

Temperature Relationships of Great Lakes Fishes:

A Data Compilation

by

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this report is to compile a temperature database for Great Lakes fishes. The database was prepared to provide a basis for preliminary decisions concerning the siting, design, and environmental performance standards of new generating stations and appropriate mitigative approaches to resolve undesirable fish community interactions at existing generating stations.

The contents of this document should also be useful to fisheries research and management agencies in the Great Lakes Basin.

1.2 Summary

The data base provides easy and rapid access to temperature data on fish species in terms of temperature categories which are pertinent to assessment of thermal effects on fish populations.

Thermal criteria for 116 fish species inhabiting the Great Lakes are summarized from published scientific literature. These data are categorized in four tables for each species as follows:

- (1) Lethal temperatures and thermal resistances
- (2) Temperature preferences and avoidances
- (3) Optimal and limiting temperatures for growth
- (4) Temperatures for reproduction and early development

The database tables are preceded by a brief text. The contents of the text are summarized in this paragraph. Section 1.3 is a review of similar literature. Section 1.4 presents a short discussion of the advantages and limitations of this report. The methods are outlined in Section 2.0. Section 2.1 is a discussion of the species list. The format used for the temperature data tables is described in detail in Section 2.2. The terms used in the database tables are defined in Section 2.3. A brief overview of the content of the temperature database tables is provided in Section 3.0. Section 3.1 explains the species cataloguing and organization. The distribution of temperature data across species is described in Section 3.2. References for the text and database tables are in Section 4.0. Section 5.0 is the fish temperature database, the first page of which is a list of abbreviations.

1.3 Literature Review

The published information on the temperature requirements of freshwater fishes is found in thousands of documents. It is convenient that several authors have condensed this information into reviews of the literature. The general reviews of fisheries biology by Carlander (1969,1977) and Scott and Crossman (1973) include some temperature data. Several reviewers have focussed on thermobiology, specifically: lethal and/or preference temperatures (Coutant 1977a; Cherry et al 1977; Kowalski et al 1978; Houston 1982). Others have widened their reviews to include data on growth, preference and lethal temperatures (Leidy and Jenkins 1977; McCauley and Casselman 1980; Jobling 1981). Comprehensive reviews on the whole range of temperature requirements for fishes (i.e., lethal, preference, growth, reproductive) were given by EPA (1974) and Brown (1974).

A summary of thermal effects literature is published each year for aquatic organisms in the June issue of the Journal of the Water Pollution Control Federation (Talmage and Coutant 1978, 1979, 1980; Cravens 1981, 1982; Cravens et al 1983; Harrelson et al 1984).

The temperature requirements of Great Lakes fishes have been reviewed by two authors. Firstly, Reutter and Herdendorf (1976) presented lethal and preference temperatures for 46 species of Lake Erie fishes. Secondly, Spotila et al (1979) reviewed 80 species covering: thermal requirements for survival, temperature preference, growth, reproduction and early development.

1.4 Database Advantages and Limitations

The major limitation of this document is its lack of an overall synthesis. The initial terms of reference did not provide for any attempt to integrate the data into summary values, figures or discussion. A brief overview of the distribution of temperature data among families of species is provided in Section 3.0. The reader is referred elsewhere for scholarly discussion of the use and application of fish temperature data (Cherry et al 1977; Richards et al 1977; Spotila et al 1979; McCauley and Casselman 1980; Jobling 1981; Mathur et al 1981; Houston 1982; Giattinna and Garton 1982; Ellis 1984).

The data summary in this report enjoys several advantages over other similar reviews. One of these is that it is current. This is the only compilation in the published literature since 1982. More importantly, the scope of the review is wider than any previous one in relation to the total species coverage and scope of thermobiological information. Furthermore, the design of the database tables makes for easy data access which aids comparisons within and across species. Access to the review of data by Spotila et al (1979) was hindered by the use of inconsistent categories of data within each table.

2.0 METHODS

2.1 Species List

The species list for this study was compiled from Christie (1982) and Scott and Crossman (1973). A total of 116 Great Lakes fishes were included. This species total is representative for the Great Lakes (Manny 1984).

Several species were omitted that no longer have a Great Lakes distribution. These species were: Atlantic salmon (*Salmo salar*); blue pike (*Stizostedion vitreum glaucum*); deepwater cisco (*Coregonus johanna*); and blackfin cisco (*Coregonus nigripinnis*) (Scott and Crossman 1973; McAllister et al 1985). The only species of the family Petromyzontidae represented in this summary was the sea lamprey (*Petromyzon marinus*). Three other Great Lakes species of this family not included in this summary were: northern brook lamprey (*Ichthyomyzon fossor*); silver lamprey (*Ichthyomyzon unicuspis*); american brook lamprey (*Lampetra lamottei*). Also, I have included the stoneroller (*Campostoma anomalum*) in the database since it is reported to have a marginal Great Lakes distribution (Scott and Crossman 1973; Spotila et al 1979; McAllister et al 1985).

2.2 Database Design Considerations

The design of the temperature database was developed after review of the literature, some of which was cited in Section 1.4. The goal was to structure a database format that would accommodate the major thermal requirements for fishes. These temperature requirements have been identified by others as pertaining to: survival, temperature preference; growth; reproduction and early development (EPA 1974; Gift 1977; Jobling 1981; Giattinna and Garton 1982). The temperature criteria for preference - avoidance and survival are useful for predicting short-term direct effects on fish

behaviour and metabolism. The thermal requirements for reproduction and growth provide a basis for estimating the long-term sublethal effects of unnatural temperature change on fish populations.

2.3 Definition of Terms

The types of data furnished in the fish temperature database are described and defined in this Section. All temperatures are in degrees Celsius. Data are listed under the scientific name of the fish species, arranged in alphabetical order. Within each species category, the information is organized in four different tables. These tables are titled as follows in order of their appearance in the database:

- (1) THERMAL TOLERANCES
- (2) PREFERRED TEMPERATURES
- (3) GROWTH TEMPERATURES
- (4) SPAWNING AND DEVELOPMENT TEMPERATURES

The types of temperature data found within each of these four major categories are described below.

(1) THERMAL TOLERANCES

This table contains data on laboratory-derived lethal temperatures and thermal resistances. These temperature thresholds were observed in experiments that were explicitly designed to measure thermal doses. Other lethal temperature values were reported in the literature from laboratory studies whose experimental designs did not conform to the accepted standards for determination of thermal tolerances and resistances. These standard methods are described in Fry et al (1946) and McCauley (1981). These latter temperature values and those reported from the field studies are less reliable than those derived from standard experimental designs. The less robust estimates of thermal tolerances are reported elsewhere in the table entitled: SPAWNING AND DEVELOPMENT TEMPERATURES. These include lethal temperature thresholds for entrainment, heat shock and cold shock.

(a) Size or Age:

Lethal temperatures vary with size and age of fish. The various descriptions of size and age used in the database are explained in Section 5.0.

(b) Acclimation Temperature:

The acclimation temperature is defined as a constant temperature in the laboratory at which fish have been held for a time sufficiently long to erase the influence of previous thermal exposure (McCauley 1981).

(c) Acclimation Time:

The time for holding fish at a given acclimation temperature. This is usually assumed a standard seven days unless reported otherwise.

(d) Season:

Lethal temperatures vary seasonally. See Section 5.0 for abbreviations used in the database.

(e) Upper Incipient Lethal Temperature:

and

(f) Lower Incipient Lethal Temperature:

The upper and lower incipient lethal temperatures represent the temperature values beyond which 50 percent of the population can no longer live given an indefinite period of time (Giattinna and Garton 1982). A standard seven-day week is used as the lethal test exposure time (McCauley 1981). The incipient lethal levels define the upper and lower boundaries to the "zone of thermal tolerance" within which there is no mortality from temperature (Figure 1).

(g) Thermal Resistance Equation:

A glance at Figure 1 will show a "zone of thermal resistance" located above the upper incipient lethal temperature. Within this zone, mortality due to temperature extremes occurs as a function of time. The length of time that 50 percent of the population will survive temperatures above the upper incipient lethal temperature is calculated from a regression relationship as follows:

$$\log(\text{time in minutes}) = a + b(\text{temperature in } ^\circ\text{C}),$$

where a and b are the intercept and slope, respectively, determined from each acclimation temperature (EPA 1974).

The values of the intercept a and slope b are provided to four decimal places in the fish temperature database tables. The value of b is almost always negative and is preceded by a minus sign in the table. This minus sign, located between the values for a and b, should not be erroneously misinterpreted as signifying a range of values.

(h) Data Limits {Upper and Lower}:

These are the data limits of the regression relationship as reported by Brown (1974).

(i) Exposure Temperature:

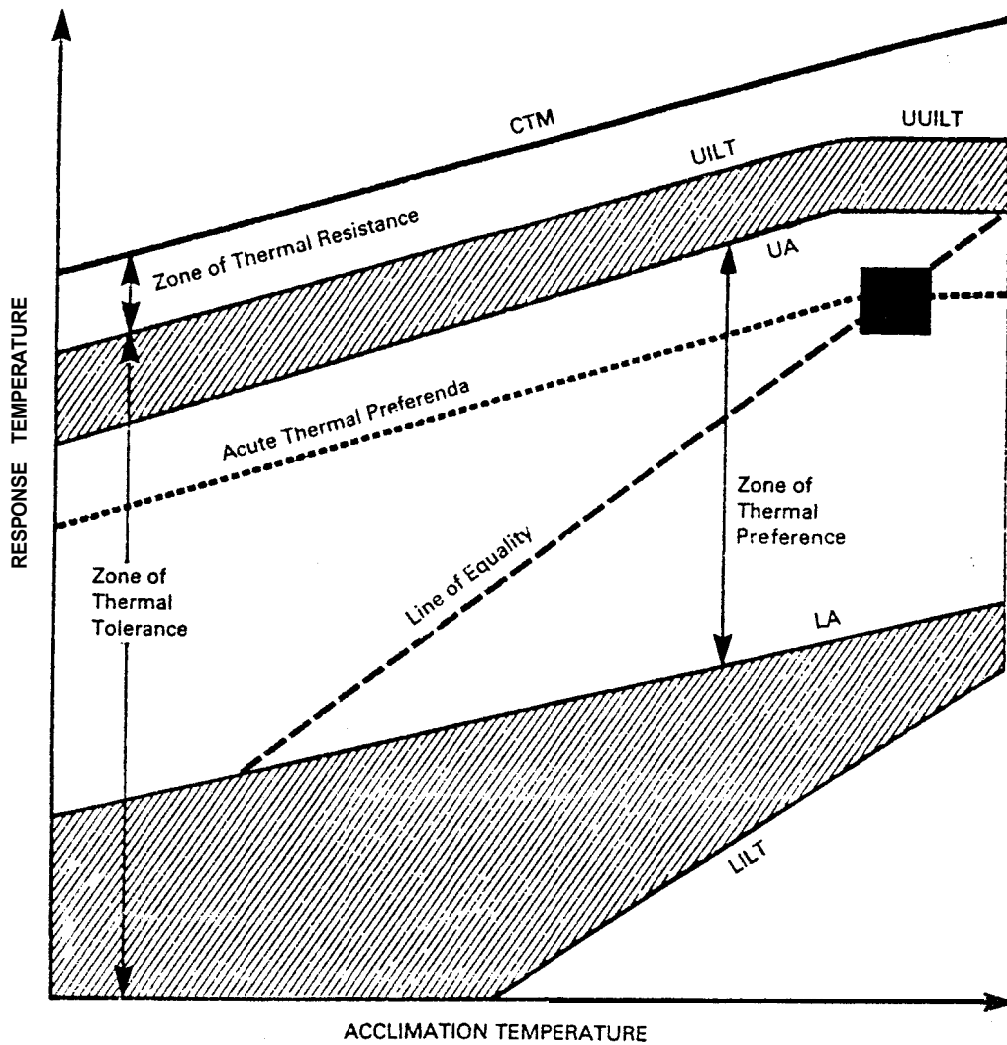
This is the test temperature a fish is exposed to in the laboratory in order to determine the time to mortality.


(j) Resistance Time:

This value is the amount of time that a sample of test fish were able to resist an exposure temperature before 50 percent mortality, or some other specified survival level, is experienced. The resistance time equation can be used to calculate thermal tolerance limits for a fish species for several time intervals up to 10,000 minutes (seven days) (Jinks et al 1981).

(k) Critical Thermal (Max):

The upper boundary of the "zone of thermal resistance" is the critical thermal maximum (CTM) (Figure 1). The CTM is lethal if fish are allowed to remain at or above that temperature (Bonin et al 1981). The CTM is determined in the laboratory by gradually increasing the water tempera-



 Zone of Final Preferendum and Optimum Growth

Broken line (line of equality) represents points at which preferred temperature equals acclimation temperature, and is often used in estimating final preferendum. CTM = critical thermal maximum; UILT = upper incipient lethal temperature; LILT = lower incipient lethal temperature; UUILT = ultimate upper incipient lethal temperature; UA = upper avoidance threshold; LA = lower avoidance threshold.

Adopted from Jobling (1981), Giattina and Garton (1982)

FIGURE 1
 Diagram Showing Temperature Relations of Fish

ture from acclimation levels to the temperature at which the onset of spasms occurs, followed by complete loss of equilibrium. This differs from determination of the upper incipient lethal temperature (l(e)) in which fish are transferred directly and abruptly into a constant lethal temperature bath from acclimation temperatures (McCauley 1981). The rate of temperature increase used by any single investigator to determine CTM can vary within a range of 1 to 60°C h for routine applications (Becker and Genoway 1979; Bonin et al 1981).

(l) Location:

This is a laboratory. Sometimes its geographic location is given.

(2) PREFERRED TEMPERATURES:

This table contains temperature preference and avoidance values. These are derived from both field and laboratory observations.

(a) Size or Age:

Preferred and avoided temperatures vary with size and age, See Section 5.0 for a description of life stages and units of size used in the database.

(b) Season:

Preferred and avoided temperatures vary with season. See Section 5.0 for abbreviations.

(c) Day or Night:

Diurnal variation in temperature preference and avoidance is common (Coutant 1977a, Giattinna and Garton 1982). See Section 5.0 for abbreviations.

(d) Upper and Lower Avoidance:

The avoidance threshold is defined as the temperature at which fish spend significantly less time in comparison to controls. Avoidance temperatures (upper and lower) can be measured directly in the lab by providing fish with a choice between water which is heated or cooled and water at the acclimation temperature of the fish (Giattinna and Garton 1982). The upper and lower avoidance temperatures define the boundary of the "zone of thermal preference" (Figure 1). Avoidance temperatures reported from field studies are less precise than those of laboratory studies because they include the influence of other non-thermal environmental influences (i.e., competition, predation, changes in water quality, food availability, physiological condition).

(e) Final Preferendum:

Within a laboratory thermal gradient, over a short period of time (two hours or less) fish will gravitate toward certain temperatures. These are termed "acute thermal preferenda" (PT) and are highly dependent upon acclimation temperature (Cherry et al 1977; Giattinna and Garton 1982) (Figure 1). The "final temperature preferendum" (FP) is the temperature around which fish will ultimately congregate in an infinite temperature gradient (Giattinna and Garton 1982) (Figure 1).

The values for PT and FP are both entered in the column labelled *Final Preferendum* in the database. One can distinguish between the two values since PT are usually accompanied by values for *Acclimation Temperatures* in the seventh column of this table. Values cited from

Coutant (1977a) are for FP only. Review of the data in Coutant (1977a) indicates values for FP vary within a narrow range of 4C. Estimates of FP from field studies whose ranges exceed 4C should be assumed to be PT for the given season and location. The manner in which temperature preference data was typically reported in the literature did not allow explicit separation of values for PT and FP. Field reported values include much uncontrolled error due to the influence of other non-thermal environmental factors. Some of the reported values from field studies are representative of only a single point-in-time field occurrence. Users of the database are encouraged to refer to the source literature for an indication of the reliability of the preferendum temperature.

(f) Acclimation Temperature:

This term was previously defined for laboratory investigations (see item I(b) in the THERMAL TOLERANCES section). In field situations, fish are exposed to a whole set of conditions and are usually subjected to fluctuating rather than constant temperatures. Adaptation to all of these variables is known as acclimatization or sometimes field acclimation (McCauley 1981).

(g) Acclimation Time:

This term was previously defined (see Item 1 (c) in the THERMAL TOLERANCES section).

(3) GROWTH TEMPERATURES:

This table contains data on thermal limits and optima for growth.

(a) Size or Age:

Sizes and or ages are specified since younger, smaller fish grow faster than older, larger fish. See Section 5.0 for a description of the terms and units of size and age.

(b) Optimum:

The optimal temperature for growth is the temperature at which growth rate is highest. This value is determined while fish are reared under conditions of maximum, or excess feeding and held at constant temperatures over the temperature range tolerated by the species (Jobling 1981; McCauley and Casselman 1980). The difference between the final thermal preferendum and temperature for optimum growth is less than 2°C for some species (Kellogg and Gift 1983) (see Figure 1).

(c) Range:

This value is the range of temperatures over which growth is known to occur.

(d) MWAT:

The maximum weekly average temperature for growth (MWAT) is a measure of the upper temperature limit for long-term exposure. The MWAT lies somewhere between the physiological optimum temperature and the ultimate upper incipient lethal temperature (UUILT). The UUILT is the highest temperature to which the species can be acclimated; above this all temperatures are lethal regardless of previous thermal exposure (Jobling 1981) (Figure 1). The MWAT is calculated as one third of the range between the optimum temperature for growth and the UUILT (EPA 1974; Wrenn 1980).

(e) ST Max:

These values are the maximum temperatures for short-term exposure (24 hours) during the

growth season to prevent against lethal effects (Wrenn 1980). It is calculated as the difference between the upper incipient lethal temperature, at an acclimation temperature equal to the MWAT, minus 2°C (EPA 1974).

(f) No Growth Limits (Upper and Lower):

These are estimates of the actual temperature end points, above or below which no growth is possible.

(4) SPAWNING AND DEVELOPMENT TEMPERATURES

This table contains information on temperature requirements for reproduction and larval development. The table also has data on lethal temperatures that are not the conventional incipient lethals or critical thermal maximas defined previously. This includes temperatures reported in the literature from field observations of mortality or lethal values which were not derived from standard laboratory techniques for estimating thermal dose. (These standard methods are described in McCauley (1981)).

(a) Event:

This column contains a keyword(s) that describes the type of temperature requirement referred to in the corresponding row. These "events" are aspects of reproduction and larval development or thermal effects from power plant cooling water intakes or discharges. The event categories found in this column include: life stage (egg, embryo, larval, juvenile, adult); mode of reproductive behaviour (migration, spawning, incubation, hatching, embryo or larval development); and type of power plant effect (entrainment, heat or cold shock). The three types of power plant effects included above are defined as follows:

entrainment: The passage of ichthyoplankton (eggs, larvae, small juveniles) through the screens of cooling water intakes into the condenser cooling system of a power plant; subject to mechanical, chemical and thermal stresses. (Temperature requirements are derived from laboratory simulation studies; laboratory thermal tolerance work and in *situ* studies of fish survival at operating power plants (Jinks et al 1981).

heat shock: Fish resident in a power plant thermal discharge are subject to a rapid increase in temperature due to changes in power plant operations.

cold shock: Fish resident in warm water discharges are exposed to a rapid decrease in temperature and a sustained exposure to low temperature that induces responses of abnormal behaviour and physiological function often leading to death (Coutant 1977b). Cold shock events occur usually in colder months due to planned or accidental shutdowns.

(b) Season and/or Acclimation Temperature:

Numerical values in this column are acclimation temperatures in degrees Celsius. The letter symbols in this column representing the four seasons are defined in Section 5.0.

(c) Optimum Temperature:

The temperature of peak occurrence, or most frequently associated with the given event.

(d) Temperature Range:

The range of temperatures over which the given event is reported to occur.

(e) MWAT:

The maximum weekly average temperature during the month of peak spawning. This should not exceed the optimum temperature for spawning or, if such data are not available, the middle of the reported range of temperatures for spawning (EPA 1974; Wrenn 1984).

(f) ST Max for Embryo Survival:

The short-term (24-hour) maximum temperature for successful embryo survival from experimental data, or if not available, the reported maximum temperature for spawning (EPA 1974; Wrenn 1984).

(g) Acclimation Time:

See item 1 (c) in THERMAL TOLERANCE section for definition.

(h) Lethal Limit (Upper and Lower):

These are any lethal temperatures observed in the field or from laboratory experiments that do not conform to the prescribed methods for determining lethal temperatures as set out in Fry (1946) and McCauley (1981).

(i) Median Lethal ΔT :

This value represents the increase from a base temperature required to kill larval fish during entrainment. This lethal value is usually much higher than a conventional upper incipient lethal temperature since the time of exposure to the lethal ΔT in a condenser is very brief allowing for no gradual acclimation (Moore 1979).

A median lethal ΔT for heat shock or cold shock events represents the change in temperature above a given acclimation level that causes abnormal behaviour or physiological responses. The numerical value for the median lethal ΔT is preceded by a plus (+) or minus (-) sign in the table to indicate whether it pertains to heat shock (+) or cold shock (-).

(j) Median Lethal Final:

This is the ultimate lethal temperature value experienced by entrained fish (ambient or base temperature + ΔT) Moore (1979).

3.0 DATABASE SUMMARY

3.1 Organization

A summary of the species list and general categories of temperature data recorded for each species is given in Table 1. The species are listed by family, scientific name and common name. The species grouping is phylogenetic as is conventional in fisheries surveys (Christie 1982; Scott and Crossman 1973; Jobling 1981; Houston 1982). An alphabetical listing of the reviewed fish species by common name is provided in Table 2.

The bulk of the report consists of the fish temperature database tables arranged in taxonomic order by family. The species within families are in alphabetical order, according to their scientific name. Temperature data tables for each species appear in the following order: thermal tolerances; preferred temperatures; growth temperatures; spawning and development temperatures.

3.2 Content

The species frequency distribution for the four temperature data tables is summarized in Table 1. Evaluation of the availability of this data with respect to both these four temperature categories and fish species highlights the fact that large gaps in the available data presently exist. Complete temperature data, in all four major categories, was available for only 45 species. Of the remaining 71 species, only 17 were represented by data in three categories, 24 species represented in two categories and 23 species in only one category. In the database, a total of 45 commercial/game fish species were listed. Of these, 84 percent were represented in at least three of the four major tables of temperature data. This contrasts sharply with the situation for forage/coarse fish species where only 41 percent of a total of 71 species were represented in the database by at least three major data tables. Spotila et al (1979) noted the lack of temperature data on forage or coarse fish species such as darters (*Etheostomidae*), minnows (*Cyprinidae*), and suckers (*Castostomidae*), which are among the most thermally sensitive species. The temperature requirements of salmon and trout (*Salmonidae*); basses and sunfishes (*Centrarchidae*) are the most completely represented.

The database was also reviewed in relation to the relative frequency of occurrence of each of the four major types of temperature data (i.e. tolerances, preferred, growth, spawning and development). The category with the poorest (least) representation was GROWTH TEMPERATURES. This was not surprising in view of the fact that experimental determinations of temperature requirements for growth are more difficult and costly than those for survival, preference and reproduction (McCauley and Casselman 1980; Jobling 1981; Kellogg and Giff 1983). The paucity of growth data is unfortunate since changes in growth rate provide one of the few long-term indicators of species response to thermal effects (Kellogg and Giff 1983). Growth may be considered as an integrator of the mix of stresses affecting the metabolism of fish and, as such, a more sensitive index of environmental effects than mortality (Rodgers and Griffiths 1983). Recent contributions to the scientific literature have shown that growth criteria may be approximated from temperature preferenda and lethal temperatures (McCauley and Casselman 1980; Jobling 1981; Kellogg and Giff 1983).

Table 1. Great Lakes Fish Species and Types of Temperature Data.
 Blank Space Means No Data Available.
 Scientific and Common Names from Scott and Crossman (1973).

Family	Species	Common Name	Type of Temperature Data			
			Thermal ¹ Tolerances	Preferred'	Growth ³	Spawning and ⁴ Develop- ment
Petromyzontidae (Lampreys)	<i>Petromyzon marinus</i>	sea lamprey	X	X	X	X
Acipenseridae (Sturgeons)	<i>Acipenser fulvescens</i>	lake sturgeon				X
Lepisosteidae (Gars)	<i>Lepisosteus oculatus</i>	spotted gar*		X		
	<i>Lepisosteus osseus</i>	longnose gar		X	X	
Amiidae (Bowfin)	<i>Amia calva</i>	bowfin	X	X		X
Clupeidae (Herrings)	<i>Alosa pseudoharengus</i>	alewife	X	X	X	X
	<i>Dorosoma cepedianum</i>	gizzard shad	X	X	X	X
Salmonidae (Salmons, trouts whitefishes)	<i>Oncorhynchus gorboscha</i>	pink salmon	X	X	X	X
	<i>Oncorhynchus kisutch</i>	coho salmon	X	X	X	X
	<i>Oncorhynchus nerka</i>	kokanee salmon	X	X	X	X
	<i>Oncorhynchus tshawytscha</i>	chinook salmon	X	X	X	X
	<i>Salmo trutta</i>	brown trout	X	X	X	X
	<i>Salmo gairdneri</i>	rainbow trout	X	X	X	X
	<i>Salvelinus fontinalis</i>	brook trout	X	X	x	X
	<i>Salvelinus namaycush</i>	lake trout	X	X	X	X
	<i>Salvelinus fontinalis</i> x <i>S. namaycush</i>	splake	X	X		X
	<i>Coregonus alpenae</i>	longjaw cisco				
	<i>Coregonus artedii</i>	cisco, lake herring			X	
	<i>Coregonus hoyi</i>	bloater*	X	X		X
	<i>Coregonus kiyi</i>	kiyi*		X		X
	<i>Coregonus reighardi</i>	shortnose cisco*				X
	<i>Coregonus zenithicus</i>	shortjaw cisco				
	<i>Coregonus clupea formis</i>	lake whitefish	X	X	X	X
<i>Prosopium coulteri</i>	pygmy whitefish*					
<i>Prosopium cylindraceum</i>	round whitefish		X		X	
Osmeridae (Smelts)	<i>Osmerus mordax</i>	rainbow smelt	X	X	X	X
Hiodontidae (Mooneyes)	<i>Hiodon tergisus</i>	mooneye		X		X

Table 1. - Continued

Family	Species	Common Name	Type of Temperature Data			
			Thermal ¹ Toler- ances	Preferred ¹	Growth ³	Spawning and ⁴ Develop- ment
Umbridae (Mudminnows)	<i>Umbra limi</i>	central mud minnow	X	X		X
Esocidae (Pikes)	<i>Esox americanus</i> <i>vermiculatus</i>	grass pickerel*		X		X
	<i>Esox lucius</i>	northern pike	X	X	X	X
	<i>Esox masquinongy</i>	muskellunge	X	X	X	X
Cyprinidae (Minnows)	<i>Campostoma anomalum</i>	stoneroller*	X	X	X	X
	<i>Chrosomus eos</i>	northern redbelly dace	X	X		X
	<i>Chrosomus neogaeus</i>	finescale dace	X			X
	<i>Couesius plumbeus</i>	lake chub				X
	<i>Cyprinus carpio</i>	carp	X	X	X	X
	<i>Exoglossum maxillingua</i>	cutlips minnow		X		X
	<i>Hybognathus hankinsoni</i>	brassy minnow				X
	<i>Hybognathus nuchalis</i>	silvery minnow				X
	<i>Hybopsis storeriana</i>	silver chub				X
	<i>Nocomis biguttatus</i>	hornyhead chub				X
	<i>Nocomis micropogon</i>	river chub	X			X
	<i>Notemigonus</i> <i>crysoleucas</i>	golden shiner	X	X		X
	<i>Notropis anogenus</i>	pugnose shiner*		X		
	<i>Notropis atherinoides</i>	emerald shiner	X	X	X	X
	<i>Notropis bifrenatus</i>	bridle shiner				X
	<i>Notropis cornutus</i>	common shiner	X			X
	<i>Notropis heterodon</i>	blackchin shiner	X			
	<i>Notropis heterolepis</i>	blacknose shiner				
	<i>Notropis hudsonius</i>	spottail shiner	X	X	X	X
	<i>Notropis rubellus</i>	rosyface shiner	X	X	X	X
	<i>Notropis spilopterus</i>	spotfin shiner	X	X	X	X
	<i>Notropis stramineus</i>	sand shiner	X			
	<i>Notropis umbratilus</i>	redfin shiner				
	<i>Notropis volucellus</i>	mimic shiner				
	<i>Pimephales notatus</i>	bluntnose minnow	X	X	X	X
	<i>Pimephales promelas</i>	fathead minnow	X	X	X	X
	<i>Rhinichthys atratulus</i>	blacknose dace	X			X
	<i>Rhinichthys cataractae</i>	longnose dace	X	X	X	X
	<i>Semotilus</i> <i>atromaculatus</i>	creek chub	X			X
	<i>Semotilus corporalis</i>	fall fish		X		X
	<i>Semotilus margarita</i>	pearl dace				X
	<i>Carassius auratus</i>	gold fish	X	X	X	X
Castostomidae (Suckers)	<i>Carpoides cyprinus</i>	quillback	X	X		X
	<i>Catostomus catostomus</i>	longnose suckers	X	X		X
	<i>Catostomus commersoni</i>	white sucker	X	X	X	X
	<i>Erimyzon sucetta</i>	lake chubsucker*				X
	<i>Hypentelium nigricans</i>	northern hog sucker	X	X	X	X

