

Bull, H. O. 1952. An evaluation of our knowledge of fish behavior in relation to hydrography. Rapp. Proc - Verb. ICES 131: 8-23. [xxx]

Burr, B. M and M. A. Morris. 1977. Spawning behavior of the shorthead redhorse, Moxostoma macrolepidotum, in Big Rock Creek, Illinois. Trans. Am. Fish. Soc. 106, no. 1: 80-82. [251]

Burrows, R. E. 1963. Water temperature requirements for maximum productivity of salmon. Proc. 12th Pacific N.W. Symp. Water Poll. Res. [71]

Bush, R. M. E. B. Welch and B. W. Mars. 1974. Potential effects of thermal discharges on aquatic systems. Env. Sci. Tech. 8, no. 6: 561-68. [36, 299]

Cabanac, M. 1975. Temperature regulation. Ann. Rev. Physiol. 37: 415-39. [xxx]

Cahn, A. R. 1927. An ecologicl study of southern Wisconsin fishes. Ill. Biol. Monogr. 11, no. 1: 1-151. [135]

Cairns, J. Jr. 1972. Coping with heated waste water discharges from steam electric power plants. BioScience 22, no. 7: 411-20. [xxx]

——. 1956a. Effects of increased tempertures on aquatic organisms. Ind. Wastes 1, no. 4: 150-152. [xxx]

——. 1956b. Effects of temperture on fish. Ind. Wastes 1, no. 5: 180-183. [262]

——. 1976. Heated waste-water effects on aquatic ecosystems. pp. 32-38, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposim Series) "CONF-750425". [xxx]

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. [66]

Carbine, W. F. Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan. Trans. 4th North Amer. Wildl. Conf. pp. 275-87. [224]

Carlander, K. D. 1969. Handbook of freshwater fishery biology. 3rd ed., 752 pp. Ames, Iowa: Iowa State University Press. [127]

——. 1977. Handbook of freshwater fishery biology. 1st ed., 431 pp. Ames, Iowa: Iowa State University Press. [xxx]

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.

Carroll, E. W. and C. R. Norden. 1971. Temperature preference of the freshewater alewife, Alosa pseudoharengus , Abst. of paper presented at Midwest Fish and Wildlife Conference. [cited in Coutant 1975)]. [65]

Carter, A. H. ms. Toronto, ON. Life history and ecology of the minnow, Nocomis biguttatus (Kirtland), M.A. Thesis. Univ. Toronto. [181]

Carufel, L. H. 1963. Life history of saugers in Garrison Reservoir. J. Wildl. Mgmt. 27, no. 3: 450-456. [229]

Cavender, T. C. 1977. Personal communication. [76]

Chagnon, N. and I. Hlohowskyj. 1989. Effects of phenol exposure on the thermal tolerance ability of the central stoneroller minnow. Bull. Environ. Contam. Toxicol. 42: 614-619.

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

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. [xxx]

——. 1975. Temperatures selected and avoided by fish at various acclimation temperatures. J. Fish. Res. Bd. Can. 32: 485-91. [5]

——. 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. [xxx]

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.

Cherry, D. S. R. K. Guthrie J. H. Rodgers J. Cairns Jr. and K. L. Dickson. 1976. Responses of mosquitofish (Gambusia affinus) to ash effluent and thermal stress. Trans. Am. Fish. Soc. 105, no. 6: 686-94. [78]

Childers, William F. 1967. Hybridization of four species of sunfishes (Centrarchidae). Ill. Natur. Hist. Surv. Bull. 29, art. 3, Sept., 1967: 214 pp. [226]

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.

Christie, W. J. 1963. Effects of artificial propagation and the weather on recruitment in the Lake Ontario whitefish fishery. J. Fish. Res. Bd. Can. 20, no. 3: 597-646. [152]

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

Clady, M. and B. Hutchinson. 1975. Effect of high winds on eggs of yellow perch, Perca flavescens, in Oneida Lake, New York. Trans. Am. Fish. Soc. 104, no. 3: 524-25. [248]

Clay, W. M. 1975. The Fishes of Kentucky. 416 pp. Frankfort, Kentucky: Kentucky Dept. of Fish and Wildl. Resources. [136]

Clugston, J. P. 1973. "The effects of heated effluents from a nuclear reactor on species diversity, abundance, reproduction and movement of fish, Ph D. Dissertation. [24]

Coble, D. W. 1966. Dependence of total annual growth in yellow perch on temperature. J. Fish. Res. Bd. Can. 23, no. 1: 15-20. [xxx]

Coker, R. E. 1927. Black-nosed dace in North Carolina. Copeia 1927, no. 162: 4. [187x]

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. Winnepeg, Man.: Univ. Manitoba Press. [xxx]

Cooper, G. P. 1936. Age and growth of the golden shiner (Notemigonus crysoleucas auratus) and its suitablility for propagation. Pap. Mich. Acad. Sci. Arts Letters 21: 587-97. [178]

——. 1935. Some results of forage fish investigations in Michigan. Trans. Am. Fish. Soc. 65, no. 1935: 132-42. [172, 177]

Cooper, G. P. and J. L. Fuller. A biological survey of Moosehead Lake and Haymock Lake, Maine, Fish. Surv. Rept. No. 6. Maine Dept. Inland Fish. and Game. [106]

Courtenay, W. R. Jr. and M. H. Roberts. 1973. Environmental effects on toxaphene toxicity to selected fishes and crustaceans, EPA-R3-035. USEPA, Washington, D.C. [329]

Coutant, C. C. 1972b. Biological aspects of thermal pollution II. Scientific basis for water temperature standards at power plants. CRC Critical Rev. Environ. Control 3, no. 1: 1-24. [xxx]

——. 1977. Compilation of temperature preference data. J. Fish. Res. Bd. Can. 34, no. 5: 739-45. [122]

——. 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 BassesWashington, D.C.: Sport Fishing Institute. [4]

——. 1975b. Temperature selection by fish - a factor in powerplant impact assessments. pp. 575-597, In Environmental Effects of Cooling Systems at Nuclear Power Plants, IAEA-SM-187/11. [123]

——. 1972a. Time-temperature relationships for thermal resitances of aquatic organisms, principally fish, ORNL-EIS72-27. Oak Ridge National Lab, Oak Ridge, Tennessee. [292]

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.

Coutant, C. C. and D. K. Cox. 1976. Growth rates of subadult largemouth bass at 24 to 35.5 C. pp. 118-120, In G.W. Esch and R.W. McFarlane[eds]. Thermal Ecology II (ERDA Symposium Series) "CONF 750425". [81]

Coutant, C. C. D. K. Cox and K. W. Moored Jr. 1976. Further studies of cold-shocked effects on the susceptibility of young channel catfish to predation. pp. 154-158, In G.W. Esch and R.W. McFarlane [eds]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425". [86]

Cox, D. K. and C. C. Coutant. 1976. Acute cold-shock resistance of gizzard shad. pp. 159-161, In G.W. Esch and R.W. McFarlane [eds]. Thermal Ecology II (ERDA Symposium Seires) "CONF-750425". [xxx]

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]

——. 1977. Physiological and behavioral reactions of fishes to temperature change. J. Fish. Res. Bd. Can. 34: 730-734. [xxx]

Creaser, C. W. 1930. Relative importance of hydrogen ion concentration, temperature, dissolved oxygen, and carbon dioxide tensions on habitat selection by brook trout. Ecology 11: 246-62. [105]

Crossman, E. J. 1962. The redfin pickerel, Esox a. americanus in North Carolina. Copeia 1962, no. 1: 114-23. [159]

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

Cvancara, V. A. 1975. Studies on the tolerance of young of the year Mississippi River fish to heated waters, OWRT 14-31-0001-9037 (C-4251). U.S. Dept. Interior. [xxx]

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.

Daiber, F. C. 1953. Notes on the spawning population of freshwater drum (Aplodinotus grunniens Rafinesque) in western Lake Erie. Am. Midl. Nat. 50, no. 1: 159-71. [242]

Davies, S.P. and S.K. Jackson. 2005. The Biological Condition GradientA descriptive model for interpreting change in aquatic ecosystems. Ecological Applications (in press).

Deason, H. J. 1933. Preliminary report on the growth rate, dominance, and maturity of the pike-perches (Stizostedion) of Lake Erie. Trans. Am. Fish. Soc. 63: 348-60. [xxx]

deKozlowski, Steven J. and Dewey L. Bunting II. 1981. Laboratory study on the thermal tolerance of four southeastern stream insect species (trichoptera, ephemeroptera). *Hydrobiologia* 79: 141-45.

Delisle, C. and W. Van Vliet. 1968. Frist records of the sculpins Myoxocephalus thompsonii and Cottus recei from the Ottawa Valley, southwester Quebec. J. Fish. Res. Bd. Can. 25, no. 12: 2733-37. [243]

Dendy, J. S. 1946. Further studies of depth distribution of fish, Norris Reservoir, Tennessee. Report of the Reelfoot Biological Station 10: 94-104. [xxx]

——. 1948. Predicting depth distribution of fish in three TVA storage type reservoirs. Trans. Am. Fish. Soc. 75: 65-71. [52]

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.

100. deVlaming, V. L. 1975. Effects of photoperiod and temperature on gonadal activity in the cyprinid teleost, Notemigonus crysoleucas. Biol. Bull. Wood Hole, Mass. 148: 402-15. [xxx]

——. 1972. Environmental control of teleost reproductive cycles: a brief review. J. Fish. Biol. 4: 131-40. [281]

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.

Dickson, K. L. J. Cairns Jr. D. S. Cherry and J. R. Stauffer. 1976. An analysis of the applicablility of EPA's draft water-temperature criteria: a site specific case history evaluation. pp. 316-326, In G.W. Esch and R.W. McFarlane [eds]. Thermal Ecology II (ERDA Symposium Series) "CONF 750425". [304]

Doudoroff, P. 1938. Reactions of marine fishes to temperature gradients. Biol. Bull. Woods Hole, Mass. 75: 494-509. [290]

Dryer, W. R. and J. Beil. 1964. Life history of the lake herring in Lake Superior. U.S. Fish. Wildl. Serv. Fish. Bull. 63, no. 3: 493-530. [150]

Eaton, J. G. J. H. McCormick B. E. Goodno D. G. O'Brien H. G. Stefany M. Hondzo and R. M. Scheller. 1995. Field information-based system for estimating fish temperature tolerances. *Fisheries* 20, no. 4: 10-18, April.

Echelle, A. A. and C. D. Riggs. 1972. Aspects of the early life history of gars in Lake Texoma. Trans. Am. Fish. Soc. 101, no. 1: 106-12. [140]

Eddy, S. and C. Underhill. 1974. Northern Fishes . 3rd ed. Minneapolis, Minn.: Univ. of Minnesota Press. [137]

Edison Electric Institute. 1977. "Analysis of the U.S. Environmental Protection Agency chlorine and temperature quality criteria for water. Vol. 1." Edison Electric Insititute, New York, N.Y. [xxx]

Edsall, T. A. 1967. Biology of the freshwater drum in western Lake Erie. Ohio J. of Sci. 67, no. 6: 321-40. [241]

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. [xxx]

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. [295]

Eipper, A. W. 1975. "Environmental influences on the mortality of bass embryos and larvae. pp. 295-305, In R.H. Stroud and H. Clepper [eds.]. National Symposium on the Biology and Management of the Centrarchid Basses." Sport Fishing Institute, Washington, D.C. [xxx]

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)

Emery, E. B., T. P. Simon, F. H. McCormick, P. A. Angermeier, J. E. DeShon, C. O. Yoder, R. E. Sanders, W. D. Pearson, G. D. Hickman, R. J. Reash, J. A. Thomas. 2003. Development of a Multimetric Index for Assessing the Biological Condition of the Ohio River. Trans. Am. Fish. Soc. 132:791-808.

Eschmeyer, P. H. 1950. The life history of the walleye, Stizostedion vitreum vitreum (Mitchell), in Michigan. Bull of Institute for Fish. Res. No. 3 (Michigan Dept. of Conserv.) . [230]

Faber, D. J. 1970. Ecological observations on newly hatched lake white fish in South Bay, Lake Huron. pp. 481-500, In C.C. Lindsey and C.S. Woods [eds]. Biology of Coregonid Fishes. 560 pp. Winnipeg, Man.: Univ. Manitoba Press. [153]

Fahy, W. E. 1954. The life history of the northern greenside darter, Etheostoma blennioides blennioides Rafinesque. Proc. of the Elisa Mitchell Sci. Soc. December, 1954 : 139-205. [240]

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.

Federal Water Pollution Control Administration. 1968. Industrial waste guide on thermal pollution. 112 pp. Corvallis, Oregon: U.S. Dept. Interior, Pacific Northwest Water Lab. [xxx]

Feminella, J. W. and W. J. Matthews. 1984. Intraspecific differences in thermal tolerance of *Etheostoma spectabile* (Agassiz) in constant versus fluctuating environments. *J. Fish Biol.* 25: 455-61.

Ferguson, R. G. 1965. Bathymetric distribution of American smelt, Osmerus mordax, in Lake Erie. Univ. Mich. Gr. Lks. Res. Div. Publ. 13: 47-60. [320]

——. 1958. The preferred temperature of fish and their midsummer distribution in temperture lakes and streams. J. Fish. Res. Bd. Can. 15, no. 4: 607-24. [22]

Fish, M. P. 1932. Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters. Bull. Bur. Fish 47: 293-398. [186]

Forney, J. L. 1955. Life history of the black bullhead, Ameiurus melas (Rafinesque), of Clear Lake, Iowa. Iowa State Coll. J. Sci. 30, no. 1: 145-62. [204]

Fry, F. E. J. 1971. The effect of environmental factors on the physiology of fish. pp. 1-98, In W.S. Hoar and D.J. Randall [eds.]. Physiological Adaptations. New York, N.Y.: Ronal Press. [xxx]

Fry, F. E. J. 1947. The effects of the environment on animal activity, University Toronto Stud., Biol. Ser. 44:91 pp. [14]

——. 1958. The experimental study of behavior in fish. PRoc. Into-Pac. Fish. Counc. 3: 37-42. [317]

——. 1937. The summer migration of the cisco, Leuichthys artedii (Le Sueur), in Lake Nipissing, Ontario, University Toronto Stud., Biol. Ser. No. 44. University Toronto Press, Toronto. [119]

Fry, F. E. J. and J. S. Hart. 1948. Cruising speed of goldfish in relation to water temperature. J. Fish. Res. Bd. Can. 7, no. 4: 169-75. [291]

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. [59]

Fry, F. E. J. J. R. Brett and G. H. Clawson. 1942. Lethal limits of temperature for young goldfish. Rev. Can. Biol. 1: 50-56. [xxx]

Fry, F. E. J. J. S. Hart and K. F. Walker. 1946. Lethal temperature relations for a sample of young speckled trout (Salvelinus fontinalis), University Toronto Sryd., Biol. Ser. No. 54, Publ. Ontario Fish. Res. Lab. No. 66: pp. 1-35. [41]

Gale, W. F. and C. A. Gale. 1977. Spawning habits of spotfin shiner (Notropis spilopterus) - a fractional, crevice spawner. Trans. Am. Fish Soc. 106, no. 2: 170-177. [250]

Gale W.F. and H.W. Mohr, Jr. 1978. Larval fish drift in large river with a comparison of sampling methods. Trans. Am. Fish. Soc. 107, no. 1: 46-55. [xxx]

Galligan, J. P. 1951. The distribution of lake trout and associated species in Cayuga Lake, M.S. Thesis. Cornell University, Ithaca, N.Y. [11]

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. [9]

——. 1971. The response of fish populations in the Wabash River to heated effluents. 3rd Nat. Symp. on Radioecology : 513-23. [32]

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. [xxx]

Garside, E. T. and J. S. Tait. 1958. Preferred temperture of rainbow trout and its unusual relationship to acclimation temperature. Can. J. Zool. 36: 565-67. [104]

Garten, C. T. Jr. and J. B. Gentry. 1976. Thermal tolerance of dragonfly nymphs. II. Comparison of nymphys from control and thermally altered environments. *Pysiological Zoology* 49, no. 2: 206-13.

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.

Geen, G. H. T. G. Northcote G. F. Hortman and C. C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteen Mile Lake, British Columbia, with particular reference to inlet spawning . J. Fish. Res. Bd. Can. 23: 1761-88. [170]

Gibson, E. S. and F. E. J. Fry. 1954. The performance of the lake trout, Salvelinus namaycush, at various levels of temperature and oxygen pressure. Can. J. Zool. 32, no. 3: 252-60. [294]

Glenn, C. L. and R. R. G. Williams. 1976. Fecundity of mooneye, Hiodon tergisus, in the Assiniboine River. Can. J. Zool. 54: 156-61. [322]

Goddard, C. I. S. W. Lilley and J. S. Tait. 1974. Effects of M.S. 222 anesthetization on temperature selection in lake trout (Salvelinus namaycush). J. Fish. Res. Bd. Can. 31: 100-103. [43]

Graham, J. J. 1956. Observations on the alewife, Pomolobus pseudoharengus (Wilson), in fresh water. University Toronto Studies, Biol. Ser. 62, Publ. Ontario Fish. Res. Lab No. 74: 1-43. [44]

Graham, J. M. 1949. Some effects of temperature and oxygen pressure on the metabolism and activity of the speckled trout, Salvelinus fontinalis. Can. J. Res. Sec. D27: 270-288. [109]

Greely, J. R. "Fishes of the Erie-Niagra watershed. pp. 150-179, In A Biological Survey of the Erie-Niagra System." Supp. 18th Ann. Rep. New York Cons. Dep. (1928) , 1929. [196]

Griffith, J. S. 1978. Effects of low temperature on the survival and behavior of threadfin shad, Dorosoma petenense. Trans. Am. Fish. Soc. 107, no. 1: 63-70. [xxx]

Hackney, P. A. W. M. Tatum and S. L. Spencer. 1969. The life history of the river redhorse, Moxostoma carinatum (Cope), in the Cahaba River, Alabama, with notes on the management of the species as a sport fish. Proc. 21st Ann. Conf. S.E. Assoc. Game Fish Comm. (1968) : 324-32. [xxx]

Hansen, D. F. 1951. Biology of the white crappie in Illinois. Ill. Nat. Hist. Surv. Bull. 25, no. 4: 211-30. [216]

——. 1965. Further observations on nesting of the white crappie, Pomoxis annularis. Trans. Amer. Fish. Soc. 94, no. 2: 182-84. [217]

——. 1943. On nesting of the white crappie, Poxomis annularis. Copeia 1943, no. 4: 259-60. [215]

Harrington, R. W. Jr. 1947. Observations on the breeding habits of the yellow perch Perca flavescens (Mitchill). Copeia 1947, no. 3: 199-200. [231]

Harris, R. H. D. 1962. Growth and reproduction of the longnose sucker, Catostomus catostomus (Forster), in Great Slave Lake. J. Fish. Res. Bd. Can. 19: 113-26. [169]

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. [28]

——. 1947. Lethal temperature relations of certain fish in the Toronto region. Trans. Roy. Soc. Can. 41, no. III: 57-71. [38]

Hassan, K. C. and J. R. Spotila. 1976. The effect of acclimation on the temperature tolerance of young muskellunge fry. pp. 136-140, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposium) "CONF 750425". [xxx]

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.

Herdendorf, C. E. 1978. Personal communication. [xxx]

Hergenrader, G. L. 1969. Spawning behavior of Perca flavescens in aquaria. Copeia 1969, no. 4: 839-41. [280]

Herman, E. W. Wisby L. Wiegert and M. Burdick. 1959. The yellow perch. Its life history, ecology, and management. Wis. Cons. Dept. Publ. 228 : 14 pp. [233]

Heuer, J.H. and W.B. Wrenn. 1981. TVA biothermal research series. IV. Effects of temperature on juvenile and adult sauger in large experimental channels. Draft completion report to EPA-Duluth (cited from Hokanson 1990).

Hile, R. and C. Juday. 1941. Bathymetric distribution of fish in lakes of the northeastern highlands, Wisconsin. Trans. Wisc. Acad. Arts Sci., Lett. 33: 147-87. [90]

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.

Hill, K. R. 1973. Feeding of black bullheads Ictalurus melas (Rafinesque) in experimental cages. Proc. Iowa Acad. Sci. 19: 10. [63]

Hlohowskyi, I. and T. E. Wissing. 1987. Seasonal changes in the thermal preferences of fantail (*Etheostoma flabellare*), rainbow (*E. caerleum*), and greenside (*E. blennioides*) darters. Pages 105-110 *In*, W.J. Matthews and D.C. Heins [eds.], Community and Evolutionary Ecology of North American Stream Fishes. Norman, OK: University of Oklahoma Press.

Hoagman, W. J. 1974. Visual activity parameters as related to the early life-history of larval and post-larval lake whitefish (Coregonus clupeaformis). pp. 547-558, In J.H.S. Blaxter [ed.]. The Early Life History of Fish. Berlin, Heidelberg, New York: Springerverlag. [121]

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. [xxx]

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. 1969. Aquatic life temperature requirements. In FWPCA Presentations - ORSANCO Engineering Committee, 70th Meeting, Cincinnati, Ohio. [cited in Brown 1975]. [263]

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]. [39]

——. 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. [273]

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. [124, 276]

Hokanson, K.E.F., J.H. McCormick, B.R. Jones, and J.H. Tucker. 1973b. Thermal requirements for the maturation, spawning, and embryo survival of the brook trout, *Salvelinus fontinalis*. J. Fish. Res. Bd. Can. 30: 975-984.

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. [xxx]

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. [xxx]

Holland, L.E. and J.R. Sylvester. 1983. Distribution of larval fishes related to potential navigation impacts on the upper Mississippi River, pool 7. Trans. Am. Fish. Soc. 112: 293-301.

Hooper, F. F. 1949. Age analysis of a population of the ameiurid fish Schilebodes mollis (Hermann). Copeia 1949, no. 1: 34-38. [207]

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. [91]

Horn, M.H. and C.D. Riggs. 1973. Effects of temperature and light on the rate of air breathing of the bowfin, Amia calva. Copeia 1973(4): 653-657.

Horning, W. B. and R. E. Pearson. 1973. Temperature requirements for juvenile smallmoth bass (Micropterus dolomieui) - growth and lower lethal temperatures. J. Fish. Res. Bd. Can. 30: 1226-30. [125, 250]

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. [261]

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.

Hubbs, C. 1961. Developmental temperature tolerance of four Etheostomative fishes occurring in Texas. Copeia 1961, no. 2: 195-98. [53]

Hubbs, C. L. 1921. An ecological study of the life history of the freshwater atherine fish Labidesthes sicculus. Ecology 2, no. 4: 262-76. [212]

Hubbs, C. L. and G. P. Cooper. 1936. Minnows of Michigan. Cranbrook Inst. Sci. Bull. 8 : 95 pp. [201]

Huet, M. 1972. Raising and maturation of pike in small ponds. Verh. Int. Ver. Limnol. 18: 1128. [cited in Brown 1974]. [282]

Huh, H. T. 1975. "Bioenergetics of food conversion and growth of yellow perch (Perca flavescens) and walleye (Stizostedion vitreum) using formulated diets." Univ. Wisconsin. [324]

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. [323]

Hunter, J. R. and A. D. Hasler. 1965. Spawning association o the refin shiner, Notropis umbratillis, and the green sunfish, Lepomis cyanellus. Copeia 1965, no. 3: 265-81. [191]

Huntsman, A. G. 1946. Heat stroke in Canadian maritime stream fishes. J. Fish. Res. Bd. Can. 6, no. 7: 476-82. [51]

Huntsman, A. G. and M. I. Sparks. 1924. Limiting factors for marine animals. Relative resistance to higher temperatures . Contr. Can. Biol. 2: 95-114. [319]

Hutchinson, V. H. 1976. Factors influencing thermal tolerances of individual organisms. pp. 10-26, In G.W. Esch and R.W. McFarlane [eds]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425". [xxx]

Illinois Natural History Survey. Anual report for Fiscal Year 1975: Lake Sangchris project. R. Weldon Larimore (principal investigator), Ill. Nat. Hist. Surv., Urbana, Ill. [287]

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.

Jackson, M. F. and J. L. Price. 1949. The preferred temperature of a sample of yearling Esox masquinongy, Unpublished manuscript in Ontario Fish. Res. Lab. Library. Toronto. [cited in Ferguson 1958]. [xxx]

Jammes, L. 1931. Sur le comportement, au lac d'Oredon, de la truite commune, Salmo trutta L., en fonction des agents thermique et nutritif. C.R. Soc. Biol. (Paris) 107: 1482-85. [cited in Coutant 1977]. [67]

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. [102]

——. 1976a. Thermal acclimation and temperature selection in Atlantic salmon, Salmo salar, and rainbow trout, Salmo gairdneri. J. Fish. Res. Bd. Can. 24, no. 7: 1507-13. [101]

Jenkins, R.E. and D.J. Jenkins. 1980. Reproductive behavior of the greater redhorse, Moxostoma valenciennesi, in the Thousand Islands region. The Can. Field Nat. 94: 426-430.

Jester, D. B. 1972. Life History, ecology, and management of the river carpsucker, Carpiodes carpio (Rafinesque), with reference to Elephant Butte Lake, Ag. Exp. Sta. Res. Rept. 243. New Mexico State Univ., Las Cruces. [163]

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.

Jobes, F. W. 1952. Age, growth, and production of yellow perch in Lake Erie. U.S. Fish Wildl. Serv. Fish. Bull. 70, no. 52: 205-66. [232]

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. [xxx]

Johnson, R. P. 1963. Studies on the life history and ecology of the bigmouth buffalo, Ictiobus cyprinellus (Valenciennes). J. Fish. Res. Bd. Can. 20, no. 6: 1397-429. [160]

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)]. [279]

Jones, D. R. J. W. Kiceniuk and O. S. Bamford. 1974. Evaluation of the swimming performance of several fish species from the MacKenzie River. J. Fish. Res. Bd. Can. 31: 1641-47. [xxx]

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. [20]

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.

Kaya, C. M. 1973. Effects of temperature and photoperiod on seasonal regression of gonads of green sunfish, Lepomis cyanellus. Copeia 1973, no. 2: 369-73. [xxx]

——. 1977. Reproductive biology of rainbow and brown trout in a geothermally heated stream: the Firehole River of Yellowstone National Park. Tans. Am. Fish. Soc. 106, no. 4: 354-61. [xxx]

Kaya, C. M. L. R. Kaeding and D. E. Burkhalter. 1977. Use of a cold-water refuge by rainbow and brown trout in a geothermally heated stream. Prog. Fish-Cult. 39, no. 1: 37-39. [xxx]

Kellogg, R. L. and J. J. Gift. 1983. Relationship between optimum temperatures for growth and preferred temperatures for the young of four fish species. *Trans. Amer. Fish. Soc.* 112: 424-30.

Kennedy, W. A. 1941. The migration of fish from a shallow lake to a deep lake in spring and early summer. Trans. Am. Fish. Soc. 70: 291-396. [113]

Khan, M. H. 1929. Early stages in the development of goldfish (Carassisus auratus L.). J. Bombay Nat. Hist. Soc. 33: 613-17. [176]

Kinney, E. Jr. 1954. "A life history study of the silver chub, Hybopsis storeriana (Kirtland), in western Lake Erie with notes on associated species." Ohio State Univ. [184]

Kleiner, C. F. and K. E. F. Hokanson. 1973. Effects of constant temperature on growth and mortality rates of juvenile white crappie, Pomoxis annularis Rafinesque, Unpublished data, National Water Quality Laboratory, Duluth, Minn. [cited in Brungs and Jones 1977]. [126]

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).

Knox, R. F. 1973. Alteration of lipid content of tissues in gonosomatic indices of white crappie by thermal addition in Thomas Hill Reservoir, Missouri, M.A. Thesis. Univ. Missouri, Columbia. 71 pp. [285]

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. [97]

Koster, W. J. 1939. Some phases of the life history and relationships of the cyprinid, Clinostomus elongatus (Kirtland). Copeia 1939, no. 4: 201-8. [190]

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.

Kramer, R. H. and L. L. Smith Jr. 1960. Utilization of nests of largemouth bass, Micropterus salmoides, by golden shiners, Notemigonus crysoleucas. Copeia 1960, no. 1: 73-74. [179]

Kurten, G. and P. Hutson. 1992. Critical thermal maxima of paddlefish fry and fingerlings. Manage. Data Series 83, Texas Parks Wildl. Div., Austin, TX. 11 pp.

Lachner, E. A. 1952. Studies of the biology of the cyprinid fishes of the chub genus Nocomis of northeastern United States. Am. Midl. Nat. 48, no. 2: 433-66. [180]

Lachner, E. A. and R. E. Jenkins. 1967. Systematics, distribution, and evolution of the chub genus Nocomis (Cyprinidae) in the southwestern Ohio River basin, with the description of a new species. Copeia 1967: 557-80. [183]

Lake, C. T. 1936. The life history of the fantailed darter, Catonotes flabellaris flabellaris (Rafinesque)_. Amer. Midland Natur. 17, no. 3: 816-30. [238]

Langlois, T. H. 1954. The western end of Lake Erie and its ecology. 479 pp. Ann Arbor, Mich.: Edwards Bros., Inc. [193]

Larimore, R. W. 1957. Ecological life history of the warmouth (Centrarchidae). Ill. Nat. Hist. Surv. Bull. 27: 83 pp. [223]

Larimore, R. W. and M. J. Duever. 1968. Effects of temperature acclimation on the swimming ability of smallmouth bass fry. Trans. Am. Fish. Soc. 97, no. 2: 175-84. [271]

Lattimore, R. E. and J. W. Gibbons. 1976. Body condition and stomach contents of fish inhabiting thermally altered areas. Amer. Midl. Nat. 95, no. 1: 215-19. [xxx]

Latvaitis, P. B. 1977. Fish eggs and larvae. pp. 435-488, In R.M. Gerhold [ed.]. Operational Environmental Monitoring in the Mississippi River Near Quad-Cities Station, Febuary 1976 through January 1977, Ann. Rept. Commonwealth Edison Co., Chicago, Ill. [xxx]

Lawler, G. H. 1965. Fluctuations in the success of year-classes of whitefish populations with special reference to Lake Erie. J. Fish. Res. Bd. Can. 22, no. 5: 1197-227. [151]

——. 1954. Observations on the trout-perch Percopsis omniscomaycus (Walbaum), at Heming Lake, Manitoba. J. Fish. Res. Bd. Can. 11, no. 1: 1-4. [211]

LeCren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J. Animal Ecol. 20: 201-19. [283]

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. [xxx]

Ludwig, G. M. and E. L. Lange. 1975. The relationship of length, age, and age-length interaction to the fecundity of the northern mottled sculpin, Cottus b. baridi. Trans. Am. Fish. Soc. 104, no. 1: 64-67. [249]

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.

Mansell, W. D. Brown trout in southwestern Ontario. Ont. Fish Wildlife Rev. 5, no. 2: 3-8. [147]

Mansueti, R. J. 1956. Alewife herring eggs reared successfully in lab. Md. Tidewater News 13, no. 1: 2-3. [143]

Marcy, B.C. 1971. Survival of young fish in the discarge canal of a nuclear power plant. J. Fish. Res. Bd. Can. 28: 1057-60. [xxx]

______. 1976. Fishes of the lower Connecticut River and the effects of the Connecticut Yankee plant including entrainment, pp. 115-139. in D. Merriman and L.M. Thorpe (eds.), The Connecticut River Ecological Study: The Impact of a Nuclear Power Plant. Amer. Fish. Soc. Monograph No. 1. 251 pp.

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.

______. 1986. Geographic variation in thermal tolerance of a widespread minnow *Notropis lutrensis* of the North American Midwest. J. Fish Biol. 28: 407-417.

Martin, N. V. 1952. A study of the lake trout, Salvelinus namaycush, in two Algonquin Park, Ontario, Lakes. Trans. Am. Fish. Soc. 81: 112-37. [115]

Martin, W. J. C. T. Garten Jr. and J. B. Gentry. 1976. Thermal tolerances of dragonfly nymphs. I. Sources of variation in estimating critical thermal maximum. *Physiological Zoology* 49, no. 2, April: 200-205.

Mathur, Dilip and Pauline L. McCreight. 1980. Effects of heated effluent on the reproductive biology of white crappie, *Pomoxis annularis*, in Conowingo Pond, Pennsylvania. *Arch. Hydrobiol.* 88, no. 4: 491-99.

Mathur, Dilip Robert M. Schutsky Edmund J. Purdy Jr. and Carl A. Silver. 1981. Similarities in acute temperature preferences of freshwater fishes. *Trans. Amer. Fish. Soc.* 110: 1-13.

——. 1983. Similarities in avoidance temperatures of freshwater fishes. *Can. J. Fish. Aquat. Sci.* 40: 2144-52.

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. [318]

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. [42, 116]

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. [129]

McCauley, R. W. and N. Huggins. 1976. Behavioral thermal regulation by rainbow trout in a temperature gradient. pp. 171-175, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425". [xxx]

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. [103]

McCormick, J. H. 1978. Effects of temperature on hatching success and survival of larvae in the white bass. The Prog. Fish-Cult. 40(4): 133-137.

McCormick, J. H. 1976. Temperature effects on young yellow perch, Perca flavescens (Mitchill), U.S. EPA Ecological Research Series, EPA-600/3-057. [98]

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. [68]

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. [269]

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. [xxx]

McFarlane, R. W. B. C. Moore and S. E. Williams. 1976. Thermal tolerance of stream cyprinid minnows. pp. 141-144, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425". [84]

McPahil, J. D. and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Fish. Res. Bd. Can. Bull. 173: 381 pp. [189]

McSwain, L. E. and R. M. Gennings. 1972. Spawning behavior of the spotted sucker Minytrema melanops (Rafinesque). Trans. Am. Fish. Soc. 101, no. 4: 738-40. [171]

Meldrin, J. W. and J. J. Gift. 1971. Temperature preference, avoidance and shock experiments with estuaurine fishes. Ichthyological Assoc. Bull. 7 : 75 pp. [49]

Meuwis, A. and M. Heuts. 1957. Temperature dependence of breathing rate in carp. Biol. Bull. 112, no. 1: 97-107. [260]

Meyer, F. A. 1970. Development of some larval centrarchids. Prog. Fish Cult. 32, no. 3: 130-136. [221]

Meyer, W. H. 1962. Life History of three species of redhorse (Moxostoma) in the Des Moines River, Iowa. Trans. Am. Fish. Soc. 91, no. 4: 412-19. [80]

Miller, E. E. 1966. Channel catifish. pp. 440-463, In Inland Fisheries Management. California Dept. Fish Game Res. Agency. [202]

Miller, H. C. The behavior of the pumpkinseed sunfish, Lepomis gibbosus, with notes on the behavior of other species of Lepomis and the pygmy sunfish, Elassoma evergladei. Ecology 22, no. 1-2: 88-151. [227]

Miller, R. R. 1964. Behavior and ecology of some North American cyprinid fishes. Amer. Midl. Nat. 72, no. 2: 313-57. [48]

——. 1960. Systematics and biology of the gizzard shad (Dorosoma cepedianum) and related fishes . Fish. Bull. of Fish and Wildl. Serv. 60, no. 173: 371-91. [145]

Morman, R.H., D.W. Cuddy, and P.C. Rugen. 1977. Factors influencing the distribution of sea lamprey (*Petromyzon marinus*) in the Great Lakes. Can. J. Fish. Aq. Sci. 37: 1811-1826.

Moulton, Stephen R. II Thomas L. Beitinger Kenneth W. Steward and Rebecca J. Currie. 1993. Upper temperature tolerance of fours species of caddisflies (Insecta: Trichoptera). *J. Freshwater Ecology* 8, no. 3, September: 193-98.

Mount, D. I. 1969. Presentation prepared by the staff of the National Water Quality Laboratory for the Joint Commission on Atomic Energy, November 5, 1969. [cited in Brown (1974)]. [274]

Muller, R. and F. E. J. Fry. 1976. Preferred temperature of fish: a new method. J. Fish. Res. Bd. Can. 33: 1815-17. [xxx]

Muncy, R. J. 1962. Life history of the yellow perch, Perca flavescens, in estuarine waters of Severn River, a tributary of Cheasapeake Bay, Maryland. Chesapeake Sci. 3, no. 3: 143-59. [234]

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

Murphy, J. C. C. T. Garten Jr. M. H. Smith and E. A. Standora. 1976. Thermal tolerance and respiratory movement of bluegill from two populations tested at different levels of acclimation temperature and water hardness. pp. 145-145, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symp. Series) "CONF-750425". [94]

Muth, S. E. and D. C. Tarter. 1975. Reproductive biology of the trout perch, Percopsis omniscomaycus (Walbaum), in Beech Fork of Twelvepole Creek, Wayne County, West Virginia. Amer. Midl. Nat. 93: 434. [321]

National Academy of Sciences (NAS). 1973. Water quality criteria 1972. A report to the committee on water quality criteria, U.S. EPA Pub. No. EPA-R3-73-033. Washington, D.C., 553 pp. [293]

National Research Council. 2001. Assessing the TMDL approach to water quality management. National Academy Press, Washington, DC. 109 pp.

National Technical Advisory Committee (NTAC) of FWPCA. 1968. Water quality criteria , U.S. Dept. Interior, Washington, D.C., 245 pp. [xxx]

Nebeker, A.V. and A.E. Lemke. 1968. Preliminary studies on the tolerance of aquatic insects to heated waters. J. Kansas Ent. Soc. 41(3): 413-418.

