IEPA ATTACHMENT NO. GG

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Temperature Criteria Options for the Lower Des Plaines River

Final Report

to

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and

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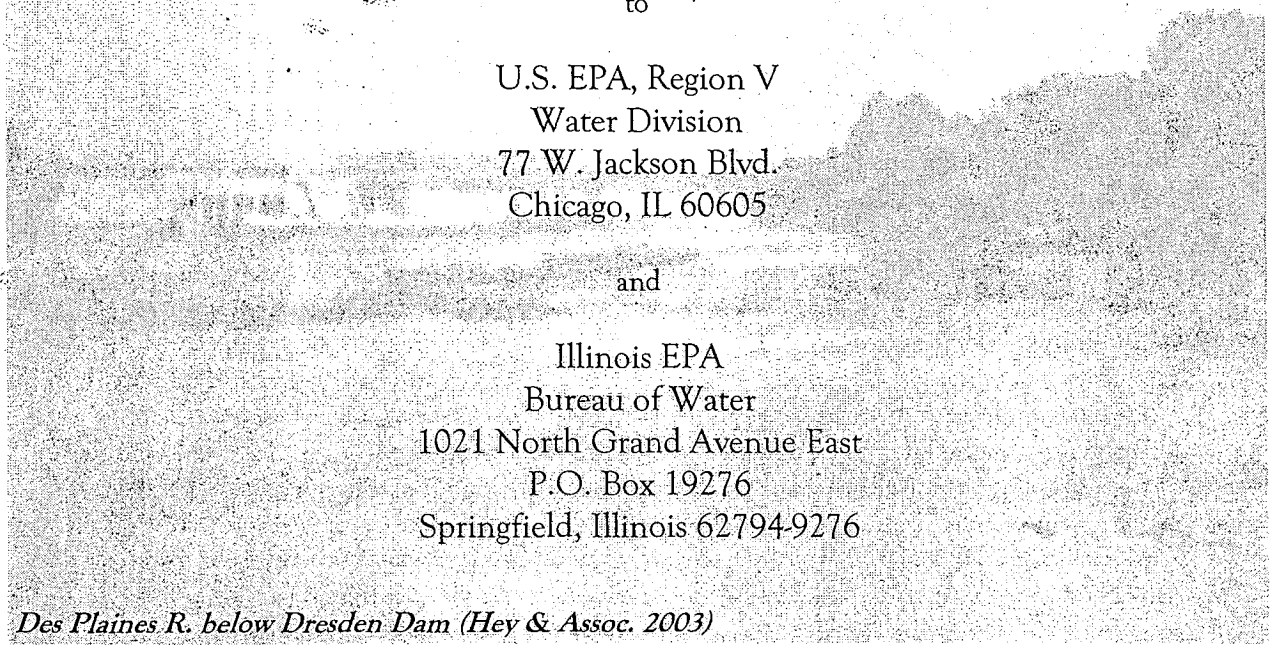

Des Plaines R. below Dresden Dam (Hey & Assoc. 2003)

October 11, 2005

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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 the 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 these 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 of the directives for this project. The temperature criteria options are the result of several variables and assumptions the most important of which are the lists of representative aquatic species (RAS) and the statistical endpoints used to analyze the ambient temperature database. Multiple RAS lists were developed and varied by use designation option and the inclusion and exclusion of key fish species within each. 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 selecting non-summer season criteria. The results of a thermo-dynamic modeling study of this area (Holly and Bradley 1995) were also used to calculate

ambient temperatures. From these 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 options emanating from the UAA process.

It is not the purpose of this report to make these 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. Presently, deriving 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 thermal regimes, thus triggering 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 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 developed and operated by Ohio EPA. The Fish Temperature Modeling system was originally 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 long standing concern with all of the 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 amply 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. Unfortunately, few if any of the available *in situ* tests reflect this type of thermal exposure. Field derived thresholds (final preferenda and upper avoidance) better represent these phenomena, but only if a full range of thermal exposures was reasonably available in the study area.

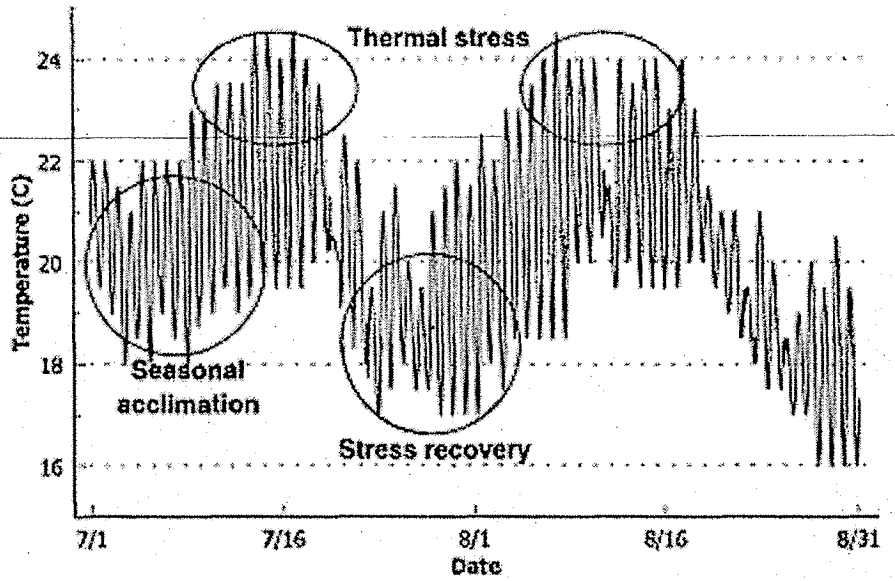

Figure 1. The important features of the thermal regime that is important in determining the effects of temperature on fish (after Bevelheimer and Bennet 2000).