Table 1. - Continued

Family	Species	Common Name	Type of Temperature Data			
			Thermal ¹ Toler- ances	Preferred ¹	Growth ³	Spawning and ⁴ Develop- ment
Castostomidae (Suckers)	<i>Ictiobus cyprinellus</i>	bigmouth buffalo*		X		X
	<i>Minytrema melanops</i>	spotted sucker*	X	X		X
	<i>Moxostoma anisurum</i>	silver redhorse				X
	<i>Moxostoma macrolepidotum</i>	shorthead red horse		X		X
Ictaluridae (Catfishes)	<i>Ictalurus melas</i>	black bullhead	X	X		X
	<i>Ictalurus natalis</i>	yellow bullhead	X	X		
	<i>Ictalurus nebulosus</i>	brown bullhead	X	X	X	x
	<i>Ictalurus punctatus</i>	channel catfish	X	X	X	X
	<i>Noturus flavus</i>	stonecat	X	X		X
	<i>Noturus gyrinus</i> <i>Noturus miurus</i>	tadpole madtom brindled madtom*	X			X
Anguillidae (Eels)	<i>Anguilla rostrata</i>	american eel		X	X	X
Cyprinodontidae (Killifishes)	<i>Fundulus diaphanus</i>	banded killifish	X	X		X
Gadidae (Cods)	<i>Lota lota</i>	burbot	X	X	X	X
Atherinidae (Silversides)	<i>Labiddesthes sicculus</i>	brook silverside		X		
Gasterosteidae (Sticklebacks)	<i>Culaea inconstans</i>	brook stickleback	X			X
	<i>Gasterosteus aculeatus</i>	threespine stickleback	X	X	X	X
	<i>Pungitius pungitius</i>	Ninespine stickleback		X		X
Percopsidae (Trout-perches)	<i>Percopsis omiscomaycus</i>	trout-perch	X	X	X	X
Percichthyidae (Temperate Basses)	<i>Morone americana</i>	white perch	X	X	X	X
	<i>Morone chrysops</i>	white bass	X	X	X	X
Centrarchidae (Sunfishes)	<i>Ambloplites rupestris</i>	rock bass	X	X	X	X
	<i>Lepomis cyanellus</i>	green sunfish*	X	X	X	X
	<i>Lepomis gibbosus</i>	pumpkinseed	X	X	X	X
	<i>Lepomis macrochirus</i>	bluegill	X	X	X	X
	<i>Lepomis megalotis</i>	longear sunfish*	X	X		X
	<i>Micropterus dolomieu</i>	smallmouth bass	X	X	X	X
	<i>Micropterus salmoides</i>	largemouth bass	X	X	X	X
	<i>Pomoxis annularis</i>	white crappie	X	X	X	X
	<i>Pomoxis nigromaculatus</i>	black crappie	X	X	X	X

Table 1. - Continued

Family	Species	Common Name	Type of Temperature Data			
			Thermal ¹ Tolerances	Preferred ²	Growth ³	Spawning and ⁴ Development
Percidae (Perches)	<i>Perca flavescens</i>	yellow perch	X	X	X	X
	<i>Stizostedion canadense</i>	sauger	X	X	X	X
	<i>Stizostedion vitreum</i>	walleye	X	X	X	X
	<i>Ammocrypta pellucida</i>	eastern sand darter*		X		
	<i>Etheostoma blennioides</i>	greenside darter	X			
	<i>Etheostoma caeruleum</i>	rainbow darter	X	X		X
	<i>Etheostoma exile</i>	lowa darter		X		X
	<i>Etheostoma flabellare</i>	fantail darter	X			X
	<i>Etheostoma microperca</i>	least darter*				X
	<i>Etheostoma nigrum</i>	johnny darter	X	X		X
	<i>Percina caprodes</i>	log perch		X		X
	<i>Percina copelandi</i>	channel darter*				X
	<i>Percina maculata</i>	blackside darter				X
	Sciaenidae (Drums)	<i>Aplodinotus grunniens</i>	freshwater drum	X	X	X
Cottidae (Sculpins)	<i>Cottus bairdi</i>	mottled sculpin	X	X		X
	<i>Cottus cognatus</i>	slimy sculpin	X	X		X
	<i>Cottus ricei</i>	Spoonhead sculpin				X
	<i>Myoxocephalus quadricornis</i>	deepwater sculpin		X		X

* listed as rare or threatened species by McAllister et al (1985).

1. Includes: upper and lower incipient lethal; thermal resistance equations and times; critical thermal maximum.
2. Includes: final preferendum; upper and lower avoidance temperatures; preferred temperatures.
3. Includes: growth optimum and range; upper and lower thermal limits for growth: maximum weekly average temperature for growth over long term; maximum temperature for non-lethal, short-term exposure.
4. Includes: temperature optimum and range for spawning: maximum weekly average for spawning; embryo survival temperature; larval entrainment temperatures and survival levels; impingement temperatures; heat and cold shock temperatures.

TABLE 2
ALPHABETICAL LISTING OF REVIEWED
FISH SPECIES BY COMMON NAME

Common Name	Scientific Name	Family Name
Alewife	<i>Alosa pseudoharengus</i>	Clupeidae
American Eel	<i>Anguilla rostrata</i>	Anguillidae
Banded Killifish	<i>Fundulus diaphanus</i>	Cyprinodontidae
Bigmouth Buffalo	<i>Ictiobus cyprinellus</i>	Castostomidae
Black Bullhead	<i>Ictalurus melas</i>	Ictaluridae
Black Crappie	<i>Pomoxis nigromaculatus</i>	Centrarchidae
Blackchin Shiner	<i>Notropis heterodon</i>	Cyprinidae
Blacknose Dace	<i>Rhinichthys atratulus</i>	Cyprinidae
Blackside Darter	<i>Percina maculata</i>	Percidae
Bloater	<i>Coregonus hoyi</i>	Salmonidae
Bluegill	<i>Lepomis macrochirus</i>	Centrarchidae
Bluntnose Minnow	<i>Pimephales notatus</i>	Cyprinidae
Bowfin	<i>Amia calva</i>	Amiidae
Brassy Minnow	<i>Hybognathus hankinsoni</i>	Cyprinidae
Bridle Shiner	<i>Notropis bifrenatus</i>	Cyprinidae
Brindled Madtom	<i>Noturus miurus</i>	Ictaluridae
Brook Silverside	<i>Labidesthes sicculus</i>	Atherinidae
Brook Stickleback	<i>Culaea inconstans</i>	Gasterosteidae
Brook Trout	<i>Salvelinus fontinalis</i>	Salmonidae
Brown Bullhead	<i>Ictalurus nebulosus</i>	Ictaluridae
Brown Trout	<i>Salmo trutta</i>	Salmonidae
Burbot	<i>Lota lota</i>	Gadidae
Carp	<i>Cyprinus carpio</i>	Cyprinidae
Central Mudminnow	<i>Umbra limi</i>	Umbridae
Channel Cat	<i>Ictalurus punctatus</i>	Ictaluridae
Channel Darter	<i>Percina copelandi</i>	Percidae
Chinook Salmon	<i>Oncorhynchus tshawytscha</i>	Salmonidae
Cisco, Lake Herring	<i>Coregonus artedii</i>	Salmonidae
Coho Salmon	<i>Oncorhynchus kisutch</i>	Salmonidae
Common Shiner	<i>Notropis cornutus</i>	Cyprinidae
Creek Chub	<i>Semotilus atromaculatus</i>	Cyprinidae
Cutlips Minnow	<i>Exoglossum maxillingua</i>	Cyprinidae
Deepwater Sculpin	<i>Myoxocephalus quadricornis</i>	Cottidae
Eastern Sand Darter	<i>Ammocrypta pellucida</i>	Percidae
Emerald Shiner	<i>Notropis atherinoides</i>	Cyprinidae
Fall Fish	<i>Semotilus corporalis</i>	Cyprinidae
Fantail Darter	<i>Etheostoma flabellare</i>	Percidae
Fathead Minnow	<i>Pimephales promelas</i>	Cyprinidae
Finescale Dace	<i>Chrosomus neogaeus</i>	Cyprinidae
Freshwater Drum	<i>Aplodinotus grunniens</i>	Sciaenidae
Gizzard Shad	<i>Dorosoma cepedianum</i>	Clupeidae
Golden Shiner	<i>Notemigonus crysoleucas</i>	Cyprinidae

TABLE 2 - Continued

Common Name	Scientific Name	Family Name
Goldfish	<i>Carassius auratus</i>	Cyprinidae
Grass Pickerel	<i>Esox americanus vermiculatus</i>	Esocidae
Green Sunfish	<i>Lepomis cyanellus</i>	Centrarchidae
Greenside Darter	<i>Etheostoma blennoides</i>	Percidae
Hornyhead Chub	<i>Nocomis biguttatus</i>	Cyprinidae
Iowa Darter	<i>Etheostoma exile</i>	Percidae
Johnny Darter	<i>Etheostoma nigrum</i>	Percidae
Kiyi	<i>Coregonus kiyi</i>	Salmonidae
Kokanee Salmon	<i>Oncorhynchus nerka</i>	Salmonidae
Lake Chub	<i>Couesius plumbeus</i>	Cyprinidae
Lake Chubsucker	<i>Erimyzon sucetta</i>	Castostomidae
Lake Herring, Cisco	<i>Coregonus artedii</i>	Salmonidae
Lake Sturgeon	<i>Acipenser fulvescens</i>	Acipenseridae
Lake Trout	<i>Salvelinus namaycush</i>	Salmonidae
Lake Whitefish	<i>Coregonus clupeaformis</i>	Salmonidae
Lamprey, Sea	<i>Petromyzon marinus</i>	Petromyzontidae
Largemouth Bass	<i>Micropterus salmoides</i>	Centrarchidae
Least Darter	<i>Etheostoma microperca</i>	Percidae
Log Perch -	<i>Percina caprodes</i>	Percidae
Longear Sunfish	<i>Lepomis megalotis</i>	Centrarchidae
Longnose Dace	<i>Rhinichthys cataractae</i>	Cyprinidae
longnose Gar	<i>Lepisosteus osseus</i>	Lepisosteidae
Longnose Sucker	<i>Catostomus catostomus</i>	Castostomidae
Mooneye	<i>Hiodon tergisus</i>	Hiodontidae
Mottled Sculpin	<i>Cottus bairdi</i>	Cottidae
Muskellunge	<i>Esox masquinongy</i>	Esocidae
Ninespine Stickleback	<i>Pungitius pungitius</i>	Gasterosteidae
Northern Hogsucker	<i>Hypentelium nigricans</i>	Castostomidae
Northern Pike	<i>Esox lucius</i>	Esocidae
Northern Redbelly dace	<i>Chrosomus eos</i>	Cyprinidae
Pearl Dace	<i>Semotilus margarita</i>	Cyprinidae
Pink Salmon	<i>Oncorhynchus gorbuscha</i>	Salmonidae
Pugnose Shiner	<i>Notropis anogenus</i>	Cyprinidae
Pumpkinseed	<i>Lepomis gibbosus</i>	Centrarchidae
Quillback	<i>Carpoides cyprinus</i>	Cyprinidae
Rainbow Darter	<i>Etheostoma caeruleum</i>	Percidae
Rainbow Smelt	<i>Osmerus mordax</i>	Osmeridae
Rainbow Trout	<i>Salmo gairdneri</i>	Salmonidae
River Chub	<i>Nocomis micropogon</i>	Cyprinidae
Rock Bass	<i>Ambloplites rupestris</i>	Centrarchidae
Rosyface Shiner	<i>Notropis rubellus</i>	Cyprinidae
Round Whitefish	<i>Prosopium cylindraceum</i>	Salmonidae
Sand Shiner	<i>Notropis stramineus</i>	Cyprinidae
Sauger	<i>Stizostedion canadense</i>	Percidae
Sea Lamprey	<i>Petromyzon marinus</i>	Petromyzontidae
Sheepshead (Freshwater Drum)	<i>Aplodinotus grunniens</i>	Sciaenidae

TABLE 2 - Continued

Common Name	Scientific Name	Family Name
Shorthead Redhorse	<i>Moxostoma macrolepidotum</i>	Castostomidae
Silver Chub	<i>Hybopsis storeriana</i>	Cyprinidae
Silver Redhorse	<i>Moxostoma anisurum</i>	Castostomidae
Silvery Minnow	<i>Hybognathus nuchalis</i>	Cyprinidae
Slimy Sculpin	<i>Cottus cognatus</i>	Cottidae
Smallmouth Bass	<i>Micropterus dolomieu</i>	Centrarchidae
Spoonhead Sculpin	<i>Cottus ricei</i>	Cottidae
Splake	<i>Salvelinus fontinalis</i> x <i>S. namaycush</i>	Salmonidae
Spotfin Shiner	<i>Notropis spilopterus</i>	Cyprinidae
Spottail Shiner	<i>Notropis hudsonius</i>	Cyprinidae
Spotted Gar	<i>Lepisosteus oculatus</i>	Lepistosteidae
Spotted Sucker	<i>Minytrema melanops</i>	Castostomidae
Stonecat	<i>Noturus flavus</i>	Ictaluridae
Stoneroller	<i>Campostoma anomalum</i>	Cyprinidae
Tadpole Madtom	<i>Noturus gyrinus</i>	Ictaluridae
Threespine Stickleback	<i>Gasterosteus aculeatus</i>	Gasterosteidae
Trout-perch	<i>Percopsis omiscomaycus</i>	Percopsidae
Walleye	<i>Stizostedion vitreum</i>	Percidae
White Bass	<i>Morone chrysops</i>	Percichthyidae
White Crappie	<i>Pomoxis annularis</i>	Centrarchidae
White Perch	<i>Morone americana</i>	Percichthyidae
White Sucker	<i>Catostomus commersoni</i>	Castostomidae
Yellow Bullhead	<i>Ictalurus natalis</i>	Ictaluridae
Yellow Perch	<i>Perca flavescens</i>	Percidae
Yellow Pickerel (Walleye)	<i>Stizostedion vitreum</i>	Percidae

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5.0 FISH TEMPERATURE DATABASE

5.1 Abbreviations

Size

- TL = total length in millimeters. See Carlander (1977) for definition.
- FL = fork length in millimeters. See Carlander (1977) for definition. A single number or range of numbers in the size column of a database table represents FL in millimeters.
- SL = standard length in millimeters. See Carlander (1977) for definition.

g = weight in grams

in = length in inches

Age

d = day(s)

mo = month(s)

wk = week(s)

yr = year

YOY = young-of-the-year

egg = embryo inside egg envelope (Balon 1984)

free embryo
(yolk-sac

larva) = hatched but uses endogenous food supply - yolk sac (Balon 1984).

embryo = endogenous feeding, not free-swimming

fry = exogenous feeding, free-swimming, rising or risen from nesting site, jerky swimming.

larval = can include fry stage, but usually implies the transition from jerky to fluent free-swimming is complete, beginning of schooling, dispersing from nest site.

juvenile = older YOY; less than or equal to one year old; younger yearlings (aged 1-1.5 year). A sub-adult is a juvenile older than 1.5 years up to the age of first maturity (McCauley and Casselman 1980).

adult = sexually mature

Temperature

Temperature, values in the columns of the database tables are given in degrees celsius unless otherwise indicated as degrees Fahrenheit by F symbol after the number.

Seasons

SP = Spring

Su = Summer

F = Fall

Wi or W = Winter

Day or Night

D = Day

N = Night

SPECIES: Petromyzon marinus (sea lamprey)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	THERMAL TOLERANCES:							Reference	
						log time =		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)		Location
						a	b	Upper	Lower					
egg (64 cell)	18			12									Spotila et al 1979	
egg (64 cell)	18			14									Spotila et al 1979	
egg (64 cell)	18			23									Spotila et al 1979	
egg	18			20									Spotila et al 1979	
				31									Jobling 1981	
prolarva ammocoetes	15120			> 29.5									Carlander 1969	
	5			28.5		17.5642-0.4680	34	29			Great Lakes		Brown 1974	
	15											29.5	Spotila et al 1979	
	25											30	Spotila et al 1979	
												31	Spotila et al 1979	
				31.4									Spotila et al 1979	

SPECIES: Petromyzon marinus (sea lamprey)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
larvae				13.6						Jobling 1981
adult				14.3			10			Talmage and Coutant 1979
	su			6-15						Morman et al 1980
	SP			< 6						Morman et al 1980
ammocoetes	Su			10-26.1				Streams		Morman et al 1980
larvae				15-20				L. Superior tributaries		Morman et al 1980

SPECIES: Petromyzon marinus (sea lamprey)

Size or Age (mm)	Optimum °C	Range	(b) ST Max		No Growth Limits		Location	GROWTH TEMPERATURES:	
			(a) MWAT	Max	Upper	Lower		Reference	
30-90 g; large	15						land locked		Farmer et al 1977
10-30 g; small	20								Farmer et al 1977
									Farmer et al 1977
			20.5	28					This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Petromyzon marinus (sea lamprey)

Event	Season and/or Acclimation Temp	Optimum Temp	(a) Temp Range MWAT		(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Lower	(d) Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
			Temp	MWAT								
spawning migration				>4.4								Scott and Crossman 1973
spawning onset				11.1-11.7								Scott and Crossman 1973
spawning		14.4-15.6		11.1-24.4							hatchery Cayuga L.. N.Y.	Scott and Crossman 1973
hatching (14d)				13.9-18.3								Scott and Crossman 1973
swim-up		18.3										Scott and Crossman 1973
hatching		21.7										Scott and Crossman 1973
metamorphosis		20-21		15.5-21							Lab	Carlander 1969 Cravens 1982
egg incubation	7.5-27	18.5					21.5	16				Beltz et al 1974
spawning		15.5									L. Huron	Manion and Hanson 1980
spawning		14.0		12.8-18.3							Gt. Lakes	Manion and Hanson 1980
spawning		15.7		10-22.8							Gt. Lakes	Manion and Hanson 1980
spawning		18.2		11.1-26.1							Gt. Lakes	Manion and Hanson 1980
spawning				11-25								Morman et al 1980
larval devel		20-21		10-26,1								Morman et al 1980

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning		13-18										Scott and Crossman 1973
hatching (5-8d)		15.6-17.8										Scott and Crossman 1973
spawning			12-15								Wisc.	Carlander 1969
spawning			12-19								Ont.	Carlander 1969
spawning		18.4									Que.	Carlander 1969
				15.5	19							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Lepisosteus oculatus* (spotted gar)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
			>35					Colbert G.S. Tennessee R.	Beltz et al 1974
				15-17				Rondeau Bay, L. Erie	McAllister et al 1985

SPECIES: *Lepisosteus osseus* (longnose gar)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
large				30-31.8				L. Monona, Wisc.	Coutant 1977a
large YOY	Su		34.5	25.3	29			Wabash R., Ind.	Coutant 1977a
adult	su			33.1				Lab	Coutant 1977a
	Su			30-34				J.M. Stuart GS, Ohio R., Ohio	Yoder and Gammon 1976
	F			24-28				J.M. Stuart GS, Ohio R., Ohio	Yoder and Gammon 1976
	W			12-16				J.M. Stuart GS, Ohio R., Ohio	Yoder and Gammon 1976
				33-35				Wabash R., Ind.	Yoder and Gammon 1976
				34				White R., Ind.	Yoder and Gammon 1976

SPECIES: *Lepisosteus osseus* (longnose gar)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
								Reference	
	26.4						Lab	Scott and Crossman	1973

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Amia calva* (bowfin)

													THERMAL TOLERANCES:	
Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	23.8		su									37	Lab	Reutter and Herdendorf 1976

SPECIES: *Amia calva* (bowfin)

										PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference		
				30.5				Lab	Houston 1982		

SPECIES: *Amia calva* (bowfin)

													SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference		
spawning		16-19		17.5	19+							Scott and Crossman 1973 This study		

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Nor incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval **entrainment** temperatures.

SPECIES: *Alosa pseudoharengus* (alewife)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper	Lower	log time =		Data Limits		Exposure Time (Min)	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Incip. Lethal Temp	Incip. Lethal Temp	a	b	Upper	Lower					
egg	12-25			24.5						60			Lab	Jinks et al 1981
larva	14-24			37.1						5				Jinks et al 1981
larva	14-24			36.1						10				Jinks et al 1981
larva	14-24			34.5						30				Jinks et al 1981
larva	14-24			33.4						60				Jinks et al 1981
larva	14-24			31.4						1440				Jinks et al 1981
71-80; YOY	23-25			32.9						60				Jinks et al 1981
71-80; YOY	23-25			32.2						1440				Jinks et al 1981
71-80; YOY	23-25			32.2						5760				Jinks et al 1981
28 47; YOY	10-12			26.5					26.5	150				Otto et al 1976
28 47; YOY	18-20			30.3					30.5	170				Otto et al 1976
28 47; YOY	24-26			32.1					32.0	520				Otto et al 1976
egg	13			28										Jinks et al 1981
juvenile					3									Richkus and Winn 1979
adult	27			28.2					27	14000	31-34		Lab	McCauley and Binkowski 1982
									20	13757				McCauley and Binkowski 1982
									29	8400				McCauley and Binkowski 1982
									30	3441				McCauley and Binkowski 1982
									31	377				McCauley and Binkowski 1982
									32	74				McCauley and Binkowski 1982
									33	37				McCauley and Binkowski 1962
	17.2				7									Spotila et al 1979
adult	10			23.5								28.6		Otto et al 1976
adult	15			23.5								30.6		Otto et al 1976
adult	20			24.5								32.6		Otto et al 1976
YOY	25			32.1								34.4		Otto et al 1976
YOY	10			26.5								26.3		Otto et al 1976
YOY	20			30.3								31.9		Otto et al 1976
adult	21				<6								Lab	Otto et al 1976
adult	5.21				3								Lab (ULILT)	Otto et al 1976

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	THERMAL TOLERANCES:				Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)						
juvenile	17		SU	24.5				31	10		Lab	McCauley 1331
juvenile	17		su					30	57		Lab	McCauley 1981
juvenile	17		su					23	106		Lab	McCauley 1381
juvenile	17		SU					28	1060		Lab	McCauley 1981
juvenile	17		su					27	1880		Lab	McCauley 1981
juvenile	17		su					26	2800		Lab	McCauley 1981
juvenile	17		SU					25	2150		Lab	McCauley 1981
juvenile	9		SU	<23							Lab	McCauley 1981
juvenile	20			24.5							Lab	McCauley 1981
adult	17			8.5							Lab	McCauley 1981
adult	15			7							Lab	McCauley 1981
juvenile			su	5-10							Lab	McCauley 1981
adult			su					5	3600		Lab (L. Ont.)	McCauley 1981
adult			su					6	4980		Lab (L. Ont.)	McCauley 1981
adult			su					7	9480		Lab (L. Ont.)	McCauley 1981
adult			su					8	8100		Lab (L. Ont.)	McCauley 1981
adult			su					9	>12360		Lab (L. Ont.)	McCauley 1981
adult			su					5	1620		Lab (L. Ont.)	McCauley 1981
adult			SU					6	2181		Lab (L. Ont.)	McCauley 1981
adult			Su						2550		Lab (L. Ont.)	McCauley 1981
adult			su					8	1662		Lab (L. Ont.)	McCauley 1981
adult			Su					9	2250		Lab (L. Ont.)	McCauley 1981
adult			su					10	6054		Lab (L. Ont.)	McCauley 1981
adult					2.5						Lab (L. Ont.)	McCauley 1981
adult	20				8							McCauley 1981
adult			W		4							McCauley 1981
	0.6-19.5									25-32		McCauley 1981
	16.9									30.5-31.8		McCauley 1981
adult				31	34							Cravens et al 1983

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Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a b	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
							Upper	Lower				Location	Reference
	23.9-30								33.5	12.5-25		Connecticut Yankee GS	Brown 1974
	23.9-30								28.2	50-100			Brown 1974
YOY	5								17	180			Brown 1974
YOY	5								15	4800	Lab		Brown 1974
YOY	9								26	60	Lab		Brown 1974
YOY	5			15					22.5	40	Lab		Brown 1974
YOY	9			22.6							Lab		Brown 1974
adult	10			> 20					24	180	Lab		Brown 1974
adult	20			<22.8					24	4800	Lab		Brown 1974
adult	20								28	300	Lab		Brown 1974
adult	15			22.8									Brown 1974
adult	28.3			33.3									Brown 1974
			Su	31.4								Maritimes stream	Brown 1974
	20		Su	23.2								Lab	McCauley 1981
	18.2		Su								30.2	Lab	Reutter and Herdendorf 1976

SPECIES: *Alosa pseudoharengus* (alewife)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
			22	18.8				Cayuga L. N.Y.	Coutant 1977a
adult	Sp			21.3	8.0			L. Michigan Lab	Coutant 1977a
			30	27.8-28.3	10				Coutant 1977a
adult	su			17.2		25	48h		Brown 1974
young	su			17-19				L. Michigan	Brown 1974
				11-14				L. Michigan	McCauley 1981
adult	F			11-16				L. Michigan	Talmage and Coutant 1980
				16-21				L. Michigan	Talmage and Coutant 1980
YOY				16-20				L. Michigan	Talmage and Coutant 1980
YOY				24-28				L. Michigan	Wyman 1981
YOY		D		17-20				L. Michigan	Brandt et al 1980b
all sizes					3.0				Brandt et al 1980b
	year		16	8-10	4			L. Michigan	Uziel 1980
subadult	F			12.3-14.5				L. Huron (27-40 m)	Michaud 1981
< 140; adult	F			12.3-16.1				L. Huron (27-42 m)	Argyle 1982
YOY	su			31.3				Lab	Argyle 1982
adult	F			19.6				Lab	Spotila et al 1979
adult	w			12.0		1-3		Lab	Spotila et al 1979
adult	SP			21		7-11		Lab	Otto et al 1976
adult	Su			19		10-11		Lab	Otto et al 1976
adult	su			16		15-18		Lab	Otto et al 1976
adult	F			16		10-12		Lab	Otto et al 1976
adult	F			16		5-9		Lab	Otto et al 1976
adult	w			11		1-4		Lab	Otto et al 1976
YOY	su			25		15-18		Lab (L. Michigan)	Otto et al 1976
YOY	SU			25		24-25		Lab (L. Michigan)	Otto et al 1976
YOY	F			24		10-12		Lab (L. Michigan)	Otto et al 1976
YOY	F			21		5-9		Lab (L. Michigan)	Otto et al 1976
YOY	w			19		1-4		Lab (L. Michigan)	Otto et al 1976
YOY	F	D		19-20				L. Michigan	Crowder et al 1981
YOY	F	N		17-18				L. Michigan	Crowder et al 1981
adult	F	D		11-14				L. Michigan	Crowder et al 1981
adult	F	N		13-16				L. Michigan	Crowder et al 1981

SPECIES: *Alosa pseudoharengus* (alewife)

Size or Age (mm)	Optimum °C	Range	(b) ST		No Growth Limits		Location	GROWTH TEMPERATURES:	
			(a) MWAT	Max	Upper	Lower		Reference	
YOY				34.4-35		2.2-5.6	L. Erie		Brown 1974
age 1.2						2.2-5.6	L a b		Griffiths 1978

(a) MWAT [maximum weekly average temperature for growth] = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth)

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Alosa pseudoharengus* (alewife)

Event	Season and/or Accli- mation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Accli- mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning			6.7	22.2	14.4							Brown 1974
spawning		12.9-13.1									L. Mattamuskeet, N.C.	Brown 1974
spawning		13-16									Wis.	Brown 1974
spawning		13-21									Me.	Brown 1974
spawning		15.6-26.7									Lab	Brown 1974
spawning		17-19									L. Hopateong, N.J.	Brown 1974
embryo devel.		17.8	10-26.7		27.8						Lab	Brown 1974
	23.9-30						35.5					Brown 1974
YOY	16					2.5d	31.2					Brown 1974
entrainment	2-0							18	38			Moore 1979
cold shock	33-34							-23	-24	10		Coutant 1977b
hatching	12.7-29.7	20.8					29.7					Cravens et al 1983
larvae	14-15					24h	31					Cravens et al 1983
spawning		22										Carlander 1969
heat shock	27-28						33.3					Carlander 1969
heat shock	20							+ 18.2			Lab (onshore)	Fahmy and Crippen 1981
heat shock	20							+ 19.0			Lab (tempering)	Fahmy and Crippen 19131
heat shock	20							3	18.6		Lab (offshore)	Fahmy and Crippen 1981
hatching		17.7										Spotila et al 1979
entrainment							30-35				Hudson R. powerplants	Hester 1985
entrainment	14-24									36.1	Hudson R. powerplants	Hester 1985
cold shock	21							6.0	-15.0		Lab	Otto et al 1976

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Dorosoma cepedianum* (gizzard shad)