Neill, W. H. 1971. "Distributional ecology and behavioral thermoregulation of fishes in relation to a heated effluent from a stream-electric power plant (Lake Monona, Wisc.)." University of Wisconsin. [12]

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, Wisonsin. Trans. Am. Fish. Soc. 103, no. 4: 664-710. [8]

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

Neill, W. H. K. Strawn and J. E. Dunn. 1966. Heat resistance experiments with longear sunfish Lepomis megalotis (Rafinesque). Proc. Ark. Acad. Sci. 20: 39-49. [31]

Nelson, J. S. 1968. Life history of the brook silverside, Labidesthes sicculus, in Crooked Lake, Indiana. Trans. Am. Fish. Soc. 97, no. 3: 293-96. [213]

Nelson, W. R. N. R. Hines and L. G. Beckman. 1965. Artificial propagation of saugers and hybridization with walleyes. Prog. Fish Cult. 27, no. 4: 216-18. [228]

Novinger, D.C. and T.G. Coon. 2000. Behavior and physiology of redside dace, *Clinostomus elongatus*, a threatened species in Michigan. Env. Biol. Fishes 57: 315-326.

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.

Ohio EPA. 1978b. Guidelines for the submittal of demonstrations pursuant to Sections 316(a) and 316(b) of the Clean Water Act and chapter 3745-1 of the Ohio administrative code. Div. Industrial Wastewater, State of Ohio Environmental Protection Agency, Columbus, Oh. 55 pp.

Opuszynski, K. 1971. Temperature preference of fathead minnow Pimephales promelas (Rafinesque) and its changes induced by copper salt CuSO4. Pol. Arch. Hydrobiol. 18: 401-18. [118]

Otto, R. G. 1973. Temperature effects on fish-laboratory studies. June 1972 - June 1973, Rept. to Comm. Edison Co., Industrial Bio-test Lab., Inc., 69 pp. [29]

Otto, R. G. and J. O. Rice. 1974. Swimming speeds of yellow perch (Perca flavescens) following an abrupt change in environmental temperature. J. Fish. Res. Bd. Can. 31: 1731-34. [xxx]

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]

Page, L. M. and P. W. Smith. 1970. The life history of the dusky darter, Percina sciera, in the Embarras River, Illinois. Ill. Nat. Hist. Surv. Biol. Notes 69 : 15 pp. [xxx]

——. 1971. The life history of the slenderhead darter, Percina phoxocephala, in the Embarras River, Illinois. Ill. Nat. Hist. Surv. Biol. Notes 74 : 14 pp. [235]

Pearse, A. S. 1918. Habits of the black crappie in inland lakes of Wisconsin, Rept. U.S. Comm. Fish. Doc. 867, 16 pp. [218]

Pearson, W.D. and L.A. Krumholz. 1984. Distiribution and status of Ohio River fishes. ORNL/Sub/79-7831/1. Oak Ridge National Laboratory, Oak Ridge, TN. 401 pp.

Peckham, R. S. and C. F. Dineen. 1957. Ecology of the central mudminnow, Umbra limi (Kirtland). Amer. Midland Natur. 58: 222-31. [158]

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

Peterson, R. H. 1973. Temperature selection of Atlantic salmon (Salmo salar) and brook trout (Salvelinus fontinalis) as influenced by various chlorinated hydrocarbons. J. Fish. Res. Bd. Can. 30: 1091-97. [112]

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". [85]

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

Peterson, S. E. R. M. Schutsky and S. E. Allison. 1974. Temperature preference, avoidance and shock experiments with freshwater fishes and crayfishes. Icthyological Associates Bull. 10. Box 12, Drumore, PA: Icthyological Associates, Inc. Bull. No. 10 [255]

Petravisz, W. P. 1938. The breeding habits of the black-sided darter, Hadropterus maculatus Girard. Copeia 1938, no. 1: 40-44. [236]

Pflieger, W. L. 1975. Reproduction and survival of the smallmouth bass in Courtois Creek. pp. 231-239, In R.H. Stroud and H. Clepper [eds.]. Black Bass Biology and Management. Nat. Symp. Biol. Mgmt. Centrarchid Basses, Sport Fishing Inst., Washington, D.C. [xxx]

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. [xxx]

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. [xxx]

Priegel, G. R. 1969. The lake Winnebago sauger - age, growth, reproduction, food habits and early life history . Wisc. Dept. Nat. Res. Tech. Bull. No. 43 : 63 pp. [xxx]

Pritchard, A. L. 1931. Taxonomic and life history studies of the ciscoes of Lake Ontario. Univ. Toronto Biol. Ser. 35, Publ. Ont. Fish. Res. Lab 41 : 78 pp. [148]

Proffitt, M. A. 1969. Effects of heated discharde upon aquatic life resources of White River at Petersburg, Indiana. Ind. University Water Res. Research Cen. Rep. Invest. 3 : 101 pp. [33]

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. [47]

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.

Purkett, C. A. Jr. 1961. Reproduction and early development of the paddlefish. Trans. Am. Fish. Soc. 90, no. 2: 125-29. [138]

Raney, E. C. 1940. The breeding behavior of the common shiner, Notropis cornutus (Mitchill). Zoologica 25, no. 1: 1-14. [192]

——. 1939. The breeding habits of the silvery minnow, Hybognathus regius Girard. Amer. Midland Nat. 21, no. 3: 674-80. [198]

——. 1940. Comparison of the breeding habits of two subspecies of black-nosed dace, Rhinichthys atratulus (Herman). Am. Midl. Nat. 23, no. 2: 399-403. [188]

——. 1971. Heated discharges and fishes in Lake Michigan in the vicinity of the Donald C. Cook Nuclear Plant, Mich. Water Res. Comm., Lansing, Mich., 14 pp. [95]

Raney, E. C. and E. A. Lachner. 1946. Age, growth, and habits of the hogsucker, Hypentelium nigricans (Le Sueur). The Amer. Midland Nat. 36, no. 1: 76-86. [166]

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. [114]

Reckhahn, J. A. 1970. Winnepeg, Manitoba: Univ. Manitoba Press. [120, 154]

Reighard, J. 1920. The breeding behavior of sucker and minnows. Biol. Bull. 38, no. 1: 1-3. [167]

Reighard, J. E. 1943. The breeding habits of the river chub, Nocomis micropon (Cope). Pap. Mich. Acad. Sci. Arts Letters 28, no. 1943: 397-423. [182]

Retutter, 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. [13]

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. [xxx]

——. 1976. Thermal discharge from a nuclear power plant: predicted effects on Lake Erie Fish. Ohio J. Sci. 76, no. 1: 39-45. [61]

Reynolds, W. W. 1977c. Fever and antipyresis in the bluegill sunfish, Lepomis macrochirus. Comp. Biochem. Physiol C. [xxx]

——. 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. [xxx]

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

Reynolds, W. W. and M. E. Casterlin. 1977. Temperature preferences of four species in an electronic thermoregulatory shuttlebox. Prog. Cult. Fish 39, no. 3: 123-25. [xxx]

——. 1976. Thermal preferenda and behavioral thermoregulation in three centrarchid fishes. pp. 185-190, In G.W. Esch and R.W. McFarlande [eds.]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425". [25]

Reynolds, W. W. M. E. Casterlin and J. B. Covert. 1976. Behavioral fever in teleost fishes. Nature 259: 41-42. [117]

Reynolds, W. W. R. W. McCauley M. E. Casterlin and L. I. Crawshaw. 1976. Body temperatures of behaviorally thermoregulating largemouth blackbass (Micropterus salmoides). Comp. Biochem. Physiol. A54: 461-63.

Reynolds, W.W. and M.E. Casterlin. 1978. Behavioral thermoregulation and diel activity in white sucker (Catostomus commersoni). Comp. Biochem. Physiol., 59A: 261-262.

Reynolds, W.W., M.E. Casterlin, and S.T. Millington. 1978. Circadian rythym of preferred temperature in the bowfin Amia calva, a primitive holostean fish. Comp. Biochem. Physiol., 60A: 107-109.

Reynolds, W.W., M.E. Casterlin, J.K. Matthey, S.T. Millington, and A.C. Ostrowski. 1978. Diel patterns of preferred temperature and locomotor activity activity in the goldfish Carrasius auratus. Comp. Biochem. Physiol., 59A: 225-227.

Richards, F. P. 1977. The selected temperatures of the brown bullhead, Ictalurus nebulosus, with references to its selection of a nuclear power plant discharge canal. M.S. Thesis, Southeastern Mass. University North Dartmouth. 42 pp. [18]

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.

Richards, F. P. W. W. Reynolds and R. W. McCauley. 1977. Temperature preference studies in environmental impact assessments: an overview with procedural recommendations. J. Fish. Res. Bd. Can. 34, no. 5: 728-61. [310]

Richardson, L. R. 1937. Observations on the mating and spawning of Pimephales promelas (Rafinesque). Cab. Field-Nat. 51, no. 1: 1-4. [200]

——. 1939. The spawning behavior of Fundulus diaphanus (LeSeur). Copeia 1939, no. 3: 165-67. [210]

Ricker, W. E. An ecological classification of certain Ontario streams. Univ. Toronto Stud. Biol. Ser. 37, Publ. Ont. Fish. Res. Lab. 49 : 114 pp. [244]

Ross, M. R. 1977. Function of creek chub (Semotilus atromaculatus) nest-building. Ohio J. Sci. 77, no. 1: 36-37. [247]

Roy, A. W. and P. H. Johansen. 1970. The temperatur selection of small hypophysectomized goldfish (Carrasius auratus L.). Can. J. Zool. 48: 423. [15]

Royce, W. F. 1951. Breeding habits of lake trout in New York. U.S. Fish Wildl. Serv. Fish. Bull. 57: 87-138. [267]

Ruelle, R. 1977. Reproductive cycle and fecundity of white bass in Lewis and Clark Lake. Trans. Am Fish. Soc. 106, no. 1: 67-76. [288]

Rupp, R. S. 1965. Shore-spawning and survival of eggs of the American smelt. Trans. Am. Fish. Soc. 94, no. 2: 160-168. [155]

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, N.L. 1987. Seasonal variation of critical thermal maximum in the redbelly dace, *Phoxinus erythrogaster* (Cyprinidae). The Southwestern Naturalist 32(4): 435-438.

Scott, D. P. 1964. Thermal resistance of pike (Esox lucius L.), muskellunge (E. masquinongy) Mitchill, and thier F hybrids. J. Fish. Res. Bd. Can. 21, no. 5: 1043-49. [56]

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184: 966 pp. [79]

Selong, J. H., T.E. McMahon, A. V. Zale, and F.T. Barrows. 2001. Effect of temperature on growth and survival of bull trout, with application of an improved method for determining thermal tolerance in fishes. *Transactions of the American Fisheries Society* 130: 1026-1037.

Sheri, A. N. and G. Power. 1968. Reproduction of white perch, Roccus americanus, in the Bay of Quinte, Lake Ontario. J. Fish. Res. Bd. Can. 25, no. 10: 2225-31. [214]

Siefert, R. E. A. R. Carlson and L. J. Herman. 1974. Effects of reducted oxygen concentrations on the early life history stages of mountain whitefish, smallmouth bass, and white bass. Prog. Fish Cult. 36, no. 4: 186-90. [277]

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. [xxx]

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

Smallwood, E. M. and M. L. Smallwood. 1931. The development of the carp, Cyprinus carpio. I. The larval life of the carp, with special reference to the development of the intestinal canal. J. of Morphol. and Physiol. 52, no. 1: 217-31. [173]

Smith, C. G. 1977. "The biology of three species of Moxostoma (Pisces: Catostomidae) in Clear Creek, Hocking and Fairlfiled Counties, Ohio, with emphasis on the golden redhorse, M. erythrurum (Rafinesque)." Ohio State Univ. [xxx]

Smith, M.H. and K.D. Fuasch. 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. [55]

Smith, M. W. and J. W. Saunders. 1958. Movements of brook trout, *Salvelinus fontinalis* (Mitchill) between and with fresh and salt water. J. Fish. Res. Bd. Can. 15: 1403-49. [108]

Smith, S. H. 1956. Life history of lake herring of Green Bay, Lake Michigan. U.S. Fish Wildl. Serv. Fish. Bull. 109 57: 87-138. [149]

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. [35]

———. 1972. Quantification of the effects of rate of temperature change on aquatic biota. Water Res. 6: 1283-90. [xxx]

Spieler, R. E. T. A. Noeske V. deVlaming and A. H. Meier. 1977. Effects of thermocycles on body weight gain and gonadal growth in the goldfish, Carrasius auratus. Trans. Am. Fish. Soc. 106, no. 5: 440-444. [xxx]

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. [27]

Spotila, James R. Kenneth M. Terpin Robert R. Koons and Ralph L. Bonati. 1979. Temperature requirements of fishes from eastern Lake Erie and the upper Niagara River: a review of the literature. *Env. Biol. Fish.* 4, no. 3: 281-307

Starrett, W. C. 1951. Some factors affecting the abundance of minnows in the Des Moines River, Iowa. Ecology 32, no. 1: 13-26. [185]

Stauffer, J. R. D. S. Cherry K. L. Dickson and J. Cairns Jr. 1975. Laboratory and field temperature preference and avoidance datat of fish related to the establishment of standards. pp. 119-139, In S.R. Saila [ed.]. Fisheries and Energy Production: A Symposium. [60]

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. [xxx]

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. [74]

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. [xxx]

Stewart, N. H. 1926. Development, growth and food habits of the white sucker, Catostomus commersoni Le Sueur. Bur. of Fish. Bull. XLII 1007: 147-84. [168]

Stone, U. B. 1941. Studies on the biology of satinfin minnows, Notropis analostanus and Notropis spilopterus. Cornell Univ. Abstr.. Theses (1940) : 288-90. [194]

Strange, K.T., J.C. Vokoun, and D.B. Noltie. 2002. Thermal tolerance and growth differences in orangethroat darter *(Etheostoma spectabile)* from thermally contrasting adjoining streams. Am. Midl. Nat. 148: 120-128.

Strawn, K. 1961. Growth of largemouth bass fry at various temperatures . Trans. Am. Fish. Soc. 90, no. 3: 334-35. [82]

——. 1958. Optimum and extreme temperatures for growth and survival; various fishes. [cited from a table in Handbook of Biological Data]. [258]

Sullivan, C. M. 1954. Temperature reception and responses in fish. J. Fish. Res. Bd. Can. 11, no. 2: 153-70. [40]

Sullivan, C. M. and K. C. Fisher. 1954. The effects of light on temperature selection in speckled trout, Salvelinus fontinalis. Biol. Bull. 107: 278-88. [111]

——. 1953. Seasonal fluctuations in the selected temperature of the speckled trout, Salvelinus fontinalis (Mitchill). J. Fish. Res. Bd. Can. 10, no. 4: 187-95. [110]

Swartz, R. C. 1972. Biological criteria of environmental change in the Chesapeake Bay. Chesapeake Sci. 13: 517-41. [296]

Swedberg, D. V. and C. H. Walburg. 1970. Spawning and early life history of the freshwater drum in Lewis and Clark Lake, Missouri. Trans. Am. Fish. Soc. 99, no. 3: 560-570. [278]

Swee, U. B. and H. R. McCrimmon. 1966. Reproductive biology of the carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario. Trans. Am. Fish. Soc. 95, no. 4: 372-80. [174]

Tagatz, M. E. 1968. Fishes of the St. Johns River, Florida. Quart. J. Fla. Acad. Sci. 30, no. 1: 25-30. [92]

Tait, J. S. Temperature preference of the brown trout, Salmo trutta. (Manuscript in prepartation). [cited in Ferguson (1958)]. [xxx]

Takle, J.C.C., T.L. Beitinger, and K.L. Dickson. 1983. Effect of the aquatic herbicide endothal on the critical thermal maximum of red shiner, *Notropis lutrensis*. Bull. Environ. Contam. Toxicol. 31: 512-517.

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

Tatarko, K. I. 1966. Effect of temperature on the early stages of post-embryonic development of pond carp. Gidrobiol. Zh. 2, no. 3: 53-59. [cited in Brown (1974)]. [254]

——. 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)]. [268]

Taylor, W. R. 1969. A revision of the catfish genus Noturus Rafinesque with an analysis of higher groups in the Ictaluridae. U.S. Nat. Mus. Bull. 282 : 315 pp. [206]

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]

Tester, A. L. 1930. Spawning habits of the smallmouthed black bass in Ontario waters. Trans. Am. Fish. Soc. 60: 1-9. [xxx]

Thomas, B. O. 1962. Behavioral studies of the brook stickleback, Eucalia inconstans (Kirtland). Am. Zool. 2, no. 3: 452. [246]

Thomas, D. L. An ecological study of four darters of the genus Percina (Percidae) in the Kaskaskia River, Illinois. Ill. Nat. Hist. Surv. Biol. Notes 70 : 18 pp. [xxx]

Tiemeier, O. and C. W. Deyoe. 1972. A report on feeding experiments at K-State. Catfish Farmer 4: 32. [99]

Trautman, M. B.The fishes of Ohio. 683 pp. Columbus, Ohio: Ohio State University Press. [73]

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. [46, 93]

Trembley, F. J. 1961. Research project on the effects of condenser discharge water on aquatic life, Progress Rept. 1960. 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.

Ulrey, L. C. Risk and W. Scott. 1938. The number of eggs produced by some of our common fresh-water fishes. Invest. Indiana Lakes Streams 1, no. 6: 73-77. [219]

Van Meter, H. D. and M. B. Trautman. 1970. An annotated list of the fishes of Lake Erie and its tributary waters exclusive of the Detroit River. Ohio J. Sci. 70: 65-78. [75]

Vladykov, V. D. 1949. Quebec lampreys (Petromyzondidae). 1. List of species and their economical importance. Dept. Fish. Prov. Quebec Contr. 26 : 76 pp. [134]

Vogele, L. E. Reproduction of spotted bass, Micropterus punctulatus, Bull Shoals Reservoir, Arkansas. U.S. Fish Wildl. Serv. Tech. Pap. 84. [327]

Walburg, C. H. and W. R. Nelson. 1966. Carp, river carpsucker, smallmouth buffalo, and bigmouth buffalo in Lewis and Clark Lake, Missouri River, Bur. Sport Fish. Wildl. Res. Rep. 69, 30 pp. [69, 164]

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. [270]

Wallace, D. C. 1973. Reproduction of the silverjaw minnow, Ericymba buccata Cope. Trans. Am. Fish. Soc. 102, no. 4: 786-93. [197]

Walsh, S. J. D. C. Haney C. M. Timmerman and R. M Dorazio. 1998. Physiological tolerances of juvenile robust redhorse, *Moxostoma robustrum*: conservation implications for an imperiled species. *Environ. Biol. Fishes* 51: 429-44.

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.

WAPORA. 1977. Continuing ecological research on the Ohio River 1976 population and spawning studies, WAPORA, Inc., Cincinnati, Ohio. [146]

Wells, L. 1968. Seasonal depth distribution of fish in Southeastern Lake Michigan. Fish. Bull. 67: 1-15. [26]

Wenholz, M. 2004. Development of thermal water quality standards and point source implementation rules in Wisconsin, p. 4-14 to 4-30. *in Proceedings from the EPRI Workshop on 316(a) Issues: Technical and Regulatory Considerations:* October 16-17, 2003, EPRI, Palo Alto CA, and American Electric Power Company, Columbus, OH: 2004. 1008476.

West, B. W. 1966. Growth rates at various termperature of the orangethroat darter Etheostoma spectabile (Agassiz). Proc. Ark. Acad. Sci. 20: 50-53. [54]

Westman, J. R. 1941. "A consideration of population life-history studies in their relation to the problems of fish management research, with special reference to the small-mouthed bass, Micropterus dolomieui Lacepede. the lake trout, Cristover namaycush (Walbaum), and the mudminnow, Umbra limi (Kirtland) ." Cornell Univ. [157]

White, A. M. M. B. Trautman E. J. Foell M. P. Kelty and R. Gaby. 1975. The fishes of the Cleveland metropolitan area including the Lake Erie shoreline, Water Quality Baseline Assess. for Cleveland Area - Lake Erie (Volume II). EPA-905/9-75-001. [72]

White, D. S. 1974. "The biology of Minytrema melanops (Rafinesque), the spotted sucker." Univ. Louisville. [326]

Whitford, W. G. 1970. The effect of water quality and environmental factors of freshwater fish, NTIS PB-1976; Water Res. Abstr. No. W71-04677(1971). [34]

Winkler, P. 1973. The ecology and thermal physiology of Gambusia affinis from a hot spring in Southern Arizona. Physiol. Behavior 7, no. 3: 375. [17]

Winn, H. E. 1960. Biology of the brook stickleback Eucalia inconstans (Kirtland). Am. Midl. Nat. 63, no. 2: 424-38. [245]

——. 1958. Comparative reproductive behavior and ecology of fourteen species of darters (Pisces - Percidae). Ecol. Monogr. 28, no. 2: 155-91. [239]

——. 1958. Observations on the reproductive habits of darters (Pisces - Percidae). Am. Midl. Nat. 59, no. 1: 190-212. [xxx]

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.

Witt, A. D. R. S. Campbell and J. D. Whitley. 1970. The evaluation of environmental alterations by thermal loading and acid pollution in the cooling reservoir of a stream-electric station, Missouri Water Res. Research Cen. Univ. Missouri, Columbia. [284]

Witt, A. Jr. and R. C. Marzolf. 1974. Spawning and behavior of the longear sunfish, Lepomis megalotis megalotis. Copeia 3: 188-90. [225]

Woiwode, J.G. and I. R. Adelman. 1992. Effects of starvation, oscillating temperatures, and photoperiod on the critical thermal maximum of hybrid striped X wahite bass. J. Thermal Biol. 17(4/5): 271-275.

Wojtalik, T. A. 1971. Unpublished manuscript. Muscle Shoals, Alabama: Tennessee Valley Authority. [cited in NAS (1973)]. [70]

Wolfert, D. R. W-D. N. Busch and H. D. VanMeter. 1977. Seasonal abundance of fish in an inshore area of southcentral Lake Erie, 1974-75, U.S. Fish Wildl. Serv. Admin. Rept. (Draft). Sandusky Biol. Sta., Sandusky, Ohio. [xxx]

Wolters, W. R. and C. C. Coutant. 1976. The effect of cold shock on the vulnerability of young bluegill to predation. pp. 162-164, In G.W. Esch and R.W. McFarlane [eds.]. Thermal Ecology II (ERDA Symposium Series) "CONF-750425". [87]

Woodward, R. L. and T. E. Wissing. 1976. Age, growth, and fecundity of the quillback (Carpiodes cyprinus) and highfin (C. velifer) carpsuckers in an Ohio stream. Trans. Am. Fish. Soc. 105, no. 3: 411-15. [161]

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". [89]

Wynne-Edwards, V. C. 1932. The breeding habits of the black-headed minnow (Pimephales promelas Rafinesque). Trans. Am. Fish. Soc. 62, no. 1932: 382-83. [199]

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. [10]

_____. 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". [62]

Yoder, C.O. and E.B. Emery. 2004. Updating a temperature criteria methodology for the Ohio River mainstem, pp. 4-1 to 4-13. *in Proceedings from the EPRI Workshop on 316(a) Issues: Technical and Regulatory Considerations:* October 16-17, 2003, EPRI, Palo Alto CA, and American Electric Power Company, Columbus, OH: 2004. 1008476.

Appendix A

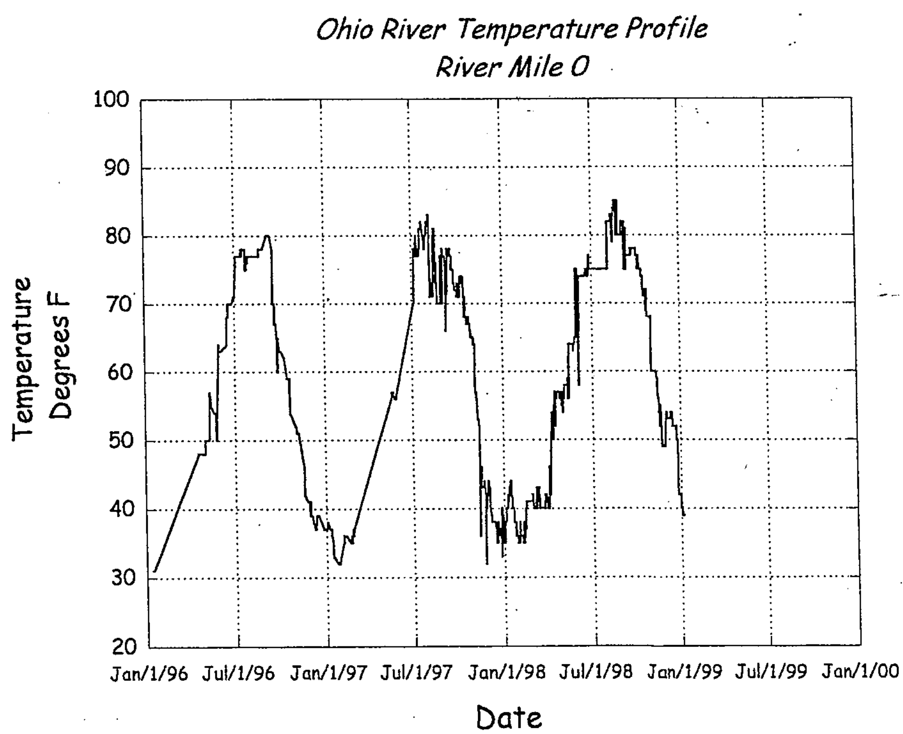
Appendix Tables for Phase I. 4: Documentation of Ambient Ohio River Conditions

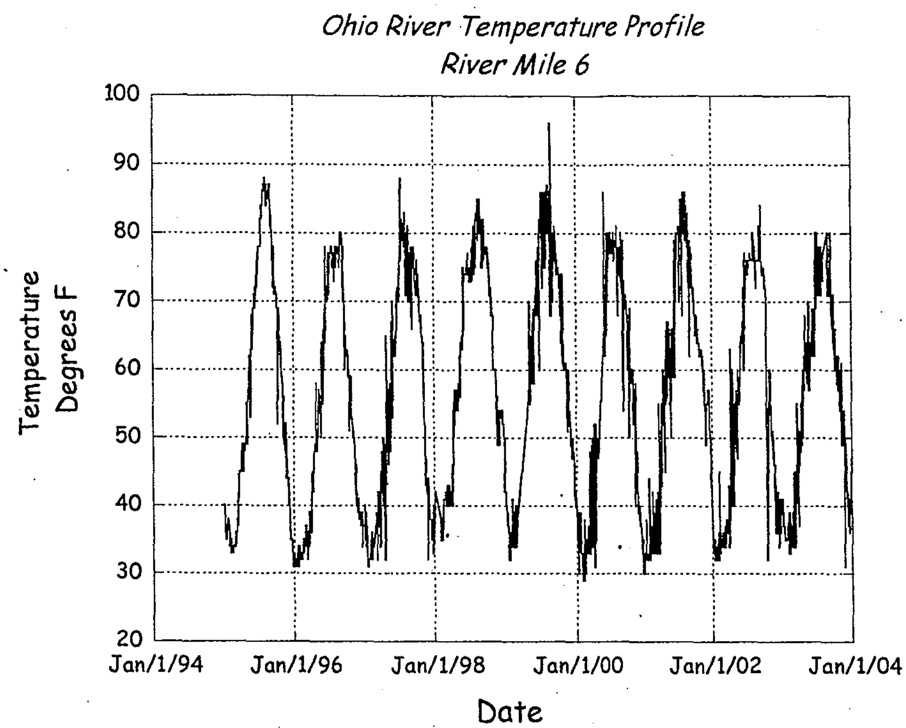
Appendix A

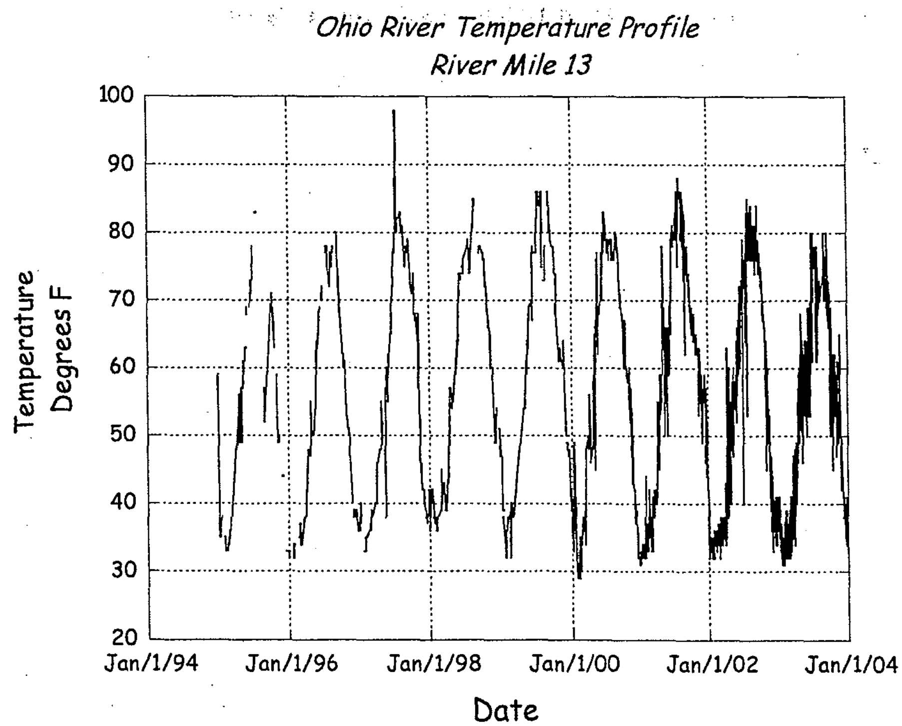
Appendix Tables for Phase I. 4:
Documentation of Ambient Ohio River Conditions

Appendix Table A-1. Temperature profiles (°F) from Ohio River stations based on U.S. ACE data from 1995 to 2003 at the following locations.

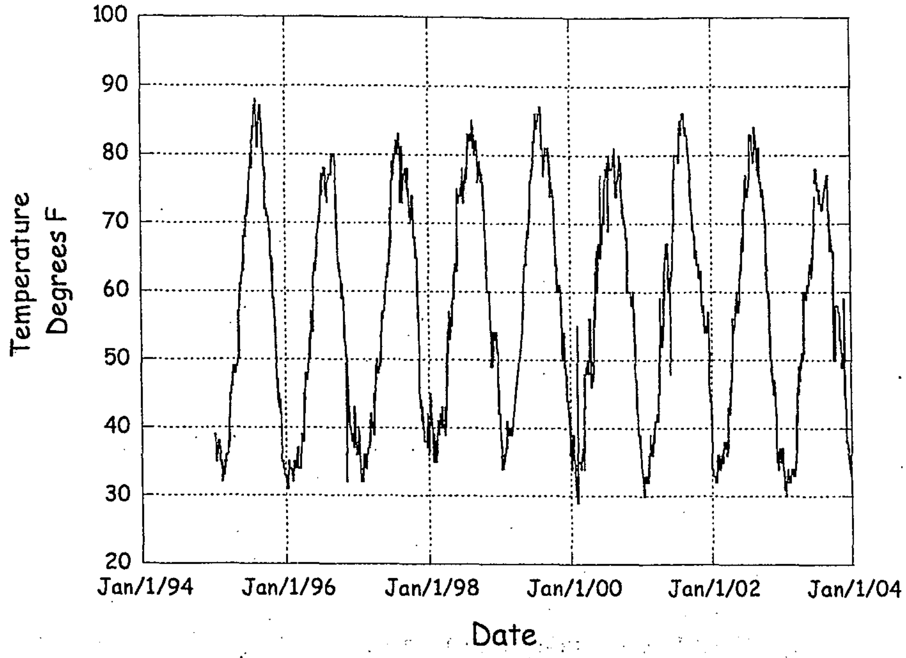
Station	USACE Code	Description	Type
OH.000	PTTP1	Pittsburgh	River Station
OH.006	EMSP1	Emsworth	Lock & Dam
OH.013	DSHP1	Dashield	Lock & Dam
OH.054	NCUW2	New Cumberland	Lock & Dam
OH.084	WHLW2	PIKE IS	Lock & Dam
OH.162	RNOO1	WILLOW I	Lock & Dam
OH.204	BEVW2	BELLEVIL	Lock & Dam
OH.238	RACW2	RACINE	Lock & Dam with Hydro
OH.279	GALW2	R.C.BYRD	Lock & Dam
OH.341	GNUK2	GREENUP	Lock & Dam with Hydro
OH.436	MELO1	MELDAHL	Lock & Dam
OH.532	MKLK2	MARKLAND	Lock & Dam with Hydro
OH.721	CNNI3	CANNELTN	Lock & Dam
OH.846	UNWK2	JT_MYERS	Lock & Dam
OH.939	BRKI2	LOCK 52	Lock & Dam
OH.963	GCTI2	LOCK 53	Lock & Dam



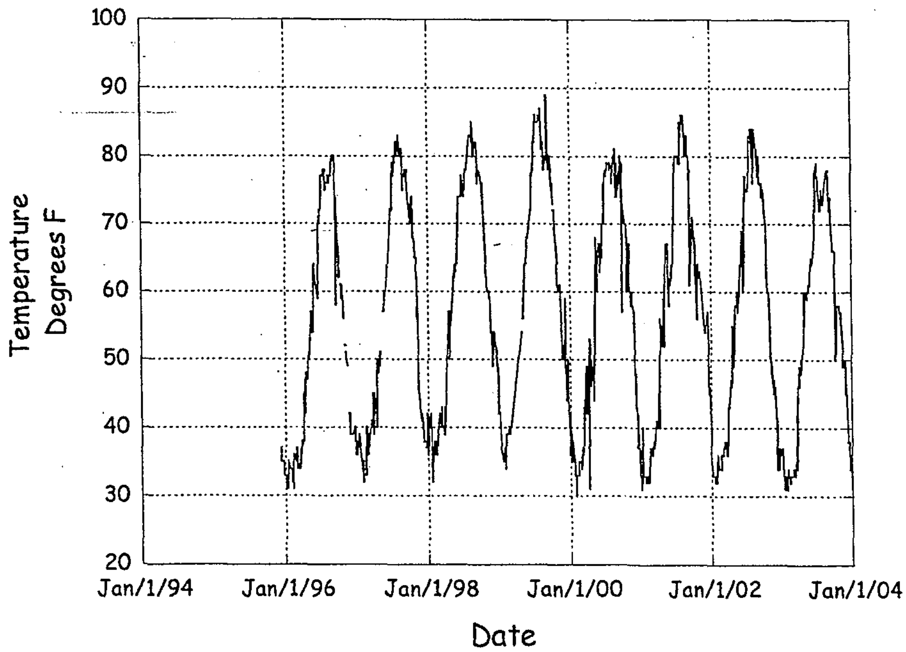

Ohio River Temperature Profile
River Mile 6
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

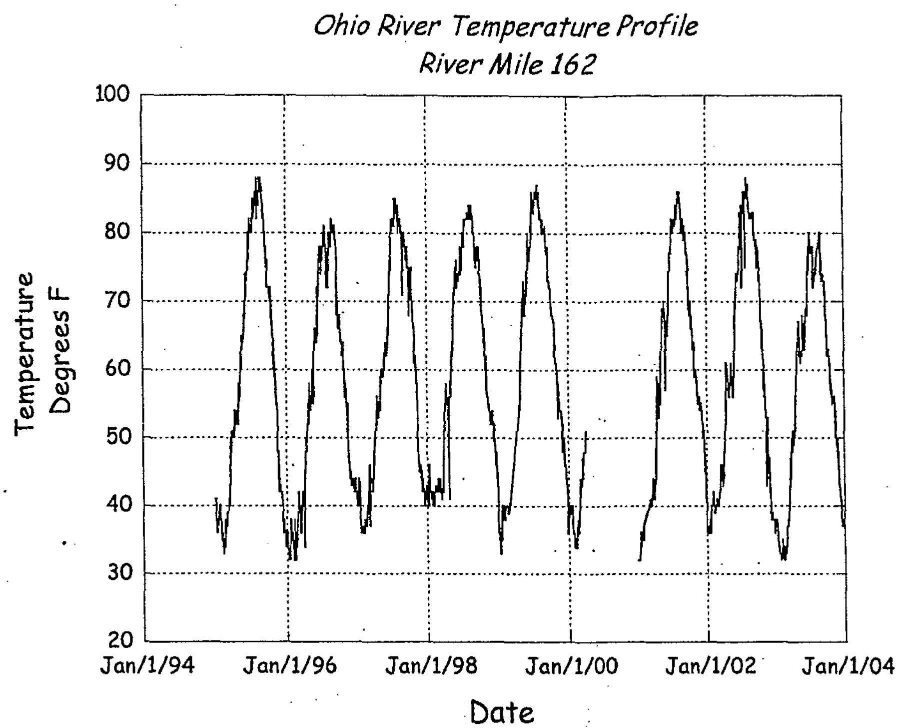

Ohio River Temperature Profile
River Mile 13
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