While thermal resistance seems to increase with slowly increasing temperatures, does it represent reality in the environment where temperatures fluctuate up and down 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.

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 the "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 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 changed 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., safety factors) to account for the inherent over-estimation of lethality.

Very few slow heating (ChTM) method test results were found by MBI (2005). In fact, much of the new 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". However, the availability of test results using this approach is virtually non-existent. The practical impact to this and similar studies is a continued need to rely on the UILT and the use of additional safety factors for the conversion of CTM results.

Methodology

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 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.

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 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 could also 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 tended to be over-represented in these databases, which is a common occurrence in databases for many water quality parameters. Tolerant species were more accessible and were 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 thermal thresholds previously described. Conversely, the data for species regarded as highly or moderately intolerant tended to be available for fewer thermal thresholds and were oftentimes based largely 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.

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.

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

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 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

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

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. 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 additional species thermal criteria 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 as 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 fall below these thresholds. It also includes the knowledge that fish can avoid or withstand occasional exceedences of the short-term survival thresholds, provided that local refuges are available and/or the duration of these periods are sufficiently brief (see Figure 1). Meeting the long-term period average requires equivalent "cool down" periods when 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 in MBI (2005), the general use RAS list now includes 49 fish species. We added two additional variations to 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 (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 are expected to occur in the Lower Des Plaines R. as water quality conditions improve in the near 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

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)

UAT of fifteen (15) RAS and the growth criterion of four (4) recreational and commercially important species.

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)

Modified Use

Twenty-seven (27) fish species are considered representative of the intent of a theorized Modified Use, which reflects the irretrievable 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 gamete development, 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 a controlling factor. Thermal 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 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 (the non-parametric analogs of standard error and standard deviation). 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 has been used previously as the average since this takes in account the occurrence of warmer temperatures in single 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 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. The 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 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.

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)	
April 16-30	57.3 (58.8) 67.7 (65.0)	Consistent with spawning criteria for all representative fish species in March, April, May, and June.
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]	
July 1-31	80.6 [79.0] 84.2 [84.7]	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.
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)	
October 1-15	63.7 (69.8) 71.2 (76.0)	Consistent with seasonal temperature measured at the Route 83 (Cal Sag) monitoring location.
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 75th percentile of the period of record based on the Rt. 83 Cal Sag site.

[7] Daily maximum temperature – set at the value exceeded 3 times during the period of record at the Rt. 83 Cal Sag site.

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.

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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	Temperature °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	Temperature °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	Temperature °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	Temperature °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
Longnose Gar
Skipjack Herring
Gizzard Shad
Northern Pike
Bigmouth Buffalo
Smallmouth Buffalo
Quillback Carpsucker
River Carpsucker
Golden Redhorse
Smallmouth Redhorse
Northern Hog Sucker
White Sucker
Common Carp
Golden Shiner
Creek Chub
Emerald Shiner
Redfin Shiner
Striped Shiner
Spottail Shiner
Spotfin Shiner
Bigmouth Shiner
Sand Shiner

Common Name
Fathead Minnow
Bluntnose Minnow
Stoneroller
Channel Catfish
Yellow Bullhead
Black Bullhead
Flathead Catfish
Stonecat Madtom
Blackstripe Topminnow
Brook Silversides
White Bass
White Crappie
Black Crappie
Rock Bass
Smallmouth Bass
Largemouth Bass
Green Sunfish
Bluegill Sunfish
Orangespotted Sunfish
Longear Sunfish
Pumpkinseed Sunfish
Dusky Darter

Common Name
Johnny Darter
Fantail Darter
Freshwater Drum

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

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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
Longnose Gar
Skipjack Herring
Gizzard Shad
Northern Pike
Bigmouth Buffalo
Smallmouth Buffalo
Quillback Carpsucker
River Carpsucker
Golden Redhorse
Smallmouth Redhorse
Northern Hog Sucker
White Sucker
Common Carp
Golden Shiner
Creek Chub
Emerald Shiner
Redfin Shiner
Striped Shiner
Spottail Shiner
Spotfin Shiner
Bigmouth Shiner
Sand Shiner

Common Name
Fathead Minnow
Bluntnose Minnow
Stoneroller
Channel Catfish
Yellow Bullhead
Black Bullhead
Flathead Catfish
Stonecat Madtom
Blackstripe Topminnow
Brook Silversides
White Bass
White Crappie
Black Crappie
Rock Bass
Smallmouth Bass
Largemouth Bass
Green Sunfish
Bluegill Sunfish
Orangespotted Sunfish
Longear Sunfish
Pumpkinseed Sunfish
Sauger

Common Name
Walleye
Yellow Perch
Dusky Darter
Johnny Darter
Fantail Darter
Freshwater Drum

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

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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]

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	Temperature °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	Temperature °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	Temperature °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	Temperature °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]			

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	Temperature °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	Temperature °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	Temperature °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]		

Fish Temperature Model -- Species Thermal Tolerance Rank Report

Temperature °C	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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	Temperature °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]	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: 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

[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	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

[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	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]	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: 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]	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	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]	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: 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

[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	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]	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: 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

[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)			Percentile					Outlier Cutoff	
						Single	Twice	Three	98th	95th	90th	75th	5th	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]	[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 (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

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

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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

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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: 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

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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	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

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