Size or Age (mm)	Acclimation Temp.	Acclimation Time	Sea-son	THERMAL TOLERANCES:		log time = a + b (temp) a b	Data Limits Upper Lower	Exposure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp							
adult	15.9		Fa							31.7	Lab	Reutter and Herdendorf 1976
	25		su					35.5	7-20			Ellis 1984
	25		su					35	50			Ellis 1984
	25		su					34.5	110			Ellis 1984
under-yearling	25			34-34.5	10.8	47.1163-1.3010	35.6	34.5			Put-in-Bay, Ohio	Brown 1974
	30			36.0	14.5	38.0658-0.9694	38.0	36.5			Put-in-Bay, Ohio	Brown 1974
	35			36.5	20.0	31.5434-0.7710	39.0	37.0			Put-in-Bay, Ohio	Brown 1974
	25					32.1348-0.8698	35.5	35.0			Knoxville, Tenn	Brown 1974
	30					44.1030-0.0547	38.0	36.5			Knoxville, Tenn	Brown 1974
	35					33.2846-0.8176	39.0	36.5			Knoxville, Tenn	Brown 1974
			su	28.5	0-0.5						L. Damadelle, Ark Mississippi R.	Talmage and Coutant 1980 Talmage 1978
juvenile	25							34	300			Wrenn 1976
<133					9							Adams et al 1982
>133					3							Adams et al 1982

SPECIES: *Dorosoma cepedianum* (gizzard shad)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference	
								Location	Reference		
adult	Su			19.0						Lab	Ruetter and Herdendorf 1976
	F			20.5						Lab	Ruetter and Herdendorf 1976
large			30		23.5					Wabash R. Ind.	Coutant 1977a
large				23.0						Norris Res. Tenn.	Coutant 1977a
	su			26-34						Nanticoke GS	Ellis 1984
				10-12						L. Mich	Brown 1974
				> 12						Ottoville Quarry, Ohio	Talmage and Coutant 1980
adult			31		8						Wyman 1981
190	su			26-34						Power plant, Ohio R.	Yoder and Gammon 1976
190	F			10-22						Power plant, Ohio R.	Yoder and Gammon 1976
190	W			4-10						Power plant, Ohio R.	Yoder and Gammon 1976
240	su			28.5-31						Lab	Yoder and Gammon 1976

SPECIES: Dorosoma cepedianum (gizzard **shad**)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits		Location	GROWTH TEMPERATURES:	
					Upper	Lower		Reference	
		29.6-31.0		>37.5		18.3	L. Erie, White R., Wabash R. Ind.	Brown 1974	
	16-18							Brown 1974	
			23.2					Leidy and Jenkins 1977	
								This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature. optimum temp for growth)

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Dorosoma cepedianum (gizzard shad)

Event	Season and/or Accli- mation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Accli- mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
cold shock	W 26	22.2							- 6	Lake Erie	Brown 1974	
heat shock	W						31.7			Sandusky R. Ohio	Brown 1974	
heat shock spawning	W	22					35.7			L. Erie	Brown 1974	
cold shock	W 27								- 18		Carlander 1969	
cold shock	10							0	- 10		Coutant 1977b	
cold shock	15							3.5	- 11.6		Edsall and Yocum 1972	
cold shock	20							7.5	- 13		Edsall and Yocum 1972	
cold shock	25							11	- 14		Edsall and Yocum 1972	
cold shock	30							14.6	- 16.6		Edsall and Yocum 1972	
cold shock	15-20							6-7			Talmage, 1978	
cold shock	W								4	Gt. Lakes power plant	Ellis 1994	
				22		722.2					This study	

(a) MWAT = maximum weekly average temperature during month of peak spawning, less then or equal to optimum. or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Oncorhynchus gorbuscha (pink salmon)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper		Lower		log time - a + b (temp)	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
				Lethal Incip. Temp	Lethal Incip. Temp	Upper	Lower		Upper	Lower				Location	Reference
young				23.9											Scott and Crossman 1973
381; fry	5			21.3		11.1627-0.4215	24	22						Lab, Wash.	Brown 1974
	10			22.5		11.9021-0.3865	26.5	23						Lab, Wash.	Brown 1974
	15			23.1		12.6937-0.4074	27	23.5						Lab, Wash.	Brown 1974
	20			23.9		16.2444-0.4074	27.5	24						Lab, Wash.	Brown 1974
	24			23.9		14.7111-0.4459	27.5	24.5						Lab, Wash.	Brown 1974

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SPECIES: Oncorhynchus gorbuscha (pink salmon)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
young				12 14					Scott and Crossman 1973
small				11.7				Lab	Coulant 1977a
newly emerged				11.7-12.8				Lab	Coulant 1977a
50 days				9.3				Lab	Coutant 1977a
				11.7				Lab	Jobling 1961
\$36 weeks				10				Lab; L. Superior fish	Cravens et al 1983

SPECIES: Oncorhynchus gorbuscha (pink salmon)

Size or Age (mm)	Optimum °C	(b)				GROWTH TEMPERATURES:		
		Range	(a) YWAT	ST Max	No Growth limits Upper Lower	acotion	Reference	
15.5		18.3	21.7					Jobling 1981 This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Oncorhynchus gorbuscha (pink salmon)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Man for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
								(d) Lethal Limit Lower	Median Lethal AT	Median Lethal Final			
spawning		10	116		> 7 15								Scott and Crossman 1973 Cravens et al 1983 This study

(a) MWAT - maximum weekly average temperature during **month** of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning,

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment **temperatures**.

SPECIES: Oncorhynchus kisutch (coho salmon)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance Time (Min)	THERMAL TOLERANCES:		Reference	
						a	b					Critical Thermal (Max)	Location		
fry				25.1									Lab	Scott and Crossman 1973	
478; fry	5			22.9	0.2	21.3050-0.7970		24	23	24	150		Lab, B.C.	Brown 1974	
478; fry	10			23.7	1.7	19.5721-0.6820		26	24.5	26	90		Lab, B.C.	Brown 1974	
478; fry	15			24.3	3.5	20.4066-0.6858		27	24.5	26.5	155		Lab, B.C.	Brown 1974	
478; fry	20			25	4.5	20.4022-0.6713		27.5	25.5	26.5	90		Lab, B.C.	Brown 1974	
478; fry	23			25	6.4	18.9736-0.6013		27.5	25	27	500		Lab, B.C.	Brown 1974	
fingerling	2.6				-0.1							26.5	Lab	Brown 1974	
	4.8				-0.1									Houston 1982	
adult	17			25										Houston 1982	
90-130; juvenile	5												25.3	Lab (18C/h)	Becker and Genoway 1979
90-130; juvenile	10												30.1	Lab (18C/h)	Becker and Genoway 1979
90-130; juvenile	15												28.7	Lab (18C/h)	Becker and Genoway 1979
90-130; juvenile	20												35.1	Lab (18C/h)	Becker and Genoway 1979
90-130; juvenile5													27.7	Lab (18C/h)	Becker and Genoway 1979
90-130; juvenile	15												29.6	Lab (18C/h)	Becker and Genoway 1979
	12			21									Lab	Cherry et al 1982	

SPECIES: Oncorhynchus kisutch (coho salmon)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
adult	SP			12-14						Scott and Crossman 1973
adult				11.4					Lab	Coutant 1977a
				16.6					L. Michigan	Coutant 1977a
				15/13						Jobling 1981
				20					Lab	Brown 1974
				>23.9					Granby Res., Colo.	Brown 1974
				17	8/12-16	3			Point Beach, L. Michigan	Michaud 1981
					15.6				Lab	Cherry et al 1982
				21	14.3	6		12	Lab	Cherry et al 1982
				21	16.6	12		18	Lab	Cherry et al 1982

SPECIES: *Oncorhynchus kisutch* (coho salmon)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			M	W A T				ST Max	Reference
14.8				18			Lab		Jobling 1981 EPA 1974
		14-17					Field in late summer		Brown 1974
17				24			Lab		Brown 1974
					<10		L. Michigan		Brown 1974

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Oncorhynchus kisutch* (coho salmon)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	lab MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference	
													hatching (38d)
hatching (48d)		8.9											Scott and Crossman 1973
heat shock	10			10	13	3 min			> + 10		Calif. Calif. Lab (physiological stress)	Spotila et al 1979 EPA 1974	
spawning													
migration		<10	4.4-11.1								Sand Ck., Oregon	Brown 1974	
spawning			4.4-7.7								Columbia R.,	Brown 1974	
cold shock 5									-4.5		Lab	Edsall and Yocum 1972	
cold shock 10									-8		Lab	Edsall and Yocum 1972	
cold shock 15									-12.5		Lab	Edsall and Yocum 1972	
cold shock 20									-15		Lab	Edsall and Yocum 1972	

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to Optimum, or middle of range of spawning temperatures

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1948).

(d) Simulated larval entrainment temperatures.

											THERMAL TOLERANCES:			
Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a + b(\text{temp})}{a - b}$		Data Upper	Limits Lower	Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	Reference
young				24.4 24.8										Scott and Crossman 1973 Jobling 1981
449g; juvenile	5			22.2	0	17.7887-0.6623	24	22.5					Lab, Wash.	Brown 1974
449g; juvenile	10			23.4	3.1	14.7319-0.4988	26.5	23.5					Lab, Wash.	Brown 1974
449g; juvenile	15			24.4	4.1	15.8799-0.5210	27.5	24.5					Lab, Wash.	Brown 1974
449g; juvenile	20			24.8	4.7	19.3821-0.6378	27.5	24.5					Lab, Wash.	Brown 1974
449g; juvenile	23			24.8	6.7	20.0020-0.6496	26.5	24.5					Lab, Wash.	Brown 1974

SPECIES: *Oncorhynchus nerka* (kokanee salmon)

											PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference	
adult young				10-15 12-14 10 10.6-12.8							Scott and Crossman 1973 Scott and Crossman 1973 Carlander 1969	
small			21	14.5						Horsetooth Res., Colo. Okanagan R., Wash. Lab	Coutant 1977a Coutant 1977a Coutant 1977a	

SPECIES: *Oncorhynchus nerka* (kokanee salmon)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		Location	GROWTH TEMPERATURES:	
			MWAT	ST Max	No Growth Upper	Limits Lower		Reference	
juvenile	15	5-15	18.3	23	24	<3		Jobling 1981 Magnuson et al 1979 Cravens et al 1983 This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Oncorhynchus nerka* (kokanee salmon)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c)				Location	Reference
							Lethal Limit Upper	Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final		
spawning			5-10.5									Scott and Crossman 1973
hatching (140d)	4									Lab		Scott and Crossman 1973
(48d)	15									Lab		Scott and Crossman 1973
(70-824) spawning			13-5.1 7-12							Lab; decreasing temp. Calif		Scott and Crossman 1973 Carlander 1969
egg dev.				8.5	12		15.5 13.5	5.1		Lab		Carlander 1969 Beltz et al 1974 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES Oncorhynchus tshawytscha (chinook salmon)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:		log time = a + b (temp)		Upper	Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	a	b							
				25.1										
444; fry	5			21.5		9.3155-0.3107	25	22.5					Lab, Wash.	Scott and Crossman 1973
444; fry	10			24.3	0.8	16.4595-0.5575	26.5	24.5					Lab, Wash.	Brown 1974
444; fry	15			25	2.5	16.4454-0.5364	27	25.5					Lab, Wash.	Brown 1974
444; fry	20			25.1	4.5	22.9065-0.7611	27.5	25					Lab, Wash.	Brown 1974
444; fry	24			25.1	7.4	18.9940-0.5992	27.5	25					Lab, Wash.	Brown 1974
1-2 yr	17			22								25.1	Lab (UUILT)	Spotila et al 1979
adult	18-19			21-22										Houston 1982

SPECIES: Oncorhynchus tshawytscha (chinook salmon)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
small				12-14						Scott and Crossman 1973
adult				11.7					Lab	Coutant 1977a
			23.3	17.3					L. Michigan	Coutant 1977a
									Thermal discharge	Spigarelli and Smith 1976
									L. Michigan	
									(max. body temp)	

SPECIES: *Oncorhynchus tshawytscha* [chinook salmon]

Size or Age (mm)	Optimum °C	Range	(a)		(b)		Location	GROWTH TEMPERATURES:	
			MWAT	Max	No Growth Upper	Limits Lower		Reference	Reference
fingerling	15.5						Lab Lab		Jobling 1981 Cravens et al 1983 Beltz et al 1974 This study
	<12 14.4		18.7	20					

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature-optimum temp for growth),

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Oncorhynchus tshawytscha* (chinook salmon)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c)				Location	Reference
							Lethal Limit Upper	lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final		
cold shock	7							0	- 6		Lab	Edsall and Yocum 1972
cold shock	10								- 9		Lab	Edsall and Yocum 1972
cold shock	15								-12.5		Lab	Edsall and Yocum 1972
cold shock	20								- 15		Lab	Edsall and Yocum 1972
egg dev.		11.1			10			14.9	5.1		Lab	Cravens et al 1983 Beltz et al 1977

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (19461).

(d) Simulated larval entrainment temperatures.

SPECIES: *Salmo gairdneri* (rainbow trout)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $a + b \frac{(\text{temp})}{h}$	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:		
							Upper	Lower				Location	Reference	
fingerling	11			24								Lab (Kamloops trout)	Scott and Crossman 1973	
adult	6.3		F								>17.5	Lab	Reutter and Herdendorf 1976	
50-100 FL; young	12-24			25 26.5 26 26.3								Lab	Cherry et al 1977 Jobling 1981 Jobling 1981 Jobling 1981	
								30 28	0.55 2			Lab (loss of equilibrium) Lab (loss of equilibrium)	Spotila et al 1979 Spotila et al 1979	
yearling	20					14.6405-0.4470	29	27				Lab (L. Superior, softwater)	Brown 1974	
yearling	20					15.0392-0.4561	29	27				Lab (L. Superior, hardwater)	Brown 1974	
yearling	20					15.1473-0.4683	29	27				Lab (L. Superior, softwater)	Brown 1974	
yearling	20					12.8718-0.3837	29	27				Lab (L. Superior, hardwater)	Brown 1974	
80-130; young				23.3-25.6									26.7	Brown 1974
37-92 TL; juvenile	15			25-26								Great Lakes	Brown 1974	
adult	16-19			21-22								Lab	Brown 1974	
fingerling	5			23.7										Houston 1982
fingerling	9			24.2										Houston 1982
fingerling	13			25.2										Houston 1982
fingerling	17			25.7										Houston 1982
fingerling	21			26.2										Houston 1982
fingerling	24.5			26.2							26.2			Houston 1982
fingerling	16			25.6										Houston 1982
juvenile				25.7										Houston 1982
150-200 FL;	10										28.5	Lab mean 24-h (TL50)	Hokanson et al 1977	
150-200 FL:	20										29.4	Lab (Arizona; 0.02 C/min)	Lee and Rinne 1980	
												Lab (Arizona; 0.02 C/min)	Lee and Rinne 1980	

SPECIES: Salmo gairdneri (rainbow trout)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
fry, fingerlings				13-15 121		10.6/12.7		Lab	Talmage and Coutant 1980
adult red fingerlings				18.9-21.7				Horsetooth Res., Colo.	Talmage and Coutant 1980 Coutant 1977a
starved fingerlings		D/N		22				Lab	Coutant 1977a
fingerlings		D/N		18				Lab	Coutant 1977a
fingerlings			22	18-19	14			Lab	Coutant 1977a
adult				13				Lab	Coutant 1977a
adult				16.5				L. Michigan	Coutant 1977a
			19	18	13			Lab	Coutant 1977a
50-100 FL; young			18	14.1	6	12		Lab (rising water temp.)	Cherry et al 1977
50-100 FL; young			21	17.1	9	15		Lab (rising water temp.)	Cherry et al 1977
W-100 FL; young			21	18.6	12	18		Lab (rising water temp.)	Cherry et al 1977
50-100 FL; young			27	20.2	12	21		Lab (rising water temp.)	Cherry et al 1977
50-100 FL; young			26	22.2	15	24		Lab (rising water temp.)	Cherry et al 1977
50-100 FL; young				19.2				Lab (rising water temp.)	Cherry et al 1977
				16					Jobling 1981
adult				11.3					Jobling 1981
				14					Jobling 1981
				15.8		10		Lab	Spotila et al 1979
				17.5		15		Lab	Spotila et al 1979
				22		20		Lab	Spotila et al 1979
				11.6		6		Lab	Spotila et al 1979
				12.6		9		Lab	Spotila et al 1979
				S-17				Lab	Brown 1974
			23.5					Thermal discharge L. Michigan (max body temp)	Spigarelli and Smith 1976
150-250g; yearlings				16.7				Lab	McCauley and Huggins 1976
small; <1kg			23-24	19				Point Beach NGS discharge L. Michigan	Spigarelli and Thommes 1979
large; >2.5kg			20-21	15				Point Beach NGS discharge L. Michigan	Spigarelli and Thommes 1979
1-2.5 kg			22	19				Pt. Beach NGS, L. Mich.	Spigarelli and Thommes 1979
< 6 months				17-21					Kwain and McCauley 1978
>1 year				13					Kwain and McCauley 1978
<6 months				17-19				Lab	Kwain and McCauley 1978
7-11 months				14-16.8				Lab	Kwain and McCauley 1978
1 year				11.4-12.7				Lab	Kwain and McCauley 1978

SPECIES: *Salmo gairdneri* (rainbow trout)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			M W A T	ST M a x				Reference	
juvenile	17.2							Jobling, 1981	
	16.5							Jobling, 1981	
	17							Jobling, 1981	
	12							Spotila et al 1979	
fingerling	16.8		19	24				McCauley and Casselman 1980	
juvenile	12.8				>20	<10		EPA 1974	
	17-18.6				24	8	Lab	Brown 1974	
			17	23	22			Hokanson et al 1977	
								Hokanson et al 1977	

SPECIES: *Salmo gairdneri* (rainbow trout)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning			10-15.5									Scott and Crossman 1973
hatching (18-101d)		7-10	3.2-15.5		<15		>15	3				Spotila et al 1979
heat shock	15						>29		+ 14		Lab	Crippen and Fahmy 1981
heat shock	9.7								+ 19.5		Lab (onshore discharge)	Crippen and Fahmy 1981(d)
heat shock	9.7								+ 20.6		Lab (tempering discharge)	Crippen and Fahmy 1981(d)
heat shock	9.7								+18.7		Lab (offshore discharge)	Crippen and Fahmy 1981(d)
spawning		6-8	0.3-10	9	13						Bothwells Ck, Ont.	EPA 1974
spawning			5.5-13								Finger Lakes, N.Y.	Brown 1974
egg dev.		5-7										Brown 1974
egg dev.		5-6-12.2	1.7-16.1									Brown 1974
larval dev.		12.8-18.9										Brown 1974
heat shock	12.2								+11.1		Lab	Brown 1974
heat shock	10								+ 19	29	Lab (simulated entrainment)	Moore 1979
heat shock	6						24-30				Lab	Cravens et al 1983
heat shock (egg)	10						36				Lab	Thorgaard et al 1981

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Salmo trutta* (brown trout)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a -t b (temp) a b	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
							Upper	Lower				Location	Reference
50-100FL; young	12-24			23								Lab	Cherry et al 1977
adult	14-18			26.4									Jobling 1981
adult	26									25		Lab (death point)	Spotila et al 1979
fry	5-6									26		Lab (death point)	Spotila et al 1979
fry	20									22.5		Lab (death point)	Spotila et al 1979
newly hatched fry	6			22		12.7756-0.4010	28	20		23		Lab; England	Spotila et al 1979
				24.7									Brown 1974
	23			25.3								Lab	Brown 1974
									26.8	1440		N.Y. (limiting temp)	Brown 1974
									27.8	720		Lab	Brown 1974
150-200TL;	10											Lab (Arizona; 0.02 c/min)	Lee and Rinne 1980
	20											Lab (Arizona; 0.02 c/min)	Lee and Rinne 1980

SPECIES: *Salmo trutta* (brown trout)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
				18.3-23.9						Scott and Crossman 1973
				12						Coutant 1977a
			20						L. Oredon, France	Coutant 1977a
young				17.6					Lab	Coutant 1977a
adult				13.8					L. Michigan	Coutant 1977a
50-100FL; young			15	11.7	6	12			Lab (rising water temps)	Cherry et al 1977
50-100FL; young			18	15.5	9	15			Lab (rising water temps)	Cherry et al 1977
50-100FL; young			21	17.9	12	18			Lab (rising water temps)	Cherry et al 1977
50-100FL; young			24	18.8	15	21			Lab (rising water temps)	Cherry et al 1977
50-100FL; young			25	18.5	17	23			Lab (rising water temps)	Cherry et al 1977
50-100FL; young				17.4					Lab (rising water temps)	Cherry et al 1977
				12.2						Jobling 1981
				12.4-17.6						Spotila et al 1979
44g; small				19.9					L. Michigan thermal discharge	Brown 1974
30009; large				16.9					L. Michigan thermal discharge	Brown 1974
			21.3						L. Michigan thermal discharge (max body temp)	Spigarelli and Smith 1976
				12-16					L. Michigan thermal discharge	Harrelson et al 1984

SPECIES: Salmo trutta (brown trout)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		Location	GROWTH TEMPERATURES:	
			M	W A T	ST	Max		No Growth Upper	Limits Lower
juvenile	10	7-19	19.1	21	<29.1	5		Jobling 1981	
	15.5							Jobling 1981	
	12							Jobling 1981	
	12.8							Jobling 1981	
	12.6							McCauley and Casselman 1980	
								Brown 1974	
								Brown 1974	
								This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

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SPECIES: Salmo trutta (brown trout)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST for Embryo Survival	Max	Acclimation Time	(c) Lethal Upper	(c) Lethal Lower		(d) Median Lethal Final	Location	Reference
									Limit	Limit			
spawning			6.7-8.9									S.E. Ontario	Scott and Crossman 1973
incubation (34-148d)			1.9-11.2	12.8				27				Lab	Brown 1974 Brown 1974
embryo spawning			4-11	7.5	11.2			15				streams SW Ontario	Cravens et al 1983 Witzel and MacCrimmon 1983 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Salvelinus fontinalis* (brook trout)

												THERMAL TOLERANCES:				
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip.	Lower Incip.	log time =		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference		
				Lethal Temp	Lethal Temp	a	b	Upper	Lower							
50-100FL; young	12-24			24									Lab	Cherry et al 1977		
				25.3											Jobling 1981	
					20.1										Jobling 1981	
	2-25g; yearling	3			23.5		13.4325-0.4556	26	23.5	26	40		Lab, Ontario	Brown 1974		
	2-25g; yearling	11			24.6		14.6256-0.4728	28	25				Lab, Ontario	Brown 1974		
	2-25g; yearling	15			25		15.1846-0.4833	28.5	25.5	27.5	30		Lab, Ontario	Brown 1974		
	2-25; yearling	20			25.3		15.0331-0.4661	29	25.5				Lab, Ontario	Brown 1974		
	2-25g; yearling	22			25.5		17.1967-0.5367	29	26.5				Lab, Ontario	Brown 1974		
	2-25g; yearling	24			25.5		17.8467-0.5507	30	25.5	28.5	40		Lab, Ontario	Brown 1974		
	2-25g; yearling	25			25.5		17.8467-0.5567	29	26				Lab, Ontario	Brown 1974		
	eggs newly hatched	12			12.7									Lab, Ontario	Brown 1974	
	swim-up				20.4										Lab, Ontario	Brown 1974
	larvae juvenile	13			24.3								24.5	Lab, Ontario	Brown 1974	
					20.1									25.3	Lab, (UUILT ₅₀)	Brown 1974
					24											Lab
	24.9														Lab	Houston 1982
	16			25.8									Lab	Houston 1982		
150-200FL;	10											28.7	Lab (Arizona; 0.02 c/m)	Lee and Rinne 1980		
150-200FL;	20											29.8	Lab (Arizona; 0.02 c/m)	Lee and Rinne 1980		

SPECIES: *Salvelinus fontinalis* (brook trout)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
	Su			<20					Scott and Crossman 1973
				19				field	Coutant 1977a
				20.3				Moosehead L., Me.	Coutant 1977a
				20				Redrock L., Ontario	Coutant 1977a
			20					field	Coutant 1977a
adult				15.7				S. Ont. streams	Coutant 1977a
adult				14.8				L. Michigan	Coutant 1977a
small				16				Lab	Coutant 1977a
small	F		20	16				Lab	Coutant 1977a
small	w			8-12				Lab	Coutant 1977a
small				18				Lab (fed)	Coutant 1977a
			20	18	14			Lab	Coutant 1977a
small				16				Lab (starved)	Coutant 1977a
young				16				Lab	Coutant 1977a
50-100FL;			15	13.7	6	12		Lab (rising water temps)	Cherry et al 1977
young									
50-100FL;			18	15.2	9	15		Lab (rising water temps)	Cherry et al 1977
young									
50-100FL;			21	17.2	15	18		Lab (rising water temps)	Cherry et al 1977
young									
50-100FL;			24	18.3	15	21		Lab (rising water temps)	Cherry et al 1977
young									
50-100FL;			26	19.0	18	24		Lab (rising water temps)	Cherry et al 1977
young									
50-100FL;				15.5				Lab (rising water temps)	Cherry et al 1977
young									
				14					Jobling 1981
fry				10		4		Lab	Brown 1974
			21		7			Lakes N.S.	Brown 1974
fry				9-1		10.6-12.7		Lab	Talmage and Coutant 1980
fingerlings				17.5		12.1		Lab	Talmage and Coutant 1980

SPECIES: Salvelinus fontinalis (brook trout)

Size or Age (mm)	Optimum °C	(a) Range	(b) ST		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			MWAT	Max				Reference	
13								Jobling 1981	
14								Jobling 1981	
16.1			19	23				Jobling 1981	
15.4	9.8-17.9				>20	8	Lab	EPA 1974	
IO-IS								Brown 1974	
								Brown 1974	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature-optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Salvelinus fontinalis (brook trout)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST		(c) Lethal Upper	(c) Lethal Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
					Max for Embryo Survival	Acclimation Time						
hatching (50-100d)			10-5									Scott and Crossman 1973
eggs				9	13			11.7				Scott and Crossman 1973
spawning		10.7									Minn.	EPA 1974
spawning incubation (15-28d)			2.2-11.7								Lab	Brown 1974
hatching		6			14.8			18				Brown 1974
spawning			4-13								SW Ont. streams	Witzel and MacCrimmon 1983

(a) MWAT-c maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Salvelinus namaycush (lake trout)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:										Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	
						Upper	Lower							
27.7/82.8g; a 1-2 yr				25.1		14.4820-0.5	142	26	23				Hatcheries, Ont.	Spotila et al 1979 Brown 1974
	15			22.7		14.5123-0.4866	27	24					Hatcheries, Ont.	Brown 1974
	20			23.5		17.3684-0.5818	27	24					Hatcheries, Ont.	Brown 1974

SPECIES: Salvelinus namaycush (lake trout)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
59 yearling young adult YOY 1-2 yrs juvenile fry fingerlings adult YOY	SU			10						Scott and Crossman 1973
				14					White L., Ont.	Coutant 1977a
			13						Moosehead, L., Me.	Coutant 1977a
			11						Lac La Ronge, Sask.	Coutant 1977a
					10				Louisa and Redrock L., Ontario	Coutant 1977a
					15.5				Cayuga L., N.Y.	Coutant 1977a
			15		11.7				Lab	Coutant 1977a
			14		11.5				Lab	Coutant 1977a
					11.8				L. Michigan	Coutant 1977a
					12		5.6			L. Superior
			17.2		3.9			L. Superior	Brown 1974	
			11.7					L. Superior	Brown 1974	
				7.2-12.1				L. Michigan	Brown 1974	
			15.5		a			field	Brown 1974	
			18.2					L. Ontario	Brown 1974	
			>14		<1			Point Beach, L. Michigan	Michaud 1981	
				9-11.5		10.6-12.7		Lab	Talmage and Coutant 1980	
					4		1-17	L. Michigan	Cravens et al 1983	
			14					L. Superior	Peck 1982	
			15		7-14					

SPECIES: *Salvelinus namaycush* (lake trout)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Limits		Location	GROWTH TEMPERATURES:	
			(a) M W A T	S T M a x	Upper	Lower		Reference	
yearling	11.7								Leidy and Jenkins 1977
1-2 yrs	16.5	4-18	19.4	21.5			Lake Louisa, Ont.; Cayuga L., N.Y.		Leidy and Jenkins 1977 Leidy and Jenkins 1977 This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Salvelinus namaycush* (lake trout)

Event	Season and/or Accli- mation Temp	Optimum Temp	Temp Range	(a) M W A T	(b) S T Max for Embryo Survival	Accli- mation Time	(c)				Location	Reference
							Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ST	(d) Median Lethal Final		
spawning			8.9-13.9									Scott and Crossman 1973
incubation (15-21 wk)			0.3-1.0								Algonquin Pk., Ontario	Scott and Crossman 1973
heat shock spawning	8.8		11-14	a.9			14.8		+ 6		Lab L. Simcoe, Ontario	Wyman 1981 Brown 1974 Brown 1974
incubation (50-162d)			1.8-10		<10						Lab	Brown 1974 Brown 1974
spawning			7.1-14.4								L. Simcoe, Ontario	MacLean et al 1981
spawning			5.5-10								L. Simcoe, Ontario	MacLean et al 1981 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Salvelinus fontinalis* x *S. namaycush* (splake)

											THERMAL TOLERANCES:		
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a t b (temp) a b		Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	5			23.5-25.5								Lab	Crippen and Fahmy 1981
	10			25.5-26.7									
	20.8			27.5-28.7									
juvenile	10			23.5-24		13.2634-0.4381	26.5	24				Lab, Ontario	Brown 1974
	15					16.9596-0.5540	28	24.5				Lab, Ontario	Brown 1974
	20			24-24.5		19.4449-0.6342	28	24.5				Lab, Ontario	Brown 1974