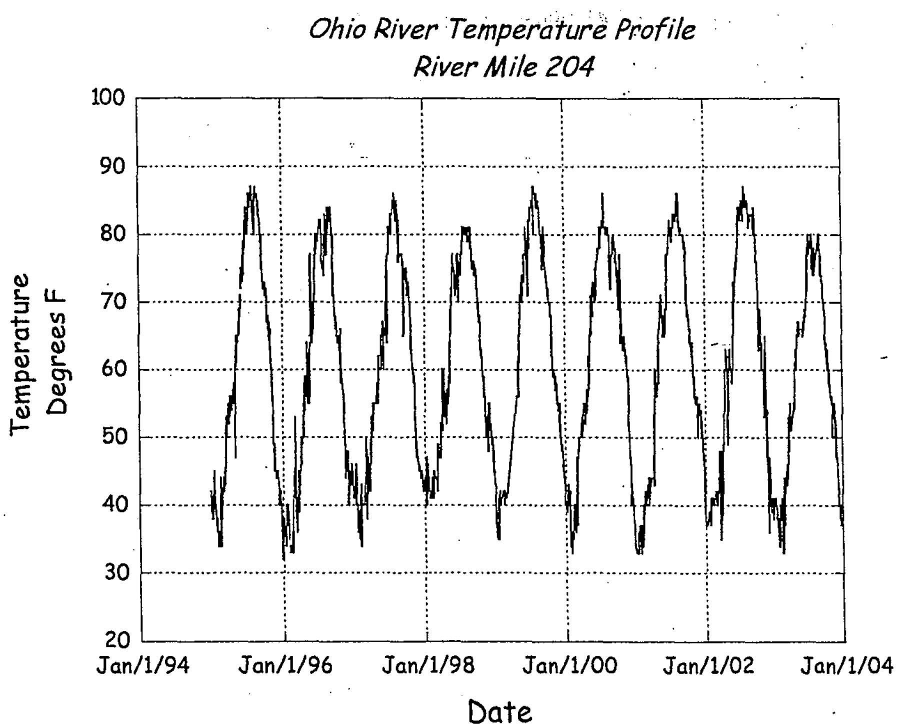
Ohio River Temperature Profile
River Mile 54

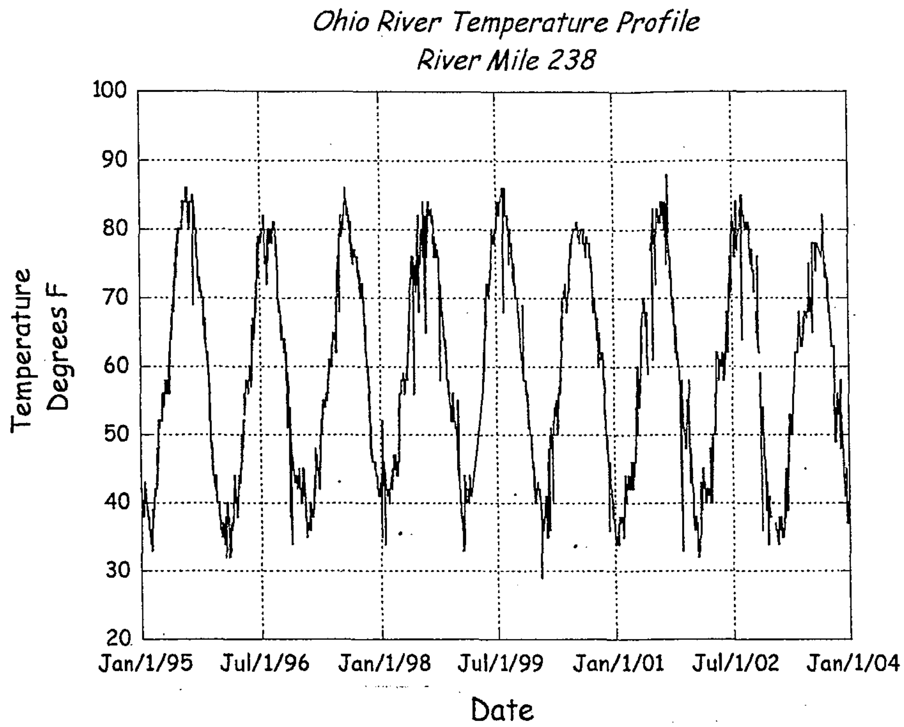


Ohio River Temperature Profile
River Mile 84

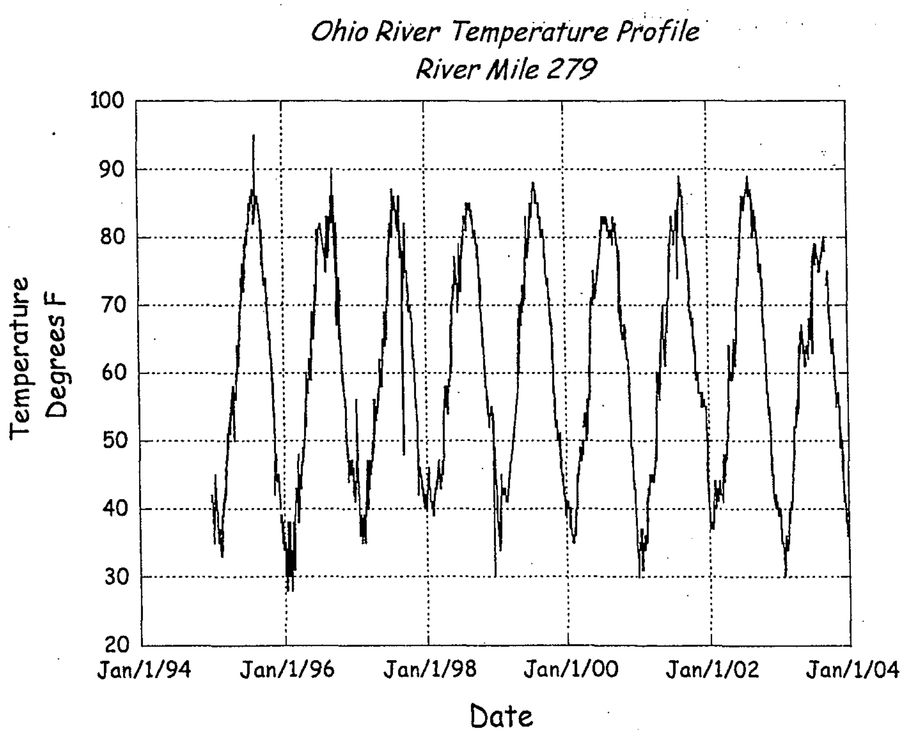



Ohio River Temperature Profile
River Mile 162
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

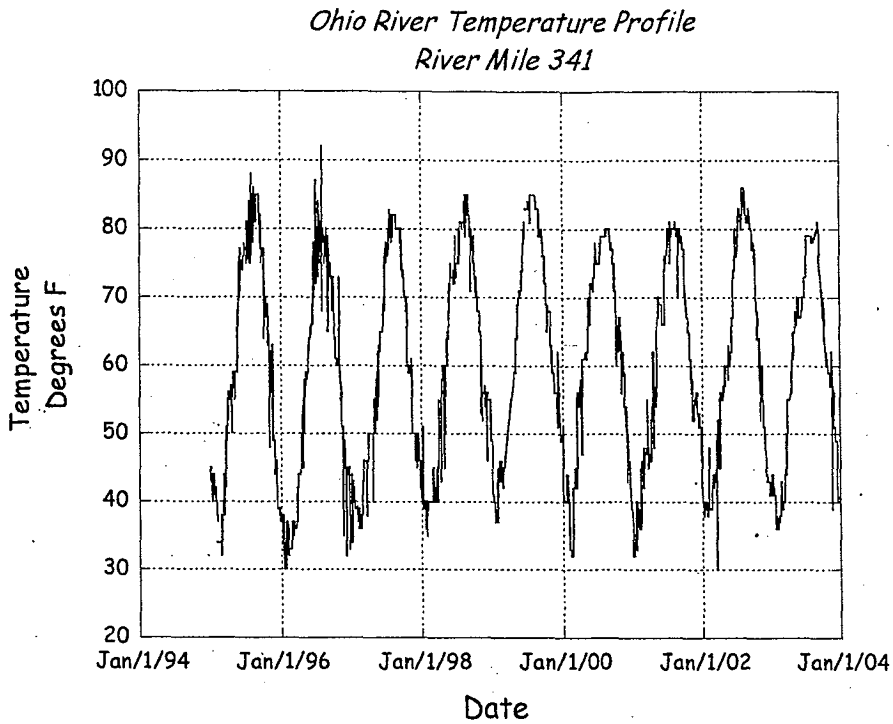

Ohio River Temperature Profile
River Mile 204
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

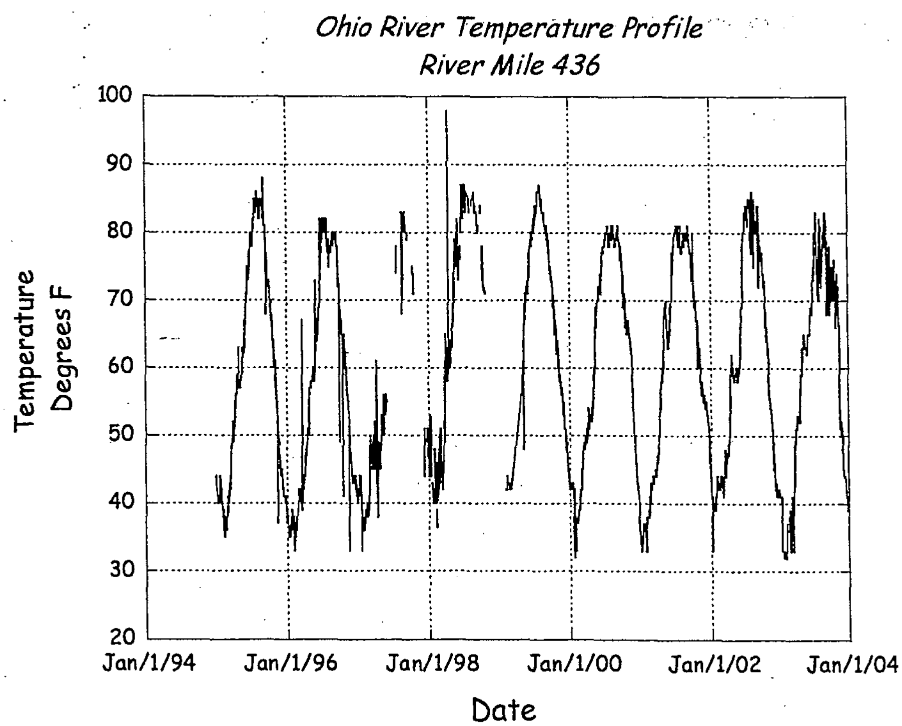


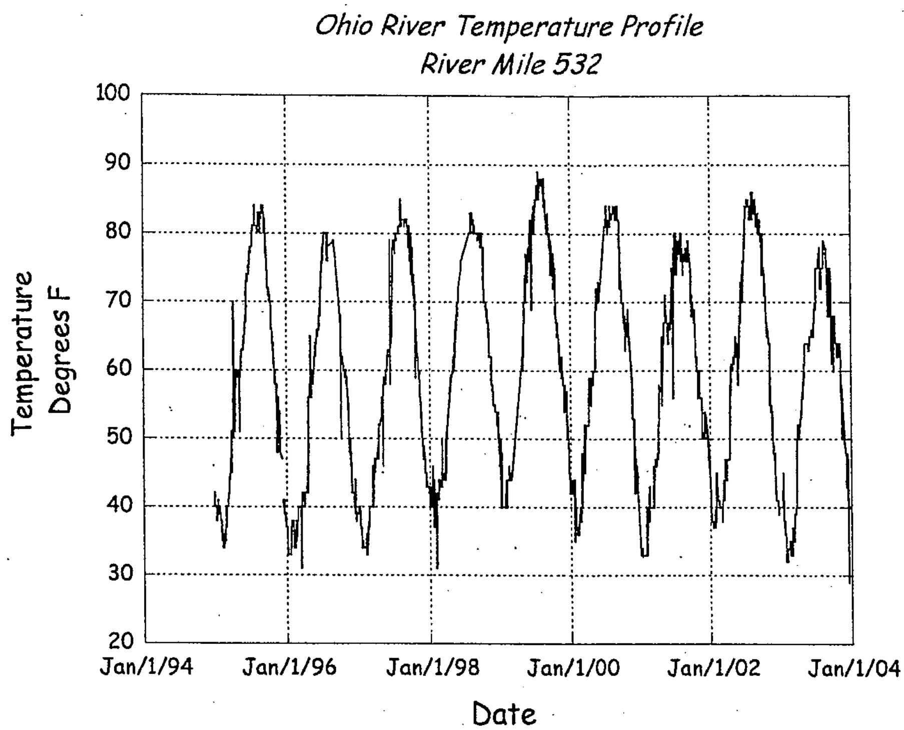
Ohio River Temperature Profile
River Mile 238
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/95
Jul/1/96
Jan/1/98
Jul/1/99
Jan/1/01
Jul/1/02
Jan/1/04
Date

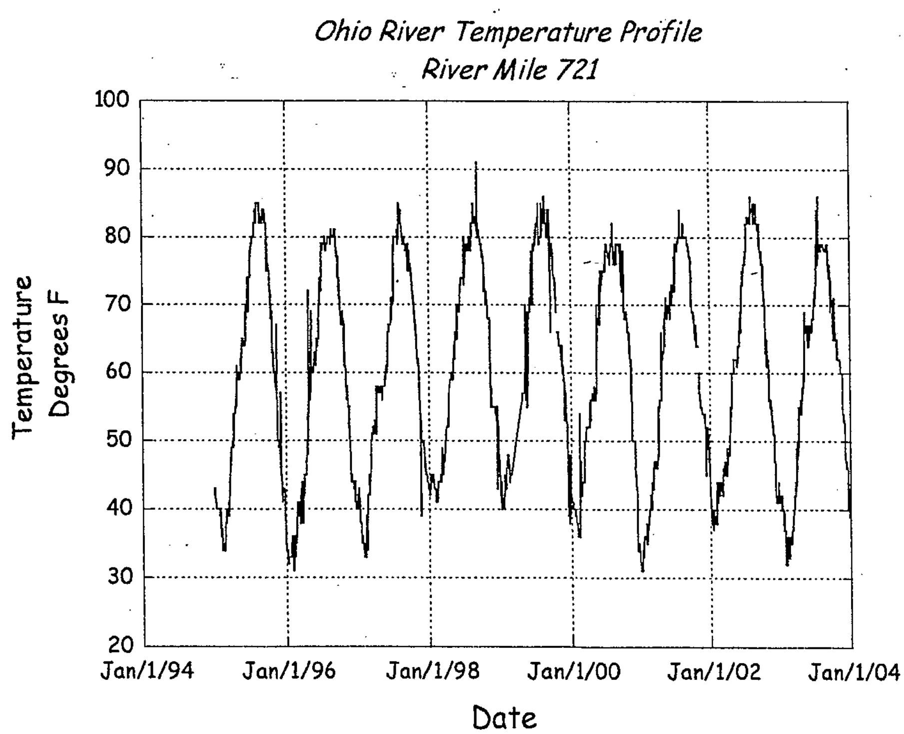


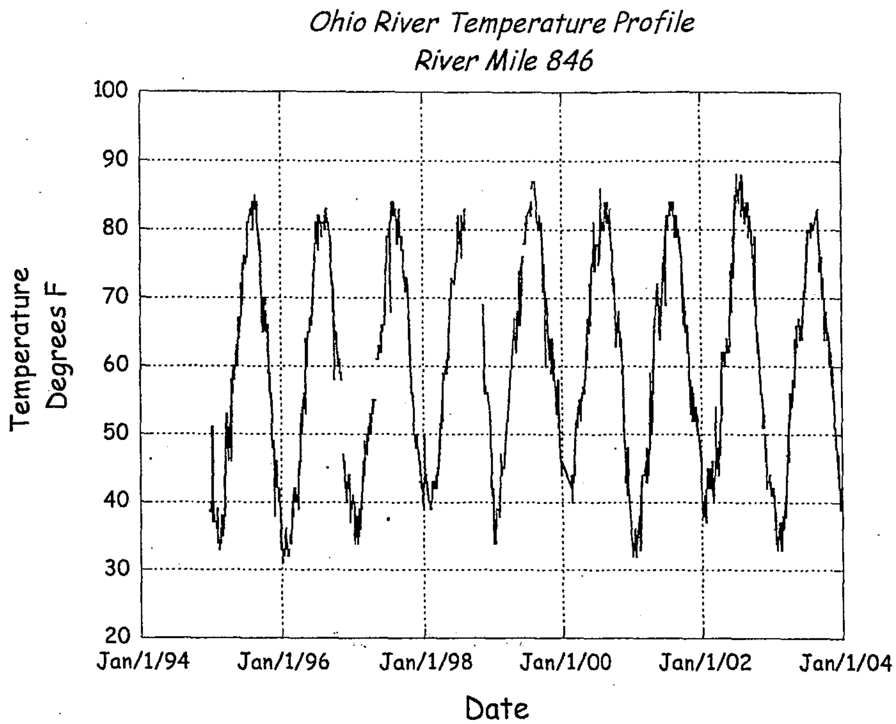
Ohio River Temperature Profile
River Mile 279
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

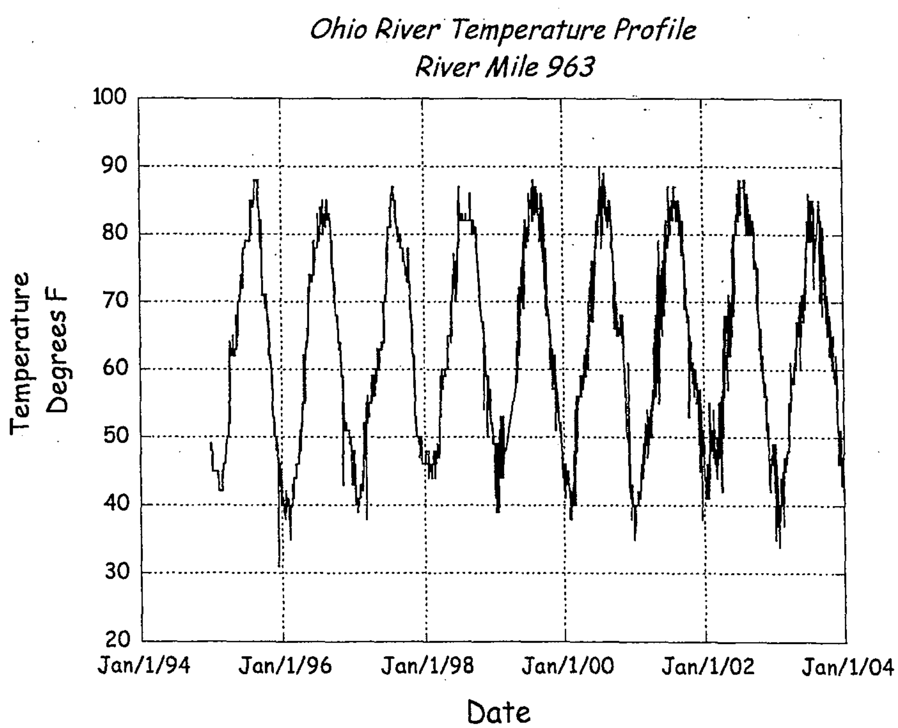

Ohio River Temperature Profile
River Mile 341
Temperature Degrees F
100
90
80
70
60
50
40
30
20
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date


Ohio River Temperature Profile
River Mile 436
Temperature Degrees F
100
90
80
70
60
50
40
30
20
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

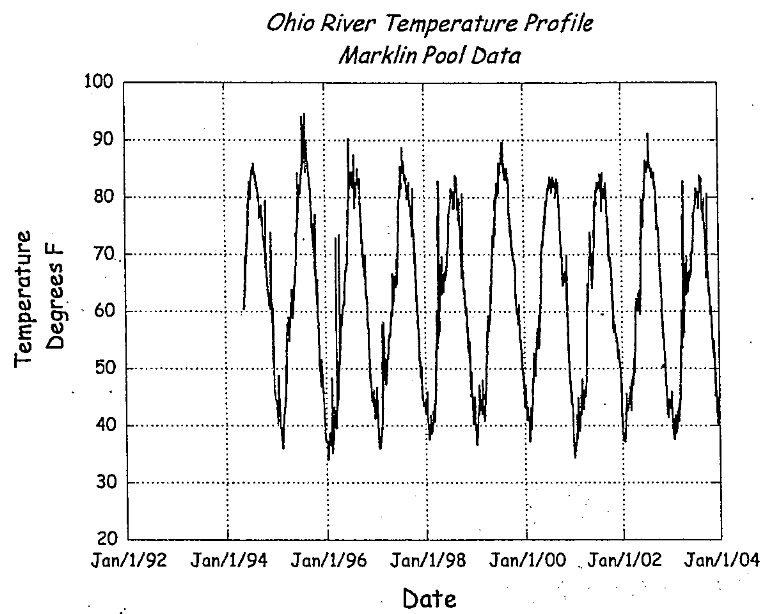

Ohio River Temperature Profile
River Mile 532
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

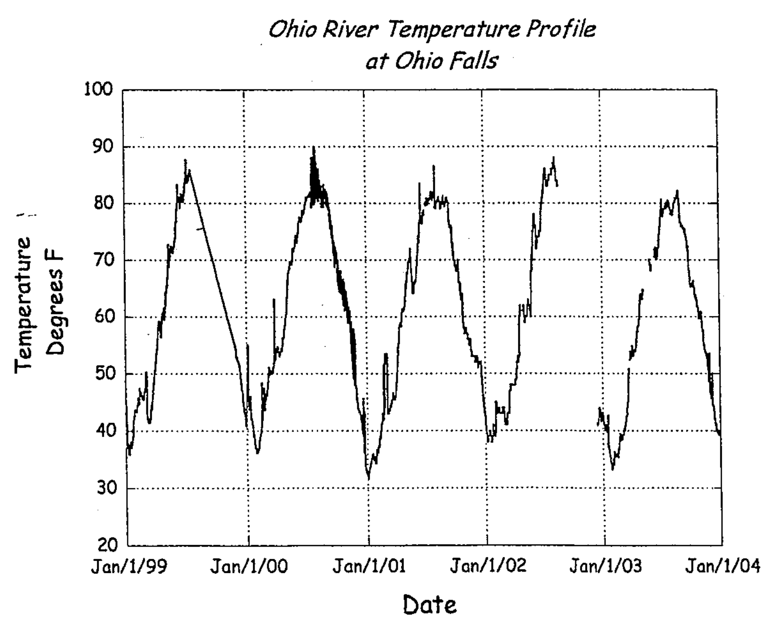

Ohio River Temperature Profile
River Mile 721
100
90
80
70
60
50
40
30
20
Temperature
Degrees F
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

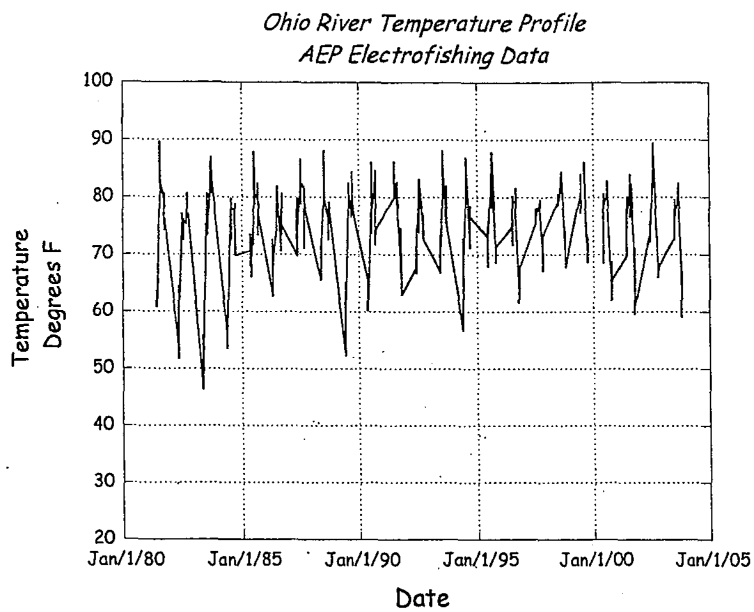

Ohio River Temperature Profile
River Mile 846
Temperature Degrees F
100
90
80
70
60
50
40
30
20
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date


Ohio River Temperature Profile
River Mile 963
Temperature Degrees F
100
90
80
70
60
50
40
30
20
Jan/1/94
Jan/1/96
Jan/1/98
Jan/1/00
Jan/1/02
Jan/1/04
Date

Appendix Table A-2. Temperature profiles (°F) from the Ohio River at the Markland (1994-2003) and Ohio Falls (1999-2003) hydroelectric sites, and from AEP electrofishing sites (1982-2003).






Ohio River Temperature Profile
AEP Electrofishing Data
Temperature
Degrees F
100
90
80
70
60
50
40
30
20
Jan/1/80
Jan/1/85
Jan/1/90
Jan/1/95
Jan/1/00
Jan/1/05
Date

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by location. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
				River Mile: 0.0							
Jan	Entire	82	37.3	37.0	44.0	43.0	42.0	42.4	41.3	40.0	32.0
	Early	43	38.2	38.0	44.0	43.0	42.0	43.4	42.2	40.0	32.3
	Late	39	36.3	36.0	42.0	43.0	42.0	40.6	40.0	38.0	32.0
Feb	Entire	64	36.4	36.0	41.0	41.0	41.0	41.0	41.0	38.0	33.0
	Early	32	35.6	36.0	40.0	41.0	41.0	39.8	38.0	36.0	33.0
	Late	32	37.2	36.0	41.0	41.0	41.0	41.0	41.0	41.0	34.0
Mar	Entire	50	41.5	41.5	45.0	45.0	45.0	45.0	45.0	43.0	37.0
	Early	20	40.4	40.5	43.0	45.0	45.0	43.0	43.0	43.0	34.0
	Late	30	42.3	42.0	45.0	45.0	45.0	45.0	45.0	45.0	40.0
Apr	Entire	47	51.1	49.0	57.0	57.0	57.0	57.0	57.0	56.8	41.7
	Early	17	48.5	49.0	55.0	57.0	57.0	55.0	54.8	51.8	40.0
	Late	30	52.6	52.0	57.0	57.0	57.0	57.0	57.0	57.0	48.0
May	Entire	60	58.1	57.0	65.0	65.0	64.0	65.0	64.0	64.0	50.0
	Early	27	55.1	56.0	62.0	65.0	64.0	59.5	58.0	58.0	50.0
	Late	33	60.6	63.0	65.0	65.0	64.0	65.0	65.0	64.0	53.2
Jun	Entire	41	72.6	74.0	77.0	75.0	75.0	75.0	75.0	75.0	63.6
	Early	19	72.1	74.0	75.0	75.0	75.0	75.0	75.0	74.0	63.0
	Late	22	73.0	74.0	77.0	75.0	75.0	75.8	75.0	75.0	68.0
Jul	Entire	43	77.5	78.0	82.0	81.0	80.0	81.0	80.2	78.0	70.7
	Early	16	76.3	77.0	80.0	81.0	80.0	79.4	78.0	78.0	70.0
	Late	27	78.3	78.0	82.0	81.0	80.0	81.2	81.0	79.8	75.9

[1] Means/medians are means/medians of daily maximum values

03/26/2004

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3 Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2]Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
Aug	Entire	74	78.2	78.5	85.0	85.0	85.0	85.0	83.1	82.0	70.0
	Early	35	78.5	79.0	83.0	85.0	85.0	83.0	83.0	82.0	71.0
	Late	39	78.0	78.0	85.0	85.0	85.0	85.0	85.0	80.8	70.0
Sep	Entire	77	75.7	77.0	82.0	82.0	82.0	82.0	81.0	78.0	64.4
	Early	35	78.4	78.0	82.0	82.0	82.0	82.0	82.0	81.0	70.5
	Late	42	73.5	76.5	78.0	82.0	82.0	78.0	78.0	78.0	63.6
Oct	Entire	77	68.9	68.0	77.0	77.0	75.0	76.7	75.0	72.3	59.0
	Early	34	71.9	73.0	77.0	77.0	75.0	77.0	77.0	75.0	62.2
	Late	43	66.5	68.0	72.0	77.0	75.0	72.0	72.0	68.0	59.0
Nov	Entire	76	51.6	52.0	65.0	65.0	64.0	64.0	60.0	58.0	41.0
	Early	38	57.2	58.0	65.0	65.0	64.0	65.0	64.0	60.0	50.4
	Late	38	46.1	44.0	56.0	65.0	64.0	54.6	54.0	49.0	41.0
Dec	Entire	82	42.8	39.0	54.0	54.0	54.0	54.0	53.0	52.0	35.0
	Early	41	44.4	39.0	54.0	54.0	54.0	54.0	54.0	53.0	37.0
	Late	41	41.3	38.0	52.0	54.0	54.0	52.0	52.0	48.0	35.0
				River Mile: 60							
Jan	Entire	246	35.1	35.0	42.0	41.0	41.0	40.0	39.0	37.0	31.0
	Early	120	36.1	36.0	42.0	41.0	41.0	41.0	40.0	39.0	31.0
	Late	126	34.2	34.0	39.0	41.0	41.0	38.0	37.0	35.0	31.0
Feb	Entire	252	35.9	35.0	45.0	41.0	41.0	41.0	40.0	37.0	33.0
	Early	133	35.6	35.0	45.0	41.0	41.0	39.9	39.0	37.0	32.0

03/26/2004

[1]Means/medians are means/medians of daily maximum values

[2]Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	119	36.2	35.0	42.0	41.0	41.0	41.0	41.0	37.0	33.0
Mar	Entire	247	40.2	40.0	55.0	55.0	50.0	49.0	47.8	42.0	34.0
	Early	119	38.2	37.0	48.0	55.0	50.0	45.0	43.0	41.0	34.0
	Late	128	42.0	41.0	55.0	55.0	50.0	50.0	49.0	45.0	36.0
Apr	Entire	245	49.6	49.0	65.0	60.0	60.0	60.0	57.0	54.0	40.0
	Early	120	46.8	48.0	63.0	60.0	60.0	55.0	54.0	50.0	39.0
	Late	125	52.2	52.0	65.0	60.0	60.0	60.0	59.0	57.0	42.3
May	Entire	240	59.7	60.0	70.0	70.0	69.0	68.0	66.0	64.0	50.0
	Early	115	57.3	57.0	70.0	70.0	69.0	66.0	64.0	60.0	48.5
	Late	125	61.8	63.0	70.0	70.0	69.0	69.0	68.0	64.0	54.8
Jun	Entire	263	70.3	70.0	86.0	82.0	80.0	80.0	78.0	74.0	62.0
	Early	131	67.5	68.0	86.0	82.0	80.0	75.0	74.0	70.0	60.0
	Late	132	73.0	72.0	82.0	82.0	80.0	80.0	80.0	77.0	65.0
Jul	Entire	254	78.5	78.0	88.0	87.0	86.0	86.0	84.1	80.0	73.0
	Early	119	77.6	78.0	88.0	87.0	86.0	85.0	80.0	80.0	72.0
	Late	135	79.4	79.0	87.0	87.0	86.0	86.0	85.0	82.0	74.0
Aug	Entire	250	80.2	80.0	96.0	87.0	87.0	87.0	86.0	84.0	72.0
	Early	126	80.2	80.0	88.0	87.0	87.0	87.0	87.0	85.0	73.0
	Late	124	80.3	80.0	96.0	87.0	87.0	87.0	86.0	84.0	70.0
Sep	Entire	255	75.5	76.0	85.0	83.0	82.0	82.0	80.0	79.0	68.0
	Early	127	77.7	78.0	85.0	83.0	82.0	82.0	81.8	80.0	71.0