SPECIES: *Salvelinus fontinalis* x *S. namaycush* (splake)

											PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference	
young fry				13.1 12	9-11.5			10.6-12.7		Jack and Sproule L., Ont. Lab Lab	Coutant 1977a Coutant 1977a Talmage and Coutant 1980	

SPECIES: *Salvelinus fontinalis* x *S. namaycush* (splake)

											SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median ΔT	(d) Median Lethal Final	Location	Reference
heat shock	3								20.5		Lab (onshore discharge)	Crippen and Fahmy 1981 (d)
heat shock	3								22.1		Lab (tempering discharge)	Crippen and Fahmy 1981 (d)
heat shock	3								22.4		Lab (offshore discharge)	Crippen and Fahmy 1981 (d)
hatching	8.8						14.8		+6		Lab	Wyman 1981
eggs spawning		7.8							+10		Lab (fall spawned)	Griffiths 1978
eggs									+7.8		Lab (+ ambient; TL50)	Griffiths 1980

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Coregonus artedii (cisco, lake herring)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Limits Upper Lower	Location	GROWTH TEMPERATURES:	
			(a) M W A T	ST M a x			Reference	
	18.1		17	25			Jobling 1981 EPA 1974	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature optimum temp for growth),

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Coregonus artedii (cisco, lake herring)

Event	Season and/or Accli- mation Temp	Optimum Temp	Temp Range	(a) M W A T	(b) ST Max for Embryo Survival	Accli- mation Time	(c)				Location	Reference
							Lethal Limit Upper	Lethal Limit L o w e r	Median Lethal ΔT	(d) Median Lethal Final		
spawning		3.3	3.3-5								Wisc. Lab	Scott and Crossman 1973
incubation (92d)		5.6										Scott and Crossman 1973
incubation			0.5-5.6								Lab	Scott and Crossman 1973
spawning			1.0-5.0								Great Lakes	Carlander 1969
incubation (111-125d)			2.4-3.3								L. Mendota, Wisc.	Carlander 1969
spawning		<3.8										Spotila et al 1979
larval devel.		5.6	2-8									Spotila et al 1979
				3	≤7 8							Spotila et al 1979
incubation		6									Lab	EPA 1974
cold shock 7									- 6			Cravens 1981
cold shock 10									- 7			
cold shock 15									- 12			
cold shock 20									-15.5			

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures,

SPECIES: Coregonus hoyi (bloater)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits		Expo- sure Temp	R e s i s - tance Critical Time Thermal		Location	Reference
						a	b	Upper	Lower		(Min)	(Max)		
60; age 1	5			22.2		15.8243-0.5831	26	22					Lab, L. Michigan	Brown 1974
60; age 1	10			23.6		9.0700-0.2896	30	23					Lab, L. Michigan	Brown 1974
60; age 1	15			24.8		17.1908-0.5707	28	24.5					Lab, L. Michigan	Brown 1974
60; age 1	20			26.2		28.6392-0.9458	29	25.5					Lab, L. Michigan	Brown 1974
60; age 1	25			26.7		21.351 I-0.6594	30	26.5					Lab, L. Michigan	Brown 1974
60; age 1	8										27		Lab, (death point)	Brown 1974
60; age 1	20										28		Lab, (death point)	Brown 1974
60; age 1	25										29		Lab, (death point)	Brown 1974
age 3	8			26-27									Lab	Brown 1974

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SPECIES: Coregonus hoyi (bloater)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
larval			4.8					L. Michigan		Scott and Crossman 1973
			>11.4	3.8-7	>1.5			L. Michigan		Carlander 1969
large	su		10		6			L. Michigan		Coutant 1977a
			16		5			L. Michigan		Cravens et al 1983
80-140 FL: juvenile	SU			11-14				L. Michigan		Crowder and Crawford 1984
150-200 FL: adult	su			7-10				L. Michigan		Crowder and Crawford 1984
YOY	F	D		22				L. Michigan		Crowder and Crawford 1984
YOY	F	N		7-18				L. Michigan		Crowder and Crawford 1984
larval				4.7				Gt. Lakes (90-110m)		McAllister et al 1985

SPECIES: Coregonus hoyi (bloater)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range (a)	MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
larval dev.		<4.7									L. Michigan	Carlander 1969

SPECIES: Coregonus kiyi (kiyi)

PREFERRED TEMPERATURES:											
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference
				3.7-4.6							Carlander 1969

SPECIES: Coregonus kiyi (kiyi)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range (a)	MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning			1.7-3.4								Great Lakes	Scott and Crossman 1973

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Coregonus reighardi* (shortnose cisco)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	(a) Temp Range MWAT		(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal		Reference
										Final	Location	
spawning			3.8-4.7								L. Michigan	Scott and Crossman 1973

SPECIES: *Coregonus clupeaformis* (lake whitefish)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Upper	Limits Lower	Exposure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
						a	b							
YOY				26.6										Jobling 1981
YOY	5			20.6										Spotila et al 1979
YOY	10			22.7										Spotila et al 1979
YOY	15			25.8										Spotila et al 1979
YOY	20			26.6										Spotila et al 1979
YOY	22.5			26.6										Spotila et al 1979
YOY	17									27.2	65		Lab (L. Michigan)	Edsall and Yocum 1972
YOY	17									29.4	7		Lab (L. Michigan)	Edsall and Yocum 1972
YOY	17									31.7	0.8		Lab (L. Michigan)	Edsall and Yocum 1972
YOY	17									33.7	0.1		Lab (L. Michigan)	Edsall and Yocum 1972

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Coregonus clupeaformis (lake whitefish)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
small; 2 yrs juvenile larvae				12.7 17				Lab South Bay, Lake Huron Ontario	Coutant 1977a Coutant 1977a
12.9; larvae				12-16				Lab	Coutant 1977a
17.8; larvae			17	13.5	12			Lab	Coutant 1977a
23.1; larvae			19	15.5	14.5			Lab	Coutant 1977a
4.2-7.2g; fingerling				11.9				Moosehead L., Me. Lab	Coutant 1977a Spotila et al 1979
1.1-1.7g; young larval				10				Lab	Spotila et al 1979
YOY larval				17				L. Erie, L. Ontario (surface water temp)	Brown 1974
larval	Sp		14 12	4	8 0			Atikokan GS, (preop.) Point Beach, L. Michigan L. Michigan	Haymes 1984 Michaud 1981 Cravens et al 1983
adult larval	SP			<9		0-13		L. Opeongo, Ontario	Ihssen et al 1981
larval	SP			6.9-9.5				L. Simcoe, Ontario	Ihssen et al 1981
larval	SP			3.5-15				Bay of Quinte, L. Ontario	Ihssen et al 1981
larval	SP			4-12				South Bay, L. Huron	Ihssen et al 1981
larval	SP			4.5-9					

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SPECIES: Coregonus clupeaformis (lake whitefish)

Size or Age (mm)	Optimum °C	Range	(a) M W A T		ST Max	(b) No Growth Limits		Location	GROWTH TEMPERATURES:	
			Upper	Lower		Upper	Lower		Reference	
	13.5									Jobling 1981
	16.8									Jobling 1981
							<10			Brown 1974

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range (a)	MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning			≤ 7.8								L. Erie	Scott and Crossman 1973
incubation		0.5	0.5-6.1				10				Lab	Scott and Crossman 1973
spawning			≤ 10								Bay of Quinte, L. Ont.	Carlander 1969
spawning			0.5-4.5									Carlander 1969
larval devel.		0.5									Heming L. field	Carlander 1969
incubation (120-140d)			0.5-1.7									Carlander 1969
incubation (40-141d)			0.5-8				10	0			Lab	Carlander 1969
spawning		85.5										Spotila et al 1979
hatching		0.5					> 10					Spotila et al 1979
					< 6.1							Spotila et al 1979
incubation		4-7.8	3.2-8.1									Spotila et al 1979
hatching (42d)		10										Spotila et al 1979
hatching (182d)		0.5										Spotila et al 1979
incubation	0.5-10						≤ 8					Wyman 1981
spawning		< 6.1	0.5-9.4									Brown 1974
hatching			4.6-6.9								L. Erie	Brown 1974
heat shock YOY	18						29 +		> + 11			Brown 1974
spawning		4									Lakes Nathalie + Helene; James Bay	Talmage and Coutant 1979
larval devel.		4-6									Lab	Griffiths 1979
spawning		4-7									L. Opeongo, Ont.	Ihssen et al 1981
spawning		3-6									L. Simcoe, Ont.	Ihssen et al 1981
spawning		6-8									Bay of Quinte, L. Ont.	Ihssen et al 1981
spawning		4-8									South Bay, L. Huron	Ihssen et al 1981
incubation (167d)			1-7								South Bay, L. Huron	Ihssen et al 1981
incubation (160d)			1-12								Bay of Quinte., L. Ont.	Ihssen et al 1981
hatching			4-12								Bay of Quinte., L. Ont.	Ihssen et al 1981
hatching			4-7								South Bay, L. Huron	Ihssen et al 1981
heat shock (fry)	17.1								+ 11		L. Michigan (Lab)	Edsall and Yocum 1972

SPECIES: *Osmerus mordax* (rainbow smelt)

													THERMAL TOLERANCES:	
Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	Upper	Lower	log time =		Data Limits		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	Reference
				Incip. Lethal Temp	Incip. Lethal Temp	a	b	Upper	Lower					
	<10		W	19										Ellis 1984
	<6			>24										Ellis 1984
	15											28.5		Ellis 1984
	6									22	51			Ellis 1984
	5.3-6.2		SP							21	736		Lab (April 13)	Ellis 1984
										23	12			McCauley 1981
										22	51			McCauley 1981
										21	736			McCauley 1981
	5.7-6.2		SP							20	1630		Lab (April 20)	McCauley 1981
										24	13			McCauley 1981
										23	30			McCauley 1981
										22	88			McCauley 1981
										27	854			McCauley 1981
150-210:	6		SP									24.9	Lab	Reutter and Herdendorf 1976
adult	10.2-15			21.5-28.5									Lab	Brown 1974
	17				8.5									Houston 1982
			W	19						37	<1			Teleki 1976
adult			SP	18.9										McCauley 1981
	1.0		SP									22.6		McCauley 1981
	1.6		SP									22.8		McCauley 1981
	3.1		Sp									23.3		McCauley 1981
	5.4		SP									24.1		McCauley 1981
	6.5		SP									20.1		McCauley 1981
	8.2		SP									25.1		McCauley 1981
	12.2		Sp									26.4		McCauley 1981

SPECIES: *Osmerus mordax* (rainbow smelt)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
			14	6.6-8.3	6			Cayuga L., N.Y.	Coutant 1977a
				12.8				L. Michigan	Coutant 1977a
			20					L. Champlain, N.Y.	Coutant 1977a
				18				Field	Ellis 1984
adult	su		>15.6	7.2				L. Erie	Brown 1974
adult			14		6			L. Michigan	Brandt et al 1980a
adult	F	D		6-8				L. Michigan	Brandt et al 1980a
adult	F	D		7.8				L. Michigan	Brandt et al 1980a
adult	F	N		11-16				L. Michigan	Brandt et al 1980a
young	SU			>21				L. Erie	Brown 1974
				<12.8				L. Cayuga, N.Y.	Brown 1974
adult				<10		0-18		L. Michigan	Michaud 1976
YOY				13-14				L. Michigan	Tin and Jude 1983
<25; larvae	Sp/Su			10.1-14				L. Michigan	Tin and Jude 1983
	s u			14.1-16				L. Michigan	Tin and Jude 1983
adult		N	15.5	7-8				L. Erie	Heist and Swenson 1983
	s u	N		11-16				L. Superior	Heist and Swenson 1983
				15				Lab	McCauley 1981
adult			12	7.6				Lab	McCauley 1981
	F	N		11-14				L. Michigan	Crowder et al 1981
	F	D		13-16				L. Michigan	Crowder et al 1981

SPECIES: *Osmerus mordax* (rainbow smelt)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits		Location	GROWTH TEMPERATURES:	
					Upper	Lower		Reference	
					18.3		L. Erie		Brown 1974

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature- optimum temp for growth)

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Osmerus mordax* (rainbow smelt)

Event	Season and/or Accli- mation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Accli- mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning			2.2-14.5							L. Superior	Brown 1974	
spawning run			3.9-5.6							L. Erie	Brown 1974	
spawning	10										Brown 1974	
incubation			5-15								Brown 1974	
spawning			8.9-18.3							Great Lakes streams	Scott and Crossman 1973	
heat shock	8.5							+22.2	30.5	Lab (simulated onshore discharge)	Crippen and Fahmy 1981(d)	
hatching		14			23						McCauley 198 1 This study	
eggs		11-17	9-19							Lab	Griffiths 1978	
spawning			< 6							Lennox GS, L. Ont.	Griffiths 1978	
embryo devel (6d)			22.5							Lab	Griffiths 1978	
embryo devel (35d)			6							Lab	Griffiths 1978	

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Hiodon tergisus* (mooneye)

								PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
large larval	su		27	22	22			Wabash R., Ind. Upper Mississippi R., Wisc.	Coutant 1977a Holland and Sylvester 1983

SPECIES: *Hiodon tergisus* (mooneye)

											SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning		10-13		11.5	13						Assiniboine R., Man.	Talmage 1978 This study

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

SPECIES: *Umbra limi* (central mudminnow)

											THERMAL TOLERANCES:	
Size or Age (mm)	Acclimation Temp	Acclimation Time	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time - $\frac{a+b}{temp}$	Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference	
										Shallow pond. Mich.	Beltz et al 1974	

SPECIES: Umbra limi (central mudminnow)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
	su		>28.9					Ontario	Scott and Crossman 1973
	SP				8			Ontario	Scott and Crossman 1973

SPECIES: Umbra limi (central mudminnow)

Event	Season and/or Acclimation Tamp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning		13									N.Y.; flood vegetation	Carlander 1969
spawning		12.8									Jones Ck., Ont.	Scott and Crossman 1973
spawning			<15.6	13	15.6							Scott and Crossman 1973 This study

SPECIES: Esox americanus vermiculatus (grass pickerel)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:			
								Location	Reference		
Small				26					Lab	Coutant 1977a Carlander 1969 Scott and Crossman 1973	
			28.9	25.5	25.6						

SPECIES: Esox americanus vermiculatus (grass pickerel)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning		7.2-11.7		9.5								Scott and Crossman 1973
hatching		7.8-8.9										Scott and Crossman 1973

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: ESOX lucius (northern pike)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	THERMAL TOLERANCES:										Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a -t b (temp)		Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)				
subadult				29.4	0.1									Lab	Casselman 1978
	30			30											Casselman 1978
				33											Spotila et al 1979
				29											Casselman 1978
≥50; juvenile	25			32.25		17.3066-0.4523	34.5	32.5	34.5		>50			Lab; Maple, Ont.	Brown 1974
≥50; juvenile	27.5			32.75		17.4439-0.4490	35.0	33.0	35		60			Lab; Maple, Ont.	Brown 1974
≥50; juvenile	30			33.25		17.0961-0.4319	35.5	33.5	33.5		>400	33.25		Lab; Maple, Ont.	Brown 1974
≥50; juvenile	2527.5								32.2-33.2		<2000				Brown 1974
larval	17.7			28.5											Brown 1974
embryo				18.9	5										Brown 1974
embryo				16.8-20.5											Brown 1974
newly hatched	17.7			25.5											Brown 1974
adult	25			32											Brown 1974
				35.6131.7										surface/bottom Clear L., Iowa	Brown 1974
				34											Jobling 1981
				28.4											Jobling 1981
larvae	18				3										EPA 1974
juvenile	31-36.5											30.8			Houston 1982
yolk-sac	14-15	24h		31											Cravens et al 1983
saclarvae															
yolk-sac larvae	17.7			24.8											Bonin and Spotila 1978
eggs, 2-4 cells				19.8											Spotila et al 1979
eggs eyed				28.0											Spotila et al 1979
yolk-sac larvae	11.8			24.1											Spotila et al 1979
	6.1			20.6											Spotila et al 1979
			su	30.8											Spotila et al 1979

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SPECIES: *Esox lucius* (northern pike)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
adult			23	19-20	6			Lab	Casselman 1978
larval				-26					Casselman 1978
				14-19				Wickett L., Ont.	Casselman 1978
				8-24				SE L. Michigan	Brown 1974
fry				23-24				Lab	McCauley and Casselman 1980
				9.9-11.1					Spotila et al 1979
			22	16.0	12.9			Connecticut R., Conn. (mean occurrence)	Marcy 1976a

SPECIES: *Esox lucius* (northern pike)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			M W A T	ST Max				Reference	
283-431FL	19	10-23			27.5	<4	Lab (gain in weight)	Casselman 1978	
	21				28.2	4	Lab (gain in length)	Casselman 1978	
2-3 yr	20.9						Lab	Casselman 1978	
2-3 yr	19.8						Wickett L., Manitoulin Isl.	Casselman 1978	
larval	26						Lab	Jobling 1981	
larval	18-25.6		23.1	30				This study	
juvenile and subadult	19-21				23.9			Brown 1974	
								McCauley and Casselman 1980	
larvae	21	18-26	28	30				EPA 1974	
juvenile	26							EPA 1974	
								EPA 1974	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Esox lucius* (northern pike)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp (a) Range MWAT		(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median ΔT	(d) Median Lethal Final		
cold shock	21.8							4.9	-16.9		L. Wabamun, Alta.	Casselman 1978
spawning	12		9.4-1	4.4							Ont.	DeMontalembert et al 1978
spawning			6.7-7.8								L. Simcoe, Ont.	Brown 1974
spawning			4.4-1	1.1							Canada	Brown 1974
incubation			2.2-16.6								Wis. Lake	Scott and Crossman 1973
incubation		6.5-17.7	2-23									Brown 1974
cold shock (embryo)	10.5								-5.5			Brown 1974
heat shock (larvae)	16						34.5		+8.5			Brown 1974
cold shock	21.8							4.9	-17		power plant outfall, L. Wabamun, Alta.	Brown 1974
spawning				12	19							EPA 1974
incubation and hatch		12	4-19									EPA 1974
spawning		<10									Niagara R. tributaries (N.Y.)	EPA 1974
hatching		20.8			<26.7		29.7					Talmage and Coutant 1979
hatch		6.4-17.7	5.8-21				24.2					Cravens et al 1983
												Spotila et al 1979

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Esox masquinongy* (muskellunge)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
						a	b	Upper	Lower					
≥50; juvenile	25			32.25		18.8879	0.5035	34.5	32.5	34.5	>35		Deer Lake Hatchery, Ontario	Brown 1974
≥50; juvenile	27.5			32.75		20.0817	0.5283	35	33.0	35	>40			Brown 1974
≥50; juvenile	30.0			33.25		18.9506	0.4851	35.5	33.5	35.5	55			Brown 1974
≥50; juvenile	25-30									32.5-33.5	500			Brown 1974
				29										Jobling 1981
				34										Jobling 1981
new hatch	7											28.8		Houston 1982
	15											31.9		Houston 1982
	25											34.5		Houston 1982
1-15d; post hatch	15											30.3-32.4		Houston 1982
25d; post swim-up	25											32.8		Houston 1982
>50 mm	25			32.5						32.5	400		Hatchery, N.Y.	Bonin and Spotila 1978

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SPECIES: *Esox masquinongy* (muskellunge)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
small	sp/su			>25.5				Stony L., Ontario	Minor and Crossman 1978
				14				L. St. Clair	Haas 1978
				24				Lab	Coutant 1977a
				25.1					Jobling 1981
200-250		D		21.9				Lab	Talmage and Coutant 1980
		D		27.3				Lab	Talmage and Coutant 1980
			32.2	25.6					Scott and Crossman 1973

SPECIES: *Esox masquinongy* (muskellunge)

Size or Age (mm)	Optimum °C	Range	(a) M W A T		(b) ST Max		No Growth Limits Upper Lower	Location	GROWTH TEMPERATURES:	
			M	W	A	T			ST	Max
fingerling	24-26.6		28.4	32			>30	10	Niagara R., N.Y.	Jobling 1981 Carlander 1969 This study Harrison and Hadley 1979

(a) MWAT (maximum weekly average temperature for growth) = optimum + 113 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Esox masquinongy* (muskellunge)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) M W A T	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit				(d) Median Lethal Final	Location	Reference
							Upper	Lower	Median ΔT				
spawning		>10										Middle Island Ck. W. Va.	Miles 1978
hatching and development			8-19									Lab	Miles 1978
spawning			10.5-15.5									Nogies Ck., Ontario	Minor and Crossman 1978
spawning		13											Haas 1978
spawning		16-18										Niagara R., N.Y.	Talmage and Coutant 1979
spawning		13	9.5-15.5										Carlander 1969
spawning		12.8	9.4-15										Scott and Crossman 1973
hatching			11.7-17.2										Scott and Crossman 1973
				12.2	19								This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Compostoma anomalum (stone roller)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	12-30			31								Lab	Cherry et al 1977

SPECIES: Compostoma anomalum (stone roller)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
all			23.8					New R., Va.	Coutant 1977a
adult			33	26.8	24			Lab	Coutant 1977a
				29				Lab	Coutant 1977a
				28.5				Lab	Houston 1982
				26.2					Houston 1982
				19-27					Spotila et al 1979
				13.4			6	Lab	Spotila et al 1979
				15.2			9	Lab	Spotila et al 1979
				20.7			12	Lab	Spotila et al 1979
				21.7			15	Lab	Spotila et al 1979
				22.3			18	Lab	Spotila et al 1979
				23.6			21	Lab	Spotila et al 1979
				25.3			24	Lab	Spotila et al 1979
				28.6			27	Lab	Spotila et al 1979
	50-100 FL		21		16.5	9	12		Lab (rising temperatures)
50-100 FL		24		17	12	15		Lab (rising temperatures)	Cherry et al 1977
50-100 FL		24		21	15	18		Lab (rising temperatures)	Cherry et al 1977
50-100 FL		27		22.4	18	21		Lab (rising temperatures)	Cherry et al 1977
50-100 FL		30		25.1	21	24		Lab (rising temperatures)	Cherry et al 1977
50-100 FL		33		28.2	21	27		Lab (rising temperatures)	Cherry et al 1977
50-100 FL		33		27.4	21	30		Lab (rising temperatures)	Cherry et al 1977

SPECIES: Compostoma anomalum (stone roller)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		Location	GROWTH TEMPERATURES:	
			MWAT	ST Max	No Growth Limits Upper	Lower		Reference	
	26.6123		27	30				Jobling 1981	This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Compostoma anomalum (stone roller)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal ΔT	Median Lethal Final	Location	Reference
nest building				12815.6							N.Y.	Brown 1974
spawning				14.4-23.9								Brown 1974
nest building				12							Illinois	Brown 1974
spawning				24-27							Illinois	Brown 1974
spawning				18.3-26.7							Illinois	Brown 1974
hatching (70h)		21										Carlander 1969
(4d)		24.3									Lab (Missouri)	Carmichael 1983
(6d)		17.7									Lab (Missouri)	Carmichael 1983
(10d)		13.9									Lab (Missouri)	Carmichael 1983
				22.5								This study
												27

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Chrosomus eos* (northern redbelly dace)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	THERMAL TOLERANCES:		log time = a + b (temp) a b	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp		Upper	Lower					
	21				2.7								Carlander 1969
	25-26			33.1									Carlander 1969
	9			28								Lab (Toronto)	Tyler 1966
	20									29		Lab (Toronto)	Tyler 1966
	6		su	21.5								Lab (Toronto)	Tyler 1966
	9.5		W	26.5								Lab (Toronto)	Tyler 1966
	10		su	30								Lab (Toronto)	Tyler 1966
	15		su	31								Lab (Toronto)	Tyler 1966
	15		W	28								Lab (Toronto)	Tyler 1966
	20		SU	31.5								Lab (Toronto)	Tyler 1966
	20		W	29.5								Lab (Toronto)	Tyler 1966
	25		Su	32.7								Lab (Toronto)	Tyler 1966
	25		w	31								Lab (Toronto)	Tyler 1966

SPECIES: *Chrosomus eos* (northern redbelly dace)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location	Location	
adult				25.3		6-33				Cravens 1981

SPECIES: *Chrosomus eos* (northern redbelly dace)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal AT	(d) Median Lethal Final	Location	Reference
Hatching (8-10d)			21.1-26.7								Scott and Crossman 1973

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Chrosomus neogaeus* (finescale dace)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:							Location	Reference	
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a + b(\text{temp})}{a}$		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)			
						Upper	Lower						
20											28.5	Lab (Toronto)	Tyler 1966
9			W	27								Lab (Toronto)	Tyler 1966
15			W	28								Lab (Toronto)	Tyler 1966
15			su	31								Lab (Toronto)	Tyler 1966
19			W	30.3								Lab (Toronto)	Tyler 1966
22			su	32.2								Lab (Toronto)	Tyler 1966
25			W	31.3								Lab (Toronto)	Tyler 1966
25			su	32.2								Lab (Toronto)	Tyler 1966

SPECIES: *Chrosomus neogaeus* (finescale dace)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	lb) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final		
Spawning		> 15									French Ck., Minn.	Stasiak 1978
Hatching (6d)		20									French Ck., Minn.	Stasiak 1978
Spawning			17-22								Lab (Minn.)	Stasiak 1978
				20	22							This Study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Couesius plumbeus* /lake chub)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(c) Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning migration		14/19									Lac Saugay, Que. (tributary/lake)	Scott and Crossman 1973
spawning onset		4		19							Montreal R., Sask	This study Brown et al 1970
spawning			4-a								Montreal R., Sask	Brown et al 1970
spawning			10								Lac La Ronge, Sask	Brown et al 1970
hatching (10d)			8-19								Lab	Brown et al 1970

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Cyprinus carpio* (carp)

THERMAL TOLERANCES:													
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
small	20			31-34								Lab	Spotila et al 1979
	26			35.7									Spotila et al 1979
large				35-36							38-39		Spotila et al 1979
	23.3		su								39.0	Lab	Spotila et al 1979 Leidy and Jenkins 1977(a)
eggs				31-35	0.7								Brown 1974
eggs	26.3										40.6		Brown 1974(b)
larval	25			35					25	1 0		Lab	Jinks et al 1981
	19-27			38.8								Lab	Talmage 1978
	16-21			36.4								Lab	Talmage 1978
late stage embryo				40-42.5								Lab	Crippen and Fahmy 1981

(a) hybrid *C. carpio* x *Carassius auratus*

(b) heating rate 3 c/h

SPECIES: *Cyprinus carpio* (carp)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
				17			10		Spotila et al 1979
				25			15		Spotila et al 1979
				27			20		Spotila et al 1979
				31			25		Spotila et al 1979
				31			30		Spotila et al 1979
				32			35		Spotila et al 1979
				32					Spotila et al 1979
adult	SP			27.4				Lab	Spotila et al 1979
adult	su			29.7				Lab	Spotila et al 1979
large			34.5		27			Wabash R., Ind.	Coutant 1977a
large		D		29.3-31.9				L. Monona, Wis.	Coutant 1977a
large		N		28.2-30.7				L. Monona, Wis.	Coutant 1977a
young			35	32	28			Lab	Coutant 1977a
young		D	33.5	31.9	30			Lab	Coutant 1977a
young		N	32.3	32	29.5			Lab	Coutant 1977a
adult			>31	29	24				LabCoutant 1977a
				25-30					Jobling 1981
				26-34					Wyman 1981
	su							J.M. Stuart GS, Ohio R., Ind.	Yoder and Gammon 1976
	F			16-20				J.M. Stuart GS, Ohio R., Ind.	Yoder and Gammon 1976
	w			5-16				J.M. Stuart GS, Ohio R., Ind.	Yoder and Gammon 1976
large				20.7-24.8				Point Beach Nuclear Power Plant	Brown 1974
			>36.1					Discharge effluent, White R., Ind.	Brown 1974
				24					Talmage and Coutant 1978
			39.2	21.6	5.1			Connecticut R., Conn. (mean occurrence)	Marcy 1976a

SPECIES: *Cyprinus carpio* (carp)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Limits Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			M W A T	ST M a x				Reference	
	27							Spotila et al 1979	
	30/32							Jobling 1981	
	32							Leidy and Jenkins 1977	
	27							Brown 1974	
	20-25							Brown 1974	
	23-27				29-30	10		Brown 1974	
		23-30						Cravens 1981	
		11-19					Israel (winter)	Carlander 1969	
early fry		14.5-18.5				>4.5		Carlander 1969	
	30				>35			Talmage and Coutant 1978	
			34	38				This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature- optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Cyprinus carpio (carp)

											SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
embryo					38							Spotila et al 1979
larval dev.		20-25										Spotila et al 1979
spawning			17-28	21	26							Scott and Crossman 1973
		19-23	16-26									EPA 1974
incubation/hatch			17-22									EPA 1974
spawning			14.525									Brown 1974
incubation		<22										Brown 1974
heat shock	20						35		> +10			Brown 1974
heat shock, larvae	25						37-38		+13	Lab		Brown 1974
heat shock, larvae							33.5			Discharge, Nuclear Plant, Conn.		Brown 1974
heat shock	28.3						33.3		+5	Discharge (warmed)		Brown 1974
heat shock, larvae							36.1		+18.1	Lab; Simulated		Talmage and Coutant 1980
hatching		23.4	11-32							Entrainment		Carlander 1969
heat shock, eggs							42.5					Crippen and Fahmy 1981
spawning		27	22-27							Connecticut R., Conn.		Marcy 1976b
larval dev. (5.22 mm)		23-24.9	13.8-26							Connecticut R., Conn.		Marcy 1976b