[1] Means/medians are means/medians of daily maximum values

03/26/2004

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	128	73.3	73.0	84.0	83.0	82.0	78.0	78.0	77.0	64.9
Oct	Entire	261	66.3	67.0	77.0	77.0	76.0	75.0	74.0	71.0	56.1
	Early	130	69.3	70.0	77.0	77.0	76.0	76.0	75.0	74.0	60.0
	Late	131	63.2	64.0	74.0	77.0	76.0	72.0	69.8	67.8	53.1
Nov	Entire	257	53.3	54.0	65.0	65.0	64.0	63.0	61.0	60.0	42.0
	Early	126	57.1	59.0	65.0	65.0	64.0	63.2	63.0	60.0	48.8
	Late	131	49.7	49.0	62.0	65.0	64.0	60.0	58.0	54.0	41.0
Dec	Entire	257	42.6	41.0	70.0	57.0	56.0	55.0	54.0	47.3	35.0
	Early	132	44.0	42.0	57.0	57.0	56.0	55.0	54.0	49.0	37.0
	Late	125	41.0	39.0	70.0	57.0	56.0	53.0	52.0	42.0	33.0
River Mile: 13.0											
Jan	Entire	200	36.2	35.0	59.0	49.0	49.0	44.5	41.5	38.0	32.0
	Early	101	38.0	37.0	59.0	49.0	49.0	49.0	42.0	40.3	32.6
	Late	99	34.4	34.0	48.0	49.0	49.0	38.0	37.6	35.0	30.0
Feb	Entire	185	35.7	36.0	44.0	40.0	40.0	40.0	39.0	37.0	32.0
	Early	87	35.0	35.0	44.0	40.0	40.0	39.0	38.0	36.0	29.9
	Late	98	36.4	36.0	42.0	40.0	40.0	40.0	39.1	37.0	34.0
Mar	Entire	187	39.9	39.0	50.0	50.0	49.0	49.0	46.0	41.0	35.0
	Early	92	38.2	38.0	48.0	50.0	49.0	42.0	41.0	40.0	34.0
	Late	95	41.6	41.0	50.0	50.0	49.0	49.0	49.0	42.0	37.0
Apr	Entire	186	50.0	49.0	63.0	63.0	60.0	60.0	57.0	55.0	40.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Early	77	46.9	48.0	63.0	63.0	60.0	60.0	55.8	49.0	36.0
	Late	109	52.1	52.0	62.0	63.0	60.0	60.0	59.0	55.0	47.0
May	Entire	199	60.2	60.0	78.0	68.0	68.0	67.0	66.0	64.0	52.5
	Early	84	59.0	59.0	78.0	68.0	68.0	66.0	66.0	62.0	49.7
	Late	115	61.1	61.0	76.0	68.0	68.0	67.8	67.0	64.0	54.0
Jun	Entire	196	69.2	69.0	80.0	79.0	78.0	77.7	77.0	73.0	60.0
	Early	93	66.3	66.0	78.0	79.0	78.0	76.6	74.0	69.0	60.0
	Late	103	71.8	72.0	80.0	79.0	78.0	78.0	77.0	76.0	64.0
Jul	Entire	181	79.5	79.0	98.0	98.0	86.0	86.0	84.4	82.0	72.0
	Early	82	79.5	80.0	98.0	98.0	86.0	86.0	86.0	80.0	71.6
	Late	99	79.6	79.0	98.0	98.0	86.0	85.0	84.0	83.0	74.0
Aug	Entire	153	79.4	80.0	88.0	88.0	86.0	86.0	86.0	83.0	73.0
	Early	83	79.1	79.0	88.0	88.0	86.0	86.0	86.0	83.0	72.7
	Late	70	79.7	80.0	86.0	88.0	86.0	86.0	85.0	84.0	75.0
Sep	Entire	174	76.7	77.5	86.0	85.0	84.0	84.0	81.0	80.0	70.0
	Early	93	78.7	79.0	86.0	85.0	84.0	84.9	84.0	80.0	72.0
	Late	81	74.4	74.0	84.0	85.0	84.0	79.0	78.4	78.0	70.0
Oct	Entire	214	67.1	68.0	78.0	77.0	77.0	76.0	75.0	71.0	57.2
	Early	120	69.5	69.0	78.0	77.0	77.0	77.0	76.0	74.0	60.0
	Late	94	64.0	65.5	72.0	77.0	77.0	70.0	68.1	67.0	56.0
Nov	Entire	212	55.3	57.0	68.0	66.0	65.0	65.0	63.0	60.0	43.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Early	122	57.8	59.0	68.0	66.0	65.0	65.0	64.0	62.0	50.0
	Late	90	52.0	51.0	65.0	66.0	65.0	62.0	60.0	59.0	42.0
Dec	Entire	199	43.6	41.0	59.0	57.0	57.0	57.0	55.0	48.8	36.0
	Early	101	44.6	42.0	57.0	57.0	57.0	56.5	55.0	49.0	38.0
	Late	98	42.6	41.0	59.0	57.0	57.0	57.0	52.0	47.0	33.0
River Mile: 54.0											
Jan	Entire	277	34.9	34.0	45.0	43.0	42.0	40.0	39.0	37.0	31.0
	Early	135	35.8	35.0	45.0	43.0	42.0	42.0	40.0	37.0	32.0
	Late	142	34.0	33.5	41.0	43.0	42.0	38.0	37.0	36.0	31.0
Feb	Entire	251	35.9	35.0	56.0	41.0	41.0	41.0	40.0	37.0	32.0
	Early	132	35.6	35.0	56.0	41.0	41.0	40.9	39.0	36.0	32.0
	Late	119	36.4	36.0	42.0	41.0	41.0	41.0	40.0	37.8	33.0
Mar	Entire	247	40.0	40.0	50.0	50.0	49.0	48.0	46.0	42.0	34.0
	Early	119	38.4	38.0	48.0	50.0	49.0	45.2	43.0	41.0	34.0
	Late	128	41.6	41.0	50.0	50.0	49.0	49.0	48.0	45.0	35.9
Apr	Entire	242	49.7	49.0	59.0	59.0	57.0	56.0	55.0	53.0	43.0
	Early	119	48.1	48.0	59.0	59.0	57.0	55.0	55.0	50.0	42.0
	Late	123	51.3	50.0	59.0	59.0	57.0	57.0	56.0	55.0	47.0
May	Entire	278	60.9	61.0	75.0	69.0	69.0	67.6	67.0	64.0	54.0
	Early	135	58.9	59.0	67.0	69.0	69.0	66.0	65.0	62.0	53.0
	Late	143	62.7	63.0	75.0	69.0	69.0	69.0	67.2	65.8	57.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
Jun	Entire	268	70.4	70.0	82.0	82.0	80.0	78.1	78.0	74.0	62.0
	Early	133	67.4	67.0	77.0	82.0	80.0	74.9	74.0	70.0	62.0
	Late	135	73.3	73.0	82.0	82.0	80.0	80.0	78.0	77.0	67.0
Jul	Entire	277	79.3	79.0	87.0	86.0	86.0	86.0	85.0	82.0	75.0
	Early	135	78.3	78.0	86.0	86.0	86.0	84.8	82.0	80.0	75.0
	Late	142	80.3	80.5	87.0	86.0	86.0	86.0	85.0	84.0	74.0
Aug	Entire	253	80.8	81.0	88.0	87.0	87.0	87.0	86.0	83.0	74.0
	Early	127	80.9	81.0	88.0	87.0	87.0	87.0	86.0	83.0	73.0
	Late	126	80.6	81.0	87.0	87.0	87.0	87.0	85.0	83.0	74.0
Sep	Entire	264	75.5	77.0	87.0	83.0	82.0	81.0	80.0	78.5	66.0
	Early	132	78.4	78.0	87.0	83.0	82.0	82.0	81.0	80.0	72.0
	Late	132	72.7	73.0	79.0	83.0	82.0	78.0	78.0	76.0	64.1
Oct	Entire	275	64.8	65.0	77.0	77.0	76.0	75.0	74.0	69.0	53.5
	Early	132	68.0	69.0	77.0	77.0	76.0	76.0	75.0	73.0	51.0
	Late	143	61.8	61.0	70.0	77.0	76.0	68.0	68.0	64.0	57.0
Nov	Entire	263	51.7	51.0	64.0	63.0	63.0	61.4	60.0	57.0	42.0
	Early	129	55.7	57.0	64.0	63.0	63.0	63.0	61.6	60.0	48.0
	Late	134	48.0	48.0	59.0	63.0	63.0	55.8	54.0	51.0	40.0
Dec	Entire	257	41.6	39.0	57.0	57.0	57.0	55.0	53.0	44.0	34.0
	Early	133	43.6	42.0	57.0	57.0	57.0	55.0	54.0	49.0	36.0
	Late	124	39.4	37.0	57.0	57.0	57.0	51.0	46.1	42.0	33.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
				River Mile: 84.0							
Jan	Entire	140	34.3	33.0	42.0	40.0	39.0	39.0	38.0	35.0	31.5
	Early	58	35.3	34.5	42.0	40.0	39.0	40.6	39.0	38.0	31.0
	Late	82	33.5	33.0	38.0	40.0	39.0	37.0	36.0	34.0	32.0
Feb	Entire	142	35.5	35.0	42.0	41.0	41.0	40.4	40.0	37.0	32.0
	Early	58	34.3	33.0	39.0	41.0	41.0	39.0	38.0	36.0	32.0
	Late	84	36.3	36.0	42.0	41.0	41.0	41.0	40.0	37.0	33.0
Mar	Entire	149	39.4	39.0	49.0	49.0	49.0	48.0	45.0	41.0	34.0
	Early	59	37.2	37.0	44.0	49.0	49.0	42.6	42.0	40.0	33.5
	Late	90	40.8	40.0	49.0	49.0	49.0	49.0	48.0	42.0	35.0
Apr	Entire	162	49.2	49.0	59.0	57.0	57.0	56.0	55.0	52.0	42.6
	Early	65	46.8	47.0	56.0	57.0	57.0	55.0	52.0	49.3	40.8
	Late	97	50.9	50.0	59.0	57.0	57.0	57.0	56.0	54.0	47.0
May	Entire	148	61.7	61.5	68.0	68.0	67.0	67.0	67.0	65.0	54.0
	Early	50	60.8	60.0	68.0	68.0	67.0	67.0	66.0	65.0	56.0
	Late	98	62.1	63.0	68.0	68.0	67.0	67.0	67.0	66.0	54.0
Jun	Entire	136	70.3	70.0	82.0	80.0	80.0	79.0	78.0	74.0	61.3
	Early	60	66.5	65.0	74.0	80.0	80.0	74.0	73.0	70.0	61.0
	Late	76	73.3	73.0	82.0	80.0	80.0	80.0	79.0	77.0	66.3
Jul	Entire	160	79.1	79.0	86.0	86.0	86.0	85.0	85.0	80.0	75.0
	Early	88	78.2	78.0	86.0	86.0	86.0	85.0	80.0	79.0	74.0
	Late	72	80.3	80.0	86.0	86.0	86.0	85.0	85.0	83.0	75.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2]			95th Percentile	90th Percentile	75th Percentile	5th Percentile
					Single	Twice	Three				
Aug	Entire	154	80.3	81.0	87.0	86.0	86.0	86.0	84.0	83.0	74.0
	Early	90	80.6	81.0	87.0	86.0	86.0	86.0	85.5	83.0	73.0
	Late	64	79.9	80.0	85.0	86.0	86.0	83.3	83.0	82.0	75.7
Sep	Entire	131	75.9	77.0	89.0	82.0	81.0	81.0	80.0	79.0	66.0
	Early	85	77.8	78.0	89.0	82.0	81.0	81.3	80.0	80.0	73.5
	Late	46	72.4	73.5	80.0	82.0	81.0	77.2	76.0	76.0	65.8
Oct	Entire	163	65.7	66.0	77.0	76.0	76.0	76.0	74.0	71.0	57.0
	Early	91	69.3	70.0	77.0	76.0	76.0	76.0	76.0	74.0	60.1
	Late	72	61.3	60.0	72.0	76.0	76.0	68.0	67.0	64.0	56.1
Nov	Entire	162	52.6	52.0	64.0	63.0	63.0	62.4	60.3	58.0	41.0
	Early	76	57.7	59.0	64.0	63.0	63.0	63.0	62.9	60.0	49.3
	Late	86	48.1	49.0	58.0	63.0	63.0	56.0	54.9	51.0	40.0
Dec	Entire	166	40.1	38.0	59.0	57.0	55.0	54.0	50.0	42.0	33.0
	Early	69	42.8	39.0	59.0	57.0	55.0	57.0	54.6	45.8	35.0
	Late	97	38.2	37.0	51.0	57.0	55.0	46.7	44.8	41.3	33.0
			River Mile: 162.0								
Jan	Entire	271	37.2	37.0	46.0	46.0	44.0	42.0	41.2	40.0	32.0
	Early	130	37.6	37.0	46.0	46.0	44.0	44.0	42.0	40.0	32.0
	Late	141	36.9	36.0	44.0	46.0	44.0	42.0	40.0	39.0	33.0
Feb	Entire	224	37.7	38.0	44.0	44.0	43.0	42.0	42.0	40.0	32.7
	Early	120	36.9	37.0	42.0	44.0	43.0	42.0	41.5	40.0	32.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2]Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	104	38.7	39.0	44.0	44.0	43.0	43.0	42.0	41.5	33.0
Mar	Entire	241	43.1	43.0	51.0	50.0	50.0	50.0	48.0	45.3	37.0
	Early	116	41.2	41.0	47.0	50.0	50.0	46.0	46.0	44.0	36.0
	Late	125	44.9	44.0	51.0	50.0	50.0	50.0	50.0	48.0	41.0
Apr	Entire	212	53.2	54.0	62.0	60.0	60.0	59.9	58.0	56.0	46.0
	Early	104	50.7	50.5	59.0	60.0	60.0	57.3	56.0	53.0	44.0
	Late	108	55.6	55.0	62.0	60.0	60.0	60.0	59.7	56.5	52.0
May	Entire	240	62.7	62.0	75.0	72.0	72.0	70.5	69.0	66.0	56.0
	Early	117	60.7	60.0	69.0	72.0	72.0	68.0	66.0	63.3	56.0
	Late	123	64.7	64.0	75.0	72.0	72.0	72.0	70.2	68.8	57.0
Jun	Entire	232	72.8	74.0	82.0	81.0	80.0	80.0	78.0	77.0	64.0
	Early	117	69.7	70.0	80.0	81.0	80.0	76.0	74.0	73.0	64.0
	Late	115	75.9	76.0	82.0	81.0	80.0	80.0	80.0	78.0	69.0
Jul	Entire	248	80.9	82.0	87.0	86.0	86.0	85.0	85.0	84.0	74.0
	Early	120	80.0	80.0	86.0	86.0	86.0	84.0	83.0	82.0	75.5
	Late	128	81.6	83.0	87.0	86.0	86.0	86.0	85.0	84.0	73.0
Aug	Entire	220	82.4	83.0	88.0	88.0	88.0	87.0	86.0	85.0	74.5
	Early	112	82.4	84.0	88.0	88.0	88.0	87.0	86.0	86.0	74.0
	Late	108	82.3	82.0	88.0	88.0	88.0	87.0	86.0	84.0	78.0
Sep	Entire	234	76.8	78.0	86.0	83.0	83.0	82.0	82.0	80.0	68.0
	Early	120	79.4	80.0	86.0	83.0	83.0	83.0	82.0	81.0	74.0

03/26/2004

[1]Means/medians are means/medians of daily maximum values

[2]Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	114	74.1	75.0	79.0	83.0	83.0	79.0	78.0	77.0	67.0
Oct	Entire	242	66.2	66.0	78.0	77.0	77.0	75.0	72.3	70.0	57.6
	Early	117	69.5	70.0	78.0	77.0	77.0	76.7	75.0	72.0	62.0
	Late	125	63.1	63.0	70.0	77.0	77.0	68.0	68.0	66.0	56.0
Nov	Entire	229	52.7	54.0	63.0	62.0	61.0	61.0	59.0	56.0	44.0
	Early	113	56.1	56.0	63.0	62.0	61.0	61.0	61.0	58.3	50.0
	Late	116	49.3	50.0	56.0	62.0	61.0	55.0	54.9	54.0	43.0
Dec	Entire	237	43.1	42.0	55.0	54.0	54.0	52.7	51.8	46.0	36.0
	Early	116	45.2	44.0	55.0	54.0	54.0	54.0	52.9	50.0	38.0
	Late	121	41.2	41.0	51.0	54.0	54.0	49.5	48.4	44.0	34.0
River Mile: 204.0											
Jan	Entire	275	38.8	39.0	47.0	46.0	45.0	44.0	43.0	41.0	33.0
	Early	133	39.5	40.0	47.0	46.0	45.0	45.0	43.2	42.0	33.0
	Late	142	38.2	38.0	45.0	46.0	45.0	42.4	42.0	40.0	34.0
Feb	Entire	251	39.3	40.0	45.0	45.0	45.0	44.0	44.0	41.0	33.0
	Early	133	38.4	40.0	45.0	45.0	45.0	43.0	42.0	41.0	33.0
	Late	118	40.3	41.0	45.0	45.0	45.0	44.0	44.0	43.0	33.4
Mar	Entire	244	45.7	45.0	55.0	55.0	53.0	53.0	51.1	48.0	39.0
	Early	119	44.3	44.0	53.0	55.0	53.0	50.0	48.0	47.0	40.0
	Late	125	47.1	47.0	55.0	55.0	53.0	53.0	53.0	50.0	38.0
Apr	Entire	242	54.6	55.0	63.0	61.0	61.0	60.0	60.0	57.0	47.0

[1] Means/medians are means/medians of daily maximum values

03/26/2004

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence)			95th Percentile	90th Percentile	75th Percentile	5th Percentile
					Single	Twice	Three				
	Early	119	52.3	52.0	60.0	61.0	61.0	60.0	56.0	55.0	44.0
	Late	123	56.9	56.0	63.0	61.0	61.0	61.0	60.0	59.0	54.0
May	Entire	277	64.1	65.0	77.0	73.0	73.0	72.0	71.0	68.0	57.0
	Early	134	61.3	61.0	71.0	73.0	73.0	69.8	67.0	64.0	56.0
	Late	143	66.8	66.0	77.0	73.0	73.0	73.0	72.0	70.0	59.7
Jun	Entire	258	73.1	73.0	82.0	82.0	81.0	80.0	79.0	77.0	65.4
	Early	129	70.4	70.0	81.0	82.0	81.0	76.1	75.0	73.0	65.0
	Late	129	75.7	77.0	82.0	82.0	81.0	81.0	80.0	78.0	69.0
Jul	Entire	271	81.1	81.0	87.0	86.0	86.0	85.0	85.0	83.0	75.0
	Early	131	80.3	81.0	84.0	86.0	86.0	84.0	84.0	82.0	74.0
	Late	140	81.8	82.0	87.0	86.0	86.0	86.0	85.0	85.0	76.0
Aug	Entire	254	81.8	82.0	87.0	87.0	87.0	86.0	86.0	85.0	75.0
	Early	128	82.1	82.0	87.0	87.0	87.0	86.0	86.0	85.0	75.0
	Late	126	81.6	82.0	87.0	87.0	87.0	86.0	86.0	84.0	75.4
Sep	Entire	263	77.3	77.0	85.0	85.0	85.0	83.0	83.0	80.0	69.0
	Early	132	79.6	80.0	85.0	85.0	85.0	84.0	83.0	82.0	75.0
	Late	131	74.9	75.0	84.0	85.0	85.0	83.0	80.4	77.0	68.0
Oct	Entire	277	66.8	66.0	81.0	78.0	77.0	75.0	73.0	70.0	59.0
	Early	135	69.7	70.0	81.0	78.0	77.0	77.0	75.0	72.0	63.0
	Late	142	64.0	64.0	72.0	78.0	77.0	70.0	68.0	67.0	57.6
Nov	Entire	267	54.0	55.0	65.0	63.0	63.0	62.0	60.0	58.0	45.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Early	133	57.2	58.0	64.0	63.0	63.0	62.0	61.0	60.0	51.2
	Late	134	50.7	50.0	65.0	63.0	63.0	58.0	55.0	54.0	45.0
Dec	Entire	263	44.0	43.0	55.0	55.0	54.0	54.0	52.0	46.0	37.0
	Early	134	45.9	45.0	55.0	55.0	54.0	54.0	54.0	50.0	40.0
	Late	129	42.0	42.0	51.0	55.0	54.0	50.0	48.0	45.0	36.0
River Mile: 238.0											
Jan	Entire	258	38.8	38.0	52.0	46.0	46.0	45.0	43.0	42.0	34.0
	Early	124	39.5	40.0	52.0	46.0	46.0	45.3	44.0	42.0	34.0
	Late	134	38.1	38.0	45.0	46.0	46.0	43.8	42.0	41.0	33.0
Feb	Entire	244	39.7	40.0	47.0	45.0	45.0	44.0	44.0	42.0	35.0
	Early	132	38.8	38.0	45.0	45.0	45.0	43.0	42.0	42.0	34.0
	Late	112	40.7	42.0	47.0	45.0	45.0	44.0	44.0	43.0	35.0
Mar	Entire	240	45.1	45.0	54.0	53.0	52.0	52.0	50.0	47.0	40.0
	Early	119	43.5	43.0	51.0	53.0	52.0	48.6	47.0	46.0	39.0
	Late	121	46.6	46.0	54.0	53.0	52.0	52.0	52.0	50.0	40.6
Apr	Entire	233	54.7	55.0	62.0	62.0	62.0	61.0	59.0	58.0	48.2
	Early	117	52.3	52.0	59.0	62.0	62.0	58.0	56.0	54.0	46.0
	Late	116	57.1	57.0	62.0	62.0	62.0	62.0	61.0	58.0	54.0
May	Entire	270	64.1	64.0	76.0	72.0	72.0	72.0	71.0	68.0	58.0
	Early	134	61.9	61.0	70.0	72.0	72.0	68.0	68.0	64.0	57.0
	Late	136	66.4	66.0	76.0	72.0	72.0	72.0	72.0	70.0	58.3

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2]			95th	90th	75th	5th
					Single	Twice	Three	Percentile	Percentile	Percentile	Percentile
Jun	Entire	241	72.5	74.0	82.0	80.0	80.0	79.5	79.0	78.0	63.6
	Early	118	69.1	69.0	80.0	80.0	80.0	76.0	75.0	73.0	61.0
	Late	123	75.9	77.0	82.0	80.0	80.0	80.0	79.0	78.0	68.0
Jul	Entire	253	79.9	80.0	86.0	85.0	85.0	84.0	84.0	82.0	74.0
	Early	119	79.0	80.0	84.0	85.0	85.0	84.0	82.6	81.0	70.0
	Late	134	80.7	81.0	86.0	85.0	85.0	85.0	84.0	84.0	76.0
Aug	Entire	243	80.8	81.0	86.0	86.0	86.0	85.4	84.0	82.8	75.7
	Early	120	80.9	81.0	86.0	86.0	86.0	86.0	85.5	82.5	74.0
	Late	123	80.7	81.0	85.0	86.0	86.0	84.4	84.0	82.8	76.0
Sep	Entire	256	76.7	77.0	88.0	88.0	83.0	82.0	81.0	80.0	69.3
	Early	124	79.2	79.0	88.0	88.0	83.0	83.0	82.0	81.0	76.0
	Late	132	74.4	74.0	81.0	88.0	83.0	80.0	78.0	76.0	68.0
Oct	Entire	260	66.3	66.0	77.0	77.0	76.0	75.0	72.0	70.0	58.0
	Early	125	69.6	70.0	77.0	77.0	76.0	76.0	75.0	72.0	63.0
	Late	135	63.3	64.0	71.0	77.0	76.0	69.8	68.0	66.0	57.3
Nov	Entire	244	53.8	55.0	76.0	63.0	62.0	62.0	61.0	58.0	44.0
	Early	121	57.3	58.0	76.0	63.0	62.0	63.0	62.0	60.3	48.6
	Late	123	50.4	50.0	58.0	63.0	62.0	56.0	56.0	54.0	44.0
Dec	Entire	238	44.2	44.0	58.0	55.0	54.0	54.0	51.7	46.0	37.0
	Early	119	46.1	44.0	58.0	55.0	54.0	54.0	54.0	50.0	40.0
	Late	119	42.3	42.0	55.0	55.0	54.0	50.6	48.0	45.0	37.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2]Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
River Mile: 279.0											
Jan	Entire	276	38.6	38.0	56.0	47.0	46.0	45.0	44.0	41.0	32.3
	Early	134	39.2	39.5	56.0	47.0	46.0	46.0	45.0	41.0	34.0
	Late	142	38.0	38.0	45.0	47.0	46.0	44.0	43.0	40.0	31.6
Feb	Entire	249	39.0	39.0	46.0	44.0	44.0	44.0	43.0	42.0	34.0
	Early	131	37.7	37.0	44.0	44.0	44.0	43.0	43.0	41.0	34.0
	Late	118	40.5	41.0	46.0	44.0	44.0	44.0	44.0	43.0	35.0
Mar	Entire	244	45.4	45.0	53.0	52.0	52.0	52.0	50.0	47.0	40.0
	Early	117	43.7	44.0	49.0	52.0	52.0	48.0	47.0	46.0	40.0
	Late	127	47.0	46.0	53.0	52.0	52.0	52.0	52.0	48.8	43.0
Apr	Entire	242	55.2	55.0	65.0	64.0	64.0	63.0	60.0	57.0	48.6
	Early	120	52.7	53.0	60.0	64.0	64.0	57.5	56.0	55.0	47.0
	Late	122	57.7	57.0	65.0	64.0	64.0	64.0	63.0	59.0	54.0
May	Entire	275	64.2	64.0	75.0	73.0	73.0	71.8	71.0	68.0	59.0
	Early	134	62.3	61.0	71.0	73.0	73.0	69.0	68.0	65.0	57.0
	Late	141	66.0	65.0	75.0	73.0	73.0	73.0	71.4	70.0	60.0
Jun	Entire	239	73.4	74.0	83.0	83.0	82.0	81.0	80.0	78.0	64.0
	Early	119	70.5	71.0	83.0	83.0	82.0	77.0	75.6	74.0	64.0
	Late	120	76.4	78.0	83.0	83.0	82.0	81.5	81.0	80.0	67.0
Jul	Entire	247	82.0	82.0	88.0	87.0	87.0	87.0	86.0	85.0	76.0
	Early	120	80.7	81.0	86.0	87.0	87.0	85.5	85.0	83.0	74.5
	Late	127	83.2	84.0	88.0	87.0	87.0	87.0	87.0	85.0	77.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
Aug	Entire	257	83.0	84.0	95.0	88.0	88.0	87.7	87.0	85.0	76.0
	Early	130	82.7	83.0	89.0	88.0	88.0	88.0	87.0	86.0	75.0
	Late	127	83.3	84.0	95.0	88.0	88.0	87.0	87.0	85.0	78.0
Sep	Entire	266	78.5	79.5	90.0	86.0	86.0	85.0	83.0	81.0	71.0
	Early	134	80.7	81.0	90.0	86.0	86.0	86.0	85.0	83.0	73.2
	Late	132	76.2	76.0	86.0	86.0	86.0	81.0	81.0	79.0	69.1
Oct	Entire	277	67.3	67.0	80.0	76.0	76.0	75.0	74.0	70.0	59.0
	Early	135	70.5	70.0	80.0	76.0	76.0	76.0	75.0	73.0	64.0
	Late	142	64.2	65.0	70.0	76.0	76.0	69.0	68.3	67.0	58.0
Nov	Entire	267	53.5	54.0	64.0	63.0	63.0	62.0	60.0	57.0	45.0
	Early	133	56.9	57.0	64.0	63.0	63.0	62.0	62.0	59.0	52.0
	Late	134	50.0	49.5	57.0	63.0	63.0	57.0	56.0	53.0	45.0
Dec	Entire	263	44.1	43.0	56.0	56.0	56.0	55.0	54.0	46.0	36.7
	Early	132	46.4	45.0	56.0	56.0	56.0	55.9	55.0	47.0	41.0
	Late	131	41.8	41.0	55.0	56.0	56.0	52.0	49.0	44.0	35.0
				River Mile: 341.0							
Jan	Entire	270	39.1	40.0	51.0	44.0	44.0	44.0	43.0	41.0	33.0
	Early	131	39.7	40.0	51.0	44.0	44.0	44.0	43.0	42.0	34.0
	Late	139	38.6	39.0	44.0	44.0	44.0	42.6	42.0	40.0	31.0
Feb	Entire	237	38.9	39.0	48.0	48.0	46.0	46.0	45.0	42.0	32.0
	Early	124	37.7	38.0	48.0	48.0	46.0	44.3	43.0	40.0	32.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	113	40.2	40.0	48.0	48.0	46.0	46.0	46.0	43.0	33.0
Mar	Entire	242	45.0	45.0	58.0	57.0	56.0	55.4	54.0	48.0	36.6
	Early	116	42.7	42.0	56.0	57.0	56.0	53.6	47.0	46.0	36.0
	Late	126	47.1	46.0	58.0	57.0	56.0	55.2	54.9	50.0	37.8
Apr	Entire	241	54.4	55.0	62.0	62.0	62.0	61.0	61.0	57.0	45.0
	Early	118	52.4	52.5	61.0	62.0	62.0	61.0	57.0	56.0	44.0
	Late	123	56.4	56.0	62.0	62.0	62.0	62.0	61.0	60.0	50.0
May	Entire	270	63.4	63.0	72.0	72.0	72.0	71.0	70.0	69.0	57.0
	Early	133	60.9	60.0	70.0	72.0	72.0	69.0	67.0	64.3	52.3
	Late	137	65.8	67.0	72.0	72.0	72.0	72.0	71.0	70.0	59.0
Jun	Entire	261	72.1	73.0	83.0	83.0	83.0	79.5	78.0	75.4	65.0
	Early	131	69.4	68.0	78.0	83.0	83.0	77.0	75.0	73.0	64.0
	Late	130	74.9	75.0	83.0	83.0	83.0	83.0	79.5	77.0	69.0
Jul	Entire	265	79.4	79.0	87.0	85.0	85.0	84.0	83.0	81.0	75.0
	Early	132	78.2	78.0	87.0	85.0	85.0	84.0	83.0	80.0	74.1
	Late	133	80.7	81.0	85.0	85.0	85.0	85.0	83.0	82.0	78.2
Aug	Entire	243	81.3	81.0	92.0	86.0	86.0	86.0	85.0	83.8	76.7
	Early	125	81.6	81.0	92.0	86.0	86.0	86.0	86.0	84.0	78.0
	Late	118	81.0	80.0	86.0	86.0	86.0	85.0	85.0	83.0	76.0
Sep	Entire	262	77.9	78.0	85.0	85.0	85.0	83.8	82.0	80.0	73.0
	Early	129	79.7	80.0	85.0	85.0	85.0	85.0	84.2	81.0	75.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	Maximum (Occurrence) [2] Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	133	76.1	77.0	82.0	85.0	85.0	80.0	79.2	78.0	71.0
Oct	Entire	271	67.4	68.0	79.0	77.0	77.0	77.0	75.0	70.0	60.0
	Early	130	70.3	70.0	79.0	77.0	77.0	77.0	77.0	74.0	63.0
	Late	141	64.7	65.0	73.0	77.0	77.0	70.0	69.0	68.0	60.0
Nov	Entire	262	55.9	56.0	65.0	65.0	65.0	63.4	62.0	59.0	49.0
	Early	128	58.5	59.0	65.0	65.0	65.0	65.0	63.7	61.0	52.0
	Late	134	53.4	54.0	63.0	65.0	65.0	59.0	58.0	56.0	48.0
Dec	Entire	254	46.3	46.0	62.0	56.0	56.0	55.0	54.0	51.0	37.0
	Early	122	48.6	48.0	62.0	56.0	56.0	56.0	55.0	53.0	42.0
	Late	132	44.2	43.0	55.0	56.0	56.0	55.0	51.0	49.0	34.0
River Mile: 436.0											
Jan	Entire	245	39.3	40.0	53.0	51.0	51.0	48.0	44.0	42.0	33.0
	Early	120	40.4	40.0	53.0	51.0	51.0	51.0	44.5	42.0	33.0
	Late	125	38.2	38.0	48.0	51.0	51.0	44.5	43.0	41.0	32.0
Feb	Entire	246	39.9	39.0	51.0	50.0	49.0	44.0	44.0	42.0	34.0
	Early	127	38.8	38.0	48.0	50.0	49.0	44.0	43.0	42.0	34.0
	Late	119	41.1	42.0	51.0	50.0	49.0	49.0	44.0	43.0	36.0
Mar	Entire	246	45.7	45.0	67.0	52.0	52.0	52.0	51.0	49.0	39.8
	Early	118	43.4	43.0	51.0	52.0	52.0	49.0	48.0	46.0	38.4
	Late	128	47.8	47.0	67.0	52.0	52.0	54.1	51.7	50.0	42.0
Apr	Entire	235	54.3	54.0	98.0	64.0	64.0	63.0	61.0	58.0	46.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2]Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Early	120	51.5	51.0	65.0	64.0	64.0	62.0	60.5	53.0	45.0
	Late	115	57.1	57.0	98.0	64.0	64.0	64.0	62.0	59.0	49.5
May	Entire	269	63.5	63.0	81.0	77.0	77.0	75.0	72.0	67.3	55.0
	Early	133	61.2	60.0	74.0	77.0	77.0	68.0	68.0	65.0	50.5
	Late	136	65.8	64.5	81.0	77.0	77.0	77.0	75.0	71.0	55.0
Jun	Entire	239	73.2	74.0	87.0	86.0	82.0	81.0	80.0	78.0	64.5
	Early	123	69.8	70.0	82.0	86.0	82.0	78.4	77.0	74.0	61.0
	Late	116	76.8	77.5	87.0	86.0	82.0	83.7	80.9	79.0	68.0
Jul	Entire	239	81.1	81.0	87.0	87.0	87.0	86.0	85.0	84.0	74.0
	Early	118	81.1	81.0	87.0	87.0	87.0	86.0	84.7	83.0	75.0
	Late	121	81.1	81.0	87.0	87.0	87.0	86.0	85.0	84.0	74.0
Aug	Entire	218	81.1	80.0	87.0	87.0	86.0	86.0	85.0	84.0	77.0
	Early	110	81.0	80.0	87.0	87.0	86.0	86.0	85.5	84.0	77.0
	Late	108	81.1	80.0	86.0	87.0	86.0	85.0	84.0	83.0	77.0
Sep	Entire	231	77.6	79.0	88.0	84.0	84.0	83.0	82.4	80.0	70.0
	Early	119	79.9	80.0	88.0	84.0	84.0	84.0	83.0	81.0	74.0
	Late	112	75.2	75.5	83.0	84.0	84.0	81.0	79.0	77.0	69.0
Oct	Entire	228	68.3	68.0	84.0	76.0	75.0	75.0	74.0	72.0	61.0
	Early	115	71.0	71.0	84.0	76.0	75.0	76.0	74.0	73.0	64.3
	Late	113	65.6	65.0	76.0	76.0	75.0	72.0	70.0	67.0	60.0
Nov	Entire	209	55.3	55.0	74.0	71.0	68.0	67.1	63.0	59.0	46.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Early	103	59.5	59.0	74.0	71.0	68.0	71.0	67.2	62.0	52.7
	Late	106	51.2	51.0	58.0	71.0	68.0	57.0	57.0	55.0	45.0
Dec	Entire	222	44.9	44.0	56.0	55.0	54.0	53.4	51.0	48.0	40.0
	Early	108	46.4	44.0	56.0	55.0	54.0	54.1	53.7	49.5	41.9
	Late	114	43.5	42.0	53.0	55.0	54.0	51.0	50.0	46.0	39.0
			River Mile: 532.0								
Jan	Entire	272	38.3	39.0	50.0	44.0	44.0	44.0	42.3	40.0	33.0
	Early	131	39.0	40.0	50.0	44.0	44.0	44.0	44.0	41.0	33.0
	Late	141	37.6	38.0	46.0	44.0	44.0	44.0	42.0	40.0	32.0
Feb	Entire	251	38.9	39.0	48.0	46.0	46.0	44.0	44.0	42.0	34.0
	Early	134	38.1	38.0	45.0	46.0	46.0	44.0	44.0	41.0	34.0
	Late	117	39.7	40.0	48.0	46.0	46.0	46.0	44.0	43.0	33.0
Mar	Entire	239	44.3	44.0	52.0	52.0	52.0	52.0	51.0	47.0	39.0
	Early	116	42.1	41.0	52.0	52.0	52.0	50.0	48.0	44.0	36.3
	Late	123	46.4	46.0	52.0	52.0	52.0	52.0	52.0	50.0	40.0
Apr	Entire	207	54.1	56.0	70.0	63.0	62.0	62.0	60.0	58.8	42.0
	Early	104	50.6	51.0	70.0	63.0	62.0	59.0	58.0	53.5	42.0
	Late	103	57.6	58.0	65.0	63.0	62.0	62.0	61.2	60.0	52.0
May	Entire	273	64.2	64.0	77.0	75.0	74.0	73.0	70.0	67.0	58.0
	Early	132	62.4	62.0	72.0	75.0	74.0	70.0	67.3	65.0	56.0
	Late	141	65.9	64.0	77.0	75.0	74.0	74.0	73.0	70.0	59.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
Jun	Entire	204	71.4	70.0	83.0	83.0	82.0	82.0	80.0	76.0	63.0
	Early	102	68.8	66.0	82.0	83.0	82.0	80.8	78.0	72.0	63.0
	Late	102	74.0	74.0	83.0	83.0	82.0	82.0	80.0	77.0	65.0
Jul	Entire	245	80.4	80.0	89.0	88.0	88.0	87.0	85.0	82.0	75.0
	Early	117	80.0	79.0	85.0	88.0	88.0	85.0	84.8	82.0	75.0
	Late	128	80.8	81.0	89.0	88.0	88.0	88.0	87.0	82.0	72.9
Aug	Entire	237	81.9	82.0	99.0	88.0	88.0	88.0	86.0	84.0	76.0
	Early	115	82.3	83.0	99.0	88.0	88.0	88.0	88.0	84.0	75.0
	Late	122	81.6	82.0	88.0	88.0	88.0	85.0	84.0	83.0	76.0
Sep	Entire	230	78.1	80.0	84.0	84.0	84.0	84.0	82.5	81.0	68.0
	Early	117	80.0	80.0	84.0	84.0	84.0	84.0	84.0	82.0	75.0
	Late	113	76.2	78.0	82.0	84.0	84.0	80.0	80.0	80.0	63.8
Oct	Entire	261	67.5	67.0	80.0	80.0	78.0	77.0	75.0	70.0	60.0
	Early	126	70.5	70.0	80.0	80.0	78.0	78.0	77.0	74.0	61.0
	Late	135	64.7	65.0	71.0	80.0	78.0	70.0	70.0	67.0	60.0
Nov	Entire	245	56.1	56.0	67.0	67.0	67.0	64.3	62.0	60.0	48.0
	Early	120	59.3	60.0	67.0	67.0	67.0	66.5	64.5	62.0	50.0
	Late	125	53.1	53.0	62.0	67.0	67.0	60.0	59.0	57.0	47.8
Dec	Entire	240	45.6	45.0	58.0	57.0	57.0	55.0	54.0	50.0	39.0
	Early	119	47.7	47.0	58.0	57.0	57.0	57.0	55.0	54.0	40.0
	Late	121	43.5	42.0	54.0	57.0	57.0	54.0	50.4	47.3	37.6

[1] Means/medians are means/medians of daily maximum values

03/26/2004

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2]Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
				River Mile: 721.0							
Jan	Entire	270	38.5	39.0	45.0	45.0	45.0	44.0	43.0	42.0	32.0
	Early	126	39.0	40.0	45.0	45.0	45.0	45.0	43.0	42.0	31.0
	Late	144	38.0	38.0	45.0	45.0	45.0	44.0	43.1	40.0	33.0
Feb	Entire	251	39.4	40.0	54.0	48.0	48.0	47.0	45.0	43.0	33.0
	Early	133	38.2	37.0	48.0	48.0	48.0	47.0	44.0	42.0	32.2
	Late	118	40.8	41.5	54.0	48.0	48.0	46.0	45.0	44.0	35.0
Mar	Entire	240	45.2	45.0	53.0	52.0	52.0	52.0	50.0	47.0	39.0
	Early	117	43.2	44.0	51.0	52.0	52.0	49.7	47.0	46.0	39.0
	Late	123	47.1	47.0	53.0	52.0	52.0	52.0	52.0	50.0	42.0
Apr	Entire	233	54.5	55.0	72.0	66.0	62.0	60.0	60.0	58.0	47.0
	Early	115	51.6	52.0	58.0	66.0	62.0	58.0	57.0	54.0	45.0
	Late	118	57.4	57.0	72.0	66.0	62.0	62.0	60.0	59.0	53.0
May	Entire	275	62.5	62.0	71.0	70.0	70.0	69.0	69.0	66.0	56.0
	Early	133	60.7	60.0	70.0	70.0	70.0	68.9	67.0	62.0	56.0
	Late	142	64.1	64.0	71.0	70.0	70.0	70.0	69.0	67.0	57.0
Jun	Entire	266	70.6	70.0	79.0	79.0	79.0	78.0	75.0	74.0	65.0
	Early	132	68.4	68.0	78.0	79.0	79.0	75.0	72.3	70.0	64.0
	Late	134	72.7	73.0	79.0	79.0	79.0	78.0	78.0	74.0	68.0
Jul	Entire	273	79.0	79.0	86.0	85.0	85.0	83.0	82.0	80.0	74.0
	Early	132	78.0	79.0	84.0	85.0	85.0	82.0	82.0	80.0	72.0
	Late	141	80.0	80.0	86.0	85.0	85.0	83.5	83.0	82.0	77.0

03/26/2004

[1]Means/medians are means/medians of daily maximum values

[2]Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

					Maximum (Occurrence)[2]			95th	90th	75th	5th
Month	Period	Samples	Mean[1]	Median[1]	Single	Twice	Three	Percentile	Percentile	Percentile	Percentile
Aug	Entire	257	81.2	81.0	86.0	85.0	85.0	85.0	84.0	84.0	77.0
	Early	128	81.2	80.0	86.0	85.0	85.0	85.0	85.0	84.0	78.0
	Late	129	81.2	82.0	86.0	85.0	85.0	85.0	84.0	83.0	76.0
Sep	Entire	261	78.6	79.0	91.0	84.0	84.0	83.5	82.0	81.0	72.6
	Early	132	80.2	80.0	91.0	84.0	84.0	84.0	83.3	82.0	76.0
	Late	129	76.9	78.0	83.0	84.0	84.0	82.0	80.0	79.0	70.0
Oct	Entire	236	68.5	68.0	78.0	78.0	78.0	78.0	76.0	72.0	62.0
	Early	115	71.5	71.0	78.0	78.0	78.0	78.0	78.0	75.0	65.0
	Late	121	65.7	65.0	73.0	78.0	78.0	72.0	70.4	68.0	61.0
Nov	Entire	260	56.8	56.0	68.0	68.0	68.0	66.0	64.0	60.0	49.0
	Early	128	60.2	60.0	68.0	68.0	68.0	68.0	66.0	62.5	55.0
	Late	132	53.5	53.5	64.0	68.0	68.0	61.0	60.0	55.0	47.0
Dec	Entire	261	45.8	45.0	57.0	57.0	55.0	55.0	53.4	50.0	38.6
	Early	131	48.2	47.0	57.0	57.0	55.0	55.0	55.0	52.8	41.1
	Late	130	43.3	42.5	55.0	57.0	55.0	53.0	51.5	46.0	35.0
				River Mile: 846.0							
Jan	Entire	238	37.6	37.0	51.0	44.0	44.0	43.0	42.0	40.0	33.0
	Early	116	37.9	39.0	51.0	44.0	44.0	44.0	42.9	41.0	32.3
	Late	122	37.2	37.0	45.0	44.0	44.0	43.0	42.0	39.0	33.0
Feb	Entire	225	39.2	39.0	47.0	46.0	45.0	45.0	45.0	43.0	33.0
	Early	118	38.0	38.0	47.0	46.0	45.0	44.6	44.0	40.0	32.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2]Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	107	40.6	42.0	46.0	46.0	45.0	45.0	45.0	44.0	34.0
Mar	Entire	233	45.7	45.0	69.0	54.0	54.0	53.0	52.0	49.0	38.0
	Early	107	43.4	43.0	69.0	54.0	54.0	51.2	50.0	45.0	36.9
	Late	126	47.6	48.0	55.0	54.0	54.0	54.0	53.0	51.0	40.0
Apr	Entire	229	54.5	55.0	67.0	62.0	62.0	61.0	60.0	57.3	47.0
	Early	115	51.7	52.0	59.0	62.0	62.0	56.0	56.0	54.0	46.0
	Late	114	57.3	57.0	67.0	62.0	62.0	62.0	61.0	60.0	51.2
May	Entire	253	64.4	64.0	74.0	73.0	73.0	71.9	70.0	67.0	58.0
	Early	123	62.4	62.0	71.0	73.0	73.0	68.4	67.0	65.0	55.0
	Late	130	66.3	66.0	74.0	73.0	73.0	73.0	71.5	69.0	62.0
Jun	Entire	218	72.0	72.0	83.0	81.0	80.0	79.0	78.0	76.0	65.0
	Early	108	69.3	69.0	81.0	81.0	80.0	77.1	75.7	72.5	65.0
	Late	110	74.6	74.5	83.0	81.0	80.0	80.0	78.5	78.0	70.0
Jul	Entire	252	80.5	80.0	88.0	87.0	86.0	86.0	85.0	82.0	76.0
	Early	124	79.4	79.0	88.0	87.0	86.0	85.0	84.0	81.0	75.0
	Late	128	81.5	81.0	87.0	87.0	86.0	86.0	85.0	83.0	78.9
Aug	Entire	211	82.0	82.0	88.0	87.0	87.0	86.0	84.0	83.0	79.0
	Early	109	82.3	82.0	88.0	87.0	87.0	87.0	86.0	83.3	80.0
	Late	102	81.8	82.0	86.0	87.0	87.0	84.4	84.0	83.0	78.0
Sep	Entire	221	77.1	78.0	84.0	84.0	83.0	82.0	81.0	80.0	69.0
	Early	115	79.9	80.0	84.0	84.0	83.0	83.0	82.0	81.0	76.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Late	106	74.1	74.0	81.0	84.0	83.0	80.0	78.0	77.0	66.8
Oct	Entire	234	66.0	66.0	79.0	76.0	73.0	73.0	72.0	68.0	60.0
	Early	110	68.6	68.0	79.0	76.0	73.0	75.0	73.0	70.0	65.0
	Late	124	63.7	64.0	72.0	76.0	73.0	68.0	67.0	66.0	59.0
Nov	Entire	237	54.9	56.0	79.0	65.0	64.0	64.0	62.0	58.3	44.0
	Early	112	58.4	58.0	69.0	65.0	64.0	64.0	64.0	60.0	53.0
	Late	125	51.8	51.0	79.0	65.0	64.0	59.0	58.0	56.0	43.0
Dec	Entire	242	45.2	44.0	58.0	57.0	56.0	55.0	53.0	48.0	39.0
	Early	126	47.6	46.0	58.0	57.0	56.0	56.0	55.0	53.0	42.0
	Late	116	42.7	42.0	53.0	57.0	56.0	50.0	49.0	44.0	37.0
River Mile: 939.0											
Jan	Entire	270	43.7	44.0	55.0	50.0	49.0	49.0	48.0	46.0	39.0
	Early	132	44.3	45.0	49.0	50.0	49.0	49.0	49.0	46.0	38.0
	Late	138	43.1	42.0	55.0	50.0	49.0	49.0	46.7	45.0	39.0
Feb	Entire	243	44.9	45.0	54.0	53.0	52.0	52.0	50.0	48.0	39.0
	Early	130	43.9	43.5	53.0	53.0	52.0	51.0	50.0	46.0	39.0
	Late	113	46.1	47.0	54.0	53.0	52.0	52.0	51.0	48.0	40.0
Mar	Entire	245	50.6	50.0	61.0	59.0	59.0	57.3	56.0	54.0	44.0
	Early	119	48.6	48.0	56.0	59.0	59.0	56.0	55.0	50.0	44.0
	Late	126	52.5	53.0	61.0	59.0	59.0	59.0	57.0	55.0	46.0
Apr	Entire	235	58.8	59.0	68.0	68.0	68.0	65.0	64.0	62.0	51.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
	Early	111	56.3	57.0	64.0	68.0	68.0	62.0	60.4	59.0	50.0
	Late	124	60.9	62.0	68.0	68.0	68.0	66.6	65.0	63.0	55.0
May	Entire	270	67.3	68.0	79.0	76.0	75.0	75.0	74.0	70.0	60.0
	Early	128	65.2	65.0	75.0	76.0	75.0	74.0	70.0	68.0	60.0
	Late	142	69.2	70.0	79.0	76.0	75.0	75.0	74.0	73.0	63.0
Jun	Entire	264	75.4	75.0	83.0	83.0	83.0	82.0	82.0	79.5	68.0
	Early	132	73.0	73.0	82.0	83.0	83.0	80.0	79.3	75.0	64.0
	Late	132	77.8	78.0	83.0	83.0	83.0	82.9	82.0	81.0	70.0
Jul	Entire	266	82.8	83.0	90.0	88.0	87.0	87.0	87.0	85.0	78.0
	Early	125	82.2	82.0	90.0	88.0	87.0	87.0	86.0	85.0	78.0
	Late	141	83.5	84.0	88.0	88.0	87.0	87.0	87.0	85.0	79.0
Aug	Entire	236	83.6	84.0	89.0	88.0	88.0	88.0	87.0	85.0	80.0
	Early	113	83.8	84.0	89.0	88.0	88.0	87.0	87.0	85.0	80.0
	Late	123	83.5	83.0	88.0	88.0	88.0	88.0	88.0	85.0	80.0
Sep	Entire	245	79.0	80.0	88.0	86.0	86.0	85.3	84.0	82.0	70.0
	Early	122	81.5	82.0	88.0	86.0	86.0	86.0	85.3	84.0	78.0
	Late	123	76.5	77.0	84.0	86.0	86.0	82.0	82.0	79.8	69.7
Oct	Entire	232	67.9	68.0	78.0	76.0	75.0	74.9	73.0	70.0	62.0
	Early	109	70.4	70.0	78.0	76.0	75.0	75.0	75.0	72.0	66.0
	Late	123	65.6	65.0	73.0	76.0	75.0	70.7	69.0	68.0	62.0
Nov	Entire	241	57.9	59.0	68.0	68.0	67.0	67.0	64.0	61.0	50.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence)			95th Percentile	90th Percentile	75th Percentile	5th Percentile
					Single	Twice	Three				
	Early	123	60.9	61.0	68.0	68.0	67.0	67.0	67.0	62.8	55.0
	Late	118	54.8	55.0	63.0	68.0	67.0	61.6	60.0	58.0	50.0
Dec	Entire	244	48.6	49.0	61.0	59.0	57.0	57.0	55.0	51.0	42.0
	Early	117	50.4	50.0	61.0	59.0	57.0	57.0	57.0	52.0	45.0
	Late	127	46.9	46.0	55.0	59.0	57.0	52.0	52.0	49.0	40.0
				River Mile: 963.0							
Jan	Entire	203	42.1	42.0	50.0	50.0	48.0	47.0	46.0	45.0	36.0
	Early	93	43.2	44.0	50.0	50.0	48.0	48.0	47.2	45.0	36.2
	Late	110	41.1	41.5	47.0	50.0	48.0	45.0	45.0	44.0	36.0
Feb	Entire	198	42.5	43.0	49.0	49.0	49.0	48.0	47.0	45.0	35.0
	Early	96	41.4	43.0	47.0	49.0	49.0	47.0	45.0	44.0	31.6
	Late	102	43.5	44.0	49.0	49.0	49.0	49.0	48.0	47.0	35.0
Mar	Entire	188	46.7	47.0	55.0	54.0	54.0	54.0	52.0	49.0	39.0
	Early	83	44.1	44.0	54.0	54.0	54.0	49.0	48.0	47.0	37.0
	Late	105	48.7	49.0	55.0	54.0	54.0	54.0	54.0	51.0	43.3
Apr	Entire	198	56.1	58.0	65.0	65.0	65.0	62.2	60.0	59.0	48.0
	Early	95	53.2	54.0	60.0	65.0	65.0	59.0	59.0	57.0	47.0
	Late	103	58.7	59.0	65.0	65.0	65.0	64.4	61.4	60.0	53.3
May	Entire	235	64.4	64.0	73.0	71.0	71.0	70.0	69.0	67.0	60.0
	Early	113	62.4	62.0	68.0	71.0	71.0	67.0	67.0	64.0	59.0
	Late	122	66.3	66.0	73.0	71.0	71.0	71.0	70.0	68.0	63.0

03/26/2004

[1] Means/medians are means/medians of daily maximum values

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix Table A-3. Monthly and bi-monthly ambient temperature statistics for the Ohio River by RM. Data collected from 1995 to 2003.

Month	Period	Samples	Mean [1]	Median [1]	[2] Maximum (Occurrence) Single	Twice	Three	95th Percentile	90th Percentile	75th Percentile	5th Percentile
Jun	Entire	232	72.4	73.0	82.0	82.0	82.0	79.0	78.0	75.0	66.0
	Early	119	69.9	70.0	78.0	82.0	82.0	76.2	74.0	73.0	65.0
	Late	113	75.0	75.0	82.0	82.0	82.0	82.0	79.0	77.0	70.0
Jul	Entire	239	81.1	81.0	87.0	87.0	87.0	85.0	84.0	83.0	77.0
	Early	119	80.1	80.0	84.0	87.0	87.0	83.0	83.0	83.0	77.0
	Late	120	82.0	82.5	87.0	87.0	87.0	86.0	85.0	83.5	79.0
Aug	Entire	209	82.8	83.0	88.0	87.0	86.0	86.0	86.0	84.0	80.0
	Early	111	82.7	83.0	88.0	87.0	86.0	86.0	85.4	84.0	79.1
	Late	98	82.8	82.0	86.0	87.0	86.0	86.0	86.0	84.0	80.0
Sep	Entire	200	79.1	80.0	87.0	84.0	84.0	84.0	84.0	81.0	72.5
	Early	103	81.2	81.0	87.0	84.0	84.0	84.0	84.0	83.0	77.0
	Late	97	76.9	76.0	82.0	84.0	84.0	81.0	81.0	80.0	71.0
Oct	Entire	203	68.5	69.0	80.0	80.0	80.0	79.0	75.0	72.0	58.0
	Early	94	71.9	71.5	80.0	80.0	80.0	80.0	79.1	75.0	65.2
	Late	109	65.7	66.0	74.0	80.0	80.0	72.0	71.0	69.0	58.0
Nov	Entire	176	56.3	55.0	69.0	69.0	67.0	67.0	64.0	61.5	50.0
	Early	82	59.4	59.0	69.0	69.0	67.0	67.8	67.0	63.0	53.0
	Late	94	53.6	53.0	64.0	69.0	67.0	62.8	62.0	55.0	49.0
Dec	Entire	211	48.2	48.0	65.0	60.0	57.0	56.0	56.0	50.0	42.0
	Early	105	49.2	49.0	60.0	60.0	57.0	57.0	56.0	51.0	39.5
	Late	106	47.2	46.0	65.0	60.0	57.0	56.0	54.0	48.0	42.0

[1] Means/medians are means/medians of daily maximum values

03/26/2004

[2] Maximum values are the Single highest values (Single), or the highest values that occurred at least Twice or Three times during the period of record (1995-2003).

Appendix B-2

Revised Fish Temperature Model Outputs

Upper Ohio River Mainstem
All Possible RAS

Trial 1 – revised Logperch values
Trial 2 – Logperch and Stonecat madtom removed

Appendix Table B1-A. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
01	001	Silver Lamprey	23.7	26.3	28.2	31.5	Ichthyomyzon unicuspis
04	001	Paddlefish	25.4	28.0	29.9	33.2	Polyodon spathula
18	001	Goldeye	22.2	25.7	29.0	32.6	Hiodon alosoides
20	001	Skipjack Herring	27.3	29.6	30.7	34.3	Alosa chrysochloris
47	001	Blue Catfish	30.9	33.0	33.9	37.2	Ictalurus furcatus
50	001	American Eel	20.5	25.8	33.0	36.3	Anguilla rostrata
54	001	Eastern Banded Killifish	27.7	31.2	34.9	38.2	Fundulus diaphanus d.
70	001	Brook Silversides	25.0	28.3	31.7	35.0	Labidesthes sicculus
74	001	White Bass	29.5	31.5	33.3	35.6	Morone chrysops
77	001	White Crappie	28.6	29.9	30.8	32.5	Pomoxis annularis
80	001	Sauger	23.9	26.9	30.3	32.9	Stizostedion canadense
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens
18	002	Mooneye	21.7	25.2	28.5	32.1	Hiodon tergisus
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
54	002	Blackstripe Topminnow	30.2	32.8	34.7	38.0	Fundulus notatus
74	002	Striped Bass	28.5	31.1	31.1	36.3	Morone saxatalis
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
80	002	Walleye	22.8	26.2	30.0	32.9	Stizostedion vitreum
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
37	003	Northern Pike	21.8	25.3	28.9	32.2	Esox lucius
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
80	003	Yellow Perch	22.6	26.0	29.8	32.9	Perca flavescens
10	004	Longnose Gar	32.5	34.3	34.5	37.8	Lepisosteus osseus
37	004	Muskellunge	24.2	27.0	29.2	32.5	Esox masquinongy oh.
40	004	Smallmouth Buffalo	28.5	31.5	34.1	37.4	Ictiobus bubalus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
80	004	Dusky Darter	22.5	26.0	29.6	32.9	Percina sciera sciera
37	005	Muskellunge X N. Pike	24.3	27.1	29.3	32.6	HYBRID
40	005	Quillback Carpsucker	30.0	31.7	34.2	35.2	Carpiodes cyprinus

Appendix Table B1-A. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
43	005	River Chub	25.3	27.2	28.6	30.9	Nocomis micropogon
47	005	Brown Bullhead	28.1	31.0	31.1	35.2	Ameiurus nebulosus
74	005	Str. Bass X Wh. Bass	28.7	31.3	32.4	36.5	HYBRID
77	005	Spotted Bass	30.6	32.4	33.3	36.0	Micropterus punctulatus
40	006	River Carpsucker	29.5	31.4	33.5	35.2	Carpiodes carpio carpio
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
01	007	Amer Brook Lamprey	21.7	24.3	26.2	29.5	Lampetra appendix
40	007	Highfin Carpsucker	30.5	32.7	33.9	37.2	Carpiodes velifer
43	007	Bigeye Chub	26.1	28.0	29.4	31.7	Notropis amblops
47	007	Flathead Catfish	31.1	33.4	34.7	38.0	Pylodictis olivaris
77	007	Warmouth Sunfish	25.1	27.7	28.8	32.9	Lepomis gulosus
47	008	Stonecat Madtom	21.2	23.8	25.7	29.0	Noturus flavus
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
40	010	Golden Redhorse	25.6	28.2	28.5	33.4	Moxostoma erythrurum
77	010	Orangespotted Sunfish	28.7	30.9	31.3	35.4	Lepomis humilis
40	011	Smallmouth Redhorse	25.5	28.1	28.5	33.3	Moxostoma macrolepidotum
43	011	W. Blacknose Dace	25.5	27.5	30.6	31.6	Rhinichthys atratulus
77	011	Longear Sunfish	24.1	28.0	31.8	35.9	Lepomis megalotis
80	011	Logperch	22.0	23.3	27.8	30.3	Percina caprodes
43	012	Longnose Dace	25.8	27.7	30.0	31.4	Rhinichthys cataractae
77	012	Redear Sunfish	21.9	26.1	30.3	34.4	Lepomis microlophus
43	013	Creek Chub	28.1	30.0	31.4	33.7	Semotilus atromaculatus
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	013	Eastern Sand Darter	25.0	27.8	30.8	33.3	Ammocrypta pellucida
80	014	Johnny Darter	22.7	26.3	30.3	33.6	Etheostoma nigrum
40	015	Northern Hog Sucker	27.3	29.2	31.6	33.0	Hypentelium nigricans
80	015	Greenside Darter	22.5	25.7	28.9	32.2	Etheostoma blennioides
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
40	018	Spotted Sucker	24.8	26.9	27.0	31.0	Minytrema melanops
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides

Appendix Table B1-A. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
43	021	Silver Shiner	26.9	29.1	31.1	33.4	Notropis photogenis
43	022	Rosyface Shiner	27.6	29.4	32.0	33.0	Notropis rubellus
80	022	Rainbow Darter	20.1	24.4	29.6	32.9	Etheostoma caeruleum
80	023	Orangethroat Darter	24.6	27.4	29.0	32.9	Etheostoma spectabile
80	024	Fantail Darter	19.7	24.1	30.6	32.8	Etheostoma flabellare
43	025	Striped Shiner	28.0	29.9	31.3	33.6	Luxilus chrysocephalus
43	026	Common Shiner	26.8	28.7	30.1	32.4	Luxilus cornutus
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	030	Bigeye Shiner	27.7	29.5	30.7	33.0	Notropis boops
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	034	Sand Shiner	29.4	31.3	32.7	35.0	Notropis stramineus
43	035	Mimic Shiner	28.4	30.5	32.5	34.6	Notropis volucellus
43	039	Silverjaw Minnow	27.0	29.1	31.1	31.4	Notropis buccatus
43	041	Bullhead Minnow	31.7	33.6	35.0	37.3	Pimephales vigilax
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
43	044	Stoneroller	28.2	30.6	33.0	35.5	Campostoma anomalum
40	100	Robust redhorse	26.3	28.9	30.8	34.1	Moxostoma robustum

Appendix Table B1-B. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	19.70	22.02	24.38	27.40
Growth	23.30	25.70	27.13	29.45
Avoidance (UAT)	25.70	28.61	29.73	31.10
Survival (LT)	27.00	29.51	30.65	31.85
Survival (ST)	29.00	31.51	32.65	33.85

Species Used **N =** 82

Common Name	Common Name	Common Name
Silver Lamprey	Rock Bass	Stonecat Madtom
Paddlefish	Yellow Perch	Green Sunfish
Goldeye	Longnose Gar	Bluegill Sunfish
Skipjack Herring	Muskellunge	Golden Redhorse
Blue Catfish	Smallmouth Buffalo	Orangespotted Sunfish
American Eel	Yellow Bullhead	Smallmouth Redhorse
Eastern Banded Killifish	Smallmouth Bass	W. Blacknose Dace
Brook Silversides	Dusky Darter	Longear Sunfish
White Bass	Muskellunge X N. Pike	Logperch
White Crappie	Quillback Carpsucker	Longnose Dace
Sauger	River Chub	Redear Sunfish
Freshwater Drum	Brown Bullhead	Creek Chub
Mooneye	Str. Bass X Wh. Bass	Pumpkinseed Sunfish
Bigmouth Buffalo	Spotted Bass	Eastern Sand Darter
Channel Catfish	River Carpsucker	Johnny Darter
Blackstripe Topminnow	Black Bullhead	Northern Hog Sucker
Striped Bass	Largemouth Bass	Greenside Darter
Black Crappie	Amer Brook Lamprey	White Sucker
Walleye	Highfin Carpsucker	Spotted Sucker
Gizzard Shad	Bigeye Chub	Emerald Shiner
Northern Pike	Flathead Catfish	
Golden Shiner	Warmouth Sunfish	

Appendix Table B1-B. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Common Name		**Common Name**		
Silver Shiner				
Rosyface Shiner				
Rainbow Darter				
Orangethroat Darter				
Fantail Darter				
Striped Shiner				
Common Shiner				
Spottail Shiner				
Bigeye Shiner				
Spotfin Shiner				
Sand Shiner				
Mimic Shiner				
Silverjaw Minnow				
Bullhead Minnow				
Fathead Minnow				
Bluntnose Minnow				
Stoneroller				
Robust redhorse				

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
19.7	67.5	Fantail Darter [1]			
20.1	68.2	Rainbow Darter [2]			
20.5	68.9	American Eel [3]			
21.2	70.2	Stonecat Madtom [4]			
21.7	71.1	Mooneye [5]			
21.7	71.1	Amer Brook Lamprey [6]			
21.8	71.2	Northern Pike [7]			
21.9	71.4	Redear Sunfish [8]			
22.0	71.6	Logperch [9]			
22.2	72.0	Goldeye [10]			
22.5	72.5	Dusky Darter [11]			
22.5	72.5	Greenside Darter [12]			
22.5	72.5	Emerald Shiner [13]			
22.6	72.7	Yellow Perch [14]			
22.7	72.9	Johnny Darter [15]			
22.8	73.0	Walleye [16]			
23.3	73.9		Logperch [1]		
23.7	74.7	Silver Lamprey [17]			
23.8	74.8		Stonecat Madtom [2]		
23.9	75.0	Sauger [18]			
24.1	75.4	Longear Sunfish [19]			
24.1	75.4		Fantail Darter [3]		
24.2	75.6	Muskellunge [20]			
24.3	75.7	Muskellunge X N. Pike [21]			
24.3	75.7		Amer Brook Lamprey [4]		
24.4	75.9		Rainbow Darter [5]		
24.6	76.3	Orangethroat Darter [22]			
24.8	76.6	Spotted Sucker [23]			
25.0	77.0	Brook Silversides [24]			
25.0	77.0	Eastern Sand Darter [25]			
25.1	77.2	Warmouth Sunfish [26]			
25.2	77.4		Mooneye [6]		

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
25.3	77.5		Northern Pike [7]		
25.3	77.5	River Chub [27]			
25.4	77.7	Paddlefish [28]			
25.5	77.9	Smallmouth Redhorse [29]			
25.5	77.9	W. Blacknose Dace [30]			
25.6	78.1	Golden Redhorse [31]			
25.7	78.3		Goldeye [8]		
25.7	78.3			Stonecat Madtom [1]	
25.7	78.3		Greenside Darter [9]		
25.7	78.3		Emerald Shiner [10]		
25.8	78.4	Longnose Dace [32]			
25.8	78.5		American Eel [11]		
26.0	78.8		Yellow Perch [12]		
26.0	78.8		Dusky Darter [13]		
26.0	78.8	White Sucker [33]			
26.1	79.0	Bigeye Chub [34]			
26.1	79.0		Redear Sunfish [14]		
26.2	79.2		Walleye [15]		
26.2	79.2			Amer Brook Lamprey [2]	
26.3	79.3		Silver Lamprey [16]		
26.3	79.3		Johnny Darter [17]		
26.3	79.3	Robust redhorse [35]			
26.8	80.2	Common Shiner [36]			
26.9	80.4		Sauger [18]		
26.9	80.4		Spotted Sucker [19]		
26.9	80.4	Silver Shiner [37]			
27.0	80.6		Muskellunge [20]		
27.0	80.6			Spotted Sucker [3]	
27.0	80.6	Silverjaw Minnow [38]			
27.1	80.8		Muskellunge X N. Pike [21]		
27.2	81.0		River Chub [22]		
27.3	81.1	Skipjack Herring [39]			

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
27.3	81.1	Northern Hog Sucker [40]			
27.3	81.1	Spottail Shiner [41]			
27.4	81.3		Orangethroat Darter [23]		
27.5	81.5		W. Blacknose Dace [24]		
27.5	81.5	Bluntnose Minnow [42]			
27.6	81.7	Black Crappie [43]			
27.6	81.7	Black Bullhead [44]			
27.6	81.7	Rosyface Shiner [45]			
27.7	81.9	Eastern Banded Killifish [46]			
27.7	81.9		Warmouth Sunfish [25]		
27.7	81.9		Longnose Dace [26]		
27.7	81.9	Bigeye Shiner [47]			
27.7	81.9	Fathead Minnow [48]			
27.8	82.0	Golden Shiner [49]			
27.8	82.0	Green Sunfish [50]			
27.8	82.0			Logperch [4]	
27.8	82.0		Eastern Sand Darter [27]		
27.8	82.0		White Sucker [28]		
28.0	82.4		Paddlefish [29]		
28.0	82.4		Bigeye Chub [30]		
28.0	82.4		Longear Sunfish [31]		
28.0	82.4	Striped Shiner [51]			
28.1	82.6	Rock Bass [52]			
28.1	82.6	Brown Bullhead [53]			
28.1	82.6		Smallmouth Redhorse [32]		
28.1	82.6	Creek Chub [54]			
28.2	82.8			Silver Lamprey [5]	
28.2	82.8		Golden Redhorse [33]		
28.2	82.8	Stoneroller [55]			
28.3	82.9		Brook Silversides [34]		
28.3	82.9	Yellow Bullhead [56]			
28.4	83.1	Pumpkinseed Sunfish [57]			

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
28.4	83.1	Mimic Shiner [58]			
28.5	83.3			Mooneye [6]	
28.5	83.3	Striped Bass [59]			
28.5	83.3	Smallmouth Buffalo [60]			
28.5	83.3			Golden Redhorse [7]	
28.5	83.3			Smallmouth Redhorse [8]	
28.6	83.5	White Crappie [61]			
28.6	83.5			River Chub [9]	
28.7	83.7	Str. Bass X Wh. Bass [62]			
28.7	83.7	Orangespotted Sunfish [63]			
28.7	83.7			White Sucker [10]	
28.7	83.7		Common Shiner [35]		
28.8	83.8			Warmouth Sunfish [11]	
28.9	84.0			Northern Pike [12]	
28.9	84.0			Greenside Darter [13]	
28.9	84.0		Robust redhorse [36]		
29.0	84.2			Goldeye [14]	
29.0	84.2				Stonecat Madtom [1]
29.0	84.2			Orangethroat Darter [15]	
29.1	84.4	Freshwater Drum [64]			
29.1	84.4	Largemouth Bass [65]			
29.1	84.4		Silver Shiner [37]		
29.1	84.4		Silverjaw Minnow [38]		
29.1	84.4		Bluntnose Minnow [39]		
29.2	84.6			Muskellunge [16]	
29.2	84.6		Northern Hog Sucker [40]		
29.3	84.7			Muskellunge X N. Pike [17]	
29.4	84.9			Bigeye Chub [18]	
29.4	84.9		Rosyface Shiner [41]		
29.4	84.9	Sand Shiner [66]			
29.5	85.1	White Bass [67]			
29.5	85.1	River Carpsucker [68]			

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
29.5	85.1				Amer Brook Lamprey [2]
29.5	85.1		Bigeye Shiner [42]		
29.6	85.3		Skipjack Herring [43]		
29.6	85.3			Dusky Darter [19]	
29.6	85.3			Rainbow Darter [20]	
29.7	85.5			Black Crappie [21]	
29.8	85.6			Yellow Perch [22]	
29.8	85.6			Emerald Shiner [23]	
29.8	85.6	Spotfin Shiner [69]			
29.9	85.8			Paddlefish [24]	
29.9	85.8		White Crappie [44]		
29.9	85.8	Bigmouth Buffalo [70]			
29.9	85.8		Golden Shiner [45]		
29.9	85.8		Striped Shiner [46]		
30.0	86.0		Black Crappie [47]		
30.0	86.0			Walleye [25]	
30.0	86.0	Gizzard Shad [71]			
30.0	86.0	Smallmouth Bass [72]			
30.0	86.0	Quillback Carpsucker [73]			
30.0	86.0			Longnose Dace [26]	
30.0	86.0		Creek Chub [48]		
30.0	86.0		Fathead Minnow [49]		
30.1	86.2			Common Shiner [27]	
30.1	86.2		Spottail Shiner [50]		
30.2	86.4	Blackstripe Topminnow [74]			
30.2	86.4		Black Bullhead [51]		
30.3	86.5			Sauger [28]	
30.3	86.5		Green Sunfish [52]		
30.3	86.5				Logperch [3]
30.3	86.5			Redear Sunfish [29]	
30.3	86.5			Johnny Darter [30]	
30.4	86.7		Rock Bass [53]		

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
30.4	86.7	Bluegill Sunfish [75]			
30.5	86.9		Freshwater Drum [54]		
30.5	86.9	Highfin Carpsucker [76]			
30.5	86.9		Pumpkinseed Sunfish [55]		
30.5	86.9			Pumpkinseed Sunfish [31]	
30.5	86.9		Mimic Shiner [56]		
30.6	87.1	Spotted Bass [77]			
30.6	87.1			W. Blacknose Dace [32]	
30.6	87.1			Fantail Darter [33]	
30.6	87.1		Stoneroller [57]		
30.7	87.3			Skipjack Herring [34]	
30.7	87.3			Golden Shiner [35]	
30.7	87.3			Bigeye Shiner [36]	
30.8	87.4			White Crappie [37]	
30.8	87.4			Eastern Sand Darter [38]	
30.8	87.4			Robust redhorse [39]	
30.9	87.6	Blue Catfish [78]			
30.9	87.6				River Chub [4]
30.9	87.6		Largemouth Bass [58]		
30.9	87.6			Green Sunfish [40]	
30.9	87.6		Orangespotted Sunfish [59]		
31.0	87.8		Yellow Bullhead [60]		
31.0	87.8		Brown Bullhead [61]		
31.0	87.8				Spotted Sucker [5]
31.1	88.0	Channel Catfish [79]			
31.1	88.0		Striped Bass [62]		
31.1	88.0			Striped Bass [41]	
31.1	88.0			Brown Bullhead [42]	
31.1	88.0	Flathead Catfish [80]			
31.1	88.0			Silver Shiner [43]	
31.1	88.0			Silverjaw Minnow [44]	
31.2	88.2		Eastern Banded Killifish [63]		

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
31.2	88.2			Freshwater Drum [45]	
31.3	88.3			Yellow Bullhead [46]	
31.3	88.3		Str. Bass X Wh. Bass [64]		
31.3	88.3			Orangespotted Sunfish [47]	
31.3	88.3			Striped Shiner [48]	
31.3	88.3		Sand Shiner [65]		
31.4	88.5		River Carpsucker [66]		
31.4	88.5				Longnose Dace [6]
31.4	88.5			Creek Chub [49]	
31.4	88.5				Silverjaw Minnow [7]
31.4	88.5			Bluntnose Minnow [50]	
31.5	88.7				Silver Lamprey [8]
31.5	88.7		White Bass [67]		
31.5	88.7		Smallmouth Buffalo [68]		
31.5	88.7				White Sucker [9]
31.5	88.7			Fathead Minnow [51]	
31.6	88.9		Smallmouth Bass [69]		
31.6	88.9			Largemouth Bass [52]	
31.6	88.9				W. Blacknose Dace [10]
31.6	88.9			Northern Hog Sucker [53]	
31.7	89.1			Brook Silversides [54]	
31.7	89.1		Quillback Carpsucker [70]		
31.7	89.1				Bigeye Chub [11]
31.7	89.1	Bullhead Minnow [81]			
31.8	89.2			Longear Sunfish [55]	
31.9	89.4		Gizzard Shad [71]		
31.9	89.4		Spotfin Shiner [72]		
32.0	89.6			Smallmouth Bass [56]	
32.0	89.6			Rosyface Shiner [57]	
32.1	89.8				Mooneye [12]
32.1	89.8		Bigmouth Buffalo [73]		
32.1	89.8			Black Bullhead [58]	

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
32.1	89.8				Emerald Shiner [13]
32.2	90.0				Northern Pike [14]
32.2	90.0				Greenside Darter [15]
32.4	90.3			Str. Bass X Wh. Bass [59]	
32.4	90.3		Spotted Bass [74]		
32.4	90.3		Bluegill Sunfish [75]		
32.4	90.3				Common Shiner [16]
32.4	90.3				Bluntnose Minnow [17]
32.5	90.5				White Crappie [18]
32.5	90.5	Longnose Gar [82]			
32.5	90.5				Muskellunge [19]
32.5	90.5			Mimic Shiner [60]	
32.6	90.7				Goldeye [20]
32.6	90.7				Muskellunge X N. Pike [21]
32.7	90.9		Highfin Carpsucker [76]		
32.7	90.9			Sand Shiner [61]	
32.8	91.0		Blackstripe Topminnow [77]		
32.8	91.0				Fantail Darter [22]
32.9	91.2				Sauger [23]
32.9	91.2				Walleye [24]
32.9	91.2				Yellow Perch [25]
32.9	91.2				Dusky Darter [26]
32.9	91.2				Warmouth Sunfish [27]
32.9	91.2				Rainbow Darter [28]
32.9	91.2				Orangethroat Darter [29]
33.0	91.4		Blue Catfish [78]		
33.0	91.4			American Eel [62]	
33.0	91.4			Rock Bass [63]	
33.0	91.4				Northern Hog Sucker [30]
33.0	91.4				Rosyface Shiner [31]
33.0	91.4				Bigeye Shiner [32]
33.0	91.4			Stoneroller [64]	

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
33.2	91.8				Paddlefish [33]
33.3	91.9			White Bass [65]	
33.3	91.9			Bigmouth Buffalo [66]	
33.3	91.9			Spotted Bass [67]	
33.3	91.9				Smallmouth Redhorse [34]
33.3	91.9				Eastern Sand Darter [35]
33.4	92.1				Freshwater Drum [36]
33.4	92.1		Flathead Catfish [79]		
33.4	92.1				Golden Redhorse [37]
33.4	92.1				Silver Shiner [38]
33.5	92.3		Channel Catfish [80]		
33.5	92.3			River Carpsucker [68]	
33.6	92.5				Johnny Darter [39]
33.6	92.5				Striped Shiner [40]
33.6	92.5		Bullhead Minnow [81]		
33.7	92.7				Creek Chub [41]
33.7	92.7			Spotfin Shiner [69]	
33.8	92.8			Bluegill Sunfish [70]	
33.9	93.0			Blue Catfish [71]	
33.9	93.0			Highfin Carpsucker [72]	
34.0	93.2			Gizzard Shad [73]	
34.0	93.2				Golden Shiner [42]
34.1	93.4			Smallmouth Buffalo [74]	
34.1	93.4				Robust redhorse [43]
34.2	93.6			Quillback Carpsucker [75]	
34.3	93.7				Skipjack Herring [44]
34.3	93.7		Longnose Gar [82]		
34.4	93.9				Redear Sunfish [45]
34.5	94.1			Longnose Gar [76]	
34.5	94.1				Largemouth Bass [46]
34.5	94.1			Spottail Shiner [77]	
34.5	94.1				Fathead Minnow [47]

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
34.6	94.3				Pumpkinseed Sunfish [48]
34.6	94.3				Mimic Shiner [49]
34.7	94.5			Blackstripe Topminnow [78]	
34.7	94.5				Black Crappie [50]
34.7	94.5				Smallmouth Bass [51]
34.7	94.5			Flathead Catfish [79]	
34.8	94.6			Channel Catfish [80]	
34.9	94.8			Eastern Banded Killifish [81]	
35.0	95.0				Brook Silversides [52]
35.0	95.0				Rock Bass [53]
35.0	95.0				Sand Shiner [54]
35.0	95.0			Bullhead Minnow [82]	
35.2	95.4				Quillback Carpsucker [55]
35.2	95.4				Brown Bullhead [56]
35.2	95.4				River Carpsucker [57]
35.3	95.5				Green Sunfish [58]
35.4	95.7				Black Bullhead [59]
35.4	95.7				Orangespotted Sunfish [60]
35.5	95.9				Stoneroller [61]
35.6	96.1				White Bass [62]
35.6	96.1				Spottail Shiner [63]
35.8	96.4				Gizzard Shad [64]
35.9	96.6				Longear Sunfish [65]
36.0	96.8				Spotted Bass [66]
36.0	96.8				Spotfin Shiner [67]
36.3	97.3				American Eel [68]
36.3	97.3				Striped Bass [69]
36.4	97.5				Yellow Bullhead [70]
36.4	97.5				Bluegill Sunfish [71]
36.5	97.7				Str. Bass X Wh. Bass [72]
36.6	97.9				Bigmouth Buffalo [73]
37.2	99.0				Blue Catfish [74]