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Exoglossum maxillingua* (cutlips minnow)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
			18.3		8			Heated discharge, Delaware R., Penn. (field occurrence)	Brown 1974
			19.4		10			Heated discharge, Delaware R., Penn. (field occurrence)	Brown 1974

SPECIES: *Exoglossum maxillingua* (cutlips minnow)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final		
spawning		<15										Brown 1974
spawning			17-21.5									Brown 1974
				19	21.5							This study

W
W

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Hybognathus hankinsoni* (brassy minnow)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp (a) Range	MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning			10-12.8	11.5	12.8							Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Hybognathus nuchalis* (silvery minnow)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp (a) Range	MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning			13-20.5	16.8	20.5							Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Hybopsis storeriana* (silver chub)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		21	18-21 t	21	21 +						Ohio	Scott and Crossman 1973 Carlander 1969 This study

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

SPECIES: *Nocomis biguttatus* (hornyhead chub)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning		23.9		23.9								Scott and Crossman 1973 This study

SPECIES: *Nocomis micropogon* (river chub)

THERMAL TOLERANCES:												
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son Temp	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	fog time = a + b (temp) a b	Data Limits Upper Lower	Exposure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
	15									30.9	Lab (N.Y.)	Spotilla et al 1979

SPECIES: Nocomis micropogon (river chub)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range (a)	MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning nest building			19-28								Illinois	Carlander 1969
nest building			11.9-20.6									Brown 1974
nest building			19.4-27.8	23.5	28						Illinois	This study

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
adult	W			16.8				Lab	Reutter and Herdendorf 1976
	SP			23.7					Reutter and Herdendorf 1976
	su			22.3					Reutter and Herdendorf 1976
	F			21.0					Reutter and Herdendorf 1976
			>30						Carlander 1969
			>32.2					Heated discharge, Delaware Ft., Penn.	Brown 1974
			>37.2	23.9-28.9				Heated discharge, Delaware R., Penn.	Brown 1974
			>35					Heated discharge, Delaware R., Penn.	Brown 1974
			40	24	6.7			Heated discharge, Connecticut R., Conn	Marcy 1976a

SPECIES: *Notemigonus crysoleucas* (golden shiner)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit		Median AT	(d) Median Lethal		Location	Reference
							Upper	Lower		Final	Final		
spawning		20											Scott and Crossman 1973
spawning		20-21										N.Y. ponds	Carlander 1969
hatching (1st)		20										Ponds, Alab. Field	Carlander 1969
spawning			15.6-21										Carlander 1969
hatching (4d)		15.6+											Brown 1974
heat shock (1.5-4.5 in)	15.6								+11.1			Lab (spring)	Brown 1974
heat shock (1.5-4.5 in)	15.6								+21.7			Lab (winter 5% mortality)	Brown 1974
spawning		<27		20	25							Lab (gonad regression)	Talmage and Coutant 1978
													This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Notropis atherinoides (Emerald shiner)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
adult	w			8.3				Lab	Reutter and Herdendorf 1976
YOY	w			10-12				Lab	Reutter and Herdendorf 1976
YOY	SP			13-15				Lab	Reutter and Herdendorf 1976
YOY	su			22-23				Lab	Reutter and Herdendorf 1976
YOY	F			13-14				Lab	Reutter and Herdendorf 1976
adult	w			5-6				Lab	Reutter and Herdendorf 1976
	SP			16				Lab	Reutter and Herdendorf 1976
	SU			22-24				Lab	Reutter and Herdendorf 1976
	F			15-17				Lab	Reutter and Herdendorf 1976
			>28-30 >31.1						Spotila et al 1979
			42		6			White R., Ind. heated discharge Field occurrence	Brown 1974
				27.8125.1					Ellis 1984
				25				L. Simcoe, Ont.	Jobling 1981
	su			25				L. Simcoe, Ont.	Brown 1974
	w			27				Ohio R.	EPA 1974

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SPECIES: Notropis atherinoides (emerald shiner)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			MWAT	ST Max				Reference	
	24-28.9 27								Spotila et al 1979
YOY juvenile	29	24-31				21	L. Erie		Jobling 1981
			30	31					Carlander 1969
YOY	28.9	19-29			29	<19	Lab (Minn.)		Brown 1974
									EPA 1974
									Talmage 1978

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Notropis atherinoides* (emerald shiner)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(c) Lethal Limit AT	(d) Median Lethal Final	Location	Reference
spawning		24										Scott and Crossman 1973
spawning			20-27									Brown 1974
hatch (24h)		23.9		23	27						L. Erie	Brown 1974
												EPA 1974
cold shock	13						0		-12.5		Lab	Edsall and Yocum 1972
cold shock	15						1.7		-13.5		Lab	Edsall and Yocum 1972
cold shock	20						5		-15		Lab	Edsall and Yocum 1972
cold shock	25						7.6		-17.5		Lab	Edsall and Yocum 1972

SPECIES: *Notropis bifrenatus* (bridle shiner)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(c) Lethal Limit AT	(d) Median Lethal Final	Location	Reference
spawning			14-27	20.5	27						N.H.	Carlander 1969 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Notropis cornutus* (common shiner)

Size or Age (mm)	Accli- mation Temp.	Accli- mation Time	Sea- son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:			
						a + b (temp)					Upper	Lower	Location	Reference
						a	b							
				32								Spotila et al 1979		
	15		W							30.6	Lab (Dec 15)	Kowalski et al 1978		
	15		SP							31.9	Lab (Mar 15)	Kowalski et al 1978		
	5			26.7-27								Carlander 1969		
	10			28.6-29								Carlander 1969		
	15			30.3	0							Carlander 1969		
	20			31-32.3	3.7-4							Carlander 1969		
	25			33.5	7.8							Carlander 1969		
4.46 in; adult	25-26		Su	32								Carlander 1969		
	10			29			29	29	29	50	Lab (Toronto, Ont.)	Brown 1974		
	15			30.5		45.4331-1.3979	31.5	31	31.5	28	Lab (Toronto, Ont.)	Brown 1974		
	20			31		34.5324-1.0116	33	31.5	33	17	Lab (Toronto, Ont.)	Brown 1974		
	25		w	31		24.9620-0.6878	34	32	34	35	Lab (Toronto, Ont.)	Brown 1974		
	25			31		28.5059-0.7741	35.5	32	35.5	15	Lab (Toronto, Ont.)	Brown 1974		
	30			31		28.1261-0.7316	36.5	34	36.5	20	31	Lab (Toronto, Ont.1)	Brown 1974	
4-5 g; adult (2 yr)	5			26.7								Lab (Don R., Ont.)	Brown 1974	
	10			28.6		40.7738-1.3522	30	29				Lab (Don R., Ont.)	Brown 1974	
	15			30.3		45.0972-1.3874	32	31				Lab (Don R., Ont.)	Brown 1974	
	20			31	3.7	34.5324-1.0116	33	31.5				Lab (Don R., Ont.)	Brown 1974	
	25			31	7.8	24.9620-0.6878	34	32	31	5000		Lab (Don R., Ont.)	Brown 1974	
	7.2		F	30.6								Delaware R., Penn.	Brown 1974	
	11.1			31.1								Delaware R., Penn.	Brown 1974	

SPECIES: *Notropis cornutus* (common shiner)

SPAWNING AND DEVELOPMENT TEMPERATURES:													
Event	Season and/or Acclimation Temp	(a)			(b) ST Max for Embryo Survival	Acclimation Time	(c)		(c) Lethal Limit Lower	(d) Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
		Optimum Temp	Range	MWAT			Lethal Upper	Lethal Lower					
spawning			15.6-18.3								Ithaca, N.Y.	Scott and Crossman 1973	
spawning			28.3								L. Erie tributary	Scott and Crossman 1973	
spawning			19-21-k									Carlander 1969	
spawning initial			15-25.5									Brown 1974	
spawning			13-15.6								Cayuga L., N.Y.	Brown 1974	
spawning	20		18.9-21.1								Big Sandy L., Minn.	Brown 1974	
spawning initial			<28									Brown 1974	
spawning			18								S. Michigan	Brown 1974	
spawning	17.8			20	28						Central N.Y.	Brown 1974	
inshore migration			12-15.5									This study	
spawning			13.5-18									Dodson and Young 1917	
												Dodson and Young 1977	

- (a) MWAT= maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

SPECIES: *Notropis heterodon* (black chin shiner)

THERMAL TOLERANCES:														
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits		Exposure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
						a	b	Upper	Lower					
													Pond Michigan	Beltz et al 1974

SPECIES: *Notropis hudsonius* (spottail shiner)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	THERMAL TOLERANCES:											
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a+b}{temp}$		Data Limits		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	Reference	
						a	b	Upper	Lower						
adult	21.7		su	>35									32.8	Lab	Reutter and Herdendorf 1976
	7.2		W	30.6										Field (active)	Carlander 1969
	11.1			31.1										Lab (0.6-1.1C/h)	Brown 1974
13-36; juvenile	23			37.3					37.3	5				Lab	Jinks et al 1981
13-36; juvenile	23			36					36	10				Lab	Jinks et al 1981
13-36; juvenile	23			36					36	30				Lab	Jinks et al 1981
13-36; juvenile	26			38.1					38.1	5				Lab	Jinks et al 1981
13-36; juvenile	26			37.9					37.9	10				Lab	Jinks et al 1981
juvenile	26			36.8					36.8	30				Lab	Jinks et al 1981
20-65; YOY	9			30.5					30.5	60				Lab	Jinks et al 1981
20-65; YOY	17			32.4					32.4	60				Lab	Jinks et al 1981
20-65; YOY	23-24			34.3					34.3	60				Lab	Jinks et al 1981
20-65; YOY	26			35.8					35.8	60				Lab	Jinks et al 1981
21; young	26			34.7									33-34	Lab	Kellogg and Gift 1983

SPECIES: *Notropis hudsonius* (spottail shiner)

								PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
		D		>13				L. Michigan	Brandt et al 1980
				11-16				L. Michigan	Brandt et al 1980
		D/N		17-20				L. Michigan	Brandt et al 1980
adult	w			9				Lab	Reutter and Herdendorf 1976
	SP			14.3				Lab	Reutter and Herdendorf 1976
			>22	14	13			L. Michigan	Spotila et al 1979
large			>35					Delaware R., Penn.	Coutant 1977a
110-116; adult				13.9		15		(6% salinity) estuary heated discharge into Delaware R., Penn.	Brown 1974
	SU		<40						Brown 1974
adult	w			10.2				L. Michigan	Houston 1982
		D		17-20				L. Michigan	Talmage and Coutant 1980
	F	N		19-20	15			L. Michigan	Crowder et al 1981
	F			17-18	11				Crowder et al 1981
24.4 TL; young				28.5		25		Lab (N.Y.)	Kellogg and Gift 1983
22.9 TL; young				29.9		25		Lab (N.Y.)	Kellogg and Gift 1983
21-30 TL; young				29				Lab (N.Y.)	Kellogg and Gift 1983
			39.2	20.1	5.1			Heated discharge into Connecticut R., Conn.	Marcy 1976a

SPECIES: *Notropis hudsonius* (spottail shiner)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Limits Upper Lower	Location	GROWTH TEMPERATURES:	
			(a) M W A T	ST Max			Reference	
Young					18	L. Erie	Carlander 1969	
YOY					>35	Delaware R., Penn.	Brown 1974	
Young	27.3	22.8-32.7			10	Lower Red L., Minn.	Brown 1974	
			30	32.7	<20	Lab (N.Y.)	Kellogg and Gift 1983	
	>26					Clear L., Iowa	This study	
							Prince and Mengel 1981	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature optimum temp for growth)

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Notropis hudsonius* (spottail shiner)

Event	Season and/or Accli- mation Temp	Optimum Temp	Temp Range	(a) M W A T	(b) ST Max for Embryo Survival	Accli- mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal ΔT	Median Lethal Final	Location	Reference
hatching		20								L. Erie	Brown 1974	
cold shock	21.8						4.9	-16.9		L. Wabamun, Alta. (30 min delta -T)	Coutant 1977b	
spawning		18C								L. Michigan tributary Great Lakes	Mansfield 1984 Mansfield 1984	
heat shock			15-20				28			Connecticut R., Conn. Nuclear GS	Talmage 1978	
				17.5	20						This study.	

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Notropis rubellus* (rosyface shiner)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	THERMAL TOLERANCES:							Reference	
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)		
				Data Limits								
	12-23			33							Lab	Cherry et al 1977

SPECIES: *Notropis rubellus* (rosyface shiner)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
adult			31	26.8	21			Lab		Coutant 1977a
adult				27.6						Houston 1982
50-100 FL; adult			21	20.8	9	12		Lab (rising water temperatures)		Cherry et al 1977
50-100 FL; adult			24	21.7	12	15		Lab (rising water temperatures)		Cherry et al 1977
50-100 FL; adult			21	22.2	15	18		Lab (rising water temperatures)		Cherry et at 1977
50-100 FL; adult			27	22.5	15	21		Lab (rising water temperatures)		Cherry et at 1977
50-100 FL; adult			27	25.8	21	24		Lab (rising water temperatures)		Cherry et al 1977
50-100 FL; adult			33	28.1	21	27		Lab (rising water temperatures)		Cherry et al 1977
50-100 FL; adult			33	28.0	21	30		Lab (rising water temperatures)		Cherry et al 1977
50-100 FL; adult			34	27.7	24	33		Lab (rising water temperatures)		Cherry et al 1977
50-100 FL; adult				26				Lab (rising water temperatures)		Cherry et al 1977

SPECIES: *Notropis rubellus* (rosyface shiner)

Size or Age (mm)	Optimum °C	(a) Range	(b)				GROWTH TEMPERATURES:	
			ST Max	No Growth Upper	Limits Lower	Location	Reference	
	25.7/25.3							Jobling 1981

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Notropis rubellus* (rosyface shiner)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	(a)		(b) ST Max for Embryo Survival	Acclimation Time	(c)		Median Lethal ΔT	(d)		Location	Reference
			Temp Range	MWAT			Lethal Limit Upper	Lethal Limit Lower		Median Lethal Final			
spawning			26.1-28.9									N.Y.	Scott and Crossman 1973
spawning			20-22.2									Penn.	Scott and Crossman 1973
hatching (59h)		21.1										Penn.	Scott and Crossman 1973
spawning		>21.1										N.Y.	Carlander 1969
spawning		>20			24.5	28							Brown 1974 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

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SPECIES: *Notropis spilopterus* (spotfin shiner)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper	Lower	log time =		Data Limits Upper Lower	Exposure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
				Lethal Temp	Lethal Temp	a	b						
	12-36			36								Lab	Cherry et al 1977

SPECIES: *Notropis spilopterus* (spotfin shiner)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
adult			35	29.5	26			Lab	Coutant 1977a
adult			>31.1	29.4				Lab White R., heated discharge, Ind.	Jobling 1981 Brown 1974
50-100 FL; adult			27	21.4	9	12		Lab (rising water temperatures)	Cherry et al 1977
			24	21.8	12	15		Lab (rising water temperatures)	Cherry et al 1977
			27	24.1	15	18		Lab (rising water temperatures)	Cherry et al 1977
			27	26.4	18	21		Lab (rising water temperatures)	Cherry et al 1977
			30	27.3	21	24		Lab (rising water temperatures)	Cherry et al 1977
			33	30.6	21	27		Lab (rising water temperatures)	Cherry et al 1977
			36	31.8	24	30		Lab (rising water temperatures)	Cherry et al 1977
			36	31	24	33		Lab (rising water temperatures)	Cherry et al 1977
			38	29.2	27	36		Lab (rising water temperatures)	Cherry et al 1977
				31				Lab (rising water temperatures)	Cherry et al 1977

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SPECIES: *Notropis spilopterus* (spotfin shiner)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Limits Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			la) M W A T	ST Max				Reference	
	28.6/29.2		31.3	35				Jobling 1981 This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Notropis spilopterus* (spotfin shiner)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(4) Median Lethal Final	Location	Reference
heat shock 22							>33		>11		Lab	Talmage 1978
cold shock 33								<22	<11		Lab	Talmage 1978

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

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SPECIES: *Notropis stramineus* (sand shiner)

THERMAL TOLERANCES:												
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a + b(\text{temp})}{a - b}$	Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	15		w							32.3	Lab (Dec 15) N.Y.	Kowalski et al 1978
	15		w							32.3	Lab (Jan 15) N.Y.	Kowalski et al 1978
	15		SP							33.0	Lab (Mar 15) N.Y.	Kowalski et al 1978

SPECIES: Pimephales notatus (bluntnose minnow)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
						a	b	Upper	Lower				Location	Reference
adult	6.0 15		SP									27.8 31.9 34.8	Lab Lab (N.Y.) Lab (1C/h) Lab	Reutter and Herdendorf 1976 Spotila et al 1979 Spotila et al 1979 Cherry et al 1977
	12-30			32										
0-2 g; adult (1 yr)	5			26		24.6417-0.8602	27	26.5	27	25			Etobicoke Ck., Ont.	Brown 1974
0-2 g; adult (1 yr)	10			28.3		55.8357-1.8588	29.5	29	29.5	10			Etobicoke Ck., Ont.	Brown 1974
0-2 g; adult (1 yr)	15			30.6	10	28.0377-0.8337	32	32	32	20			Etobicoke Ck., Ont.	Brown 1974
0-2 g; adult (1 yr)	20			31.7	4.2	34.3240-0.96882	34	32.5	34	15			Etobicoke Ck., Ont.	Brown 1974
0-2 g; adult (1 yr)	25			33.3	7.5	50.8212-1.4181	35	34	35	21 38			Etobicoke Ck., Ont. S. Michigan pond	Brown 1974 Brown 1974
17-23; young adult				38									S. Michigan pond (one fish)	Brown 1974

SPECIES: Pimephales notatus (bluntnose minnow)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
				23-29.5				F i e l d	Spotila et al 1979
				15.7		6		Lab	Spotila et al 1979
				17.2		9		Lab	Spotila et al 1979
				20.5		12		Lab	Spotila et al 1979
				20.4		15		Lab	Spotila et al 1979
				21.5		18		Lab	Spotila et al 1979
				22.8		21		Lab	Spotila et al 1979
				25.7		24		Lab	Spotila et al 1979
				28.9		27		Lab	Spotila et al 1979
adult		31		29	21			Lab	Coutant 1977a
		>31.1						(max temp of occurrence in field) discharge White R., Ind.	Brown 1974
				28.4				Lab	Houston 1982
				28.1				Lab	Houston 1982
50-100 FL;		21		19.3	9	12		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;		24		20.9	12	15		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;		27		21.9	15	18		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;		27		23.2	18	21		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;		27		26.4	21	24		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;		30		27.9	21	27		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;		33		29	24	30		Lab (rising water temperatures)	Cherry et al 1977
				28.1					

SPECIES: Pimephales notatus (bluntnose minnow)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			MWAT	Max	ST	Max				Reference	
	27.2124									Jobling 1981	
			27.9	31						This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Pimephales notatus (bluntnose minnow)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(4) Median Lethal Final	Location	Reference
spawning			≥ 20									Scott and Crossman 1973
spawning			21.1-26.1								Illinois	Carlander 1969
spawning			>21								Michigan	Carlander 1969
spawning			19-31								Outdoor spawning pools, Penn.	Gale 1983
				25	31							This study

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

SPECIES: Pimephales promelas (fathead minnow)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			M W A T	ST M a x				Reference	
	26/25.5		28	33	32	<2-7	experiment Alabama (winter)	Jobling 1981 Carlander 1969 Beltz et al 1974 This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Pimephales promelas (fathead minnow)

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Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning hatching (5d)		25	15.6-17.8								Lake, Que. (minimum temp)	Scott and Crossman 1973 Scott and Crossman 1973
spawning onset	SP	15.6										Carlander 1969
spawning cessation F			15.6-18.4									Carlander 1969 Carlander 1969
spawning Su		>27									Outdoor exptal pool, Penn.	Gale and Buynak 1982
spawning		<23.5	<32		23	28					Lab	Beltz et al 1974 This study

(a) MWAT - maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Rhinichthys atratulus* (blacknose dace)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	Upper	Lower	log time =			Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:		
				Incip. Lethal Temp	Incip. Lethal Temp	a	b	Upper				Lower	Location	Reference
				Temp	Temp	a + b (temp)	Data Limits							
	5			25									Carlander 1969	
	10			27									Carlander 1969	
	20			29.3	1								Carlander 1969	
adult	5			27										
adult	15			29.3		19.8158-0.5771	31.5	30				Lab (Toronto, Ont.)	Brown 1974	
adult	20			29.3		24.5749-0.7061	33	30				Lab (Toronto, Ont.)	Brown 1974	
adult	25			29.3		20.1840-0.5389	35	32				Lab (Toronto, Ont.)	Brown 1974	
Z-3.9; adult	5			26.5		77.1877-2.7959	27.5	27				Lab (Don. R., Ont.)	Brown 1974	
2-3.9; adult	10			28.8		49.1469-1.6021	30.5	29.5				Lab (Don. R., Ont.)	Brown 1974	
2-3.9; adult	15			29.6		19.6975-0.5734	31.5	30				Lab (Don. R., Ont.)	Brown 1974	
2-3.9; adult	20			29.3	2.2	26.5952-0.7719	33.5	29.5				Lab (Don. R., Ont.)	Brown 1974	
2-3.9; adult	25			29.3	5	23.5765-0.6629	34	30			29.5	Lab (Don. R., Ont.)	Brown 1974	
	5		W						27	50		Lab (Toronto, Ont.)	Brown 1974	
	10		W						30	40		Lab (Toronto, Ont.)	Brown 1974	
	15		W						31.5	50		Lab (Toronto, Ont.)	Brown 1974	
	20		W						33	20		Lab (Toronto, Ont.)	Brown 1974	
	25		W						34	20		Lab (Toronto, Ont.)	Brown 1974	
	28		W						35.5	15		Lab (Toronto, Ont.)	Brown 1974	
	7.2			31.7								Lab (2 F/h) Penn.	Brown 1974	
adult											29.3		Houston 1982	
	20			29.9									Lab (16 h day/8 h night)	Houston 1982
	20			28.8									Lab (8 h day/16 h night)	Houston 1982
	20			30									Lab (24 h day/O h night)	Houston 1982
											31.9			

SPECIES: *Rhinichthys atratulus* (blacknose dace)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference
spawning		21.1									Upstate N.Y.	Scott and Crossman 1973
spawning			16-22.2									Brown 1974
spawning			15.6-17.8								W. Va.	Brown 1974
spawning		22.2		21	22.2						N.Y.	This study
spawning onset		19									Mink R.; Valley R., Man.	Bartnik 1970

(a) MWAT - maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Rhinichthys cataractae* (longnose dace)

THERMAL TOLERANCES:												
Size or Age (mm)	Acclimation Temp	Acclimation Time	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a + b(\text{temp})}{a - b}$	Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
15										31.4	Lab (N.Y.)	Spotila et al 1979

SPECIES: *Rhinichthys cataractae* (longnose dace)

PREFERRED TEMPERATURES:											
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference
	W			10-19.7						heated discharge into Delaware R., Penn.	Brown 1974
95-134;	S	P		8-14	5.2					L. Michigan (nearshore occurrence)	Brazo et al 1978
51-104;	su			10-22.7						L. Michigan (nearshore occurrence)	Brazo et al 1978
32-116;	F			7.2-14.7						L. Michigan (nearshore occurrence)	Brazo et al 1978

SPECIES: *Rhinichthys cataractae* (longnose dace)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			(a) M W A T	ST M a x				Reference	
					(1.2		L. Michigan (fall nearshore last occurrence)	Brazo et al 1978	

- (a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).
 (b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Rhinichthys cataractae* (longnose dace)

Event	Season and/or Accli- mation Temp	Optimum Temp	Temp Range	(a) M W A T	(b) ST Max for Embryo Survival	Accli- mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(4) Median Lethal Final	Location	Reference
hatching (7-10d)		15.6									Manitoba	Scott and Crossman 1973
spawning migration Sp		> 8									L. Michigan	Brazo et al 1978
spawning		15	14-19								L. Michigan	Brazo et al 1978
spawning				15	20						L. Winnipeg	Brazo et al 1978
spawning			15.5-20								L. Winnipeg	This study Gee and Machniak 1972

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
 (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
 (c) Not incipient lethal temperatures as defined by Fry et al (1946).
 (d) Simulated larval entrainment temperatures.

SPECIES: *Semotilus atromaculatus* (creek chub)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:										Reference	
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) b		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location		
	5			24.7											Carlander 1969
	10			27											Carlander 1969
	17.1-17.5			30.1-30.5											Carlander 1969
	20			30	1.0										Carlander 1969
	21-21.9			31.8	1.7										Carlander 1969
	22.8			32.1											Carlander 1969
	25-26			32.6											Carlander 1969
2-3.9 g; adult	5			24.7		42.1859-1.6021	26	25				30.3	Don Ft., Thornhill, Ont.		Brown 1974
	10			27.3		31.0755-1.0414	29	28					Don R., Thornhill, Ont.		Brown 1974
	15			29.3		20.8055-0.6226	31	30					Don R., Thornhill, Ont.		Brown 1974
20				30.3	0.7	21.0274-0.5933	33.5	30.5					Don R., Thornhill, Ont.		Brown 1974
	25			30.3	4.5	16.8951-0.4499	35	31					Don R., Thornhill, Ont.		Brown 1974
	10			27.5			29	28	29	55	31.5		Toronto, Ont.; Knoxville, Tenn.		Brown 1974
	15			29		20.8055-0.6226	31	30	31	35			Toronto, Ont.; Knoxville, Tenn.		Brown 1974
	20			30.5		19.1315-0.5328	33	30.5	33	30			Toronto, Ont.; Knoxville, Tenn.		Brown 1974
	25			31.5		19.3186-0.4717	36	32	35.5	50			Toronto, Ont.; Knoxville, Tenn.		Brown 1974
	30			31.5		22.8982-0.5844	37	33	37	20			Toronto, Ont.; Knoxville, Tenn.		Brown 1974
	7.2			31.1								32.3	Lab (Delaware R; 2F/h) Lab (Savannah R., 4C/h)		Brown 1974 McFarlane et al 1976

SPECIES: *Semotilus atromaculatus* (creek chub)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	SPAWNING AND DEVELOPMENT TEMPERATURES:										Reference
					(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location				
spawning onset		12.8													Scott and Crossman 1973
spawning			12.8-26.7										Illinois		Brown 1974
spawning		>14		19.8	27								Manitoba		Brown 1974 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Semotilus corporalis* (fall fish)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
			28					Eastern U.S.	Scott and Crossman 1973

SPECIES: *Semotilus corporalis* (fall fish)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal AT	(d) Median Lethal Final	Location	Reference
nest building		12									Brome L., Que.	Scott and Crossman 1973
spawning		16.6		16.6	28						Brome L., Que.	Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Semotilus margarita* (pearl dace)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(d) Lethal Limit Lower	(d) Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		17.2									Pentwater R., Mich.	Scott and Crossman 1983
spawning		18.3		17.2	>18.3						Pine Ck., Mich.	Scott and Crossman 1983 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Carassius auratus* (goldfish)

												THERMAL TOLERANCES:			
Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip.	Lower Incip.	log time -		Data Limits		Exposure Lower Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference	
				Lethal Temp	Lethal Temp	a	b	Upper	Lower						
Juvenile				38.6										Jobing 1981	
				40										Jobing 1981	
	5-30			29-38.6								36.6		Spotila et al 1979	
	5-40			29.9-41										Spotila et al 1979	
	23.9											>35	Lab	Reutter and Herdendorf 1976	
	19													Houston 1982	
	24													Houston 1982	
	38													Houston 1982	
	1-2			28									41		Houston 1982
	9.3		F										>25.3	Lab	Reutter and Herdendorf 1976(a)
larval	10				0									Leidy and Jenkins 1977	
	35			40.5										Leidy and Jenkins 1977	
	32							20.0213-0.4523						Brown 1974	
	38							21.9234-0.4773						Brown 1974	
	21-23			39.3										Jinks et al 1981	
				38.5										Lab	Jinks et al 1981
				37.5										Lab	Jinks et al 1981
	25											37.6	Lab	Talmage and Countant 1979	
5											32	Lab	Talmage and Countant 1979		

(a) hybrid *C. carpio* x *Carassius auratus*

SPECIES: *Carassius auratus* (goldfish)

										PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference
small			33	30						Lab	Coutant 1977a
small				28.1						Lab	Coutant 1977a
adult	w			24.2						Lab	Coutant 1977a
adult	SP			25.3						Lab	Coutant 1977a
adult	su			27.0						Lab	Coutant 1977a
adult	F			24.0						Lab	Coutant 1977a
medium				27.9						Lab	Coutant 1977a
				29.7						Lab	Coutant 1977a
							26-30			Lab	Talmage and Coutant 1979
80-100 mm				19.2			15				Talmage and Coutant 1980
				26			25				Talmage and Coutant 1980
				28							Talmage and Coutant 1980

SPECIES: Carassius auratus (goldfish)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Limits			GROWTH TEMPERATURES:	
			(a) M W A T	ST M a x	Upper	Lower	Location	Reference	
Juvenile	25 28.1		30.4	32					Jobing 1981 Leidy and Jenkins 1977 This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Carassius auratus (goldfish)

Event	Season and/or Accli- mation Temp	Optimum Temp	(a)		(b)		(c) Lethal Limit Upper	(4) Lethal Limit L o w e r	(d) Median Lethal Final	Location	Reference
			Temp Range	MWAT	ST Max for Embryo Survival	Accli- mation Time					
incubation			18.5-29.5								Scott and Crossman 1973
spawning			18.4-24.9								Scott and Crossman 1973
1st hatching			15.5-18.4								Carlander 1969
spawning			17-24	24	29.5						Talmage and Coutant 1978 This Study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Carpoides cyprinus* (quillback)

THERMAL TOLERANCES:													
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $a + b_{(temp)}$	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
						a	Upper	Lower					

	23.3										37.2	Lab	Spotila et al 1979
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SPECIES: *Carpoides cyprinus* (quillback)

PREFERRED TEMPERATURES:									
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference

adult large	F		34.5	22.1	27.0			Lab Wabash, R., Ind.	Coutant 1977a
	su			26.32				J.M. Stuart, GS, Ohio R., Ind.	Yoder and Gammon 1976
	W			10-16				J.M. Stuart, GS, Ohio R., Ind.	Yoder and Gammon 1976

SPECIES: *Carpoides cyprinus* (quillback)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference

spawning			19-28	23.5	28						Four Mile Ck., Ohio	Talmage 1978 This study
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(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Catostomus catostomus* (longnose sucker)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:		log time = a + b (temp) a b	Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp							
44 g;	14			26.5								Scott and Crossman 1973
44 g;	11.5			27								Carlander 1969

SPECIES: *Catostomus catostomus* (longnose sucker)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location	Location	
				11-11.6 8-17 8				Moosehead L., Me. Pt. Beach, L. Michigan Escanaba, L. Michigan		Coutant 1977a Michaud 1981 Michaud 1981

SPECIES: *Catostomus catostomus* (longnose sucker)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal AT	(d) Median Lethal Final		
spawning run		5									B.C.	Scott and Crossman 1973
hatching (8-11d)			10-15								B.C.	Scott and Crossman 1973
migration			11-14								Pyramid L., Sask	Brown 1974
spawning		> 15									Gt. Slave Lake	Brown 1974
spawning		5									Stream	Fuiman and Witman 1979
				5-10	13							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Catostomus commersoni* (white sucker)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time --		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
						a	b	Upper	Lower					
adult	19		SP									31.6	Lab	Reutter and Herdendorf 1976
Juvenile	5			26						26	310			Brown 1974
larvae/ Juvenile	10			28						28	310			Brown 1974
larvae	15			31										EPA 1974
Juvenile	15			29										EPA 1974
Juvenile	20			29	2-3					29	2000			Brown 1974
larvae	21			30	6									EPA 1974
Juvenile	25			29	6					29	8000			Brown 1974
Juvenile	25-26			31						31	720			Brown 1974
1-2 yr	5			26.3		33.6957	-1.1797	27.5	27					Brown 1974
	10			27.7		19.9890	-0.6410	29	29					Brown 1974
	15			29.3		31.9007	-1.0036	30	29.5					Brown 1974
	20			29.3	2.5	27.0023	-0.8068	31.5	30					Brown 1974
	25			28.3	6.6	22.2209	-0.6277	32.5	29.5					Brown 1974
120 Juvenile				31.4								35.1-36.1		Brown 1974
				30-33.3									Nova Scotia R. Power plant discharge	Brown 1974
	32.2			35						35	600			Brown 1974
	7.2			30						30	600			Brown 1974
	11.1			31						31	2160			Brown 1974
larval	9-10			28.3-28.8										Jinks et al 1981
	15-16			30-31.1										Jinks et al 1981
newly hatched	21			30.5-31.7										Jinks et al 1981
swim-up	21.2	7d		>28.2	4.8								Lab	McCormick et al 1977
	21.1	7d		30.5	6.1								Lab	McCormick et al 1977
	15.8	7d		30.7									Lab	McCormick et al 1977
	10.0	7d		28.1									Lab	McCormick et al 1977
newly hatched	15.2	7d		30.0	4.8								Lab	McCormick et al 1977
	8.9	7d		28.6									Lab	McCormick et al 1977
larvae				30.2									Lab	Crippen & Fahmy 1981
												32.7	(temp. incr. 1 c/h)	Spotila et al 1979

SPECIES: *Catostomus commersoni* (white sucker)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		
								Location	Reference	
large adult	F			20.6				Wisconsin lakes Moosehead L. Me. Horse tooth Res., Colo Lab	Coutant 1977a	
				18.3					Coutant 1977a	
				18.9-21.1						Coutant 1977a
				22.4						Coutant 1977a
				14.1-18.3	< 5					Brown 1974
		20.6	11.8					Brown 1974		
	SP	>29.4		23.9		17.2		Discharge	Brown 1974	
	su	20			14				Haymes 1984	
	Year	17			8			Point Beach L Mich.	Michaud 1981	
	su			25-27				Ohio R.	Yoder and Gammon 1976	
	F			16-19				Ohio R.	Yoder and Gammon 1976	
				24					EPA 1978a	
adult			31.2						McCormick et al 1977	
				19-21				Oswego or Pickering L. Ontario	Wyman 1981	
			26.1	24.1	22.8			Lab	Reynolds and Casterlin 1978	
				26.7				New River, Va.	Reynolds and Casterlin 1978	
			19.9	14.4	10			Connecticut R., Conn.	Marcy 1976a	
								(mean field occurrence)		
Larval			30					Jack L., Ont.	Corbett and Powles 1983	

SPECIES: *Catostomus commersoni* (white sucker)

Size or Age (mm)	Optimum °C	Range	(a) MWAT		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			W	A T				ST Max	Reference
larvae	27	24-27	28	30				EPA 1974	
100; juvenile	24	12-29				<12	Lab	EPA 1974	
4-5 mg; larva	26.9						Lab	EPA 1974	
100; juvenile	26						Lab (summer)	EPA 1978b	
juvenile	24						Lab (winter)	EPA 1978b	
larvae	26.9	15.7-26.9			29.7	10	Lab	McCormick et al 1977	
adult	24						Lab	Smagula and Adelman 1982	
104; age I	24	12-30					Lab	Adelman 1980	
263; age II	24	12-30					Lab	Adelman 1980	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Catostomus commersoni* (white sucker)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max far Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:					Location	Reference
							(c) Lethal Limit Upper	(4) Lethal Limit Lower	Median Lethal AT	(4) Median Lethal Final			
spawning incubation/hatch		10	4-18	10	21							EPA 1974	
spawning heat shock incubation/hatch	12	15	8-21 10-20						20	32	Lab	EPA 1974 Brown 1974 Moore 1979(d)	
spawning cold shock	6.2-42.1	15.2	9-17.2		<24.1	24.1	6.2				Lab	McCormick et al 1977	
spawning cold shock	16	17.8	27.2				0	- 1 6			Lab	McCormick et al 1977	
cold shock	20						3	- 1 7			Lab	Edsall and Yocum 1972	
cold shock	25						6	- 1 9			Lab	Edsall and Yocum 1972	
cold shock	33-34						10	- 1 3			Sandusky, R. (L. Erie)	Coutant 1977b	
cold shock	27						2	- 2 5			Susquehanna R.	Coutant 1977b	
heat shock	12.2							+20.6			Lab, simulated onshore discharge	Crippen and Fahmy 1981	
	12.2							+23.5			Lab, simulated tempering discharge	Crippen and Fahmy 1981	
	12.2							i-23.3			Lab, simulated offshore discharge	Crippen and Fahmy 1981	
spawning		11.16									N.Y. and Penn.	Fuiman 1979	
spawning larval dev.		23.4	12.2-24								Connecticut R., Conn.	Marcy 1976b	
spawning migration		23.8	14.0-24								Connecticut R., Conn.	Marcy 1976b	
spawning larval dev. (9-11 mm TL)		211.8	3-16.5								Jack L., Ont.	Corbett and Powles 1983	
		16.8	10-16.9-k								Jack L., Ont.	Corbett and Powles 1983	
			6-16.8								Jack L., Ont.	Corbett and Powles 1983	

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Erimyzon sucetta (lake chubsucker)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference
hatching (6.7d)			22-29.5									Scott and Crossman 1973
spawning			15-22								N.Y. and Penn. (E. oblongus)	Fuiman 1979
				18.5	22							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

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SPECIES: Hypentelium nigricans (northern hog sucker)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a b	Data Limits Upper Lower Temp	Exposure Time (Min)	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
15										30.8		Kowalski et al 1978
18-33				33							Lab	Cherry et al 1977
18				27								Cherry et al 1977
21				30								Cherry et al 1977
24				33								Cherry et al 1977
27				33								Cherry et al 1977
30				33								Cherry et al 1977
33				34								Cherry et al 1977

SPECIES: *Hypentelium nigricans* (northern hog sucker)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
				26.6					Jobling 1981
50-100 FL;				15.3		12		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				20.2		15		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				16.9		18		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				23		21		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				27		24		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				28.7		27		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				29.4		30		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				28.8		33		Lab (rising water temperatures)	Cherry et al 1977
50-100 FL;				28.6				Lab (rising water temperatures)	Cherry et al 1977
				29.2					Cherry et al 1977
				25.2				Wabash Ft., Ind.	Brown 1974

SPECIES: *Hypentelium nigricans* (northern hog sucker)

Size or Age (mm)	Optimum °C	(a) Range	(b) ST Max		No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES:	
			MWAT	Max				Reference	Reference
		13.3-15.5					Annulus formation	Scott and Crossman 1973	
	25.8/25.3					3 1 0		Scott and Crossman 1973	
			28.1	30				Jobling 1981	
								This study	

(a) MWAT (maximum weekly average temperature for growth) = Optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Hypentelium nigricans* (northern hog sucker)

Event	Season and/or Acclimation Temp	Optimum Temp	(a) Temp Range	(b) ST Max for Embryo Survival	(c) Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal AT	Median Lethal Final	Location	Reference
spawning			> 15.6								Scott and Crossman 1973
spawning			12-23							N.Y. and Penn.	Fuiman 1979
hatching (10d)			17.4							Lab	Buynak and Mohr, Jr. 1978
				17.5	23						This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (19461).

(d) Simulated larval entrainment temperatures.

SPECIES: Ictiobus cyprinellus (bigmouth buffalo)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
Large			34.5		27			Wabash R., Ind. (buffalo sp.)	Coutant 1977a
	W			6-24				J.M. Stuart GS, Ohio R., Ohio (I. bubalus)	Yoder and Gammon 1976
	F			18-26				J.M. Stuart GS, Ohio R., Ohio (I. bubalus)	Yoder and Gammon 1987
	su			22-23				J.M. Stuart GS, Ohio R., Ohio (I. bubalus)	Yoder and Gammon 1976

SPECIES: Ictiobus cyprinellus (bigmouth buffalo)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final		
spawning		15.5-18.3										Scott and Crossman 1973
spawning			14.4-26.7									Carlander 1969 EPA 1974
spawning				17	27							
spawning hatching		17										EPA 1974 EPA 1974 This study
			14-27									
				17	26.7							

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Minytrema melanops* (spotted sucker)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
						a	b	Upper	Lower				Location	Reference
	20		SU									>31	Lab	Reutter and Herdendorf 1976

SPECIES: *Minytrema melanops* (spotted sucker)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
	SU			25-27				J.M. Stuart, GS, Ohio R.,	Yoder and Gammon 1976
	F			16-19				J.M. Stuart, GS, Ohio R.,	Yoder and Gammon 1976

SPECIES: *Minytrema melanops* (spotted sucker)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:						
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference	
spawning			15-17.8	16.4	17.8							Oklahoma	Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Moxostoma anisurum* (silver redhorse)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		13.3										Scott and Crossman 1973
spawning		13.5										Carlander 1969
				13.5								This study

SPECIES: *Moxostoma macrolepidotum* (shorthead redhorse)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
large			37.2 26		22			Wabash R., Ind. (<i>Moxostoma</i> sp.)	Scott and Crossman 1973 Coutant 1977
				26-27.5					Yoder and Gammon 1976

SPECIES: *Moxostoma macrolepidotum* (shorthead redhorse)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		11									Iowa	Scott and Crossman 1973
spawning		16									Big Rock Ck, Ill.	Talmage and Coutant 1978
spawning		12									Susquehanna R., Penn.	Buynak and Mohr, Jr. 1979
hatching (8d)		15.6									Lab	Buynak and Mohr, Jr. 1979
				13.5	16+							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Ictalurus melas* (black bullhead)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp		Lower Incip. Lethal Temp		log time = a + b (temp)		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
				Lethal Temp	Lethal Temp	a	b	Upper	Lower	Location	Reference					
YOY	23	33-37	su	35	35.7							35.7	2880	37.5	Lab Mississippi R.	Carlander 1969 Spotila et al 1979 Jinkes et al 1981 Talmage 1978
YOY			su	35	35.7											

SPECIES: *Ictalurus melas* (black bullhead)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
juvenile	su		35					Discharge L. Monona Steam GS, Wisc.	Beltz et al 1974
	W		14					Discharge L. Monona Steam GS, Wisc.	Beltz et al 1974

SPECIES: *Ictalurus melas* (black bullhead)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final		
spawning		21										Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Ictalurus natalis* (yellow bullhead)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
						a	b	Upper	Lower					
	22.2		su									36.4		Spotila et al 1979

SPECIES: *Ictalurus natalis* (yellow bullhead)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
adult	su			28.3				Lab		Coutant 1977a
juvenile				28.8						Coutant 1977a
adult				27.6						Coutant 1977a

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THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper	Lower	log time =		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Lethal Temp	Lethal Temp	a	b (temp)	Upper	Lower					
				36.1										Scott and Crossman 1973
5-6				28.6-29										Carlander 1969
10				30-30.2										Carlander 1969
20				33-33.4	-1/+1									Carlander 1969
25				35.5	1.3									Carlander 1969
30				36.5-37	3.7									Carlander 1969
36				37.5	7.0									Carlander 1969
37-38				37.2										Carlander 1969
10				29										Spotila et al 1979
20				32.3										Spotila et al 1979
25				33.7										Spotila et al 1979
30				34.7										Spotila et al 1979
5				29.9										Spotila et al 1979
10				31.5										Spotila et al 1979
15				33										Spotila et al 1979
20				35										Spotila et al 1979
25				37.5										Spotila et al 1979
30				39										Spotila et al 1979
35				41										Spotila et al 1979
40				41										Spotila et al 1979
			SU	35.5										Spotila et al 1979
			w	29.0										Spotila et al 1979
			SP	29.1-32.6									Algonquin Pk., stream Ont.	Spotila et al 1979
			su	33.2-35.5										Spotila et al 1979
			F	32.9										Spotila et al 1979
23			su								37.8			Spotila et al 1979
5				27.8		14.6802-0.4539	29.5	28.0					Florida to Ontario (combined)	Brown 1974
10				29		16.4227-0.4842	31.5	29.5					Florida to Ontario (combined)	Brown 1974
15				31		28.3281-0-8239	33	32.5					Florida to Ontario (combined)	Brown 1974
20				32.5	0.5	23.9586-0.6473	35	32.5					Florida to Ontario (combined)	Brown 1974
25				33.8	4.0	22.4970-0.5732	37	34					Florida to Ontario (combined)	Brown 1974
30				34.8	6.8	24.2203-0.5917	38.5	35.5					Florida to Ontario (combined)	Brown 1974
34				34.8		19.3194-0.4500	37.5	36.0					Florida to Ontario (combined)	Brown 1974
											≅38		S. Michigan pond	Brown 1974
			SP	28									L. Opeongo	Brown 1974
			su	34.8									L. Opeongo	Brown 1974

Size or Age (mm)	Accli- mation Temp.	Accli- mation Time	Sea- son	THERMAL TOLERANCES:									
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	Reference	
						a	b						Upper
larval	25			38.2					38.2	10		Lab	Jinks et al 1981
				36.4					36.4	30		Lab	Jinks et al 1981
				36.4					36.4	60		Lab	Jinks et al 1981
early juvenile	26			37.6					37.6	10		Lab	Jinks et al 1981
				36.5					36.5	30		Lab	Jinks et al 1981
44; YOY	24			35.9					35.9	60		Lab	Jinks et al 1981
44; YOY	24			35.6					35.6	1440		Lab	Jinks et al 1981
44; YOY	24			35.7					35.7	5760		Lab	Jinks et al 1981

SPECIES: Ictalurus nebulosus (brown bullhead)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
			40					Delaware R., discharge power plant	Brown 1974
adult	w			11.9				Lab	Coutant 1977a
adult	SP			23.5				Lab	Coutant 1977a
adult	su			24.9				Lab	Coutant 1977a
adult	F			23.6				Lab	Coutant 1977a
adult				29-31				Lab	Coutant 1977a
93-1 93				27.3				Lab	Coutant 1977a
				26				Lab	Spotila et al 1979
	w			10.9				Lab	Reutter and Hendendorf 1976
	SP			22.4				Lab	Reutter and Hendendorf 1976
				29-31					Jobling 1981
young				31					Wyman 1981
			40	19.6	5.1			Connecticut R., Conn. (field occurrence)	Marcy 1976a
young				31.1		26.1			Brown 1974
young			36.1			25			Brown 1974
93-193			21	13	7	3.5		Lab	Richards and Ibara 1978
93-193			26	15-16	7	11.0		Lab	Richards and Ibara 1978
93-193			24	17-18	9	15.5		Lab	Richards and Ibara 1978
93-193			26	25	21	21		Lab	Richards and Ibara 1978
93-1 93			28	27	22	28		Lab	Richards and Ibara 1978
93-193			30					Connecticut Yankee GS, Connecticut R., Conn.	Richards and Ibara 1978

SPECIES: *Ictalurus nebulosus* (brown bullhead)

Size or Age (mm)	Optimum °C	Range	(a) MWAT		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			(a) MWAT	(b) ST Max				Reference	
	32					<18		Carlander 1969	
	28.2/29.9					4-10	Connecticut Yankee GS, Connecticut R. Conn. (winter migration)	Spotila et al 1979	
			32	37				Jobling 1981	
								Richards and Ibara 1978	
								This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Ictalurus nebulosus* (brown bullhead)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit				Location	Reference
							Upper	Lower	Median AT	(d) Median Lethal Final		
spawning		21.1										Scott and Crossman 1973
hatching (6-9d)			20.6-25									Brown 1974
spawning migration		> 4									Connecticut Yankee GS, Connecticut River, Conn.	Richards and Ibara 1978
				21.1	25							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Ictalurus punctatus* (channel cat)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	THERMAL TOLERANCES:										Reference	
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location		
						a	b	Upper	Lower						
	15			30.3	0										Carlander 1969
	20			32.8	2.5										Carlander 1969
	25			33.5	6.0										Carlander 1969
				35											Carlander 1969
44-57d; juvenile	26			36.6		34.7	119-0.8816	39	36.6				33.5	Hatchery, Ark.	Brown 1974
44-57d; juvenile	30			37.8		32.1	736-0.7811	40.6	37.4						Brown 1974
44-57d; juvenile	34			38.0		26.4	204-0.6149	42	38						Brown 1974
	12														Spotila et al 1979
	16														Spotila et al 1979
	20														Spotila et al 1979
	24														Spotila et al 1979
	28														Spotila et al 1979
	32														Spotila et al 1979
	22.7		su												Spotila et al 1979
				36.1											Jobling 1981
				36.4											Jobling 1981
11.5 mo; juvenile	25			35.5		34.5	554-0.8854	37.5	35.5					Hatchery, Ark.	Brown 1974
11.5 mo; juvenile	30			37		17.7	125-0.4058	40	37.5					Hatchery, Ark.	Brown 1974
11.5 mo; juvenile	35			38		28.3	031-0.6554	41	38					Hatchery, Ark.	Brown 1974
adult	15			30.4	0	34.7	829-1.0637	31.5	30.5					Put-in-Bay, Ohio + Fla	Brown 1974
adult	20			32.8	0	39.4	967-1.1234	34	33					Put-in-Bay, Ohio + Fla	Brown 1974
adult	25			33.5	0	46.2	155-1.2899	35	44					Put-in-Bay, Ohio + Fla	Brown 1974
	7.2			32.8							32.8				Brown 1974
	11.			35							35				Brown 1974

SPECIES: *Ictalurus punctatus* (channel cat)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
large			32		26			Wabash R., Ind.	Coutant 1977a
large			34					White R., Ind.	Coutant 1977a
adult	SU			25.2				Lab	Coutant 1977a
adult	F			25.3				Lab	Coutant 1977a
			35	30.5	23			Lab	Coutant 1977a
				23-32.5				in field	Spotila et al 1979
				>32					Spotila et al 1979
				18.9		6			Spotila et al 1979
				20.4		9			Spotila et al 1979
				19.9		12			Spotila et al 1979
				21.7		15			Spotila et al 1979
				22.9		18			Spotila et al 1979
				26.1		21			Spotila et al 1979
				29.4		24			Spotila et al 1979
				29.5		27			Spotila et al 1979
				30.5		30			Spotila et al 1979
				17		12			Spotila et al 1979
				21		16			Spotila et al 1979
				22		20			Spotila et al 1979
				28		24			Spotila et al 1979
				26		28			Spotila et al 1979
				30		32			Spotila et al 1979
			28.5	15.2		5.1		Connecticut R., Conn. (field occurrence)	Marcy 1976a
fry				28-29					Brown 1974
	SU			32-36				J.M. Stuart GS, Ohio R., Ohio	Yoder and Gammon 1976
	F			30-32				J.M. Stuart GS, Ohio R., Ohio	Yoder and Gammon 1976
	w			s-14				J.M. Stuart GS, Ohio R., Ohio	Yoder and Gammon 1976

SPECIES: *Ictalurus punctatus* (channel cat)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			(a) M W A T	ST Max				Reference	
larvae	29								Jobling 1981
	30								Jobling 1981
juvenile	28-30	21-34			36				Jobling 1981
	29/31	18.3-34			>34	15.6			Brown 1974
	28/32		32	36					Brown 1974
									EPA 1974
	30								Leidy and Jenkins 1977
	30					10			Cravens 1981

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth),

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Ictalurus punctatus* (channel cat)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) M W A T	(b)		(c) Lethal Upper	(c)		(d) Median Lethal Final	Location	Reference
					ST Max for Embryo Survival	Acclimation Time		Lethal Limit Lower	Median ΔT			
spawning		26.7	23.9-29.5									Scott and Crossman 1973
hatching (5-10d)			15.6-27.8									Scott and Crossman 1973
spawning		23.9										Carlander 1969
hatching		22	23.9-22.8				>28.4					Brown 1974
				27		29						EPA 1974
spawning hatch		27	21-29									EPA 1974
wintering			18-29									EPA 1974
cold shock			5-15									Yoder and Gammon 1976
heat shock									-6 / -10		Lab	Coutant et al 1976
									+15		Lab; simulated entrainment	Cada et al 1981
(16-26 mm) cold shock	34								-14		Sandusky R. to L. Erie	Coutant 1977b

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Noturus flavus* (stone cat)

											THERMAL TOLERANCES:			
Size or Age (mm)	Acclimation Temp.	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	1.6		W									29.0		Spotila et al 1979

SPECIES: *Noturus flavus* (stone cat)

										PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference		
adult	W			5.5				Lab	Coutant 1977a		
adult	F			25.1				Lab	Coutant 1977a		

SPECIES: *Noturus flavus* (stone cat)

												SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference	
spawning		27.8		27.8								Scott and Crossman 1973 This study	

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Noturus gyrinus* (tadpole madtom)

													THERMAL TOLERANCES:	
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a b		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference

												38	Shallow Michigan pond.	Beltz et al 1974
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SPECIES: *Noturus miurus* (brindled madtom)

													SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference		

spawning		25.6									Michigan	Scott and Crossman 1973 This study
spawning			25-27	25.6							Ohio	McAllister et al 1985

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

SPECIES: *Anguilla rostrata* (american eel)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
adult			33-35 33	16.7 20.5	11.9	6-30		Maryland Connecticut Yankee GS discharge, Conn. Ft., Conn.	Carlander 1969 Cravens 1961 Marcy 1976a

SPECIES: *Anguilla rostrata* (american eel)

Size or Age (mm)	Optimum °C	(a) Range	(b) ST Max		No Growth Limits Upper Lower	Location	GROWTH TEMPERATURES:	
			MWAT	Max			Reference	
	25				10	Lab		Talmage and Coutant 1978

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Anguilla rostrata* (american eel)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max Embryo Survival	Acclimation Time	(c) (c)				(d) Median Lethal Final	Location	Reference
							Lethal Upper	Lethal Lower	Median Lethal AT	Median Lethal Final			
spawning		17		17	35							Ocean	Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures,

SPECIES: Fundulus diaphanus (banded killifish)

											THERMAL TOLERANCES:	
Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	Upper	Lower	log time =		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	Reference
				Incip. Lethal Temp	Incip. Lethal Temp	a	b					
adult	15			27.5							Lab Field	Brown 1974
				≥38.3								Leidy and Jenkins 1977
adult	25			34.5								Houston 1982
				26.5								Beltz et al 1974

SPECIES: Fundulus diaphanus (banded killifish)

								PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
adult			>15	19.3	0.5	6-33		SW Penn.	Cravens 1982 Talmage and Coutant 1978

SPECIES: Fundulus diaphanus (banded killifish)

											SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Accli- mation Temp	Optimum Temp	Tamp Range	(a) MWAT	(b) ST Max for Embryo Survival	Accli- mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d)	Location	Reference
										Median Lethal Final		
spawning		23	21-23								Lab	Scott and Crossman 1973
hatching (11-12d)			22-26.7								-Hatchery pond, Mich.	Scott and Crossman 1973
spawning			21									Carlander 1969
spawning			21-23								L. St. Louis, L. Renaud, Quebec	Talmage 1978
				23	26							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Lota lota (burbot)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:							Reference	
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time - $\frac{a+b}{temp}$		Data Limits	Exposure Temp	Resistance Time (Min)		-Critical Thermal (Max)
						Upper	Lower					
				23.3								Scott and Crossman 1973

SPECIES: Lota lota (burbot)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
small				21.2						Spotila et al 1979
				21.2				Lab		Coutant 1977a
	Sp/Su			11.4				Moosehead L., Me.		Coutant 1977a
3-7.5	Sp/Su			8-17				Atikokan GS Preop Study, Ontario		Haymes 1984
				6-11				L. Michigan		Mansfield et al 1983

SPECIES: Lota lota (burbot)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		Location	GROWTH TEMPERATURES:	
			MWAT	ST Max	No Growth Upper	Limits Lower		Reference	
	15.6-18.3		20	24				Scott and Crossman 1973	This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature- optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Lota lota (burbot)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		0.6-1.7									Surface water temp.	Scott and Crossman 1973
incubation (70d)		0-1.5										Mansfield et al 1983
hatching		<8-10		1.2	1.7							Mansfield et al 1983 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

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SPECIES: Labidesthes sicculus (brook silverside)

PREFERRED TEMPERATURES:											
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference
larval	SU			22-27						Mississippi R.	Holland and Sylvester 1983

SPECIES: *Culaea inconstans* [brook stickleback]

THERMAL TOLERANCES:														
Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	25-26			30.6										Carlander 1969

SPECIES: *Culaea inconstans* (brook stickleback)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning			8-19									Scott and Crossman 1973
hatching (8-9d)		18.3										Scott and Crossman 1973
spawning			4.5-21									Carlander 1969
hatching			15-18									Carlander 1969
				18.3	21							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Gasterosteus aculeatus* (three spine stickleback)

THERMAL TOLERANCES:														
Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	Upper	Lower	log time =		Data Limits		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	Reference
				Lethal Temp	Lethal Temp	a	b	Upper	Lower					
37 mm	19			28.5										
	19			25.8										
	19			25.8		19.34	9.1	9.59	4.0	3.2	2.6		Columbia R., Oregon	Jobling 1981 Houston 1982 Brown 1974 Talmage 1978 Carlander 1969(a)
				26										
					-0.7									

(a) fatal body temperature

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SPECIES: *Gasterosteus aculeatus* (*three* spine stickleback)

PREFERRED TEMPERATURES:										
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference	
adult				7.5-10					Jobling 1981	
				16-18					Jobling 1981	
				12-16					Wyman 1981	
				4-8		11			Cravens 1981	
				10		20			Talmage and Coutant 1980	
					4.0				Talmage 1978	
				16					Talmage and Coutant 1978	

SPECIES: *Gasterosteus aculeatus* (three spine stickleback)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Limits		Location	GROWTH TEMPERATURES:	
			(a) MWAT	ST Max	Upper	Lower		Reference	
		12.8-19.3						Jobling 1981	
>19		3-19						Jobling 1981	
			22.4	28.5				Cravens et al 1983	
								This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Gasterosteus aculeatus* (three spine stickleback)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d)		Location	Reference
										Median Lethal Final	Median Lethal		
hatching (7d) spawning		19	5-20										Scott and Grossman 1973 Carlander 1969
				19	20								This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Pungitius pungitius* (nine spine stickleback)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
	SU			17-24				Atikokan GS, Ontario	Haymes 1974
	F	N		5-6				L. Michigan (bottom trawl)	Brandt et al 1980
	F	D		13-14				L. Michigan (bottom trawl)	Brandt et al 1980

SPECIES: *Pungitius pungitius* (nine spine stickleback)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:				Location	Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal A T	(d) Median Lethal Final		
eggs		19-24	16-26	21	26							Carlander 1969 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24111 maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Percopsis omiscomaycus (trout perch)

Size or Age (mm)	Acclimation Temp.	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time =		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
						a	b	Upper	Lower				Location	Reference
adult	1.7		W									22.9	Lab	Reutter and Herdendorf 1976

SPECIES: Percopsis omiscomaycus (trout perch)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
adult			16		10			L. Michigan	Coutant 1977a
adult				16-18				L. Michigan	Brandt et al 1980
adult		D		15-16				L. Michigan	Brandt et al 1980
adult		N		7-16				L. Michigan	Brandt et al 1980
adult	F	D		15-16				L. Michigan	Crowder et al 1981
adult	F	N		7-8				L. Michigan	Crowder et al 1981

SPECIES: Percopsis omiscomaycus (trout perch)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			MWAT	ST Max				Reference	
						15.5	L. Erie	Carlander 1969	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Percopsis omiscomaycus (trout perch)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference
spawning		15									Twelvepole Ck., W. Va.	Talmage 1978
spawning			16-20								L. Winnebago, Wis.	Carlander 1969
spawning			6-11								Heming L., Man.	Carlander 1969
spawning		20	19-21.4								L. Erie	Carlander 1969
				20	21.4							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946)

(d) Simulated larval entrainment temperatures.