Appendix Table B1-C. Upper Ohio River (all RAS) - revised logperch values

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
37.2	99.0				Highfin Carpsucker [75]
37.3	99.1				Bullhead Minnow [76]
37.4	99.3				Smallmouth Buffalo [77]
37.8	100.0				Longnose Gar [78]
38.0	100.4				Blackstripe Topminnow [79]
38.0	100.4				Flathead Catfish [80]
38.2	100.8				Eastern Banded Killifish [81]
38.3	100.9				Channel Catfish [82]

Appendix Table B2-A. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
01	001	Silver Lamprey	23.7	26.3	28.2	31.5	Ichthyomyzon unicuspis
04	001	Paddlefish	25.4	28.0	29.9	33.2	Polyodon spathula
18	001	Goldeye	22.2	25.7	29.0	32.6	Hiodon alosoides
20	001	Skipjack Herring	27.3	29.6	30.7	34.3	Alosa chrysochloris
47	001	Blue Catfish	30.9	33.0	33.9	37.2	Ictalurus furcatus
50	001	American Eel	20.5	25.8	33.0	36.3	Anguilla rostrata
54	001	Eastern Banded Killifish	27.7	31.2	34.9	38.2	Fundulus diaphanus d.
70	001	Brook Silversides	25.0	28.3	31.7	35.0	Labidesthes sicculus
74	001	White Bass	29.5	31.5	33.3	35.6	Morone chrysops
77	001	White Crappie	28.6	29.9	30.8	32.5	Pomoxis annularis
80	001	Sauger	23.9	26.9	30.3	32.9	Stizostedion canadense
85	001	Freshwater Drum	29.1	30.5	31.2	33.4	Aplodinotus grunniens
18	002	Mooneye	21.7	25.2	28.5	32.1	Hiodon tergisus
40	002	Bigmouth Buffalo	29.9	32.1	33.3	36.6	Ictiobus cyprinellus
47	002	Channel Catfish	31.1	33.5	34.8	38.3	Ictalurus punctatus
54	002	Blackstripe Topminnow	30.2	32.8	34.7	38.0	Fundulus notatus
74	002	Striped Bass	28.5	31.1	31.1	36.3	Morone saxatalis
77	002	Black Crappie	27.6	30.0	29.7	34.7	Pomoxis nigromaculatus
80	002	Walleye	22.8	26.2	30.0	32.9	Stizostedion vitreum
20	003	Gizzard Shad	30.0	31.9	34.0	35.8	Dorosoma cepedianum
37	003	Northern Pike	21.8	25.3	28.9	32.2	Esox lucius
43	003	Golden Shiner	27.8	29.9	30.7	34.0	Notemigonus crysoleucas
77	003	Rock Bass	28.1	30.4	33.0	35.0	Ambloplites rupestris
80	003	Yellow Perch	22.6	26.0	29.8	32.9	Perca flavescens
10	004	Longnose Gar	32.5	34.3	34.5	37.8	Lepisosteus osseus
37	004	Muskellunge	24.2	27.0	29.2	32.5	Esox masquinongy oh.
40	004	Smallmouth Buffalo	28.5	31.5	34.1	37.4	Ictiobus bubalus
47	004	Yellow Bullhead	28.3	31.0	31.3	36.4	Ameiurus natalis
77	004	Smallmouth Bass	30.0	31.6	32.0	34.7	Micropterus dolomieui
80	004	Dusky Darter	22.5	26.0	29.6	32.9	Percina sciera sciera
37	005	Muskellunge X N. Pike	24.3	27.1	29.3	32.6	HYBRID
40	005	Quillback Carpsucker	30.0	31.7	34.2	35.2	Carpiodes cyprinus

Appendix Table B2-A. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
43	005	River Chub	25.3	27.2	28.6	30.9	Nocomis micropogon
47	005	Brown Bullhead	28.1	31.0	31.1	35.2	Ameiurus nebulosus
74	005	Str. Bass X Wh. Bass	28.7	31.3	32.4	36.5	HYBRID
77	005	Spotted Bass	30.6	32.4	33.3	36.0	Micropterus punctulatus
40	006	River Carpsucker	29.5	31.4	33.5	35.2	Carpiodes carpio carpio
47	006	Black Bullhead	27.6	30.2	32.1	35.4	Ameiurus melas
77	006	Largemouth Bass	29.1	30.9	31.6	34.5	Micropterus salmoides
01	007	Amer Brook Lamprey	21.7	24.3	26.2	29.5	Lampetra appendix
40	007	Highfin Carpsucker	30.5	32.7	33.9	37.2	Carpiodes velifer
43	007	Bigeye Chub	26.1	28.0	29.4	31.7	Notropis amblops
47	007	Flathead Catfish	31.1	33.4	34.7	38.0	Pylodictis olivaris
77	007	Warmouth Sunfish	25.1	27.7	28.8	32.9	Lepomis gulosus
77	008	Green Sunfish	27.8	30.3	30.9	35.3	Lepomis cyanellus
77	009	Bluegill Sunfish	30.4	32.4	33.8	36.4	Lepomis macrochirus
40	010	Golden Redhorse	25.6	28.2	28.5	33.4	Moxostoma erythrurum
77	010	Orangespotted Sunfish	28.7	30.9	31.3	35.4	Lepomis humilis
40	011	Smallmouth Redhorse	25.5	28.1	28.5	33.3	Moxostoma macrolepidotum
43	011	W. Blacknose Dace	25.5	27.5	30.6	31.6	Rhinichthys atratulus
77	011	Longear Sunfish	24.1	28.0	31.8	35.9	Lepomis megalotis
43	012	Longnose Dace	25.8	27.7	30.0	31.4	Rhinichthys cataractae
77	012	Redear Sunfish	21.9	26.1	30.3	34.4	Lepomis microlophus
43	013	Creek Chub	28.1	30.0	31.4	33.7	Semotilus atromaculatus
77	013	Pumpkinseed Sunfish	28.4	30.5	30.5	34.6	Lepomis gibbosus
80	013	Eastern Sand Darter	25.0	27.8	30.8	33.3	Ammocrypta pellucida
80	014	Johnny Darter	22.7	26.3	30.3	33.6	Etheostoma nigrum
40	015	Northern Hog Sucker	27.3	29.2	31.6	33.0	Hypentelium nigricans
80	015	Greenside Darter	22.5	25.7	28.9	32.2	Etheostoma blennioides
40	016	White Sucker	26.0	27.8	28.7	31.5	Catostomus commersoni
40	018	Spotted Sucker	24.8	26.9	27.0	31.0	Minytrema melanops
43	020	Emerald Shiner	22.5	25.7	29.8	32.1	Notropis atherinoides
43	021	Silver Shiner	26.9	29.1	31.1	33.4	Notropis photogenis
43	022	Rosyface Shiner	27.6	29.4	32.0	33.0	Notropis rubellus

Appendix Table B2-A. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Selected Species Report

Family Code	Species Code	Common Name	Optimum °C	MWAT Growth °C	Upper Avoidance °C	UILT °C	Latin Name
80	022	Rainbow Darter	20.1	24.4	29.6	32.9	Etheostoma caeruleum
80	023	Orangethroat Darter	24.6	27.4	29.0	32.9	Etheostoma spectabile
80	024	Fantail Darter	19.7	24.1	30.6	32.8	Etheostoma flabellare
43	025	Striped Shiner	28.0	29.9	31.3	33.6	Luxilus chrysocephalus
43	026	Common Shiner	26.8	28.7	30.1	32.4	Luxilus cornutus
43	028	Spottail Shiner	27.3	30.1	34.5	35.6	Notropis hudsonius
43	030	Bigeye Shiner	27.7	29.5	30.7	33.0	Notropis boops
43	032	Spotfin Shiner	29.8	31.9	33.7	36.0	Cyprinella spiloptera
43	034	Sand Shiner	29.4	31.3	32.7	35.0	Notropis stramineus
43	035	Mimic Shiner	28.4	30.5	32.5	34.6	Notropis volucellus
43	039	Silverjaw Minnow	27.0	29.1	31.1	31.4	Notropis buccatus
43	041	Bullhead Minnow	31.7	33.6	35.0	37.3	Pimephales vigilax
43	042	Fathead Minnow	27.7	30.0	31.5	34.5	Pimephales promelas
43	043	Bluntnose Minnow	27.5	29.1	31.4	32.4	Pimephales notatus
43	044	Stoneroller	28.2	30.6	33.0	35.5	Campostoma anomalum
40	100	Robust redhorse	26.3	28.9	30.8	34.1	Moxostoma robustum

Appendix Table B2-B. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Optimum	19.70	22.47	24.75	27.55
Growth	24.10	25.82	27.35	29.55
Avoidance (UAT)	26.20	28.79	29.80	31.10
Survival (LT)	27.50	29.69	30.88	32.05
Survival (ST)	29.50	31.69	32.88	34.05

Species Used **N =** 80

Common Name	Common Name	Common Name
Silver Lamprey	Rock Bass	Green Sunfish
Paddlefish	Yellow Perch	Bluegill Sunfish
Goldeye	Longnose Gar	Golden Redhorse
Skipjack Herring	Muskellunge	Orangespotted Sunfish
Blue Catfish	Smallmouth Buffalo	Smallmouth Redhorse
American Eel	Yellow Bullhead	W. Blacknose Dace
Eastern Banded Killifish	Smallmouth Bass	Longear Sunfish
Brook Silversides	Dusky Darter	Longnose Dace
White Bass	Muskellunge X N. Pike	Redear Sunfish
White Crappie	Quillback Carpsucker	Creek Chub
Sauger	River Chub	Pumpkinseed Sunfish
Freshwater Drum	Brown Bullhead	Eastern Sand Darter
Mooneye	Str. Bass X Wh. Bass	Johnny Darter
Bigmouth Buffalo	Spotted Bass	Northern Hog Sucker
Channel Catfish	River Carpsucker	Greenside Darter
Blackstripe Topminnow	Black Bullhead	White Sucker
Striped Bass	Largemouth Bass	Spotted Sucker
Black Crappie	Amer Brook Lamprey	Emerald Shiner
Walleye	Highfin Carpsucker	Silver Shiner
Gizzard Shad	Bigeye Chub	Rosyface Shiner
Northern Pike	Flathead Catfish	
Golden Shiner	Warmouth Sunfish	

Appendix Table B2-B. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Thermal Thresholds Percentile Report

Category	100%	90%	75%	50%
Common Name		**Common Name**		
Rainbow Darter				
Orangethroat Darter				
Fantail Darter				
Striped Shiner				
Common Shiner				
Spottail Shiner				
Bigeye Shiner				
Spotfin Shiner				
Sand Shiner				
Mimic Shiner				
Silverjaw Minnow				
Bullhead Minnow				
Fathead Minnow				
Bluntnose Minnow				
Stoneroller				
Robust redhorse				

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
19.7	67.5	Fantail Darter [1]			
20.1	68.2	Rainbow Darter [2]			
20.5	68.9	American Eel [3]			
21.7	71.1	Mooneye [4]			
21.7	71.1	Amer Brook Lamprey [5]			
21.8	71.2	Northern Pike [6]			
21.9	71.4	Redear Sunfish [7]			
22.2	72.0	Goldeye [8]			
22.5	72.5	Dusky Darter [9]			
22.5	72.5	Greenside Darter [10]			
22.5	72.5	Emerald Shiner [11]			
22.6	72.7	Yellow Perch [12]			
22.7	72.9	Johnny Darter [13]			
22.8	73.0	Walleye [14]			
23.7	74.7	Silver Lamprey [15]			
23.9	75.0	Sauger [16]			
24.1	75.4	Longear Sunfish [17]			
24.1	75.4		Fantail Darter [1]		
24.2	75.6	Muskellunge [18]			
24.3	75.7	Muskellunge X N. Pike [19]			
24.3	75.7		Amer Brook Lamprey [2]		
24.4	75.9		Rainbow Darter [3]		
24.6	76.3	Orangethroat Darter [20]			
24.8	76.6	Spotted Sucker [21]			
25.0	77.0	Brook Silversides [22]			
25.0	77.0	Eastern Sand Darter [23]			
25.1	77.2	Warmouth Sunfish [24]			
25.2	77.4		Mooneye [4]		
25.3	77.5		Northern Pike [5]		
25.3	77.5	River Chub [25]			
25.4	77.7	Paddlefish [26]			
25.5	77.9	Smallmouth Redhorse [27]			

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
25.5	77.9	W. Blacknose Dace [28]			
25.6	78.1	Golden Redhorse [29]			
25.7	78.3		Goldeye [6]		
25.7	78.3		Greenside Darter [7]		
25.7	78.3		Emerald Shiner [8]		
25.8	78.4	Longnose Dace [30]			
25.8	78.5		American Eel [9]		
26.0	78.8		Yellow Perch [10]		
26.0	78.8		Dusky Darter [11]		
26.0	78.8	White Sucker [31]			
26.1	79.0	Bigeye Chub [32]			
26.1	79.0		Redear Sunfish [12]		
26.2	79.2		Walleye [13]		
26.2	79.2			Amer Brook Lamprey [1]	
26.3	79.3		Silver Lamprey [14]		
26.3	79.3		Johnny Darter [15]		
26.3	79.3	Robust redhorse [33]			
26.8	80.2	Common Shiner [34]			
26.9	80.4		Sauger [16]		
26.9	80.4		Spotted Sucker [17]		
26.9	80.4	Silver Shiner [35]			
27.0	80.6		Muskellunge [18]		
27.0	80.6			Spotted Sucker [2]	
27.0	80.6	Silverjaw Minnow [36]			
27.1	80.8		Muskellunge X N. Pike [19]		
27.2	81.0		River Chub [20]		
27.3	81.1	Skipjack Herring [37]			
27.3	81.1	Northern Hog Sucker [38]			
27.3	81.1	Spottail Shiner [39]			
27.4	81.3		Orangethroat Darter [21]		
27.5	81.5		W. Blacknose Dace [22]		
27.5	81.5	Bluntnose Minnow [40]			

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
27.6	81.7	Black Crappie [41]			
27.6	81.7	Black Bullhead [42]			
27.6	81.7	Rosyface Shiner [43]			
27.7	81.9	Eastern Banded Killifish [44]			
27.7	81.9		Warmouth Sunfish [23]		
27.7	81.9		Longnose Dace [24]		
27.7	81.9	Bigeye Shiner [45]			
27.7	81.9	Fathead Minnow [46]			
27.8	82.0	Golden Shiner [47]			
27.8	82.0	Green Sunfish [48]			
27.8	82.0		Eastern Sand Darter [25]		
27.8	82.0		White Sucker [26]		
28.0	82.4		Paddlefish [27]		
28.0	82.4		Bigeye Chub [28]		
28.0	82.4		Longear Sunfish [29]		
28.0	82.4	Striped Shiner [49]			
28.1	82.6	Rock Bass [50]			
28.1	82.6	Brown Bullhead [51]			
28.1	82.6		Smallmouth Redhorse [30]		
28.1	82.6	Creek Chub [52]			
28.2	82.8			Silver Lamprey [3]	
28.2	82.8		Golden Redhorse [31]		
28.2	82.8	Stoneroller [53]			
28.3	82.9		Brook Silversides [32]		
28.3	82.9	Yellow Bullhead [54]			
28.4	83.1	Pumpkinseed Sunfish [55]			
28.4	83.1	Mimic Shiner [56]			
28.5	83.3			Mooneye [4]	
28.5	83.3	Striped Bass [57]			
28.5	83.3	Smallmouth Buffalo [58]			
28.5	83.3			Golden Redhorse [5]	
28.5	83.3			Smallmouth Redhorse [6]	

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
28.6	83.5	White Crappie [59]			
28.6	83.5			River Chub [7]	
28.7	83.7	Str. Bass X Wh. Bass [60]			
28.7	83.7	Orangespotted Sunfish [61]			
28.7	83.7			White Sucker [8]	
28.7	83.7		Common Shiner [33]		
28.8	83.8			Warmouth Sunfish [9]	
28.9	84.0			Northern Pike [10]	
28.9	84.0			Greenside Darter [11]	
28.9	84.0		Robust redhorse [34]		
29.0	84.2			Goldeye [12]	
29.0	84.2			Orangethroat Darter [13]	
29.1	84.4	Freshwater Drum [62]			
29.1	84.4	Largemouth Bass [63]			
29.1	84.4		Silver Shiner [35]		
29.1	84.4		Silverjaw Minnow [36]		
29.1	84.4		Bluntnose Minnow [37]		
29.2	84.6			Muskellunge [14]	
29.2	84.6		Northern Hog Sucker [38]		
29.3	84.7			Muskellunge X N. Pike [15]	
29.4	84.9			Bigeye Chub [16]	
29.4	84.9		Rosyface Shiner [39]		
29.4	84.9	Sand Shiner [64]			
29.5	85.1	White Bass [65]			
29.5	85.1	River Carpsucker [66]			
29.5	85.1				Amer Brook Lamprey [1]
29.5	85.1		Bigeye Shiner [40]		
29.6	85.3		Skipjack Herring [41]		
29.6	85.3			Dusky Darter [17]	
29.6	85.3			Rainbow Darter [18]	
29.7	85.5			Black Crappie [19]	
29.8	85.6			Yellow Perch [20]	

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
29.8	85.6			Emerald Shiner [21]	
29.8	85.6	Spotfin Shiner [67]			
29.9	85.8			Paddlefish [22]	
29.9	85.8		White Crappie [42]		
29.9	85.8	Bigmouth Buffalo [68]			
29.9	85.8		Golden Shiner [43]		
29.9	85.8		Striped Shiner [44]		
30.0	86.0		Black Crappie [45]		
30.0	86.0			Walleye [23]	
30.0	86.0	Gizzard Shad [69]			
30.0	86.0	Smallmouth Bass [70]			
30.0	86.0	Quillback Carpsucker [71]			
30.0	86.0			Longnose Dace [24]	
30.0	86.0		Creek Chub [46]		
30.0	86.0		Fathead Minnow [47]		
30.1	86.2			Common Shiner [25]	
30.1	86.2		Spottail Shiner [48]		
30.2	86.4	Blackstripe Topminnow [72]			
30.2	86.4		Black Bullhead [49]		
30.3	86.5			Sauger [26]	
30.3	86.5		Green Sunfish [50]		
30.3	86.5			Redear Sunfish [27]	
30.3	86.5			Johnny Darter [28]	
30.4	86.7		Rock Bass [51]		
30.4	86.7	Bluegill Sunfish [73]			
30.5	86.9		Freshwater Drum [52]		
30.5	86.9	Highfin Carpsucker [74]			
30.5	86.9		Pumpkinseed Sunfish [53]		
30.5	86.9			Pumpkinseed Sunfish [29]	
30.5	86.9		Mimic Shiner [54]		
30.6	87.1	Spotted Bass [75]			
30.6	87.1			W. Blacknose Dace [30]	

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
30.6	87.1			Fantail Darter [31]	
30.6	87.1		Stoneroller [55]		
30.7	87.3			Skipjack Herring [32]	
30.7	87.3			Golden Shiner [33]	
30.7	87.3			Bigeye Shiner [34]	
30.8	87.4			White Crappie [35]	
30.8	87.4			Eastern Sand Darter [36]	
30.8	87.4			Robust redhorse [37]	
30.9	87.6	Blue Catfish [76]			
30.9	87.6				River Chub [2]
30.9	87.6		Largemouth Bass [56]		
30.9	87.6			Green Sunfish [38]	
30.9	87.6		Orangespotted Sunfish [57]		
31.0	87.8		Yellow Bullhead [58]		
31.0	87.8		Brown Bullhead [59]		
31.0	87.8				Spotted Sucker [3]
31.1	88.0	Channel Catfish [77]			
31.1	88.0		Striped Bass [60]		
31.1	88.0			Striped Bass [39]	
31.1	88.0			Brown Bullhead [40]	
31.1	88.0	Flathead Catfish [78]			
31.1	88.0			Silver Shiner [41]	
31.1	88.0			Silverjaw Minnow [42]	
31.2	88.2		Eastern Banded Killifish [61]		
31.2	88.2			Freshwater Drum [43]	
31.3	88.3			Yellow Bullhead [44]	
31.3	88.3		Str. Bass X Wh. Bass [62]		
31.3	88.3			Orangespotted Sunfish [45]	
31.3	88.3			Striped Shiner [46]	
31.3	88.3		Sand Shiner [63]		
31.4	88.5		River Carpsucker [64]		
31.4	88.5				Longnose Dace [4]

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
31.4	88.5			Creek Chub [47]	
31.4	88.5				Silverjaw Minnow [5]
31.4	88.5			Bluntnose Minnow [48]	
31.5	88.7				Silver Lamprey [6]
31.5	88.7		White Bass [65]		
31.5	88.7		Smallmouth Buffalo [66]		
31.5	88.7				White Sucker [7]
31.5	88.7			Fathead Minnow [49]	
31.6	88.9		Smallmouth Bass [67]		
31.6	88.9			Largemouth Bass [50]	
31.6	88.9				W. Blacknose Dace [8]
31.6	88.9			Northern Hog Sucker [51]	
31.7	89.1			Brook Silversides [52]	
31.7	89.1		Quillback Carpsucker [68]		
31.7	89.1				Bigeye Chub [9]
31.7	89.1	Bullhead Minnow [79]			
31.8	89.2			Longear Sunfish [53]	
31.9	89.4		Gizzard Shad [69]		
31.9	89.4		Spotfin Shiner [70]		
32.0	89.6			Smallmouth Bass [54]	
32.0	89.6			Rosyface Shiner [55]	
32.1	89.8				Mooneye [10]
32.1	89.8		Bigmouth Buffalo [71]		
32.1	89.8			Black Bullhead [56]	
32.1	89.8				Emerald Shiner [11]
32.2	90.0				Northern Pike [12]
32.2	90.0				Greenside Darter [13]
32.4	90.3			Str. Bass X Wh. Bass [57]	
32.4	90.3		Spotted Bass [72]		
32.4	90.3		Bluegill Sunfish [73]		
32.4	90.3				Common Shiner [14]
32.4	90.3				Bluntnose Minnow [15]

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
32.5	90.5				White Crappie [16]
32.5	90.5	Longnose Gar [80]			
32.5	90.5				Muskellunge [17]
32.5	90.5			Mimic Shiner [58]	
32.6	90.7				Goldeye [18]
32.6	90.7				Muskellunge X N. Pike [19]
32.7	90.9		Highfin Carpsucker [74]		
32.7	90.9			Sand Shiner [59]	
32.8	91.0		Blackstripe Topminnow [75]		
32.8	91.0				Fantail Darter [20]
32.9	91.2				Sauger [21]
32.9	91.2				Walleye [22]
32.9	91.2				Yellow Perch [23]
32.9	91.2				Dusky Darter [24]
32.9	91.2				Warmouth Sunfish [25]
32.9	91.2				Rainbow Darter [26]
32.9	91.2				Orangethroat Darter [27]
33.0	91.4		Blue Catfish [76]		
33.0	91.4			American Eel [60]	
33.0	91.4			Rock Bass [61]	
33.0	91.4				Northern Hog Sucker [28]
33.0	91.4				Rosyface Shiner [29]
33.0	91.4				Bigeye Shiner [30]
33.0	91.4			Stoneroller [62]	
33.2	91.8				Paddlefish [31]
33.3	91.9			White Bass [63]	
33.3	91.9			Bigmouth Buffalo [64]	
33.3	91.9			Spotted Bass [65]	
33.3	91.9				Smallmouth Redhorse [32]
33.3	91.9				Eastern Sand Darter [33]
33.4	92.1				Freshwater Drum [34]
33.4	92.1		Flathead Catfish [77]		

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
33.4	92.1				Golden Redhorse [35]
33.4	92.1				Silver Shiner [36]
33.5	92.3		Channel Catfish [78]		
33.5	92.3			River Carpsucker [66]	
33.6	92.5				Johnny Darter [37]
33.6	92.5				Striped Shiner [38]
33.6	92.5		Bullhead Minnow [79]		
33.7	92.7				Creek Chub [39]
33.7	92.7			Spotfin Shiner [67]	
33.8	92.8			Bluegill Sunfish [68]	
33.9	93.0			Blue Catfish [69]	
33.9	93.0			Highfin Carpsucker [70]	
34.0	93.2			Gizzard Shad [71]	
34.0	93.2				Golden Shiner [40]
34.1	93.4			Smallmouth Buffalo [72]	
34.1	93.4				Robust redhorse [41]
34.2	93.6			Quillback Carpsucker [73]	
34.3	93.7				Skipjack Herring [42]
34.3	93.7		Longnose Gar [80]		
34.4	93.9				Redear Sunfish [43]
34.5	94.1			Longnose Gar [74]	
34.5	94.1				Largemouth Bass [44]
34.5	94.1			Spottail Shiner [75]	
34.5	94.1				Fathead Minnow [45]
34.6	94.3				Pumpkinseed Sunfish [46]
34.6	94.3				Mimic Shiner [47]
34.7	94.5			Blackstripe Topminnow [76]	
34.7	94.5				Black Crappie [48]
34.7	94.5				Smallmouth Bass [49]
34.7	94.5			Flathead Catfish [77]	
34.8	94.6			Channel Catfish [78]	
34.9	94.8			Eastern Banded Killifish [79]	

Appendix Table B2-C. Upper Ohio River (all RAS) - logperch and stonecat madtom removed.

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	°F	Optimum Exceeded	Growth Exceeded	UAT Exceeded	ULIT Exceeded
35.0	95.0				Brook Silversides [50]
35.0	95.0				Rock Bass [51]
35.0	95.0				Sand Shiner [52]
35.0	95.0			Bullhead Minnow [80]	
35.2	95.4				Quillback Carpsucker [53]
35.2	95.4				Brown Bullhead [54]
35.2	95.4				River Carpsucker [55]
35.3	95.5				Green Sunfish [56]
35.4	95.7				Black Bullhead [57]
35.4	95.7				Orangespotted Sunfish [58]
35.5	95.9				Stoneroller [59]
35.6	96.1				White Bass [60]
35.6	96.1				Spottail Shiner [61]
35.8	96.4				Gizzard Shad [62]
35.9	96.6				Longear Sunfish [63]
36.0	96.8				Spotted Bass [64]
36.0	96.8				Spotfin Shiner [65]
36.3	97.3				American Eel [66]
36.3	97.3				Striped Bass [67]
36.4	97.5				Yellow Bullhead [68]
36.4	97.5				Bluegill Sunfish [69]
36.5	97.7				Str. Bass X Wh. Bass [70]
36.6	97.9				Bigmouth Buffalo [71]
37.2	99.0				Blue Catfish [72]
37.2	99.0				Highfin Carpsucker [73]
37.3	99.1				Bullhead Minnow [74]
37.4	99.3				Smallmouth Buffalo [75]
37.8	100.0				Longnose Gar [76]
38.0	100.4				Blackstripe Topminnow [77]
38.0	100.4				Flathead Catfish [78]
38.2	100.8				Eastern Banded Killifish [79]
38.3	100.9				Channel Catfish [80]

Appendix C

New Fish Temperature Model Program: Read Me File for Operation

Appendix Table Z.1

Database of temperature endpoints and thermal effect for 125 freshwater fish species, 2 subspecies, 5 hybrids, and
28 macroinvertebrate taxa

Instructions for Operation of the Fish Temperature Modeling Program

1. Open the Master File (named "MasterFile.xls") in Excel. A security warning dialog box will appear if your security level is set to high or medium. Click the "Always trust macros from this source" box which will add MBI to your list of trusted sources. The macro has been digitally signed.

2. Please use the "File" menu at the top of the screen and the "Save As" menu option to save the Master File under a work file name that you choose. Under no circumstances should you employ the Master File in any of your trials–always use a copy. By using "Save As", you are replacing the Master File as the active workbook file.

3. Make any changes to the temperature values on your work file. Only make changes on the "MasterFile" worksheet. Do not make changes or alter in any way the data or formatting on the "Selected Taxa" worksheet.

4. If you have made changes to species with no temperature values (i.e., all numbers for that species were originally zero), then place your cursor in the blank gray cell in the upper left-hand corner of the spreadsheet to the left of the "A" column and above the "1" row. At the top of the screen, choose the "Data" menu and the "Sort" menu option. When the Sort box comes up, sort by Column "E" in the uppermost selection window, and select the "Descending" option. Make sure that the "My list has header row" button is selected. Then press "OK".

5. Place a lower case "x" in Column A (labeled "SEL") opposite each fish species you wish to include in a given analysis (see Figure 1).

Figure 1. Selection of fish ("x") from the worksheet.

x	40	002	Bigmouth Buffalo	32.0	34.1	35.0	36.3	Ictiobus cyprinellus
	40	003	Black Buffalo	32.0	34.1	35.0	36.3	Ictiobus niger
x	77	002	Black Crappie	28.3	29.9	30.2	31.0	Pomoxis nigromaculatus
x	43	011	Blacknose Dace	23.9	25.8	27.2	27.5	Rhinichthys atratulus
	77	009	Bluegill Sunfish	31.8	33.5	33.6	34.8	Lepomis macrochirus
	43	043	Bluntnose Minnow	28.9	30.4	31.1	31.3	Pimephales notatus
	25	003	Brook Trout	18.0	20.4	23.0	23.3	Salvelinus fontinalis
	47	005	Brown Bullhead	31.1	33.2	36.1	35.5	Ameiurus nebulosus
	25	001	Brown Trout	13.8	17.0	20.0	21.4	Salmo trutta
	43	044	Central Stoneroller	28.6	30.8	33.8	33.2	Campostoma anomalum
x	47	002	Channel Catfish	30.5	32.8	35.0	35.3	Ictalurus punctatus
	25	006	Chinook Salmon	17.3	19.9	24.1	23.0	Oncorhynchus tshawytscha
	25	005	Coho Salmon	16.6	19.4	23.5	23.0	Oncorhynchus kisutch
x	43	001	Common Carp	33.0	35.7	36.0	39.0	Cyprinus carpio
x	43	026	Common Shiner	25.4	27.3	28.7	29.0	Luxilus cornutus
x	43	013	Creek Chub	23.9	26.5	29.4	29.6	Semotilus atromaculatus
	80	004	Dusky Darter	25.0	27.8	30.8	31.3	Percina sciera sciera
	43	020	Emerald Shiner	27.0	29.0	31.1	31.0	Notropis atherinoides
	80	024	Fantail Darter	23.9	26.4	27.2	29.4	Etheostoma flabellare
x	43	042	Fathead Minnow	28.9	30.3	32.0	31.2	Pimephales promelas
	47	007	Flathead Catfish	32.0	33.9	34.5	35.8	Pylodictis olivaris
	85	001	Freshwater Drum	29.0	30.9	31.5	32.8	Aplodinotus grunniens
x	20	003	Gizzard Shad	29.0	31.3	34.0	34.0	Dorosoma cepedianum
x	40	010	Golden Redhorse	26.0	27.9	28.5	29.0	Moxostoma erythrurum
	43	003	Golden Shiner	27.2	29.6	33.5	32.5	Notemigonus crysoleucas
	18	001	Goldeye	28.0	29.5	29.0	30.6	Hiodon alosoides

6. When your selection process is complete, once again highlight all the worksheet's cells by clicking on the blank gray cell in the upper left-hand corner of the worksheet. Select "Data" and "Sort" again. This time sort on Column A or "SEL", whichever comes up in the uppermost selection window. Make sure that the header row button is on. Then press "OK".

7. Once the data matrix has sorted and all the selected fish are grouped at the top of the worksheet (see Figure 2), place your cursor in cell "B2" and drag it to the right and down until all of the selected data is highlighted (see Figure 3). DO NOT include column A ("SEL").

8. Hold down the "CTRL" key and briefly press the "a" key. Screens will flash before your eyes, followed by a return to the Master File worksheet and your highlighted cells. Your default printer will generate three reports (example included with these instructions).

9. You can rerun the program with a subset of your selected records or a new set. Generating a new selection of species will require some sorting. Please be sure that your first record begins in cell "B2", and that all the selected records are grouped together prior to highlighting them. The "x" in column "A" is not absolutely necessary, but the grouping of selected records is required.