SPECIES: *Morone americana* (white perch)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:							Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)		
						Upper	Lower					
larvae				32.4-34					24-336h	35.6-36.4		Ellis 1964
	8			33-36	8				10			Talmage and Coutant 1979
	26			35								Talmage 1978
larvae	15			35.6					10		Lab	Talmage 1978
				31.4					30		Lab	Jinks et al 1981
				30.3					1440		Lab	Jinks et al 1981
		21-22		38.4					10		Lab	Jinks et al 1981
				35.2					30		Lab	Jinks et al 1981
				34.8					60		Lab	Jinks et al 1981
				31.0					1440		Lab	Jinks et al 1981
	24			38					10		Lab	Jinks et al 1981
				36.1					30		Lab	Jinks et al 1981
				35.4					60		Lab	Jinks et al 1981
34-41	26-27			36.8					5		Lab	Jinks et al 1981
				36.8					10		Lab	Jinks et al 1981
				37.2					30		Lab	Jinks et al 1981
31-35	25-26			35.4					60		Lab	Jinks et al 1981
				34.6					1440		Lab	Jinks et al 1981
				34.5					5760		Lab	Jinks et al 1981
larvae	18-24			38.5							Lab	Jinks et al 1981
juvenile	27			36							Lab	Jinks et al 1981
larvae				34.8							Lab	Kellogg and Gift 1983

SPECIES: *Morone americana* (white perch)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
Small			35	32				Lab		Coutant 1977a
			40	27.5	5.7			Connecticut	Yankee plant	Marcy 1976a
				> 24						Scott and Crossman 1973
51-65				28.9-30.6		6-33		Lab		Talmage and Coutant 1980
				31.6-32.5		6-33		Lab	N.C.	Talmage and Coutant 1979
				29.3-30.6		6-33		Lab	Maryland	Talmage and Coutant 1979
				29.2-29.6		6-33		Lab	N.J.	Talmage and Coutant 1979
larvae			32							Talmage and Coutant 1979
	su		31-34	29-32		26				
	W		24-25	13-19	9-10	3-4		Lab		Talmage 1978
32-39 TL				30				L a b		Kellogg and Gift 1983
35.1 TL				30.6		26		Lab		Kellogg and Gift 1983
29.5 TL				29.3		26		Lab		Kellogg and Gift 1983
3.88; larvae	sp/su			21-27				Connecticut	R.	Marcy 1976b

SPECIES: *Morone americana* (white perch)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		Location	GROWTH TEMPERATURES:	
			MWAT	ST Max	No Growth Upper	Limits Lower		Reference	
27.5	28.5	26.3-31.7	30.6	33	34		Lab, Hudson R. N.Y.	Kellogg and Gift 1983	This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Morone americana* (white perch)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower			(d) Median Lethal Final	Location	Reference
								Lethal Limit	Median Lethal	Median Lethal			
spawning hatch			11-15									Bay of Quinte, L. Ont	Scott and Crossman 1973
hatch	8-26	14.1/17.6	15-20										Scott and Crossman 1973
eggs	18				18		24		6				Cravens et al 1983
cold shock	20							2	-18				Wyman 1981
spawning hatch		15.6-19.4	12-22.2	17	25							Lab	Talmage 1978
embryo		14.1	10-24									Lab	Morgan II and Rasin, Jr. 1982
spawning		17.6	10-24									Lab	Morgan II and Rasin, Jr. 1982
eggs		19.0-20.9	8.9-27									Connecticut R.	Marcy 1976b
heat shock							28					Connecticut R.	Marcy 1976b
heat shock	27								t 8.5			Lab	Marcy 1976b
													Beltz et al 1974

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Morone chrysops (white bass)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Temp	Temp	a	b	Upper	Lower					
larvae	14-26			30-32							24h			Ellis 1984
YOY				33.5							48h			Ellis 1984
larvae	21.7											35.3	Lab	Reutter & Herdendorf 1976
	14			31.7	12.8								Lab	McCormick 1978
	18			30.8										McCormick 1978
	20			32.0										McCormick 1978
	26			30.6										McCormick 1978
YOY	14-26			31.3										McCormick 1978
				36.1									Mississippi R.	Talmage 1978
	30-35			33.5										Houston 1982
			su	33.5										Spotila et al 1979

SPECIES: Morone chrysops (white bass)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
large			29					Wabash R., Ind.	Coutant 1977a
YOY	W			10-13				Lab	Coutant 1977a
YOY	SP			16-18				Lab	Coutant 1977a
YOY	su			31.0				Lab	Coutant 1977a
YOY	F			28.0				Lab	Coutant 1977a
YOY	su			27.8				Lab	Coutant 1977a
adult	W			12-17				Lab	Coutant 1977a
adult	SP			12-17				Lab	Coutant 1977a
adult	su			28-30				Lab	Coutant 1977a
adult	F			16-17				Lab	Coutant 1977a
			>29.8					Pickering GS L. Ont	Ellis 1984
			>34					Colbert plant, Alabama	Ellis 1984
				29				J.M. Stuart GS, Ohio R.	Brown 1974
				33.9-34.4				Power plant discharge, Tennessee R.	Brown 1974
adult	SU			30-34				L. Erie	Brown 1984
			35						Ellis 1984
	su			27.8				Lab	Reutter and Herdendorf 1976
young	su			30-32					Wyman 1981
	SU			26-29				Power plant, Ohio R., Ohio	Yoder and Gammon 1976
	F			16-28					Yoder and Gammon 1976
	Wi			12-16					Yoder and Gammon 1976
			29-34.4					Ohio R., Ind.	Spotila et al 1979

SPECIES: *Morone chrysops* (white bass)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES:	
			M	W A T	ST	Max				Reference	
Juvenile larvae	23-24								Reservoir, S.D.	EPA 1974	
juvenile	16					19		15.6		Brown 1974	
			26.7		34					Brown 1974	
										This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 113 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Morone chrysops* (white bass)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
hatch		16-17									L. Erie	EPA 1974
spawning		23.9									L. Erie	Brown 1974
cold shock	w 27		14.4-21.1					9	- 18		Little-Three Mile Ck. Ohio A.	Scott and Crossman 1973
eggs	19		18-26		26		30.2	10			Lab	Coutant 1977b
spawning		14.7-16.3									Lewis & Clark L. (S.D.)	McCormick 1978
spawning			13-26								L. Mendota. Wis.	McCormick 1978
												Talmage & Coutant 1978
												Horrall 1981

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Ambloplites rupestris* (rock bass)

											THERMAL TOLERANCES:			
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
50-l 00														
<1 yr	18-36		Su	36										
	23.9			37.5										
adult	23.5		su											
	30			35										

SPECIES: *Ambloplites rupestris* (rock bass)

											PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference	
				21.3						Wisconsin lakes	Coutant 1377a	
				20.7						S. Ontario Streams	Coutant 1377a	
		D		27-27.8						L. Monona, Wisc.	Coutant 1377a	
		N		26.8-28.3						L. Monona, Wisc.	Coutant 1377a	
small		D	29.0	26.2	25.5					Lab	Coutant 1377a	
small		N	29.5	28.8	26.0					Lab	Coutant 1377a	
adult	w			21.6						Lab	Coutant 1377a	
adult	SP			20.5						Lab	Coutant 1377a	
adult	F			22.8						Lab	Coutant 1977a	
50-100 FL												
≤1 yr	su			30.6						Lab	Cherry et al 1977	
50-100 FL	su		27		15	18				Lab	Cherry et al 1977	
50-100 FL	su		30		18	21				Lab	Cherry et al 1377	
50-100 FL	su		33		21	24				Lab	Cherry et al 1377	
50-100 FL	SU		33		24	27				Lab	Cherry et al 1377	
50-100 FL	su		33		24	33				Lab	Cherry et al 1377	
50-100 FL	su		35		27	33				Lab	Cherry et al 1377	
48-59 TL												
juvenile				27.3						Lab	Brown 1974	
98-182 TL												
adult				27.5						L. Monona, Wisc.	Brown 1974	
				27.4						Wabash R.	Brown 1374	
				30							Talmage and Coutant 1373	
adult	SP			19.6						Lab	Reutter & Herdendorf 1976	
	SU			20.2							Reutter & Herdendorf 1376	
		N	30.5		27						Carlander 1377	
	su			18.7							Spotila et al 1379	

SPECIES: *Ambloplites rupestris* (rock bass)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			MWAT	ST Max				Reference	
	27.7 29		31.8	35		8.5	Ontario stream	Carlander 1977 Jobling 1981 Jobling 1981 This study	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth)

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

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SPECIES: *Ambloplites rupestris* (rock bass)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a)		(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal AT	(d) Median Lethal Final	Location	Reference
				MWAT									
spawning		20.5-21										Lab	Brown 1974
survival								38				Michigan pond	Brown 1974
spawning		15.6-21.1	20.5-26	21	26								Scott and Crossman 1973 Carlander 1977 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Lepomis cyanellus (green sunfish)

											THERMAL TOLERANCES:			
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Upper	Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
													White R., Ind. Field study	Brown 1974 Brown 1974 Carlander 1977 Leidy and Jenkins 1977

SPECIES: Lepomis cyanellus (green sunfish)

											PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference	
			>36.1	15.9				6			Brown 1974	
				22.7				15			Carlander 1977	
				30.6				30			Carlander 1977	
				26.8							Beltz et al 1974	
<74; adult			30	27.3	24					Lab	Coutant 1977a	
			33	30.6	23					Lab	Coutant 1977a	
small			30.3	28.2	26.5					Lab	Coutant 1977a	

SPECIES: *Lepomis cyanellus* (green sunfish)

Size or Age (mm)	Optimum °C	Range	(b)				Location	GROWTH TEMPERATURES:	
			(a) MWAT	ST Max	No Growth Upper	Limits Lower		Reference	
	28	13.2-28			>34	20		Carlander 1977 Beitinger and Magnuson 1979	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Lepomis cyanellus* (green sunfish)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower				Location	Reference	
								Median Lethal AT	(d) Median Lethal Final					
spawning			15.6-28										Brown 1974	
spawning	16.7						21.1							Brown 1974
heat shock spawning	F/W/SU		20-24						>11.1					Brown 1974
hatching		29.1			21.8	28								Carlander 1977 Carlander 1977 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larvalentrainment temperatures.

SPECIES: *Lepomis gibbosus* (pumpkinseed)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:		log time = a + b (temp) a b	Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp							
17-18			su	<38							Pond (Mich.)	Brown 1974
	18			28								Brown 1974
	24			30.2								Brown 1974
	21.1			38.9								Brown 1974
adult	23.1		su							37.5	Lab	Reutter and Herdendorf 1976
	25.26			34.5						>35.6	Lab	Carlander 1977
	25			24.5							Lab	Carlander 1977
				36.6								Leidy and Jenkins 1977
				34.8								Jobling 1981
					8.5							Jobling 1981
	30				5							Schneider and et al 1975
	25											Schneider and et al 1975
90-140	10									30.1	Lab	Becker and Genoway 1979
	20									35.1	Lab	Becker and Genoway 1979
adult	12		su	27.7-28.3	3.6						Lab	Evans 1977
adult	20		su	32.3-32.9	6.4						Lab	Evans 1977
adult	28		su	35.2-35.3	11.3						Lab	Evans 1977
adult	34		su		16.1						Lab	Evans 1977
adult	5		Wi		1.1						Lab	Evans 1977
adult	10		Wi		1.2						Lab	Evans 1977
adult	12		Wi	28.5							Lab	Evans 1977
adult	20		Wi	31.6	6.4						Lab	Evans 1977
adult	28		Wi	31.9							Lab	Evans 1977
adult	30		Wi		13.4						Lab	Evans 1977
adult	32		Wi	33.5							Lab	Evans 1977
adult	20		F	31.7	5.9						Lab	Evans 1977
adult	34		F	37.0							Lab	Evans 1977
YOY	20		su		5.9						Lab	Evans 1977
YOY	12		su		2.1						Lab	Evans 1977
YOY	20		F	31.7	6.0						Lab	Evans 1977
YOY	8		Wi	26							Lab	Evans 1977
YOY	16		Wi	30.5							Lab	Evans 1977
YOY	24		Wi	34.2							Lab	Evans 1977

SPECIES: *Lepomis gibbosus* (pumpkinseed)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
large		D		28.5-32				L. Monona, Wis.	Coutant 1977a
large		N		27-29				L. Monona, Wis.	Coutant 1977a
small				31.5				Lab	Coutant 1977a
adult	SP			24.2				Lab	Coutant 1977a
adult	su			27.7				Lab	Coutant 1977a
large			>31	26	>22			Lab	Coutant 1977a
YOY	F/W		31.4		24.5	20			Evans 1977
100-161TL		D		28				L. Monona, Wis.	Brown 1974
100-161TL		N		30.5				L. Monona, Wis.	Brown 1974
			32.2					Delaware R.	Brown 1974
adult	W			28.5				Lab	Talmage and Coutant 1979
	SP			31.7				Lab	Talmage and Coutant 1979
	su			31.7				Lab	Talmage and Coutant 1979
			31.7	31.5	31			Lab	Carlander 1977
			34					Lab	Beitinger and Magnuson 1979
			40	28.4	11.9			Connecticut R., Conn. (field occurrence)	Marcy 1976a
adult	W		26.1	22.9	18.5	8		Lab	Evans 1977
adult	W		29.2	25.3	20.8	12		Lab	Evans 1977
adult	W		30.3	26.9	23	20		Lab	Evans 1977
adult	W		31	27	22.4	24		Lab	Evans 1977
adult	SP		25	23.2	21.4	8		Lab	Evans 1977
adult	SP		28.8	25.5	21.2	12		Lab	Evans 1977
adult	SP		31.4	28.8	25.9	20		Lab	Evans 1977
adult	SP		32.3	29.5	25.6	24		Lab	Evans 1977
adult	su		29.3	25.6	21.8	12		Lab	Evans 1977
adult	su		31.3	28.1	24.5	20		Lab	Evans 1977
adult	su		32.7	30.3	26.7	24		Lab	Evans 1977

SPECIES: *Lepomis gibbosus* (pumpkinseed)

								GROWTH TEMPERATURES:	
Size or Age (mm)	Optimum °C	(a) Range	W ST Max	No Growth Upper	Limits Lower	Location	Reference		
underyearling	25				13	Gt. lakes	Carlander 1977		
	30				5		Jobling 1981		
		29.3	36				Griffiths 1978		
							Spotila et al 1979		
							This study		

(a) MWAT (maximum weekly average temperature for growth) = optimum + 113 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Lepomis gibbosus* (pumpkinseed)

												SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference	
spawning		28	20-29								Lake, N.Y. Lab	Brown 1974	
		24										Brown 1974	
hatching		28										Brown 1974	
spawning			20-27.8								Georgian Bay, Ontario	Scott and Crossman 1973	
spawning			13-18									Carlander 1977	
cold shock	15						0.5	- 10	1.8		Lab	Scheider and Becker et al 1975	
cold shock	20						2	-10	2.7		Lab	Scheider and Becker et al 1975	
cold shock	25						5	-18	8.5		Lab	Scheider and Becker et al 1975	
cold shock	25							-10	6.3		Lab	Scheider and Becker et al 1975	
cold shock	30						8.5	-18	12		Lab	Scheider and Becker et al 1975	
cold shock	30							-10	8-9		Lab	Scheider and Becker et al 1975	

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Lepomis macrochirus* (bluegill)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:											
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference	
						a	b	Upper	Lower						
adult	15			31	3										EPA 1974
juvenile	12			27	3										EPA 1974
adult	20			32	5										EPA 1974
adult	25			33	7										EPA 1974
juvenile	26			36	10										EPA 1974
adult	30			34	11										EPA 1974
juvenile	33			37	15										EPA 1974
adult	22.8		SU									38.3	Lab		Reutter and Herdendorf 1976
				35.5								41.5			Carlander 1977
juvenile	19			33	6										Carlander 1977
eggs	26			33.8	21.9										Carlander 1977
fry	26			34	11										Carlander 1977
	16											31.5			Murphy et al 1976
	24											35.6-37.5			Murphy et al 1976
	32											38.5-41.4			Murphy et al 1976
90	27			35.8									Lab		Peterson and Schutsky 1976
	13			29.3									Lab		Peterson and Schutsky 1976
	1			23.3									Lab		Peterson and Schutsky 1976
	25											35.6-37.3			Beitinger and Magnuson 1979
	30											37.8			Spotila et al 1979
	35											40			Spotila et al 1979
												43.4			Spotila et al 1979
			su	28.5											
									38	48					Brown 1974
	25			38.3								41.4			Brown 1974
50-100	12-36		Su	36									Lab		Cherry et al 1977
adult	20-23					38.6247-1.0581	35.5	34							Brown 1974
5.8-14.2g	30			33.8		30.1609-0.7657	38	36	36.5	240					Brown 1974

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SPECIES: *Lepomis macrochirus* (bluegill1)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
adult				31		26			Cravens 1982
juvenile				31.2		25			Talmage and Coutant 1978
juvenile			33.1		29.5	25			Talmage and Coutant 1978
50-100; <1 yr Su				31				Lab	Talmage and Coutant 1980
				31.4					Talmage and Coutant 1980
				29.4-31.3				L. Monona, Wis.	Coutant 1977a
53-99		D		28.8-31.2				L. Monona, Wis.	Coutant 1977a
53-99		N		27-29				L. Monona, Wis.	Coutant 1977a
100-193		D		29.6-32.6				L. Monona, Wis.	Coutant 1977a
100-193		N		27.2-29				L. Monona, Wis.	Coutant 1977a
young				32.3				Lab	Coutant 1977a
young		D	32.1	30.2	28.5			Lab	Coutant 1977a
young		N	32.5	31.5	28.5			Lab	Coutant 1977a
young			33.1	31.2	29.3			Lab	Coutant 1977a
adult		W		27.4				Lab	Coutant 1977a
adult			35	32	26			Lab	Coutant 1977a
45-110			33	32.3	26			Lab	Coutant 1977a
120-155				30.5				Lab	Coutant 1977a
		W						Thermal discharge	Brown 1974
								White R., Ind.	
			35	30		30-34		Penn.	Brown 1974
				18.7		6			Carlander 1977
				19.6		9			Carlander 1977
		su	34		22			Ohio R.	Yoder and Gammon 1976
		F	24		14			Ohio R.	Yoder and Gammon 1976
		W	a		5			Ohio R.	Yoder and Gammon 1976
			33.5	30.7	27			Lab	Peterson and Schutsky 1976
			30.3	24.6	13			Lab	Peterson and Schutsky 1976
			27.6		1			Lab	Peterson and Schutsky 1976
			33.4	31.8	30.2				Beitinger 1976
			34						Beitinger and Magnuson 1979

SPECIES: *Lepomis macrochirus* (bluegill)

Size or Age (mm)	Optimum °C	Range	(a)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			M W A T	ST Max				Reference	
						13	Gt. Lakes	Griffiths 1978	
						16-20	Indiana Lakes	Evans 1984	
juvenile	30	20-36						Talmage and Coutant 1978	
juvenile	30							Cravens 1981	
subadult	30-31							Talmage and Coutant 1980	
	30.1							McCauley and Casselman 1980	
	29-30							McCauley and Casselman 1980	
	31							McCauley and Casselman 1980	
adult	24-27	24-34		32.2				Brown 1974	
		16-30						Brown 1974	
			29	32				EPA 1974	
					26.7	10-13	Ponds	Carlander 1977	
	27			31			Lab	Carlander 1977	
75-125	31.2							Stuntz and Magnuson 1976	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Lepomis macrochirus* (bluegill)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b)		(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
					ST Max for Embryo Survival	Acclimation Time						
spawning			17-26									Carlander 1977
hatching	26	22.2-23.9					33.8					Spotila et al 1979
heat shock									+ 16.7			Brown 1974
heat shock									+ 17.8			Brown 1974
heat shock									+20			Brown 1974
spawning		25		25	34							EPA 1974
hatching		22-24	22-34									EPA 1974
cold shock	25								- 10		Lab	Wolters and Coutant 1976
cold shock	30								- 14		Lab	Wolters and Coutant 1976
cold shock	32								- 16		Lab	Wolters and Coutant 1976
heat shock									+16.7/+20			Brown 1974
									+20			
heat shock Su									+ 6.7			Brown 1974

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Lepomis megalotis* (longear sunfish)

											THERMAL TOLERANCES:			
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a + b(\text{temp})}{a}$		Data Upper	Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Temp	Temp	a	b							
>12; juvenile	25			35.6		35.4953	0.9331	36.9	35.4				Middle Fork & White R., Ark.	Brown 1974
>12; juvenile	30			36.8		20.5981	0.4978	39	36.5				Middle Fork & White R., Ark.	Brown 1974
>12; juvenile	35			37.5		30.7245	9.7257	41.5	37.3				Middle Fork & White FL, Ark.	Brown 1974
young	25	14h		35.5						36.9	8		Lab	Brown 1974
young	30	14h		36.6						39	10		Lab	Brown 1974
young	35	14h		38.2						41.5	8		Lab	Brown 1974
young	25									35.6	160		Lab	Brown 1974
young	30									36.7	<250		Lab	Brown 1974
young	35									37.3	9000		Lab	Brown 1974
	15.5			31.1										Houston 1982
	>30			37.9										Houston 1982
						<7							Field Study	Leidy and Jenkins 1977

SPECIES: *Lepomis megalotis* (longear sunfish)

											PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference	
			>37.8								Carlander 1977	

SPECIES: *Lepomis megalotis* (longear sunfish)

											SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference
spawning			23.4-25									Scott and Crossman 1973
spawning			24-30								Kansas	Carlander 1977
				27	30							This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Micropterus dolomieu* (smallmouth bass)

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Size or Age (mm)	Accli- mation. Temp	Accli- mation Time	Sea- son	Upper		Lower		log time = $\frac{a + b(\text{temp})}{a - b}$	Data Limits Upper Lower	Expo- sure Temp	Resis- tance Time (Min)	Critical T h e r m a l (Max)	THERMAL TOLERANCES:		Reference
				Lethal Temp	Incip. Temp	Lethal Temp	Incip. Temp						Location	Reference	
larvae				33											EPA 1974
juvenile				35											EPA 1974
juvenile	15					2									EPA 1974
larvae						4									EPA 1974
juvenile	18					4									EPA 1974
juvenile	22					7									EPA 1974
juvenile	26					10									EPA 1974
YOY	35			37									Outdoor expt. channels, Alabama		Wrenn 1980
adult	35			37											Ellis 1984
fry				38									field and lab		Wrenn 1980
larvae				30		10							Lab		Shuter et al 1980
juvenile	15					2							Lab		EPA 1974
juvenile	18					4							Lab		EPA 1974
juvenile	22					7							Lab		EPA 1974
juvenile	26					10							Lab		EPA 1974
	23.3		SU									36.3	Lab		Reutter and Herdendorf 1976
	12.8					29.4-32.2									Brown 1974
adult/ juvenile				35											Wrenn 1980
50-l 00; <1yr	18-33		su	35									Lab		Cherry et al 1977
larvae				35.8											Fahmy and Crippen 1981
juvenile	26					10.1							Lab		Leidy and Jenkins 1977
	35					1.6							Lab		Leidy and Jenkins 1977

SPECIES: *Micropterus dolomieu* (smallmouth bass)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
small				28				Lab	Coutant 1977a
YOY	W			18				Lab	Coutant 1977a
YOY	SP			19-24				Lab	Coutant 1977a
				21.3				Nebish L., Wis.	Coutant 1977a
				21.4				S. Ont. streams	Coutant 1977a
YOY	su			31				Lab	Coutant 1977a
YOY	F			24-27				Lab	Coutant 1977a
YOY	F			26.6				Lab	Coutant 1977a
YOY		D	35	31.1	25			Lab	Coutant 1977a
adult	W			12-13				Lab	Coutant 1977a
adult	SP			15-16				Lab	Coutant 1977a
adult	su			30				Lab	Coutant 1977a
adult	F			21-23				Lab	Coutant 1977a
			33	31.3	26			Lab	Coutant 1977a
adult	su			30-31				Tennessee R., Alab. (outdoor exptal channels)	Wrenn 1980
164 juvenile				28-29				Lab	Shuter et al 1980
		D		30.1				Lab	Talmage and Coutant 1979
		N		26.6				Lab	Talmage and Coutant 1979
				30.3				Lab	Cherry et al 1977
50-100; \leq1yr							Lab	Cherry et al 1977	
50-100; &1yr			27	15	18		Lab	Cherry et al 1977	
50-100; \leq1yr			30	18	21		Lab	Cherry et al 1977	
50-100; *1yr			33	21	24		Lab	Cherry et al 1977	
50-100; *1yr			33	24	27		Lab	Cherry et al 1977	
50-100; \leq1yr			33	24	30		Lab	Cherry et al 1977	
50-100; \leq1yr			35	27	33		Lab	Cherry et al 1977	
adult	F			26.6				Lab	Cherry et al 1977
	W			20		1			Ellis 1984
			136.7						Spotila et al 1979

SPECIES: *Micropterus dolomieu* (smallmouth bass)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			(a) MWAT	ST Max				Reference	
YOY juvenile	28	14-31.5			35	7	Lab and field (Baie du Dore, L. Huron)	Shuter et al 1980	
juvenile/adult			29				Tennessee R.. (outdoor exptal channels), Alab.	EPA 1974	
			32/33	35			Lab	Wrenn 1990	
15-35SL; fry	25-26							Coutant and DeAngelis 1983	
	25							McCauley and Casselman 1980	
	29							McCauley and Casselman 1980	
	27							McCauley and Casselman 1980	
						10		Carlander 1977	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth)

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Micropterus dolomieu* (smallmouth bass)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b)		(c) Lethal Upper	(c) Lethal Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
					ST Max for Embryo Survival	Acclimation Time						
spawning		18	15-17	17		26					Baie du Dore, L. Huron Tennessee R., Ala. (outdoor expt. channel)	Shuter et al 1980 Wrenn 1984
egg/larval devel.		21	13-26			25		30	10		Lab and field (Baie du Dore, L. Huron)	EPA 1974 Shuter et al 1980
w	19							29	17			Brown 1974
egg	16.1							23.1				Brown 1974
heat shock	20								+7	37		Moore 1979 (d)
cold shock	27								-20	2		Coutant 1977b
heat shock	20								+16.6		Lab (onshore discharge)	Crippen and Fahmy 1981
heat shock	20								+17.7		Lab (tempering discharge)	Crippen and Fahmy 1981

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for ^{successful} embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures,

SPECIES: *Micropterus salmoides* (largemouth bass)