Figure 2. Sorting of selected fish ("x").

x	40	002	Bigmouth Buffalo	32.0	34.1	35.0	36.3	Ictiobus cyprinellus
x	77	002	Black Crappie	28.3	29.9	30.2	31.0	Pomoxis nigromaculatus
x	43	011	Blacknose Dace	23.9	25.8	27.2	27.5	Rhinichthys atratulus
x	47	002	Channel Catfish	30.5	32.8	35.0	35.3	Ictalurus punctatus
x	43	001	Common Carp	33.0	35.7	36.0	39.0	Cyprinus carpio
x	43	026	Common Shiner	25.4	27.3	28.7	29.0	Luxilus cornutus
x	43	013	Creek Chub	23.9	26.5	29.4	29.6	Semotilus atromaculatus
x	43	042	Fathead Minnow	28.9	30.3	32.0	31.2	Pimephales promelas
x	20	003	Gizzard Shad	29.0	31.3	34.0	34.0	Dorosoma cepedianum
x	40	010	Golden Redhorse	26.0	27.9	28.5	29.0	Moxostoma erythrurum
	40	003	Black Buffalo	32.0	34.1	35.0	36.3	Ictiobus niger
	77	009	Bluegill Sunfish	31.8	33.5	33.6	34.8	Lepomis macrochirus
	43	043	Bluntnose Minnow	28.9	30.4	31.1	31.3	Pimephales notatus
	25	003	Brook Trout	18.0	20.4	23.0	23.3	Salvelinus fontinalis
	47	005	Brown Bullhead	31.1	33.2	36.1	35.5	Ameiurus nebulosus
	25	001	Brown Trout	13.8	17.0	20.0	21.4	Salmo trutta
	43	044	Central Stoneroller	28.6	30.8	33.8	33.2	Campostoma anomalum
	25	006	Chinook Salmon	17.3	19.9	24.1	23.0	Oncorhynchus tshawytscha
	25	005	Coho Salmon	16.6	19.4	23.5	23.0	Oncorhynchus kisutch
	80	004	Dusky Darter	25.0	27.8	30.8	31.3	Percina sciera sciera
	43	020	Emerald Shiner	27.0	29.0	31.1	31.0	Notropis atherinoides
	80	024	Fantail Darter	23.9	26.4	27.2	29.4	Etheostoma flabellare
	47	007	Flathead Catfish	32.0	33.9	34.5	35.8	Pylodictis olivaris
	85	001	Freshwater Drum	29.0	30.9	31.5	32.8	Aplodinotus grunniens
	43	003	Golden Shiner	27.2	29.6	33.5	32.5	Notemigonus crysoleucas

Figure 3. Highlight selected fish beginning in cell B2.

x	40	002	Bigmouth Buffalo	32.0	34.1	35.0	36.3	Ictiobus cyprinellus
x	77	002	Black Crappie	28.3	29.9	30.2	31.0	Pomoxis nigromaculatus
x	43	011	Blacknose Dace	23.9	25.8	27.2	27.5	Rhinichthys atratulus
x	47	002	Channel Catfish	30.5	32.8	35.0	35.3	Ictalurus punctatus
x	43	001	Common Carp	33.0	35.7	36.0	39.0	Cyprinus carpio
x	43	026	Common Shiner	25.4	27.3	28.7	29.0	Luxilus cornutus
x	43	013	Creek Chub	23.9	26.5	29.4	29.6	Semotilus atromaculatus
x	43	042	Fathead Minnow	28.9	30.3	32.0	31.2	Pimephales promelas
x	20	003	Gizzard Shad	29.0	31.3	34.0	34.0	Dorosoma cepedianum
x	40	010	Golden Redhorse	26.0	27.9	28.5	29.0	Moxostoma erythrurum
	40	003	Black Buffalo	32.0	34.1	35.0	36.3	Ictiobus niger
	77	009	Bluegill Sunfish	31.8	33.5	33.6	34.8	Lepomis macrochirus

Appendix Tables

Appendix Table Z.1

Database of temperature endpoints and thermal effect for 125 freshwater fish species, 2 subspecies, 5 hybrids, and 28 macroinvertebrate taxa

Appendix Table Z-1. Key to footnotes: behavioral and physiological temperature endpoints for all life stages of 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.
Lab A-1:	Lethal endpoint derived from slow heating laboratory test; temperature raised <1°C/day.
Lab A-2:	Lethal endpoint derived from constant increase in temperature of >0.5°C/minute.
Lab B:	Physiological optimum determined (growth, gametogenesis, fertilization, 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.
Review:	Based on literature compilation or calculation of various endpoints (e.g., MWAT)

Experimental Endpoints:
a - growth optimum
b - net biomass gain
c - swimming
d - egg viability
e - egg hatching
f - egg fertilization

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

Experimental Endpoints: (continued)

g - egg incubation
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_{max})
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

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

Experimental Endpoints: (continued)
mm - 100% mortality
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 - upper incipient lethal temperature based on slow heating method (<1°C/day); also chronic thermal maximum (Fields et al. 1987)
xx - 7 day upper lethal temperature
yy - escape behavior observed
zz - critical thermal minimum (CTM_{min})
aaa - acclimation temperature exceeded lethal tolerance
bbb – mean weekly average temperature for growth (MWAT; Brungs and Jones 1977)
ccc – short-term exposure limit (Wrenn 1980)
ddd – optimum growth range (Kellog and Gift 1983)

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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
Petromyzondidae	Silver lamprey (*Ichthyomyzon unicuspis*)	W.L. Erie - Ohio	1973-74	Lab A	Ad.					(4.5)31.6[ee]	Reutter and Herdendorf 1976
	Northern brook lamprey (*Ichthyomyzon fossor*)	Big Garlic R. - Mich.	1975	Lab A	larvae (ammocoetes)					(15) 30.5[q]	Potter and Beamish 1975
	American brook lamprey (*Lampetra appendix*)	Big Creek - Ontario	1975	Lab A	larvae (ammocoetes)					(15) 29.5[q]	Potter and Beamish 1975
	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
		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]			Jobling 1981
					Ad.			(10) 14.3[dd]			Talmadge and Coutant 1979
		L. Superior tribs.			Ad. larvae (ammocoetes)			(Su) 6-15[kk] (Sp) 10-26.1[kk] (Su) 15-20[kk]			Moman et al. 1980
					larvae (ammocoetes)		15-20				Farmer et al. 1977
Polyodontidae	Paddlefish (*Polyodon spathula*)	Texas	1990+	Lab A-2	yoy					(21) 33.4[ee] [5 da.] (21) 33.5[ee] [25 da.] (21) 35.2[ee] [80 da.]	Kurten and Hutchinson 1992
Lepisosteidae	Longnose gar (*Lepisosteus osseus*)	L. Monona - Wisc.	1970	Field A	Ad. Ad.			30.2 - 31.8[i,l,m]	32[i,l,m] 32[l,m]		Neill and Magnuson 1974
		Wabash R. - Ind.	1968-73	Field A	Ad.			(Su) 33-35[kk]	34.8[m]		Gammon 1973
		W.L. Erie - Ohio	1973-74	Lab C	yoy (1) Ad. (1)			(Su) 25.3[tt,dd] (Su) 33.1[tt,dd]			Reutter and Herdendorf 1974, 1976

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
		Ohio R. - Ohio, Ky.	1974	Field A	Ad. - juv.	(Su) 30-34[kk] (Fa) 24-28[kk] (Wi) 12-16[kk]					Yoder and Gammon 1976b
	Longnose gar (cont'd)	Ohio R. - Ohio, Ky.	1970-75	Field A	Ad. - juv.	(Su) 31-34[kk]			35[m]		Yoder and Gammon 1976a
		White R. - Indiana	1965-72	Field A	Ad. - juv.				33.9[yy]		Proffitt and Benda 1971
				Lab C			26.4				Scott and Crossman 1973
	Shortnose gar (*Lepisosteus platosomus*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 33-35[kk]	34.8[m]		Gammon 1973
		White R.-Indiana		Field A	Ad.				36.1[yy]		Proffitt and Benda 1971
Amiidae	Bowfin (*Amia calva*)	Western Pennsylvania	1978	Lab D	Ad.			30.5[dd] 31.3[tt,k] 29.6[tt,l]			Reynolds et al. 1978
		W. L. Erie - Ohio	1973-74	Lab A	Ad.					(23.8) 37[ee]	Reutter and Herdendorff 1976
		Pond - Oklahoma	1965	Lab B	Ad.					(24) 35.2[ee]	Horn and Riggs 1973
								30.5[dd]			Houston 1982
Hiodontidae	Mooneye (*Hiodon tergisus*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 27.5-29[kk]	28.5[m]		Gammon 1973
	Goldeye (*Hiodon alosoides*)	Wabash R. - Indiana	1968-73	Filed A	Ad.			(Su) 27-29[kk]	29[m]		Gammon 1973
	American eel (*Anguilla rostrata*)	Connecticut - Connecticut R.		Field A	Ad.			20.5[dd]	33[j]		Marcy 1976
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	Date	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[f],28.3[ee] (18-20)30.3[f],32.7[ee] (24-26)32.1[f],34.4[ee]	
		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]			
					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] Dec (1-4) 19[s]			
		W. L. Erie - Ohio	1973-74	Lab C	Ad.			(Su) 21.3[tt,dd]			Reutter and Herdendorff 1974
		W. L. Erie - Ohio	1973-74	Lab A	Ad.					(18.2) 30.2[ee]	Reutter and Herdendorff 1976
		L. Michigan - Wisconsin	1979	Lab A	yoy					(27) 28.2[t] (30) 31-34[ww]	McCauley and Binkowski 1982
	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 1975
		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[ee]		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
		White R. - Indiana	1965-72	Field A	Ad. - juv.						Proffitt and Benda 1971
	Gizzard shad (cont'd)	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
	Skipjack herring (*Alosa chrysochloris*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 26-28.5[kk]	31.6[m]		Gammon 1973
		Tennessee R. - Alabama	1972-73	Field A	Ad. - juv.				30[co]		Wrenn 1975
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad. - juv.	(Fa) 16-30[kk] (Wi) 10-16[kk]					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad. - juv.	(Su) 25-29[m,kk]			30.5[m]		Yoder and Gammon 1976a
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
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Brook Trout (cont'd)	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

Family	Species	Location	Date	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 Lab E	yoy yoy	17-20[kk] 17-18[kk]		19s,18.4[tt] 18s,18.4[tt]			McCauley and Pond 1971
		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	Date	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
	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[e],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[l]	13.8[l,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	Date	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[cc]	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
		Hatchery -									
	Chinook salmon *(Oncorhynchus tshawytscha)*	Hatchery - Washington	1949, 1950	Lab A	yoy					(5) 21.5[q] (10)24.3[q] (15)25[q] (20)25.1[q] (24)25.1[r],25.5[q],25.1[t]	Brett 1952
		L. Michigan - Wisconsin	1972-73	Field A	Ad.	10.6 - 23.3[l]	17.3[l,tt]				Spigarelli 1975
	Coho salmon *(Oncorhynchus kisutch)*	Hatchery - British Columbia	1949, 1950	Lab A	yoy					(5) 22.9[q] (10) 23.7[q] (15) 24.3[q] (20) 25[q] (23) 25[q],24.9[r],25[t]	Brett 1952
		L. Michigan - Wisconsin	1972-73	Field A	Ad.	12.8 - 22.8[l]	16.6[l,tt]				Spigarelli 1975
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Sp) 11.4[tt,dd]			Reutter and Herdendorff 1974, 1976
		Hatchery - Michigan	198	Lab C	Juv.			(12) 14.3[dd] (18) [illegible][dd]	(12) 21[j] (18) 21[j]	(12) 21[ww]	Cherry et al. 1982
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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Cisco (cont'd)	Pickerel L. - Michigan	1967	Lab A						(2) 19.8[f] (5) 21.8[f] (10) 24.3[f] (20) 26.3[f] (25) 25.8[f] 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[f] (10) 22.7[f] (15) 25.8[f] (20) 26.6[f] (22.5) 26.6[f] 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[ee]	Reutter and Herdendorff 1976
				Lab A-2						(15) 28.5[ee]	Ellis 1984
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Central mudminnow (cont'd)	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
	Grass 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[f] (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[e] 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[f]	Lillelund 1966
		Brahmsee - Germany	1966	Lab B	egg					19.3[f]	Hokanson et al. 1973a
		England	1965	Lab B	egg	6-16[e]	16[e]			18.9[f]	Switt 1965
		Hatchery - Ontario	1963	Lab A	juv.					(25) 32.2[o] (27.5) 32.7[o] (30) 33.2[o]	Scott 1964 (56)
		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
	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Muskellunge X Northern pike	Hatchery - Ontario	1963	Lab A	juv.					(25) 32.5^{e} (27.5) 32.7^{e} (30) 33.2^{e}	Scott 1964
		Hatchery - New York	1975	Lab A	larvae					(20-25) 34^{ee}	Bonin and Spotila 1978
Catostomidae	Smallmouth buffalo (*Ictiobus bubalus*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 31-34^{kk}	34.8^{m}		Gammon 1973
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 22-32^{kk} (Fa) 18-26^{kk} (Wi) 6-14^{kk}					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su) 29-31^{m,kk}			34^{m}		Yoder and Gammon 1976a
		White R. - Indiana	1965-1972	Field A	Ad.				33.6^{yy}		Proffitt and Benda 1971
				Lab A-2	Juv.					(10) 31.3^{ee}	Lutterschmidt and Hutchinson 1997
	Bigmouth buffalo (*Ictiobus cyprinellus*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 31-34^{kk}	34.8^{m}		Gammon 1973
		White R. - Indiana	1965-1972	Field A	Ad.				31.7^{yy}		Proffitt and benda 1971
	River Carpsucker (*Carpiodes carpio*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 31.5-34.5^{kk}	34.8^{m}		Gammon 1973 (9)
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 26-32^{kk} (Fa) 16-22^{kk} (Wi) 12-16^{kk}					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su) 28-31^{m,kk}			33.5^{m}		Yoder and Gammon 1976a
		White R. - Indiana	1965-1972	Field A	Ad.				37.5^{yy}		Proffitt and benda 1971
		Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 35.2^{p}	Cvancara et al. 1977
	Quillback carpsucker (*Carpiodes cyprinus*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 29-31^{kk}	34.3^{m}		Gammon 1973
		W.L. Erie - Ohio	1973-74	Lab C	Ad (1)			(Fa) 22.1^{tt,dd}			Reutter and Herdendorff 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad (1)					(23.3) 37.2^{ee}	Reutter and Herdendorff 1976
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 26-32^{kk} (Wi) 10-16^{kk}					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su) 29-33^{m,kk}			34^{m}		Yoder and Gammon 1976a

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Quillback carpsucker (cont'd)	Indian Cr.- Ohio	199	Lab A-2	Ad.?					(24) 38.8[ee]	Mundahl 1990
	Highfin carpsucker (*Carpiodes velifer*)	White R. - Indiana	1965-1972	Field A	Ad.				33.9[yy]		Proffitt and Benda 1971
	Golden redhorse (*Moxostoma erythrurum*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 26-27.5[kk]	28.5[m]		Gammon 1973
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su)26-27.5[m,kk]			28[m]		Yoder and Gammon 1976a
		Walhonding R. - Ohio	200	Lab A-2	juv.-Ad.					(21.1) 35.4[ee]	Reash et al. 2000
	Smallmouth redhorse (*Moxostoma breviceps*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 26-27.5[kk]	28.5[m]		Gammon 1973
		Walhonding R. - Ohio	200	LabA-1 Lab A-2	Ad. Juv.					(20.6-23.8) 31.5[ww] (20.6-23.8) 34.4[ww] (19.9) 35.1[ee]	Reash et al. 2000
	Robust redhorse (*Moxostoma robustum*)	Oconee R. - Georgia (parent stock)	1993-5	Lab A-2	Juv.					(20) 34.9[ee] (30) 37.2[ee]	Walsh et al. 1998
	White sucker (*Catostomus commersonii*)	L. Amikeus, L. Opeongo - Ontario	1941	Lab A	juv.					(25-26) 31.2[n],29[g]	Brett 1944
		Greenwood L. - Michigan	1968-69	Lab A,B	eggs larvae larvae (newly hatched) larvae (swim-up)	9-17.2[a]	15.2[a] 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[e]					Horak and Tanner 1964
		W.L. Erie - Ohio	1973-74	Lab C	Ad (3)			(Fa) 2.4[tt,dd]			Reutter and Herdendorf 1974

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	White sucker (cont'd)	W.L. Erie - Ohio	1973-74	Lab A	Ad (3)					(19) 31.6[ee]	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	Juv.					(23) 26.6-27.0[t]	Black 1953
				Lab A-2	larval					(23) 37.0[ee]	Tatarko 1966
				Lab A-2	Juv.					(26.3-28) 40.6[ee]	Horoszewicz 1973
				Lab A-2	Ad.					35-36[ee]	Meuwis and Heuts 1957
	Longnose sucker *(Catostomus catostomus)*	British Columbia	1950+	Lab A	Juv.					(11.5) 27[t] (14) 26.5[t]	Black 1953
	Hog sucker *(Hypentelium nigricans)*	New R. - Virginia	1973	Field A	Ad. - juv.	26.7 - 27.2[cc,kk]			31.7[m] 35[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Lab C	Ad.			(20.6) 25.9[tt] (23.9) 26.8[tt] (27.2) 27.7[tt] (30) 28.5[tt] (33.3) 29.4[tt] 27.8[dd]	27[m]		Stauffer et al. 1975
		New R. - Virginia	1973-74	Field A Lab C	Ad. - juv. Ad. - juv.			26.6 - 27.7[cc] 27.9[dd]	27[m] (18) 27 (21) 30 (24) 33 (27) 30 (30) 33		Stauffer et al. 1976

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Hog sucker (cont'd)	New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 12.5-19.8[kk] (15) 15.4-21.2[kk] (18) 18.1-22.8[kk] (21) 20.6-24.6[kk] (24) 23.7-26.8[kk] (27) 24.5-29.2[kk] (30) 26.1-30.2[kk] (33) 27.6-34.8[kk] (36) [aaa]		(12) 15.3[tt] (15) 20.2[tt] (18) 16.9[tt] (21) 23.0[tt] (24) 27.0[tt] (27) 28.7[tt] (30) 29.4[tt] (33) 28.8[tt] (36)[aaa] 29.8[dd]	(12) - (15) - (18) 27[j] (21) 30[j] (24) 33[j] (27) 33[j] (30) 33[j] (33) 34[j] (36)[aaa]	(33) 33[xx]	Cherry et al. 1977
		?	1975+	Lab A-2	Juv.					(15) 30.8[ee]	Kowalski et al. 1978
	Spotted sucker (*Minytrema melanops*)	Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 25-27[kk] (Fa) 16-19[kk]					Yoder and Gammon 1976a
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su) 21-26[kk]			27[m]		Yoder and Gammon 1976b
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(20) >31.0[ee]	Reutter and Herdendorff 1976
Cyprinidae	Grass carp (*Ctenopharyngodon idella*)	Hatchery - Arkansas	198	Lab A-2 Lab C	Juv.			(23) 25.3[tt]		(23) 39.3[ee]	Bettoli et al. 1985
	Bighead carp (*Hypophthalmichthys nobilis*)	Hatchery - Arkansas	198	Lab A-2 Lab C	Juv.			(23) 25.4[tt]		(23) 38.8[ee]	Bettoli et al. 1985
	Grass X Bighead Carp	Hatchery - Arkansas	198	Lab A-2 Lab C	Juv.			(23) 28.2[tt]		(23) 40.3[ee]	Bettoli et al. 1985

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	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[l,k,m] 29.3 - 31.8[i,l,m]	32.6[l,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[f] 35.5 - 37[f]	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[e] (15) 25[e] (20) 27[e] (25) 31[e] (30) 31[e] (35) 32[e] 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]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23.3) 39[ee]	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[e]			Reynolds and Casterlin 1977
		White R. - Indiana	1965-72	Field A	Ad.				36.1[yy]		Proffitt and Benda 1971
	Goldfish (*Carrasius auratus*)	Commercial supplier - Ontario	1942	Lab A	juv.					(1-2) 28[m,o] (10) 31[m,o] (17) 34[m,o] (24) 36.5[m,o] (32) 39.5[m,o] (36.5) 41[m,o],41[t]	Fry et al. 1942
		pet store - Ontario	1968-69	Lab C	juv.	(15) 25-29 (20) 28-32		(15) 27-29[kk] (20) 29-31[kk]			Roy and Johansen 1970

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Goldfish (cont'd)	Commercial supplier - Ontario	1946				(5) 18[c] (15) 23[c] (25) 28[c] (35) 38[c] 28[c]				Fry and Hart 1948
		Hatchery - British Columbia	1955	Lab A	yoy					(20) 36.5[f] (20) 36.1[f]	Hoar 1956
		Hatchery - Pennsylvania	1977	Lab D	juv.	26 - 30[kk]		27.7[dd,tt]			Reynolds et al. 1978
		W.L. Erie - Ohio	1973-74	Lab C	Ad (1)			(Su) 27[tt,dd] (Fa) 24[tt,dd] (Wi) 24.2[tt,dd] (Sp) 25.3[tt,dd]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23.9) 35[ee]	Reutter and Herdendorf 1976
		Commercial supplier - Ontario	1950+	Lab A-2	Juv.					(5) 29.0[t] (10) 30.8[t] (15) 32.8[t] (20) 34.8[t] (25) 36.6[t] (30) 38.6[t]	Brett 1956
		Commercial supplier - Ontario	1940+	Lab A-2	Juv.					(5) 29.9[t] (10) 31.5[t] (15) 33.0[t] (20) 35.0[t] (25) 37.5[t] (30) 39.0[t] (35) 41.0[t] (40) 41.0[t]	Brett 1944
				Lab A-2	Juv.					(25) 36.6[ee]	Hart 1947
	Carp X Goldfish	W.L. Erie - Ohio	1973-74	Lab A	Ad.					(9.3) 25.3[ee] (14.4) 30.5[ee]	Reutter and Herdendorf 1976
	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Golden shiner (cont'd)	New Jersey	1972	Lab A	juv.					(22) 39.5-40[ee]	Alpugh 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]			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
	Bigeye chub *(Hybopsis amblops)*			Lab A-2						(10) 31.7[ee]	Lutterschmidt and Hutchinson 1997
	Sand shiner *(Notropis stramineus)*	Arkansas/Oklahoma streams	198	Lab A Lab C	Ad.			18.9		(15) 36.1[ee]	Matthews 1981
			1975+	Lab A-2	Ad.					(Dec.) 32.3[ee] (Jan.) 32.3[ee] (March) 31.9[ee]	Kowalski et al. 1976
				Lab A-2						(15) 32.3-33.0[ee]	Kowalski et al. 1978
		Missouri streams	1990+	Lab A-2	Ad.					(26) 37.0[ee]	Smale and Rabeni 1995

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	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
		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) 15-16[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]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab C	Ad.			(Wi) 8.3[tt,dd]		(7.8) 28.6[ee]	Reutter and Herdendorf 1976
		Toronto, Ontario Put-in-Bay - Ohio	1947 1946	Lab A Lab A	Ad Ad.					(25-Wi)32.1[o],30.7[q] (25-Su)30.7[o]	Hart 1952
		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/Oklahom a 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
	Bigeye shiner *(Notropis boops)*	Arkansas/Oklahom a streams	198	Lab A Lab C	Ad.			18.9[tt], 27.7[tt]		(15) 35[ee]	Matthews 1981
	Common shiner *(Luxilis cornutus)*	L. Opeongo, L. Amikeus-Ontario	1941	Lab A	juv.					(25-26) 32[n],30[ll]	Brett 1944

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Common shiner (cont'd)	Toronto, Ontario	1947	Lab A	Ad.					(5) 26.7[e] (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
	Striped shiner *(Luxilis chrysocephalus)*	Knoxville, Tennessee	1947	Lab A	Ad.					(25) 32.3[o] (30) 33.5[o]	Hart 1952
		Arkansas/Oklahoma streams	198	Lab A Lab C	Ad.			15.3[tt]		(15) 34.5[ee]	Matthews 1981
		Indian Cr.- Ohio	199	Lab A-2	Ad.?					(24) 36.2[ee]	Mundahl 1990
		Dicks Cr.- Ohio	1987-8	Lab A-2	Ad.					(11) 30.8[ee]	Hockett and Mundahl 1989
		Missouri streams	1990+	Lab A-2	Ad.					(26) 36.2[ee]	Smale and Rabeni 1995
	Spotfin shiner *(Cyprinella spiloptera)*	Susquehanna R. - Pennsylvania	1973	Lab B	Juv.		30[c]				Hocutt 1973
		New R. - Virginia	1973	Field A	Ad. - juv.	20 - 27.2[cc,kk]			35[m,yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Lab C	Ad.			(12.2) 21.5[tt] (15) 22.8[tt] (17.8) 24.1[tt] (21.1) 25.7[tt] (24.4) 27.3[tt] (27.2) 28.6[tt] (30) 29.9[tt] (32.8) 31.2[tt] (35.6) 32.5[tt]	35[m]		Stauffer et al. 1975

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Spotfin shiner (cont'd)	New R. - Virginia	1973-74	Lab C	Ad. - juv.			29.8[dd]	(12) 24 (15) 24 (21) 27 (24) 30 (27) 33 (30) 36 (33) 36		Stauffer et al. 1976
		Conowingo Pond - Pennsylvania	1974	Lab C	Ad.			(26.7) 30[a]	(25.5) 32.2		Robbins and Mathur 1974
		White R. - Indiana	1965-72	Field A	Ad.				31.1[yy]		
		Dicks Cr.- Ohio	1987-8	Lab A-2	Ad.					(11) 31.8[ee]	Hockett and Mundahl 1989
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 19.3-24.4[kk] (15) 21.0-25.2[kk] (18) 22.7-26.2[kk] (21) 24.3-27.2[kk] (24) 25.7-28.4[kk] (27) 26.9-29.8[kk] (30) 28.0-31.4[kk] (33) 28.9-33.1[kk] (36) 29.8-34.8[tt]		(12) 21.4[tt] (15) 21.8[tt] (18) 24.1[tt] (21) 26.4[tt] (24) 27.3[tt] (27) 30.6[tt] (30) 31.8[tt] (33) 31.0[tt] (36) 29.2[tt] 31.9[dd]	(12) 27[j] (15) 24[j] (18) 27[j] (21) 27[j] (24) 30[j] (27) 33[j] (30) 36[j] (33) 36[j] (36) 38[j]	(36) 36[xx]	Cherry et al. 1977
		New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) 14.7-16.9[kk] (9) 16.6-18.5[kk] (12) 18.6-20.1[kk] (15) 20.4-21.7[kk] (18) 22.2-23.5[kk] (21) 23.9-25.2[kk] (24) 25.6-27.1[kk] (27) 27.2-29.0[kk] (30) 28.7-30.9[kk]		(6) 16.3[tt] (9) 16.0[tt] (12) 20.4[tt] (15) 21.4[tt] (18) 22.4[tt] (21) 24.7[tt] (24) 26.5[tt] (27) 28.2[tt] (30)29.7[tt]	(6) 21[j] (9) 22[j] (12) 25[j] (15) 26[j] (18) 28[j] (21) 29[j] (24) 29[j] (27) 33[j] (30) 35[j]		Cherry et al. 1975
							28.6-29.2				Jobling 1981
	Rosyface shiner (*Notropis rubellus*)	New R. - Virginia	1973	Field A	Ad. - juv.	20 - 27.2[cc,kk]			27.2[m] 35[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A Lab C	Ad. - juv.			28.8 - 30[cc] 28.8[dd]	35[yy] (12) 21 (15) 24 (18) 21 (21) 27 (24) 27 (27) 33		Stauffer et al. 1976

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Rosyface shiner (cont'd)	Arkansas/Oklahoma streams	1981-2	Lab A Lab C	Ad.			21.3[tt]		(15) 34.6[ee]	Matthews 1981
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 18.7-22.2[kk] (15) 20.2-23.0[kk] (18) 21.7-24.0[kk] (21) 23.0-25.0[kk] (24) 24.2-26.2[kk] (27) 25.2-27.5[kk] (30) 26.2-29.0[kk] (33) 27.0-30.5[kk] (36)[aaa]		(12) 20.8[tt] (15) 21.7[tt] (18) 22.2[tt] (21) 22.5[tt] (24) 25.8[tt] (27) 28.1[tt] (30) 28.0[tt] (33) 27.7[tt] (36)[aaa] 28.4[dd]	(12) 21[j] (15) 24[j] (18) 21[j] (21) 27[j] (24) 27[j] (27) 33[j] (30) 33[j] (33) 34[j] (36)[aaa]	(33) 33[xx]	Cherry et al. 1977
		New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) 13.3-16.9[kk] (9) 15.3-18.3[kk] (12) 17.3-19.7[kk] (15) 19.2-21.3[kk] (18) 20.9-22.9[kk] (21) 22.5-24.9[kk] (24) 23.9-26.9[kk] (27) 25.3-28.9[kk] (30)[aaa]		(6) 15.8[tt] (9) 14.8[tt] (12) 19.4[tt] (15) 21.3[tt] (18) 21.7[tt] (21) 22.7[tt] (24) 26.2[tt] (27) 26.8[tt] (30)[aaa]	(6) 21[j] (9) 22[j] (12) 24[j] (15) 25[j] (18) 26[j] (21) 26[j] (24) 28[j] (27) 31[j] (30)[aaa]		Cherry et al. 1975
				Lab A-2						(15) 31.8[ee]	Kowalski et al. 1978
		Missouri streams	1990+	Lab A-2	Ad.					(26) 35.3[ee]	Smale and Rabeni 1995
							25.3-25.7				Jobling 1981
	Silver shiner *(Notropis photogenis)*	New R. - Virginia	1973	Field A	Ad. - juv.	26.7 - 27.2[cc,kk]			27.2[m] 35[w]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A	Ad. - juv.				35[w]		Stauffer et al. 1976
	Scarlet shiner *(Lythrurus ardens)*	New R. - Virginia	1973-74	Field A	Ad. - juv.				32.2[w]		Stauffer et al. 1976
	Redfin shiner *(Lythrurus umbratilis)*	Arkansas/Oklahoma streams	198	Lab A Lab C	Ad.			13.2[tt]		(15) 35.5[ee]	Matthews 1981
		Missouri streams	1990+	Lab A-2	Ad.					(26) 36.2[ee]	Smale and Rabeni 1995
	Red shiner *(Cyprinella lutrensis)*	Denton Co.- Texas	1980+	Lab A-2	Ad.					(22) 36.2[ee]	Takle et al. 1983

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Red shiner (cont'd)	Kansas, Oklahoma, Texas	198	Lab A-2	Ad.					(21) 35.9-36.3[ee]	Matthews 1986
	Mimic shiner *(Notropis volucellus)*	New R. - Virginia	1973-74	Field A	Ad. - juv.				35[yy] 32.5[m]		Stauffer et al. 1976
	Bigmouth shiner *(Notropis dorsalis)*	Missouri streams	1990+	Lab A-2	Ad.					(26) 36.6[ee]	Smale and Rabeni 1995
	Blackchin shiner *(Notropis heterodon)*	Michigan - Pond		Field B	Ad.					38[cc]	Beitz et al. 1974
	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]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A,C	Ad.			(Wi) 9[tt,dd]		(21.7) 32.8[ee]	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
	Telescope shiner *(Notropis telescopus)*	New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 11.5-16.3[kk] (15) 14.4-18.0[kk] (18) 17.0-19.9[kk] (21) 19.3-22.1[kk] (24) 21.2-24.8[kk] (27) 22.8-27.6[kk] (30)[aaa] (33)[aaa] (36)[aaa]		(12) 14.2[tt] (15) 15.4[tt] (18) 17.7[tt] (21) 22.6[tt] (24) 23.2[tt] (27) 24.4[tt] (30)[aaa] (33)[aaa] (36)[aaa] 23.6[dd]	(12) 18[j] (15) 21[j] (18) 24[j] (21) 27[j] (24) 27[j] (27) 29[j] (30)[aaa] (33)[aaa] (36)[aaa]	(27) 30[xx]	Cherry et al. 1977

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluehead chub *(Nocomis leptocephalus)*	New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) - (9) - (12) 13.4-14.1[kk] (15) 15.4-15.9[kk] (18) 17.4-17.8[kk] (21) 19.3-19.8[kk] (24) 21.2-21.8[kk] (27)[aaa] (30)[aaa]		(6) - (9) - (12) 13.7[tt] (15) 15.0[tt] (18) 17.5[tt] (21) 19.6[tt] (24) 21.5[tt] (27)[aaa] (30)[aaa]	(6) - (9) - (12) 16[j] (15) 17[j] (18) 21[j] (21) 22[j] (24) 25[j] (27)[aaa] (30)[aaa]		Cherry et al. 1975
	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
	River chub *(Nocomis micropogon)*		1975+	Lab A-2	Ad.					(15) 30.9[ee]	Kowalski et al. 1978
	Hornyhead chub *(Nocomis bigguttatus)*	Missouri streams	1990+	Lab A-2	Ad.					(26) 35.6[ee]	Smale and Rabeni 1995
	Suckermouth minnow *(Phenacobius mirabilis)*			Lab A-2						(10) 33.4[ee]	Lutterschmidt and Hutchinson 1997

Family	Species	Location	Date	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Fathead minnow (cont'd)	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[ee]	Reutter and Herdendorf 1976
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluntnose minnow (cont'd)	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
	Bullhead minnow *(Pimephales vigilax)*	Denton Cr. - Texas	199	Lab A-2	Ad.					(30) 39.3[ee]	Rutledge and Beitinger 1989
	Silverjaw minnow *(Notropis buccatus)*	White R. - Indiana	1965-72	Field A	Ad.				31.1[w]		Proffit and Benda 1971
		Indian Cr.- Ohio	199	Lab A-2	Ad.?					(24) 37.0[ee]	Mundahl 1990
	Western Blacknose dace *(Rhinichthys obtusus)*	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
		Knoxville, Tennessee	1947	Lab A	Ad.					(25-Su) 31.2[a] (20-Su) 30.2[o],29.3[q] (25-Su) 31.6[o],30.5[q]	
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Western blacknose dace (cont'd)	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
	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
	Redside dace *(Clinostomus elongatus)*	Cattaraugus Co., New York	1995+	Lab A-2	Ad.					(6) 25.5[ee] (12) 27.5[ee] (20) 32.6[ee]	Novinger and Coon 2000
	Southern Redbelly Dace *(Phoxinus erythrogaster)*	L. Coyote Cr.- New Mexico	1981-2	Lab A-2	Ad.					(0) 17.6, 19.7[ee] (1) 18.2[ee] (10) 29.3[ee] (19) 25.4[ee] (21.5) 32.2[ee]	Scott 1987
		Missouri streams	1990+	Lab A-2	Ad.					(26) 35.9[ee]	Smale and Rabeni 1995
	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
	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
	Stoneroller *(Campostoma anomalum)*	New R. - Virginia	1973	Field A	Ad. - juv.	23.3 - 27.2[cc,kk]			27.2[m] 35[w]		Stauffer et al. 1974

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Stoneroller (cont'd)	New R. - Virginia	1973-74	Lab C	Ad.			(11.7) 16.1[aaa] (15) 18.4[aaa] (18.3) 20.8[aaa] (21.7) 23.2[aaa] (23.9) 24.8[aaa] (26.7) 26.7[aaa] (29.4) 28.7[aaa] 36.9[dd]			Stauffer et al. 1975
		New R. - Virginia	1973-74	Field A Lab C				22.7 - 28.3[cc]	34.3[yy] 27[m] (12) 21 (15) 24 (18) 24 (21) 27 (24) 30 (27) 33		Stauffer et al. 1976
		Brier Creek - Oklahoma	198	Lab A Lab C	Ad.			24[tt]		(15) 35.5[ee]	Matthews 1981
		Indian Cr.- Ohio	199	Lab A-2	Ad.?					(24) 37.7[ee]	Mundahl 1990
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) 14.2-18.2[kk] (15) 16.7-19.8[kk] (18) 19.2-21.6[kk] (21) 21.4-23.6[kk] (24) 23.4-25.9[kk] (27) 25.2-28.3[kk] (30) 26.9-30.8[kk] (33)[aaa] (36)[aaa]		(12) 16.5[tt] (15) 17.0[tt] (18) 21.0[tt] (21) 22.4[tt] (24) 25.1[tt] (27) 28.2[tt] (30) 27.4[tt] (33)[aaa] (36)[aaa] 28.8[dd]	(12) 21[j] (15) 24[j] (18) 24[j] (21) 27[j] (24) 30[j] (27) 33[j] (30) 33[j] (33)[aaa] (36)[aaa]	(30) 31[xx]	Cherry et al. 1977
		New R./East R. - Virginia	1973+	Lab C[aa]	yoy	(6) 12.2-16.5[kk] (9) 14.6-18.1[kk] (12) 16.9-19.7[kk] (15) 19.1-21.5[kk] (18) 21.1-23.5[kk] (21) 22.9-25.7[kk] (24) 24.6-28.0[kk] (27) 26.2-30.4[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) 18[j] (9) 19[j] (12) 23[j] (15) 22[j] (18) 25[j] (21) 30[j] (24) 29[j] (27) 33[j] (30)[aaa]		Cherry et al. 1975
		?	?	Lab A-2						(7.5) 28.8[ee] (23) 35.8[ee]	Chagnon and Hlohowskyj 1989
		Missouri streams	1990+	Lab A-2	Ad.					(26) 37.2[ee]	Smale and Rabeni 1995

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Stoneroller (cont'd)			Lab A-2						(10) 31.8[ee]	Lutterschmidt andHutchinson 1997
		New York - Niagra R. tribs.		Lab C	Ad.			(6) 13.4[dd] (9) 15.2[dd] (12) 20.7[dd] (15) 21.7[dd] (18) 22.3[dd] (21) 23.6[dd] (24) 25.3[dd] (27) 28.6[dd]			Spotila et al. 1979
Poecillidae	Mosquitofish *(Gambusia affinis)*	Savannah R. Project - S. Carolina	1976	Lab F,G	Ad.			(6) 24.4[e] (12) 27.9[e] (18) 30.9[e] (24) 32[e] (30) 35.3[e] (36) 33.6[e]	(12) 30 (18) 33 (24) 36 (30) 39 (36) 39	(30) 39[f] (36) 39[f]	Cherry et al. 1976
		Knoxville, Tenn. Weleka, Florida	1947 1945-47	Lab A Lab A	Ad. Ad.					(30) 37.3[o] (15) 35.4[o] (20) 37.3[o] (35) 37.3[o]	Hart1952
		S. Carolina stream	198	Lab C	Juv.			(12) 26.8[dd] (24) [illegible][dd]	(12) 30[j] (24) 36[j]	(12) 38[xx]	Cherry et al. 1982
Fundulidae	Blackstripe topminnow *(Fundulus notatus)*	Denton Cr. - Texas	199	Lab A-2	Ad.					(30) 41.6[ee]	Rutledge and Beitinger 1989
		Missouri streams	1990+	Lab A-2	Ad.					(26) 38.3[ee]	Smale and Rabeni 1995
	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 Harrison, 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
Atherinidae	Brook silversides *(Labidesthes sicculus)*	Missouri streams	1990+	Lab A-2	Ad.					(26) 36.0[ee]	Smale and Rabeni 1995
		Mississippi R.			larvae			22-27[kk]			Holland and Sylvester 1983

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
Percichthyidae	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
		Hatchery - Tennessee	1979	Lab C	Juv.			23.2-26.4[kk]			Coutant et al. 1984
	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
	White bass *(Morone chrysops)*	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 28-29.5[kk]	32[m]		Gammon 1973
		L. Erie - Ohio	1972	Lab C	yoy	(Su) 30-34[s] (Fa) 28-29[s] (Wi) 18-21[s] (Sp) 18-20[s]		(Su) 30.2[m,s] (Fa) 14[m,s] (Wi) 10.5[m,s] (Sp) 15[m,s]	(Su) 34[m] (Fa) 29[m] (Wi) 22[m] (Sp) 22[m]		Reutter and Herdendorf 1974
					Ad.	(Su) 30-32[s] (Fa) 14-25[s] (Wi) 19-25[s] (Sp) 16-21[s]		(Su) 30.2[m,s] (Fa) 25.5[m,s] (Wi) 18[m,s] (Sp) 19.5[m,s]	(Su) 32.5[m] (Fa) 26[m] (Wi) 26[m] (Sp) 24.2[m]		
		Tennessee R. - Alabama	1972-73	Field A	Ad. - juv.				34[yy]		Wrenn 1975
		W. L. Erie - Ohio	1973-74	Lab C	yoy			(Su) 27.8[tt,dd]			Reutter and Herdendorf 1976
		W. L. Erie - Ohio	1973-74	Lab A	Ad.					(21.7) 35.3[ee]	Reutter and Herdendorf 1976
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 26-29[kk] (Fa) 16-28[kk] (Wi) 12-16[kk]					Yoder and Gammon 1976a
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad.	(Su) 26-29[m,kk]			31[m]		Yoder and Gammon 1976b
		Mississippi R. - Minnesota	197	Lab A	larvae					(14) 31.7[q] (18) 30.8[q] (20) 32.0[q] (26) 30.6[q]	McCormick 1978
		Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 35.6[p]	Cvancara et al. 1977
				Field A	Juv.				33.9-34.4[j]		Churchill and Wojtalik 1969.

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Striped Bass X White Bass	Unknown	1990+	Lab A-2	Unknown					(6.5) 28.0[ee] (12.2) 30.5-31.0[ee] (18.0) 30.7-33.4[ee] (23.0) 35.8-36.2[ee] (27.0) 38.1-38.3[ee] (29.2) 39.0-39.1[ee] (31.0) 38.8-39.2[ee] (33.1) 40.3-40.5[ee]	Woiwode and Adelman 1992
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]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(22.7) 38[tt,dd]	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Channel catfish (cont'd)	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
	Blue catfish (*Ictalurus furcatus*)	White R. - Indiana	1965-72	Field A	Ad.				33.9[yy]		Proffitt and Benda 1971
	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
	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Brown bullhead (cont'd)	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[l]				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]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23) 37.8[ee]	Reutter and Herdendorf 1976
		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
	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]			Reutter and Herdendorf 1974
		W.L. Erie -Ohio	1973-74	Lab A	Ad.					(22.2) 36.4[t]	Reutter and Herdendorf 1976

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	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
	Flathead catfish (*Pylodictis olivaris*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 31.5-33.5[cc]	34.3[m]		Gammon 1973
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad.	(Su) 24-36[kk] (Fa) 18-29[kk]					Yoder and Gammon 1976a
		New R. - Virginia	1973	Field A	Ad. - juv.	26.7 - 35[cc,kk]			35[m] 35[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A	Ad. - juv.				35[yy] 35[m]		Stauffer et al. 1976
		White R. - Indiana	1965-72	Field A	Ad.				33.6[yy]		Proffitt and Benda 1971
	Stonecat madtom (*Noturus flavus*)	W.L. Erie -Ohio	1973-74	Lab C	Ad.			(Fa) 25.1[tt,dd] (Wi) 5.5[tt,dd]			Reutter and Herdendorf 1974, 1976
		W.L. Erie -Ohio	1973-74	Lab A	Ad.					(16) 29[ee]	Reutter and Herdendorf 1976
	Tadpole mdatom (*Noturus gyrinus*)	Michigan - Pond		Field B	Ad.					38[cc]	Beltz et al. 1974
Percopsidae	Troutperch (*Percopsis omiscomaycus*)	W.L. Erie -Ohio	1973-74	Lab A	Ad.					(17) 22.9[ee]	Reutter and Herdendorf 1976
	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
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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	White crappie (cont'd)	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]		
		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[ee]	Reutter and Herdendorf 1976
		? - Pennsylvania	1977	Lab D	Ad.			24[a]			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
	Rockbass (*Ambloplites rupestris*)	L. Monona - Wisconsin	1970	Lab D	juv.				29.4m		Neill et al. 1972

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Rockbass (cont'd)	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] (W) 21.6[tt,dd] (Sp) 20.5[tt,dd]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(23.5) 36[ee]	Reutter and Herdendorf 1976
		New R. - Virginia	1973-74	Lab A	Ad. - juv.			30.2[dd]	35yy (18) 27 (21) 27 (24) 30 (27) 33 (30) 33		Stauffer et al. 1976
		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] 29.8[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
	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Largemouth bass (cont'd)	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 yoy	15 - 25[g]	 27[a] 25 - 30[ss]				Coutant 1975a
		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[ee]	Reutter and Herdendorf 1976
		Put-in-Bay - Ohio	1945-47	Lab A	Ad. - juv.					(20) 32.5[o] (25) 34.5[o]	Hart 1952
		Knoxville, Tenn.	1945-47	Lab A	Ad. - juv.					(30) 36.4[o]	
		Welaka, Florida	1945-47	Lab A	Ad. - juv.					(30) 36.4[o] (20) 31.8[o] (25) 32.7[o] (30) 33.7[o]	
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Largemouth bass (cont'd)	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
	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[f] (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
	Florida Largemouth Bass *(Micropterus salmoides floridanus)*	Florida	1976	Lab A, B	gamete embryo fry yoy Juv.		32[b] 35.3[v] 33.6[bbb]			fry (24) 32.8[o] fry (27) 31.9[o] fry (20) 32.0[f] fry (24) 32.7[o] fry (27) 33.6[f] (early emryo) 29.1[o] (late embryo) 30.9[o]	McCormick and Wegner 1981
		L. Dora - Florida	1980-1	Lab A-2	Juv.					(8) 30.4[ee] (16) 34.1[ee] (24) 37.5[ee] (32) 41.8[ee] (32) 39.2[ww]	Fields et al. 1987
	Spotted bass (*Micropterus punctulatus*)	Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 27-28.5[kk]	31.5[m]		Gammon 1973
		Ohio R. - Ohio, Kentucky	1970-74	Field A	Ad.	(Fa) 16-21[kk] (Wi) 6-15[kk]					Yoder and Gammon 1976b

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Spotted bass (cont'd)	New R. - Virginia	1973-74	Lab C	Ad.- juv.			(17.7) 27.6[aaa] (21.1) 28.6[aaa] (23.9) 29.5[aaa] (27.2) 30.5[aaa] (30) 31.4[aaa] (32.8) 32.2[aaa] 30[dd]			Stauffer et al. 1975
		New R. - Virginia	1973-74	Field A Lab C	Ad. - juv. Ad. - juv.			32[dd]	32.2[w] (18) 33 (21) 30 (24) 33 (27) 33 (30) 39 (33) 39		Stauffer et al. 1976
		White R. - Indiana	1965-72	Field A	Ad.						Proffitt and Benda 1971
		New R. - Virginia	1974+	Lab C[bb]	Ad.	(12) - (15) 20.5-24.4[kk] (18) 25.6-28.2[kk] (21) 26.8-28.8[kk] (24) 27.8-29.6[kk] (27) 28.7-30.5[kk] (30) 29.5-31.6[kk] (33) 30.2-32.7[kk] (36) 30.8-33.9[kk]		(12) - (15) 24.8[tt] (18) 26.8[tt] (21) 28.0[tt] (24) 30.6[tt] (27) 29.9[tt] (30) 30.5[tt] (33) 31.5[tt] (36) 31.4[tt] 31.4[dd]	(12) - (15) - (18) 33[j] (21) 30[j] (24) 33[j] (27) 33[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	(6) 14.7-19.4[kk] (9) 17.2-21.2[kk] (12) 19.8-23.1[kk] (15) 22.2-24.9[kk] (18) 24.4-27.0[kk] (21) 26.5-29.3[kk] (24) 28.4-31.7[kk] (27) 30.2-34.2[kk] (30) 31.9-36.8[kk]		(6) 16.9[tt] (9) 17.9[tt] (12) 20.1[tt] (15) 24.8[tt] (18) 26.7[tt] (21) 29.5[tt] (24) 32.2[tt] (27) 31.4[tt] (30) 32.1[tt]	(6) 18[j] (9) 21[j] (12) 25[j] (15) 29[j] (18) 31[j] (21) 32[j] (24) 33[j] (27) 34[j] (30) 34[j]		Cherry et al. 1975
	Smallmouth bass (*Micropterus dolomieui*)	St. Croix R. - Minnesota	1970-71	Lab A,B	juv.	26 - 29[a]	26[a]		29[w]		Horning and Pearson 1973

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Smallmouth bass (cont'd)	L. Erie - Ohio	1971	Lab C	yoy	(Su) 29-31[s] (Fa) 26-30[s] (Wi) 24-28[s] (Sp) 22-28[s]		(Su) 30[m,s] (Fa) 28.8[m,s] (Wi) 25[m,s] (Sp) 24.5[m,s]	(Su) 33[m] (Fa) 31[m] (Wi) 27.8[m] (Sp) 27.5[m]		Barans and Tubb 1973
					Ad.	(Su) 30-31[s] (Fa) 21-27[s] (Wi) 13-26[s] (Sp) 18-26[s]		(Su) 30.8[m,s] (Fa) 25[m,s] (Wi) 25.7[m,s] (Sp) 17.7[m,s]	(Su) 33[m] (Fa) 29[m] (Wi) 27.8[m] (Sp) 25.8[m]		
		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 1975
		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[ee]	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Smallmouth bass (cont'd)	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
		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
	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[f]	Speakman and Krenbel 1972

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluegill (cont'd)	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
		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 1974
		Muddy Run Pond-Pennsylvania	1975	Lab A,C	Ad.			(27.2) 27.2[dd]	(27.2) 35	(27.2) 35.6[p]	Peterson & Saburtsky 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. juv. juv. juv. Ad. Ad. Ad. Ad.			27.1 - 29.1[i,k,m] 28.8 - 31.2[i,l,m] 27.8 - 28.9[i,k,m] 29.6 - 32.7[i,l,m]	29.3[i,k,m] 31.3[i,l,m] 30[k,m] 32.2[l,m] 30.2[i,k,m] 32.8[i,l,m] 30.5[k,m]		Neill and Magnuson 1974
				Lab D	juv. juv.			29.6 - 31.2[l,m] 29.3 - 31.4[k,m]	33[l,m] 32[l,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[ee]	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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluegill (cont'd)	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 Lab C	Ad. - juv. Ad. - juv.				35[yy] (12) 24 (15) 27 (18) 30 (21) 30 (24) 33 (27) 33 (30) 33 (33) 36		Stauffer et al. 1976
		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
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Bluegill (cont'd)	Oklahoma streams	1995+	Lab A-2	Ad./juv.					(10) 32.6[ee] (Su) (10) 30[ee] (Wi)	Schaefer et al. 1999
	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[e]	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
		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
	Pumpkinseed sunfish *(Lepomis gibbosus)*	L. Monona - Wisconsin	1970	Field A	Ad. Ad. Ad. Ad.			27 - 29.1[j,k,m] 28.5 - 32[j,l,m]	30.4[j,k,m] 32.2[j,l,m] 30.5[k,m] 33[l,m]		Neill and Magnuson 1974

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
		L. Amikeus, L. Opeongo,Ontario	1941	Lab A	juv.					(25-26) 34.5[n],33[s]	Brett 1944
		Laboratory - Massachusetts	1976	Lab A	juv.					32 - 39[ee]	Power and Todd 1976
	Pumpkinseed sunfish (cont'd)	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[ee]	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
	Longear sunfish *(Lepomis megalotis)*	White R. - Arkansas	1964	Lab A	yoy - juv.					(25)35.5[n],35.5[o,m],35.4[q,m],35.4[r,m] (30)36.6[n],36.5[o,m],36.5[q,m],36.5[r,m] (35)38.2[n],37.8[o,m],37.5[q,m],37.2[r,m]	Neill et al. 1966
		Lake Texoma - Oklahoma	1971	Lab C	y.			(16) 20.1[tt] (21) 23.2[tt] (26) 24.1[tt]			Hill et al. 1975
		White R. - Indiana	1965-72	Field A	Ad.				37.8[yy]		Proffitt and Benda 1971
		Brier Cr. - Oklahoma	198	Lab A Lab C	Ad.			20.8[tt]		(15) 36.5[ee]	Matthews 1981
		Texas, Oklahoma, Mississippi	200	Lab A-2	Ad.?					(10) 34.7-34.9[ee] (20) 36.6-37.2[ee] (30) 40.0[ee]	Dent and Lutterschmidt 2003
		Oklahoma streams	1995+	Lab A-2	Ad./juv.					(10) 31.6[ee] (Su) (10) 29.8[ee] (Wi)	Schaefer et al. 1999
		Missouri streams		Lab A-2						(26) 37.8[ee]	Smale and Rabeni 1995
				Lab A-2						(10) 34.1[ee]	Lutterschmidt and Hutchison 1997
	Redear sunfish *(Lepomis microlophus)*	Lake Texoma - Oklahoma	1971	Lab C	y.			(16) 22.5[tt] (21) 23.1[tt] (26) 28.7[tt]			Hill et al. 1975

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(22.7) 37.4**	Reutter and Herdendorf 1976

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Orangespotted sunfish *(Lepomis humilis)*	Lake Texoma - Oklahoma	1971	Lab C	y.			(16) 18.6[tt] (21) 20.8[tt] (26) 21.9[tt]			Hill et al. 1975
		W.L. Erie - Ohio	1973-74	Lab A	Ad.					(5.6) 26[ee]	Reutter and Herdendorf 1976
		Brier Cr. - Oklahoma	198	Lab A Lab C	Ad.			21.0[tt]		(15) 37.2[ee]	Matthews 1981
		Missouri streams		Lab A-2						(26) 36.4[ee]	Smale and Rabeni 1995
	Warmouth *(Lepomis gulosus)*			Lab A-2						(10) 32.9[ee]	Lutterschmidt and Hutchinson 1997
Percidae	Yellow perch *(Perca flavescens)*	Park L. - Minnesota	1973	Lab B	yoy		28[e]			(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 Lab D	juv. juv. juv. juv.			26.7 - 28.3[i,l,m] 23.7 - 24.2[l,m] 21.2 - 23.7[k,m]	28.9[i,l,m] 32.2[l,m] 26.3[l,m] 25[k,m]		Neill and Magnuson 1974
		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[e,ff]				Huh et al. 1976
		Clear L., Ontario	1976	Lab E	larvae			(20) 21.5[e],22.8[tt] (23) 24.5[e],24[tt] (25) 22.5[e],22.6[tt]			Ross et al. 1977

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Yellow perch (cont'd)	W.L. Erie - Ohio	1971	Lab C	yoy Ad.	(Su) 28-29[s] (Fa) 24-31[s] (Wi) 11-15[s] (Sp) 17-25[s] (Su) 23-26[s] (Fa) 13-21[s] (Wi) 12-16[s] (Sp) 10-14[s]		(Su) 29[m,s] (Fa) 25[m,s] (Wi) 13[m,s] (Sp) 24[m,s] (Su) 25[m,s] (Fa) 17[m,s] (Wi) 15[m,s] (Sp) 10[m,s]	(Su) 31[m] (Fa) 30.7[m] (Wi) 20.2[m] (Sp) 27.5[m] (Su) 30[m] (Fa) 29[m] (Wi) 18.5[m] (Sp) 19.8[m]		Barans and Tubb 1973
		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]			Reutter and Herdendorf 1974
		W.L. Erie - Ohio	1973-74	Lab A						(22) 35[ee]	Reutter and Herdendorf 1976
		Toronto, Ontario Put-in-Bay - Ohio	1945-46 1946	Lab A Lab A	Ad. - juv. Ad. - juv.					(25-Wi) 29.7[o] (25-Su) 32.3[o]	Hart 1952
		L. Mendota - Wisconsin	1927	Lab A	juv.					(23) 29.6[zz]	Hathaway 1927
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Walleye *(Sander vitreus)*	L. Cutfoot Sioux L., Upper Red L. - Minnesota	1971, 1972	Lab A Lab B	egg egg larvae		6 - 12[f] 9 - 15[g] 15 - 21[e]				Smith and Koenst 1975; Koenst and Smith 1976
					juv. (small) juv. (large) juv.		25[e] 22[e]			(8) 27[q],26[r] (10.1) 28.6[q],28[r] (12.1) 29[q],28[r] (13.9) 29.5[q],28.6[r] (16) 30.6[q],30[r] (18.2) 30.5[q],30[r] (20.2) 30.5[q],30[r] (22.1) 30.5[q],30[r] (24) 31.5[q],30.8[r] (25.8) 31.6[q],31[r]	
		Canada ?	?	?	juv.		20[e]				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 1975
		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
		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

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Sauger (*Sander canadense*)	L. Winnebago-Wisconsin; Mississippi R. - Minnesota; L. Pepin - Minnesota	1971, 1972, 1973	Lab A Lab B	egg egg larvae juv.		12 - 15[g] 9 - 15[f] 9 - 21[e] 22[e]			(10.1) 26.6[q],26[ll] (12.0) 26.7[q],26[ll] (13.9) 28.4[q],27.8[ll] (16.0) 28.6[q],28[ll] (18.3) 28.7[q],28[ll] (19.9) 29.5[q],29[ll] (22.0) 29.9[q],29[ll] (23.9) 30.4[q],29.8[ll] (25.8) 30.4[q],29.8[ll]	Smith and Koenst 1975; Koenst and Smith 1976
		Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 26 - 28[kk]	28.7[m]		Gammon 1973
		Tennessee R. - Alabama	1972-73	Field A	Ad. - juv.				30[cc]		Wrenn 1975
		Ohio R. - Ohio, Kentucky	1974	Field A	Ad. - juv.	(Fa) 14 - 21[kk] (Wi) 8 - 11[kk]					Yoder and Gammon 1976b
		Ohio R. - Ohio, Kentucky	1970-75	Field A	Ad. - juv.	(Su) 27 - 28[m,kk]			29[m]		Yoder and Gammon 1976a
		White R. - Indiana	1965-72	Field A	Ad.				33.6[yy]		Proffitt and Benda 1971
		Ottawa R. - Canada	1978	Review			24.6[bbb]				Christie 1979
		Tennessee R. - Alabama		Lab C	Ad. Juv.					(cont.) 33.2[j] (cont.) 33.9[j]	Heuer and Wrenn 1981
		Tennessee - reservoir		Field B	Ad.			18.6-19.2[dd]			Dendy 1948
	Orangethroat darter (*Etheostoma spectabile*)	Colorado R. - Texas	1960	Lab B	egg larvae		23[m,f] 23[m]			27[m]	Hubbs 1961
		5 streams-Arkansas-Missouri 4 streams-Texas	1962	Lab B	egg larvae	23 - 28[f] 25 - 27	26m,f 26[m]			29[m]	Hubbs and Armstrong 1962
			1962	Lab B	egg larvae	18 - 26[f] 18 - 24	26[m,f] 22m			28[m]	
		Clear Creek - Arkansas	1965	Lab B			26[a]				West 1966
		Brier Cr. - Oklahoma	198	Lab A Lab C	Ad.					(15) 35.8[ee]	Matthews 1981
		Boone Co., Missouri	200	Lab A-2	Ad.				(16) 29.0[yy]	(16) 31.0[ee]	Strange et al. 2002

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
		4 creeks in Oklahoma	198	Lab A-2	Ad.				(20) 29.0[yy]	(20) 32.28[ee] [low ambient flux] (20) 32.9[ee] [intermediate flux] (20) 34.0[ee] [intermediate flux] (20) 34.3[ee] [high ambient flux]	Feminella and Matthews 1984
	Rainbow darter *(Etheostoma caeruleum)*	Indian Cr.- Ohio	1983-4	Lab C	Ad.	16.0-24.4 (Su) 13.2-23.8 (Fa) 14.5-25.6 (Wi) 17.2-25.7 (Sp)		19.8[tt] (Su) 18.0[tt] (Fa) 19.5[tt] (Wi) 20.4[tt] (Sp)			Hlohowskyi and Wissing 1987
		?	1975+	Lab A-2						(15) 32.1[ee]	Kowalski et al. 1978
		Missouri streams		Lab A-2						(26) 35.6[ee]	Smale and Rabeni 1995
	Dusky darter *(Percina sciera)*	Colorado R. - Texas	1960	Lab B	egg larvae		22[m,f] 23[m]			27[m]	Hubbs 1961
	Eastern Sand Darter *(Ammocrypta pellucida)*	Quebec - Chateauguay R.						25[dd]			Scott and Crossman 1973
	Logperch *(Percina caprodes)*	Colorado R. - Texas	1960	Lab B	egg larvae		22[m,f] 22[m]			26[m]	Hubbs 1961
	Greenside darter *(Etheostoma blennioides)*	New R. - Virginia	1973	Field A	Ad. - juv.	20 - 27.2[cc,kk]			35[m,yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A	Ad. - juv.				35[yy]		Stauffer et al. 1976
		Indian Cr.- Ohio	1983-4	Lab C	Ad.	18.4-25.7 (Su) 18.8-27.6 (Fa) 19.2-26.2 (Wi) 16.9-28.3 (Sp)		21.4[tt] (Su) 21.5[tt] (Fa) 22.8[tt] (Wi) 23.8[tt] (Sp)			Hlohowskyi and Wissing 1987
		?	1975+	Lab A-2	Ad.					(15) 32.2[ee]	Kowalski et al. 1978
	Fantail darter *(Etheostoma flabellare)*	New R. - Virginia	1973	Field A	Ad. - juv.	20 - 23.9[cc,kk]			23.9[m] 30.6[yy]		Stauffer et al. 1974
		New R. - Virginia	1973-74	Field A	Ad. - juv.				23.9[m]		Stauffer et al. 1975
		New R. - Virginia	1973-74	Field A	Ad. - juv.			19.4 - 20[cc]	30.6[yy] 23.9[m]		Stauffer et al. 1976
		Indian Cr.- Ohio	199	Lab A-2	Ad.?					(24) 37.7[ee]	Mundahl 1990
		Harker's Run - Ohio	198	Lab A-2 Lab C	Ad.	16.2-24.5 (Su) 12.2-23.2 (Wi)		20.3[tt (Su)] 19.3[tt] (Wi)		(15) 31.3[ee] (Su) (15) 31.1[ee] (Wi)	Ingersoll and Claussen 1984

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
		Indian Cr.- Ohio	1983-4	Lab C	Ad.	14.5-24.0 (Su) 14.8-27.6 (Fa) 15.0-25.4 (Wi) 13.5-26.3 (Sp)		19.0[tt] (Su) 20.6[tt] (Fa) 20.4[tt] (Wi) 19.8[tt] (Sp)			Hlohowskyi and Wissing. 1987
	Fantail darter (cont'd)	?	1975+	Lab A-2	Ad.					(15) 32.1[ee]	Kowalski et al. 1978
		Missouri streams		Lab A-2						(26) 36.0[ee]	Smale and Rabeni 1995
	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
Sciaenidae	Freshwater drum *(Aplodinotus grunniens)*	L. Monona - Wisconsin	1970	Field A	Ad. Ad. Ad. Ad.			27.3 - 29[i,k,m] 29.4 - 30.2[i,l,m]	29.2[i,k,m] 30[i,l,m] 32.2[k,m] 33.2[l,m]		Neill and Magnuson 1974
		Wabash R. - Indiana	1968-73	Field A	Ad.			(Su) 29-31[kk]	31.4[m]		Gammon 1973
		W.L. Erie - Ohio	1973-74	Lab A,C	yoy Ad.			(Su) 31.3[tt,dd] (Su) 26.5[tt,dd] (Fa) 19.6[tt,dd]		(21.2) 34[ee]	Reutter and Herdendorf 1976
		Ohio R. - Ohio, Kentucky	1970-74	Field A	Ad.	(Fa) 22-30[kk] (Wi) 6-11[kk]					Yoder and Gammon 1976
		Mississippi R. - Minnesota	1973-4	Lab A-2	yoy					(26) 32.8[p]	Cvancara et al. 1977
		Tennessee - Resrvoir	1945+	Field B	Ad.			21.6-22.2[dd]			Dendy 1948
Gasterosteidae	Brook Stickleback *(Culeae inconstans)*	L. Amikeus, L. Opeongo- Ontario	1941	Lab A	Ad.					(25-26) 30.6[n],29[ll]	Brett 1844
	Three-spine Stickleback *(Gasterosteus aculeatus)*									(19) 25.8[t]	Houston 1982

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
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
	Mottled sculpin (cont'd)	?	1975+	Lab A-2	Ad.					(15) 30.9[ee]	Kowalski 1978
	Winter stonefly *(Teniopteryx maura)*	Duluth, MN area streams		Lab A-2	Larvae					(10) 21[q]	Nebeker and Lemke 1968
	Mayfly *(Ephemerella subvaria)*									(10) 21.5[q]	
	Stonefly *(Isogenus frontalis)*									(10) 22.5[q]	
	Winter stonefly *(Allocapnia granulata)*									(10) 23[q]	
	Mayfly *(Stenonema tripunctatum)*									(10) 25.5[q]	
	Caddisfly *(Brachycentrus americanus)*									(10) 29[q]	
	Stonefly *(Pteronarcys dorsata)*									(10) 29.5[q]	
	Stonefly *(Acroneuria lycorius)*									(10) 30[q]	
	Stonefly *(Paragnetina media)*									(10) 30.5[q]	
	True Fly *(Atherix variegata)*									(10) 32[q]	
	Dragonfly *(Boyeria vinosa)*									(10) 32.5[q]	
	Dragonfly *(Ophigomphus rupinsulensis)*									(10) 33[q]	
	Dragonfly *(Neurocordulia alabamensis)*	Steel Cr./Skinface Pond - S. Carolina	1974	Lab A-2						38.2[ee]	Garten and Gentry 1976
	Dragonfly *(Macromia illinoiensis)*									38.8[ee]	
	Dragonfly *(Celithemis sp.)*									40.8[ee]	
	Dragonfly *(Epitheca cynosura)*									41.0[ee]	

Family	Species	Location	Date	Type	Age Class	Observed Range	Physiological Optimum	Behavioral Optimum	Upper Avoidance (UAT)	Upper Lethal	Reference(s)
	Dragonfly *(Ladona deplanata)*									41.3[ee]	
	Dragonfly *(Pachydiplax longipennis)*									41.7, 42.8[ee]	
	Dragonfly *(Libellula auripennis)*									42.4, 43.6[ee]	
	Mayfly *(Ephemerella invaria)*	L. River - Tennessee	1978	Lab A						(10) 22.9[f]	deKozlowski and Bunting 1981
	Caddisfly *(Symphitopsyche morosa)*									(10) 30.4[f]	
	Mayfly *(Stenonema ithaca)*									(10) 31.8[f]	
	Caddisfly *(Brachycentrus lateralis)*									(10) 32.8[f]	
	Dragonfly *(Libellula auripennis)*	Four Mile Cr.- S. Carolina	1974	Lab A-2						(16) 42.8[ee] (24) 43.6[ee] (32) 44.8[ee]	Martin et al. 1976
	Caddisfly *(Hydropysche simulans)*	Brazos R.- Texas	1991	Lab A-2						(12) 34.3[ee] (19) 35.6[ee] (26) 37.5[ee]	Moulton et al. 1993
	Caddisfly *(Chimarra obscura)*									(12) 31.4[ee] (19) 36.5[ee] (26) 38.5[ee]	
	Caddisfly *(Ceratopsyche morosa)*									(19) 34.2[ee]	
	Caddisfly *(Chimarra aterrima)*									(19) 33.6[ee]	

Appendix Table Z.2. Conversion factors (± 1 SE) used to estimate temperature criteria (optimum, upper avoidance, and upper incipient lethal temperatures) in Appendix Table Z.3 (all values in degrees C).

Family	UAT[a] - Optimum	UILT[b] - Optimum	CTM[c] - Optimum	UILT-UAT	CTM-UAT	CTM-UILT
Lepisosteidae	1.5 (± 0.3)	-	-	-	-	-
Hiodontidae, Clupeidae	2.2 (± 0.5)	-	-	3.6 (± 0.1)	-	1.3 (± 0.6)
Coregonidae, Salmonidae, Osmeridae	6.8 (± 1.0)	8.5 (± 1.9)	15.9 (± 0.3)	-	5.8 (± 0.9)	-
Esocidae	-	8.3 (± 0.7)	-	-	-	-
"Deep-bodied" Catostomidae	3.4 (± 0.1)	-	-	-	-	-
"Round-bodied" Catostomidae	2.9 (± 0.6)	-	-	-	-	2.5 (± 0.6)
"Large" Cyprinidae	2.7 (± 0.5)	8.5 (± 1.5)	8.4 (± 0.4)	-	-	-
"Small" Cyprinidae	4.1 (± 0.4)	5.6 (± 0.5)	11.2 (± 0.5)	2.3 (± 0.0)	-	2.5 (± 1.5)
Ictaluridae	3.0 (± 0.8)	-	-	-	-	4.0 (± 0.8)
Percichthyidae, Centrarchidae	2.6 (± 0.2)	7.8 (± 0.6)	8.7 (± 1.1)	4.1 (± 1.2)	4.5 (± 0.7)	-
Percidae	5.8 (± 1.2)	8.3 (± 1.0)	10.3 (± 1.2)	-	1.5 (± 0.2)	-
Average*	3.5 (± 0.5)	7.8 (± 0.6)	10.9 (± 1.4)	3.3 (± 0.5)	3.9 (± 1.3)	2.6 (± 0.5)

a - Upper Avoidance Temperature (UAT)
b - Upper Incipient Lethal Temperature (UILT)
c - Critical Thermal Maximum (CTM)
* - Does not include Amiidae, Scianidae, Cottidae, or Poecillidae

Appendix Table Z-3. Thermal tolerance values selected for use in Fish Temperature Model.

Species	Optimum		MWAT for Growth[a]	UAT[b]		Upper Lethal[c,d]		March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Spawning References
								Spawning Periods and Associated Low and High Temperatures										
Silver lamprey	23.7	X	26.3	28.2	X	31.5												
No. Brook Lamprey	22.7	X	25.3	27.2	X	30.5												
Am. Brook Lamprey	21.7	X	24.3	26.2	X	29.5												
Paddlefish	25.4	X	28.0	29.9	X	33.2												
Longnose Gar	32.5		34.3	34.5		37.8	X				26.4/	30.0/						Carlander 1969; Wojtalik 1971
Shortnose gar	32	X	34.3	35.5		38.8	X											
Bowfin	27.4		30.0	31.9	X	35.2			/16.0	19.0/								Scott and Crossman 1973
Mooneye	21.7		25.2	28.5		32.1	X		/	/	/							
Goldeye	22.2		25.7	29.0		32.6	X											
Alewife	21.7		25.2	30.0		32.1				/23.0	/26.7							Carlander 1969
Gizzard Shad	30		31.9	34.0		35.8				19.5/	/26.7	29.0/						Carlander 1969
Skipjack Herring	27.3		29.6	30.7		34.3	X											
Central mudminnow	25.4	X	28.9	28.9		36												
Grass pickerel	26.6		29.2	30.1		34.3												
Chain pickerel	24		26.8	29.0	X	32.3	X											
Northern Pike	21.8		25.3	28.9	X	32.2		4.4/10.0	11.1/14.0	17.2/20.0								Carlander 1969
Muskellunge	24.2	X	27.0	29.2	X	32.5			12.8/15	17.2/								Carlander 1969
Muskellunge x N. Pike	24.3	X	27.1	29.3	X	32.6												
Smallmouth Buffalo	28.5		31.5	34.1		37.4	X											
Bigmouth Buffalo	29.9	X	32.1	33.3		36.6	X		/15.5	18.3/								Carlander 1969
River Carpsucker	29.5		31.4	33.5		35.2												
Quillback Carpsucker	30		31.7	34.2		35.2												
Highfin Carpsucker	30.5	X	32.7	33.9		37.2	X											
Golden Redhorse	25.6	X	28.2	28.5		33.4												
Smallmouth Redhorse	25.5	X	28.1	28.5		33.3												
River Redhorse									22.2/24.4									Hackney et al. 1969
Greater Redhorse											14.5/17.5	18.0/						Jenkins and Jenkins 1980
Robust Redhorse	26.3	X	28.9	30.8	X	34.1												
Common White Sucker	26		27.8	28.7		31.5		/10.0		/20.0	23.3/							
Longnose Sucker	18.7	X	21.3	23.2	X	26.5			5.0/	15.0/								Harris 1962
Hog Sucker	27.3		29.2	31.6		33												
Spotted Sucker	24.8		26.9	27.0		31												
Grass Carp	25.3		29.3	34.0	X	37.3												
Bighead Carp	25.4		29.2	33.5	X	36.8												
Grass x Bighead Carp	28.2		31.6	35.0	X	38.3												
Common Carp	31.5		33.4	34.9		37.3				17.0/	/26.0	28.0/28.0						Carlander 1969
Goldfish	30		32.6	34.6	X	37.9				16.0/	/	30.0/30.0						Carlander 1969
Carp x Goldfish																		
Golden Shiner	27.8		29.9	30.7	X	34				/20.0		27.0/27.0	27.0/27.0					Carlander 1969

Appendix Table Z-3. (continued)

Species	Optimum		MWAT for Growth[a]	UAT[b]		Upper Lethal[c,d]		March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Spawning References
								Spawning Periods and Associated Low and High Temperatures										
Bigeye Chub	26.1	X	28.0	29.4	X	31.7												
Sand Shiner	29.4	X	31.3	32.7	X	35												
Emerald Shiner	22.5		25.7	29.8	X	32.1					20.0/	/27.0	27.0/27.0					Carlander 1969
Bigeye Shiner	27.7		29.5	30.7	X	33												
Common Shiner	26.8	X	28.7	30.1	X	32.4												
Striped Shiner	28	X	29.9	31.3	X	33.6												
Spotfin Shiner	29.8		31.9	33.7		36					/25.0	27.0/27.0	27.0/27.0					Carlander 1969
Rosyface Shiner	27.6		29.4	32.0		33												
Silver Shiner	26.9		29.1	31.1		33.4	X											
Scarlet Shiner	28.1	X	30.2	32.2		34.5	X											
Redfin Shiner	28.6	X	30.5	31.9	X	34.2												
Red Shiner	30.5	X	32.4	33.8	X	36.1												
Mimic Shiner	28.4	X	30.5	32.5		34.8	X											
Bigmouth Shiner	29	X	30.9	32.3	X	34.6												
Blackchin Shiner	30.4	X	32.3	33.7	X	36												
Spottail Shiner	27.3		30.1	34.5		35.6				/	20.0/		/					Fish 1932
Creek Chub	28.1	X	30.0	31.4		33.7												
River Chub	25.3	X	27.2	28.6	X	30.9												
Hornyhead Chub	28	X	29.9	31.3	X	33.6												
Suckermouth Minnow	27.8	X	29.7	31.1	X	33.4												
Stoneroller	28.2		30.6	33.0		35.5												
Fathead Minnow	27.7		30.0	31.5		34.5												
Bluntnose Minnow	27.5		29.1	31.4		32.4					20.0/	26.1/	/					Carlander 1969
Bullhead Minnow	31.7	X	33.6	35.0	X	37.3												
Silverjaw Minnow	27	X	29.7	31.1		35												
W. Blacknose Dace	25.5		27.5	30.6		31.6												
Longnose Dace	25.8	X	27.7	30.0		31.4				/17.2								Trautman 1957, 1981
Mosquitofish	32.9		34.8	36.8		38.5												
Blackstripe Topminnow	30.2	X	32.8	34.7	X	38												
E. Banded Killifish	27.7		31.2	34.9	X	38.2												
Brook Silversides	25		28.3	31.7	X	35												
Striped Bass	28.5		31.1	31.1	X	36.3	X											
White Bass	29.5		31.5	33.3		35.6			12.8/	18.5/22.8	24.0/							Carlander 1969
Striped x White Bass	28.7	X	31.3	32.4	X	36.5												
Channel Catfish	31.1		33.5	34.8		38.3					23.9/	26.7/27.8						Carlander 1969
Blue Catfish	30.9	X	33.0	33.9		37.2	X											
Brown Bullhead	28.1		31.0	31.1	X	35.2				/21.1								Carlander 1969
Yellow Bullhead	28.3		31.0	31.3	X	36.4												
Black Bullhead	27.6	X	30.2	32.1	X	35.4				/21.0	/	/	/					Scott and Crossman 1973
Flathead Catfish	31.1		33.4	34.7		38	X											
Stonecat Madtom	21.2	X	23.8	25.7	X	29												

Appendix Table Z-3. (continued)

Species	Optimum		MWAT for Growth[a]	UAT[b]		Upper Lethal[c,d]		Spawning Periods and Associated Low and High Temperatures										Spawning References
								March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	
Tadpole Madtom	28.2	X	30.8	32.7	X	36												
American Eel	20.5		25.8	33.0		36.3	X											
White Crapple	28.6		29.9	30.8		32.5			14.0/	20/23								Carlander 1969
Black Crappie	27.6		30.0	29.7		34.7			/19.0									Carlander 1969
Rockbass	28.1		30.4	33.0		35				15.6/	21.1/							Carlander 1969
Largemouth Bass	29.1		30.9	31.6		34.5				15.6/17.8	/23.9							Carlander 1969
Spotted Bass	30.6		32.4	33.3		36												
Smallmouth Bass	30		31.6	32.0		34.7				12.8/18.3	/23.9							Carlander 1969
Bluegill	30.4		32.4	33.8		36.4				16.0/	/23.9	27.8/						Carlander 1969
Green Sunfish	27.8		30.3	30.9		35.3												
Pumpkinseed Sunfish	28.4		30.5	30.5	X	34.6				/20.0		/29.0	/29.0					Carlander 1969
Longear Sunfish	24.1		28.0	31.8	X	35.9												
Redear Sunfish	21.9		26.1	30.3	X	34.4												
Orangespotted Sunfish	28.7		30.9	31.3	X	35.4												
Warmouth	25.1	X	27.7	28.8	X	32.9												
Yellow Perch	22.6		26.0	29.8		32.9		2.0/		8.5/14.0	16.1/18.6							Jones et al. (ms)
Walleye	22.8		26.2	30.0		32.9		2.2/	5.6/	8.9/11.1	15.0/ 15.6							Scott and Crossman 1973; Hokanson 1977
Sauger	23.9		26.9	30.3		32.9			3.9/11.7	15.0/	/							Scott and Crossman 1973
Orangethroat Darter	24.6		27.4	29.0		32.9												
Rainbow Darter	20.1		24.4	29.6	X	32.9												
Dusky Darter	22.5		26.0	29.6	X	32.9												
E. Sand Darter	25.0		27.8	30.8	X	33.3	X											
Logperch	22.0		23.3	22.7	X	31.5	X											
Greenside Darter	22.5		25.7	28.9	X	32.2												
Fantail Darter	19.7		24.1	30.6		32.8												
Johnny Darter	22.7		26.3	30.3	X	33.6												
Freshwater Drum	29.1		30.5	31.2		33.4				/18.0	/24.5							Carlander 1969

a - Calculated as: Optimum + 0.333(UUILT[e]-Optimum); "MWAT: for growth (95).

b - Upper Avoidance Temperature (UAT)

c - Ultimate Upper Incipient Temperature (UUILT) or equivalent endpoint (i.e., Chronic Thermal Maximum)

d - Default translation from CTM used when UILT was not available: UUILT + CTM - 2°C

X - Best estimate based on available data (see conversion factors used in Appendix Table Z.2).

From: Vera Herst
To: sanders@rendlake.org
Date: 12/19/2007 9:18:20 AM
Subject: Rend Lake

Hi Larry,

The Civil Rights Compliance Report is contained in the loan application package, along with its instructions.

Let me know if you can't find it.

Thanks.

Vera

Please note my new e-mail address is vera.herst@illinois.gov