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Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:		log time = a + b (temp) a b	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp		Upper	Lower					
juvenile	12			36									Cherry et al 1982 EPA 1974 EPA 1974 EPA 1974 EPA 1974
	20			33	5								
	25			35	7								
	30			36	11								
	35			36									
9-11 months	20			32		35.5107	-1.0112						Brown 1974
9-11 months	25			33		19.9918	-0.5123						Brown 1974
S-11 months	30			33.7		17.5645	-0.4200						Brown 1974
adult	20			32.5		50.8091	-1.4638	34	33			Put-in-Bay, Ohio	Brown 1974
adult	25			34.5		26.3169	-0.6846	36.5	35			Put-in-Bay, Ohio	Brown 1974
adult	30			36.4		29.0213	-0.7150	38.5	37			Put-in-Bay, Ohio	Brown 1974
under yearling	20				5.5							Put-in-Bay, Ohio	Brown 1974
	30				11.8							Put-in-Bay, Ohio	Brown 1974
	30			36.4		36.0620	X1.9055	38.5	37			Knoxville, Tenn.	Brown 1974
0.18g; fingerling	35			36.4		23.9185	-0.9958	40	37.5			Knoxville, Tenn.	Brown 1974
	22			31.5		34.3649	-0.9789	33.8	32.0			Lake Mendota, Wis.	Brown 1974
	30					35.2777	-0.9845	37.5	35.5			Lake Mendota, Wis.	Brown 1974
0.18g; fingerling	7.2	21 h		30.6								Pennsylvania	Brown 1974
	11.1	43h		35									Brown 1974
0.18g; fingerling	15			35									Venables et al 1978
0.18g; fingerling	20			35								Lab (Texas)	Venables et al 1978
0.18; fingerling	25			40								Lab (Texas)	Venables et al 1978
0.18; fingerling	30			40	10							Lab (Texas)	Venables et al 1978
0.18; fingerling	35			40	15				40	19m		Lab (Texas)	Venables et al 1978
0.18; fingerling	35								15	12-20h		Lab (Texas)	Venables et al 1978
0.18; fingerling	35												Venables et al 1978
adult	0.7		W								>12.0	Lab	Reutter and Herdendorf 1976
eggs				36.7/389									Carlander 1977
	20-21			28.9									Spotila et al 1979
				32.5									Spotila et al 1979
	20										36.7		Spotila et al 1979
28										40.1		Spotila et al 1979	
			SU	35.6									Spotila et al 1979

SPECIES: *Micropterus salmoides* (largemouth bass)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
large				26.6-27.7				Norris Res., Tenn.	Coutant 1977a
large			30	27-30				Par Pond, S.C.	Coutant 1977a
72-99;				29.3-30.9				L. Monona, Wis.	Coutant 1977a
100-408;		D		29.3-32				L. Monona, Wis.	Coutant 1977a
100-408;		N		26.5-29.1				L. Monona, Wis.	Coutant 1977a
adult			29	27	25.5			small lakes, Tenn.	Coutant 1977a
small				30-32				Lab	Coutant 1977a
small			30.7	29	27.5			Lab	Coutant 1977a
adult			30					Pond C, Savannah Ft. GS, S.C.	Coutant 1977a
110-160; YOY		D		30.1				Lab	Coutant 1977a
110-150; YOY		D	34	30	21			Lab	Coutant 1977a
50-460g		N		30.2				Lab	Coutant 1977a
65-75TL;			31	29.1	27.2				Brown 1974
50-90TL;			30.6-32.8			25			Brown 1974
adult				28		3-8		Lab	Cravens 1981
adult				27-32				Lab	Talmage and Coutant 1979
		N		29.5				Lab	Talmage and Coutant 1979
		D		27.1				Lab	Talmage and Coutant 1979
			24	30.4	9	12		Lab	Cherry et al 1982
			33		21	24		Lab	Cherry et al 1982
			28.7	21.3	14.8			Connecticut R., Conn. (field occurrence)	Marcy 1976a

SPECIES: *Micropterus salmoides* (largemouth bass)

Size or Age (mm)	Optimum °C	Range	(b) ST		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			(a) M W A T	M a x				Reference	
juvenile	25							McCauley and Casselman 1980	
subadult	26-28		32	34				McCauley and Casselman 1980	
larval	27	20-30					Lab	EPA 1974	
juvenile	30	23-31						EPA 1974	
fry		15.9-32.5					Lab	Brown 1974	
	23.9						Texas reservoirs	Brown 1974	
15.35SL; fry	27						Lab	Coutant and DeAngelis 1983	
fry		17.5-27.5			> 36	10		Carlander 1977	
	25-30						Lab	Smagula and Adelman 1982	
	18							Spotila et al 1979	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Micropterus salmoides* (largemouth bass)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		15.6-21	12-20	21	27						field	EPA 1974
hatching		20	13-26									Carlander 1977
eggs							32.5					EPA 1974
spawning				23.9								Brown 1974
					29-32						Lab (Wis., Minn.)	Brown 1974
embryo devel.20							32.1				Lab	EPA 1978
embryo devel. 24							32.1				Lab	Cravens 1982
embryo devel.27							32.1				Lab	Cravens 1982
embryo devel.30							32.1				Lab	Cravens 1982
eggs 17-21							26.7				Lab (N.Y.)	Venables et al 1978
spawning		20									Lab (Minn.)	Carlander 1977
hatching			10-30									Carlander 1977
heat shock (adult)	Su								+10			Brown 1974
heat shock (larval)	15-35								+ 20-25	35-40	Lab (Texas)	Venables et al 1978

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Pomoxis annularis (white crappie)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:		log time = a + b (temp) a b	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp		Upper	Lower					
juvenile adult	24.4		su	<33							>32.8	Lab (UUILT) Lab	EPA 1974 Reutter and Herdendorf 1976

SPECIES: Pomoxis annularis (white crappie)

Size or Age (mm)	Season	Day or Night	PREFERRED TEMPERATURES:		Acclimation Temperature	Acclimation Time	Location	Reference
			Upper Avoidance	Final Preferendum				
large adult	W		27		22		Wabash R., Ind.	Coutant 1977a
adult	SP			19.8			Lab	Coutant 1977a
adult	F			18.3			Lab	Coutant 1977a
adult	su			10.4			Lab	Coutant 1977a
	SU		31		26		Lab	Reutter and Herdendorf 1976
	F		26		18		Ohio R.	Yoder and Gammon 1976
	W		8		5			Yoder and Gammon 1976
	su	D	24-30	23			Kansas Reservoir	O'Brien et al 1984
	F	D		23-24				O'Brien et al 1984

SPECIES: Pomoxis annularis (white crappie)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			M	W A T	ST	Max				Reference	
juvenile	25		27							EPA 1974	
	27-28.5				32.2		27	15.6	Ohio R.	Brown 1974	
		5-30								Carlander 1977	
										Yoder and Gammon 1976	
										O'Brien et al 1984	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Pomoxis annularis (white crappie)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b)		(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
					ST Max for Embryo Survival	Acclimation Time						
spawning	sp/su	16-20	14-23									EPA 1974
spawning		18-20										EPA 1974
hatching				18	23							EPA 1974
spawning		14-16	18.3-20									Carlander 1977
												O'Brien et al 1984

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Pomoxis nigromaculatus (black crappie)

THERMAL TOLERANCES:													
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip.	Lower Incip.	log time =			Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Lethal Temp	Lethal Temp	a	b	Upper					
juvenile	29			<33								Lab (UUILT)	EPA 1974
	7.2	1°C/h		28.9								Lab	Brown 1974
adult	23.8		su	34							34.9	Lab	Reutter and Herdendorf 1976 Carlander 1977
>200TL			su	32.5								Hayes Centre L., Neb. (observed)	Leidy and Jenkins 1977 Ellison 1984

SPECIES: Pomoxis nigromaculatus (black crappie)

PREFERRED TEMPERATURES:												
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time			Location	Reference	
large		D		27.8-29.8						L. Monona, Wis.	Coutant 1977a	
large		N		27-28.2						L. Monona, Wis.	Coutant 1977a	
small			30		26.5					Lab	Coutant 1977a	
small			29.5		25.5					Lab	Coutant 1977a	
adult	w			20.5						Lab	Coutant 1977a	
adult	Sp			21						Lab	Coutant 1977a	
adult	SU			21.7						Lab	Coutant 1977a	
adult	F			22.2						Lab	Coutant 1977a	
medium			26	24	20					Lab	Coutant 1977a	
larvae	Su			18-20						Northern Wis. Lakes	EPA 1974	
adult	s u		34		24					Lab	EPA 1974	
75-88TL;				28.3						L. Monona, Wis.	Brown 1974	
adult	w			20.7						Lab	Reutter and Herdendorf 1976	
adult	F			24.6						Lab	Reutter and Herdendorf 1976	
			30.5		24					L. Monona, Wis.	Carlander 1977	
			27.3	21.3	16.5					Connecticut R., Conn. (field occurrence)	Marcy 1976a	

SPECIES: Pomoxis nigromaculatus (black crappie)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits		Location	GROWTH TEM	
					Upper	Lower		Reference	Reference
juvenile	22-25		27	32.2	30	11		EPA 1974	
<76TL;		27-29				6.5	L. Monona, Wis.	Brown 1974	
>200TL;	9-17	9-25			26		Ontario	Brown 1974	
					27		Hayes Center State Lake, Neb.	Carlander 1977	
							Clear L., Iowa	Ellison 1984	

- (a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).
 (b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

S. Pomoxis nigromaculatus (black crappie)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
spawning			14-18									EPA 1974
spawning			14-20									EPA 1974
spawning		19-20									Buckeye L., Ohio	Scott and Crossman 1973
spawning			4.4-15.6								Wis.	Carlander 1977
spawning		17.8-20									L. Opinicon, Ont.	Carlander 1977
larval devel.			13-23									Carlander 1977
hatching		18.3									Lab (Minn.)	Carlson and Herman 1978
spawning			14-21									Carlson and Herman 1978
hatching/ devel.		16-20		8	2							This study

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum; or middle of range of spawning temperatures.
 (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
 (c) Not incipient lethal temperatures as defined by Fry et al (1946).
 (d) Simulated larval entrainment temperatures.

SPECIES: *Perca flavescens* (yellow perch)

Size or Age (mm)	Acclimation Temp.	Acclimation Time	Season	THERMAL TOLERANCES:		log time = a + b (temp) a b	Data Limits Upper Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp							
adult	5			21							Toronto, Ontario	EPA 1974
larvae	10			10								EPA 1974
adult	11			25								EPA 1974
adult	15			28								EPA 1974
larvae	19			19								EPA 1974
	18			26.5								Spotila et al 1979
adult	25		su	32.3								EPA 1974
juvenile	25				4							EPA 1974
49; juvenile	19	4 day				15.3601-0.4126	38 32				Columbia R., Oregon	Brown 1974
4 yr; adult	5			21.3		7.0095-0.2214	26.5 22				Black Ck., L.Simcoe, Ont.	Brown 1974
	11			25.0	1.1	17.6536-0.6021	26.5 26				Black Ck., L.Simcoe, Ont.	Brown 1974
	15			27.7		12.4149-0.3641	30.5 28.5				Black Ck., L.Simcoe, Ont.	Brown 1974
	25			28.7	3.7	21.2718-0.5909	33.0 30.0				Black Ck., L.Simcoe, Ont.	Brown 1974
larvae				23.9								Brown 1974
young	22-23			29.6				31.5	240			Brown 1974
young	22-23			29.6				32	60			Brown 1974
y o u n g	22-23			29.6				34	15			Brown 1974
125 TL adult	23-25		SU	30.9								Hokanson 1977
30-50 TL				26								Cherry et al 1977
adult	22		Su							35	Lab	Reutter and Herdendorf 1976
larval	15			33.7					10			Jinks et al 1981
				31.3					30			Jinks et al 1981
larval					9.8							Dunford 1978
embryo				19.9	6.8							Hokanson 1977
6-24 g juvenile	25		W	29.7						33.4		Hokanson 1977
0.5 g juvenile	28		SU	33-34								Hokanson 1977
larval	7.6			>24						34.8	Lab	Dunstall 1979
larval	15.8			>26.6						37.6		Dunstall 1979
	22-24			29.2								Spotila et al 1979
hatch				19.9	6.8							Spotila et al 1979
swim-up larvae				18.8	9.8							Spotila et al 1979

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Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
small				12.2				Muskellunge L., Wis.	Coutant 1977a
large				20.2				Muskellunge L., Wis.	Coutant 1977a
				20.2				Silver L., Wis.	Coutant 1977a
				21.0				Nebish L., Wis.	Coutant 1977a
				20.8				Trout L., Wis.	Coutant 1977a
				19.7				L. Nipissing, Ont.	Coutant 1977a
				21.1				L. Opeongo, Ont.	Coutant 1977a
adult	W			21.0				Costello L., Ont.	Coutant 1977a
					11			L. Michigan	Coutant 1977a
small				21.0				Lab	Coutant 1977a
small				24.2				Lab	Coutant 1977a
small		D	26.5	23.3	20.2			Lab	Coutant 1977a
small		N	25	22.5	19.5			Lab	Coutant 1977a
small				23.3				Lab	Coutant 1977a
adults				20.1				Lab	Coutant 1977a
YOY	W			10-13				Lab	Coutant 1977a
YOY	SP			18.0				Lab	Coutant 1977a
YOY	su			25-27				Lab	Coutant 1977a
YOY	F			28.0				Lab	Coutant 1977a
adult	W			7-12				Lab	Coutant 1977a
adult	SP			13-16				Lab	Coutant 1977a
adult	su			27.0				Lab	Coutant 1977a
adult	F			22-25				Lab	Coutant 1977a
adult	W			14.1				Lab	Coutant 1977a
adult	su			20.9				Lab	Coutant 1977a
adult	F			19.9				Lab	Coutant 1977a
juvenile	w			22				Lab	EPA 1974
juvenile	su			24				Ont. Lakes	EPA 1974
juvenile				20-23		24		Lab	EPA 1974
adult				18-20		24		Lab	EPA 1974
larva				13-18					Brown 1974

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
small underyear- lings	W		30.5	13		1		L. Monona, Wis.	Brown 1974 Brown 1974
82-118TL			26	23	20	20-22			Brown 1974
121-169TL			33.3-34.4			25			Brown 1974
30-50FL			21	19.2	12	15		Lab	Cherry et al 1977
30-50FL			27	20.4	15	18		Lab	Cherry et al 1977
30-50FL			27	21.1	18	21		Lab	Cherry et al 1977
30-50FL			29	22.4	18	24		Lab	Cherry et al 1977
30-50FL				21.4				Lab	Cherry et al 1977
juvenile	F	D		>15				L. Michigan	Brandt et al 1980
juvenile	F	N		>17				L. Michigan	Brandt et al 1980
larvae	su			12-25				Atikokan GS, Ont.	Haymes 1984
adult	F			12.3-13.8		5		Lab	EPA 1976
adult	F			13.5-18.8		10		Lab	EPA 1976
adult	F			17.6-20.2		15		Lab	EPA 1976
adult	F			16.1-24.2		20		Lab	EPA 1976
adult	Wi			25				Lab	EPA 1976
adult	su			17				Lab	EPA 1976
adult	Wi			6.3		5.4		power plant thermal effluent	Cravens et al 1983
adult				8.0		0			Cravens et al 1983
adult				22		18			Cravens et al 1983
	Wi			5.4				Pokegama Res., Minn. near thermal outfall, Minn.	Cravens 1981
	Wi			6.3					Cravens 1981
adult	F			7-8, 11-17 14-19				L. Michigan Wickett L., Manitoulin Isl., Ont.	Talmage and Coutant 1980 Talmage and Coutant 1980
60 g				20.2		20		Lab	Talmage and Coutant 1980
newly hat- ched larvae				24.3		20			Talmage and Coutant 1980
				24.2		23			Talmage and Coutant 1979
				21.7		25			Talmage and Coutant 1979
8-11 adult	SP su		>29	12-16 18-21				Keowee Res., S.C.	Clugston et al 1978 Clugston et al 1978
juvenile	su			20-24					Clugston et al 1978

SPECIES: *Perca flavescens* (yellow perch)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			(a) MWAT	ST Max				Reference	
adult		13-20	22	29		12.513		EPA 1974	
juvenile	22.5							EPA 1974	
	23							McCauley and Casselman 1980	
juvenile		20-23.3						Smagula and Adelman 1982	
adult		17.6-20.1						Leidy and Jenkins 1977	
	24.2							Leidy and Jenkins 1977	
5.2-23.7 g	23							Leidy and Jenkins 1977	
0.5 g	28							Jobling 1981	
	23-24							Jobling 1981	
YOY	29						32	Kitchell et al 1977	
juvenile/adult	23						28	Kitchell et al 1977	
	26-30							Ney 1978	
	24.7							Casselman 1978	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 113 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Perca flavescens* (yellow perch)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b)		(c) Lethal Upper	(c) Lethal Lower	(d)		Location	Reference
					ST Max for Embryo Survival	Acclimation Time			Median Lethal ΔT	Median Lethal Final		
spawning		12	7-15	12	20							EPA 1974
incubation/hatch		10-20	7-20									EPA 1974
wintering		<6	4-11									Brown 1974
spawning		7.8-12.2	7-16									Brown 1974
incubation			7-15								L. Monona, Wis.	Brown 1974
heat shock							32					Ellis 1984
							<37					Teleki 1976
spawning		5-6	3								Big Point, Bay of Quinte, L. Ont.	Dunford 1978

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp (a) Range	MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference
larval devel		13.1-18.2									Lab	Griffiths 1978
hatching		<12	8-19								Lab	Griffiths 1978
hatching		8.4	7-10								Lab	Griffiths 1978
heat shock/ 7								+17	24			Moore 1979(d)
spawning		8-10									Long Point Bay, L. Erie	Talmage and Coutant 1978
spawning		10									Lab	Talmage and Coutant 1980
spawning		10									Keowee Res., S.C.	Talmage and Coutant 1980
incubation		9.9									Lab	Talmage and Coutant 1980
Incubation		<16					22				Lab	Wyman 1981
heat shock/ 7 larvae								+17			Lab; simulated onshore discharge	Crippen and Fahmy 1981
heat shock/ 7 larvae								+21.6			Lab; simulated tempering discharge	Crippen and Fahmy 1981
heat shock/ 7 larvae								+15.5			Lab; simulated offshore discharge	Crippen and Fahmy 1981
spawning			4-18.5	11.9								Hokanson 1977
spawning		6-12										Houston 1982
spawning		<9-10									L. Opinicon, L. Ont. Wisc.	Thorpe 1977
heat shock (larval)	7.6-15.8		7.2-11					> +15			Lab; simulated once-through cooling	Clugston et al 1978 Dunstall 1979

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Stizostedion canadense (sauger)

THERMAL TOLERANCES:														
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a b		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
119; juvenile larval	25.8		F	30.4 20.9	6.0									Hokanson 1977 Hokanson 1977
119; juvenile	10.1			26.6						27	114		Lab	Smith and Koenst 1975
119; juvenile	12.0			26.7						28	68		Lab	Smith and Koenst 1975
119; juvenile	13.9			28.4						30	16		Lab	Smith and Koenst 1975
119; juvenile	16.0			28.6						30	18		Lab	Smith and Koenst 1975
119; juvenile	18.3			28.7						30	19		Lab	Smith and Koenst 1975
119; juvenile	19.9			29.5						31	122		Lab	Smith and Koenst 1975
119; juvenile	22.0			29.9						31	545		Lab	Smith and Koenst 1975
119; juvenile	23.9			30.4						32	348		Lab	Smith and Koenst 1975
119; juvenile	25.8			30.4						32	246		Lab	Smith and Koenst 1975
juvenile	26			31										EPA 1974

SPECIES: Stizostedion canadense (sauger)

PREFERRED TEMPERATURES:												
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location		Reference		
large				19.2				Norris Res., Tenn.		Coutant 1977a		
large			28		22			Wabash R., Ind.		Coutant 1977a		
				22.6						Jobling 1981		
				21.3						Jobling 1981		
				18.6-19.2				lake		Hokanson 1977		
				22-28				stream		Hokanson 1977		
				19				field		EPA 1974		
adult	su			27-29				Wabash Ft., Ind.		EPA 1974		
	F			14-21				power plant, Ohio R.		Yoder and Gammon 1976		
	W			8-11				power plant, Ohio R.		Yoder and Gammon 1976		
				26-28				power plant, Ohio R.		Yoder and Gammon 1976		
	SP			7.2				Norris Res., Tenn.		Brown 1974		
	su			21.1				Norris Res., Tenn.		Brown 1974		
				<20				Lewis and Clark Res., S.D.		Brown 1974		

SPECIES: *Stizostedion canadense* (sauger)

Size or Age (mm)	Optimum °C	Range	(a)		(b)		Location	GROWTH TEMPERATURES:	
			MWAT	ST Max	No Growth Upper	Limits Lower		Reference	
juvenile	22	16.1-26	25	30	26		Lab	Smith and Koenst 1975 EPA 1974 Talmage and Coutant 1980 Fitz and Holbrook II 1978	
	315.4					5			

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: *Stizostedion canadense* (sauger)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c)				Location	Reference
							Lethal Limit Upper	Lethal Limit Lower	Median Lethal AT	Median Lethal Final		
spawning			4-14.4								N. Dak., Tenn.	Hokanson 1977
spawning		9-15										Hokanson 1977
incubation		12-15										Hokanson 1977
spawning		9	S-12	10	21							Smith and Koenst 1975 EPA 1974
spawning		10	6-14								Norris Res., Tenn	EPA 1974
incubation/hatch		12-15	10-16									EPA 1974
spawning			3.0-11									Brown 1974

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Stizostedion vitreum (walleye)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	THERMAL TOLERANCES:							Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)	Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	
				Data Limits							
115; juvenile larval	25.8		F	31.6	6.0						Hokanson 1977
115; juvenile	8.0			27						Lab	Hokanson 1977
115; juvenile	10.1			28.6						Lab	Smith and Koenst 1975
115; juvenile	12.1			29						Lab	Smith and Koenst 1975
115; juvenile	13.9			29.5						Lab	Smith and Koenst 1975
115; juvenile	16.0			30.6						Lab	Smith and Koenst 1975
115; juvenile	18.2			30.5						Lab	Smith and Koenst 1975
115; juvenile	20.2			30.5						Lab	Smith and Koenst 1975
115; juvenile	22.1			30.5						Lab	Smith and Koenst 1975
115; juvenile	24.0			31.5						Lab	Smith and Koenst 1975
adult	23.3		su						234.4	Lab	Reutter and Herdendorf 1976
adult	7.2			28.9							Ellis 1984
adult				31							Ellis 1984
42;	26			34						Wheeler Res.. Tenn.	Wrenn and Forsythe 1978

SPECIES: Stizostedion vitreum (walleye)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location	Location	
large				20.6				Trout Lake, Wis.		Coutant 1977a
large				23.2				Norris Res., Tenn.		Coutant 1977a
				23						Jobling 1981
				20.6-23.2				field		Houston 1982
				21				field		Houston 1982
larvae	SP			16				Atikokan GS, Ont.		Haymes 1984
				10.6-11.2				(epilimnion) West Blue Lake, Man.		Talmage and Coutant 1980
			24					Norris Res., Tenn.		Fitz and Holbook II 1978
adult			21					L. Winnibigoshish, Minn.		Inskip and Magnuson 1983
adult				22						Spotila et al 1979
				20						Spotila et al 1979

SPECIES: Stizostedion vitreum (walleye)

Size or Age (mm)	Optimum °C	Range	(b)		No Growth Upper	Limits Lower	Location	GROWTH TEMPERATURES:	
			(a) M W A T	ST M a x				Reference	
			25	31				This study	
age 0		12-28			27		West Blue Lake. Man.	Cheshire and Steel 1972	
85	22.1				29			Kelso and Ward 1972	
65	25.2							Hokanson 1977	
1.81-2.00 g	22	19-25						Hokanson 1977	
							outdoor experimental channels, Alabama	Smith and Koenst 1975	
	22.6							Talmage and Coutant 1980	
<35; fry	15				20	10	Lab	Casselman 1978	
425; fingerling	22				27		Lab	Nickum 1978	

(a) MWAT (maximum weekly average temperature for growth) = optimum + 113 (upper incipient lethal temperature - optimum temp for growth).

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Stizostedion vitreum (walleye)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	(d) Median Lethal		Location	Reference
									AT	Final		
spawning			2.2-15.6								Wis.	Hokanson 1977
hatching		6	6-12									Hokanson 1977
spawning		8	4.4-14.4									Marshall 1977
hatching		9-15									Lab	Smith and Koenst 1975
spawning		6-12									Lab	Smith and Koenst 1975
incubation		19-15						20.9			Lab	Smith and Koenst 1975
larval devel		9-21									Lab	Smith and Koenst 1975
heat shock (fry-5 day)	6						21		+15		Lab	Smith and Koenst 1975
cold shock (fry-2 day)	11							6	- 5		Lab	Smith and Koenst 1975
cold shock (fry-7 day)	21							6	- 15		Lab	Smith and Koenst 1975
cold shock (80-100 mm)	25							8.1	-16.9		Lab	Smith and Koenst 1975
hatching		17.8-19.4										Smith and Koenst 1975
spawning		6.1-8.3	4.4-10.0								Kawartha Lakes, Ont.	Smith and Koenst 1975
incubation		7.8-8.9									Northern Minn.	Smith and Koenst 1975
spawning			6.7-13.0								Manitoba	Smith and Koenst 1975
spawning		7.2-10									Lake Gogebic, Mich.	Smith and Koenst 1975
spawning		4.4-6.7									Muskegon R., Mich.	Smith and Koenst 1975
spawning		3.4-10									Bay of Quinte, L. Ont.	Smith and Koenst 1975
spawning		5-10									Northern Wis.	Smith and Koenst 1975
hatching		16.7-19.4									Lab	Smith and Koenst 1975
spawning			8-12								Clinch and Powell R, Tenn.	Talmage and Coutant 1980
heat shock (42 mm)	26								+ 6		Wheeler Res., Tenn. Ft.,	Wrenn and Forsythe 1978
juvenile		21									Lab	Smith and Koenst 1975
spawning		7.1-9.9		8.9	15.6							This study Spotila et al 1979
incubation		10.5-15.5	5-19					20			Lab	Griffiths 1981

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(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Ammocrypta pellucida* (eastern sand darter)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
				25				Chateauguay R., Que	Scott and Crossman 1973
				24				Lake of Two Mountains, Que.	Scott and Crossman 1973

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SPECIES: *Etheostoma blennoides* (greenside darter)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a + b(\text{temp})}{a \cdot b}$	Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES:	
							Upper	Lower				Location	Reference
	15										32.2	Lab (N.Y.)	Kowalski et al 1978

SPECIES: Etheostoma caeruleum (rainbow darter)

											THERMAL TOLERANCES:		
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = $\frac{a-t}{a-b}$ (temp)	Data Upper	Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	15										32.1	Lab (N.Y.)	Kowalski et al 1978

SPECIES: Etheostoma caeruleum (rainbow darter)

								PREFERRED TEMPERATURES:	
Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
prolarva	SP			20				Drake's Ck., Ky.	Floyd et al 1984

SPECIES: Etheostoma caeruleum (rainbow darter)

											SPAWNING AND DEVELOPMENT TEMPERATURES:	
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference
hatching (Ild)		17-18.5										Scott and Crossman 1973

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for Spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Etheostoma exile (Iowa darter)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
larval	Sp/Su			12-25				Field, Atikokan GS site, Ont.	Haymes 1984

SPECIES: Etheostoma exile (Iowa darter)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
hatching		13-16										Scott and Crossman 1973

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

SPECIES: Etheostoma flabellare (fantail darter)

THERMAL TOLERANCES:														
Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	Upper incip. Lethal Temp	Lower incip. Lethal Temp	log time = a + b (temp) a b		Data Limits Upper Lower		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference

15												32.1	Lab, N.Y.	Kowalski et al 1978
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SPECIES: Etheostoma flabellare /fantail darter)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference

hatching spawning		21.1										Scott and Crossman 1973
spawning			18.9-24.4								N.Y.	Brown 1974
spawning migration			7-15								N.Y.	Cooper 1979
hatching (30-354)			17-20									Cooper 1979
hatching (21d)		21-22										Cooper 1979
hatching (14-16d)		23.5										Cooper 1979

SPECIES: Etheostoma microperca (least darter)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	Median Lethal Final	Location	Reference

hatching		18-20										Scott and Crossman 1973
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(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Etheostoma nigrum* (johnny darter)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:										
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits	Exposure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference	
						Upper	Lower	Temp						
	15		W									30.7	N.Y. Lab	Kowalski et al 1978
	15		SP									31.4	N.Y. Lab	Kowalski et al 1978

SPECIES: *Etheostoma nigrum* (johnny darter)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
larval	SP		28.8	11-22 17-20 24.5	20.1			Oswego GS, L. Ont. Drake's Ck., Ky. Connecticut Ft., Conn. (field occurrences)	Wyman 1981 Floyd et al 1984 Marcy 1976a

SPECIES: *Etheostoma nigrum* (johnny darter)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Accli-mation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:						
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference	
hatching		22-24										L. Erie,	Scott and Crossman 1973

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Percina caprodes* (logperch)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
larval	SP			16				Field, Atikokan GS site	Haymes 1984
larval	SP			9-16				Mississippi R.	Holland and Sylvester 1983
prolarva	SP			11.8				Drake's Ck., Ky.	Floyd et al 1984
mesolarva	SP			20-23				Drake's Ck., Ky.	Floyd et al 1984
metalarva	Sp/Su			21-25				Drake's Ck., Ky.	Floyd et al 1984

SPECIES: *Percina caprodes* (logperch)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
egg/larval			22-25								Texas	Brown 1974

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures,

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Percina copelandi (channel darter)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning			20.5-21.2								Cheboygan Ft., Mich.	Scott and Crossman 1973

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

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SPECIES: Percina maculata (blackside darter)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		16.5									S. Michigan	Scott and Crossman 1973

- (a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.
- (b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.
- (c) Not incipient lethal temperatures as defined by Fry et al (1946).
- (d) Simulated larval entrainment temperatures.

SPECIES: Aplodinotus grunniens (freshwater drum)

Sire or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	THERMAL TOLERANCES:										Reference
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	
						a	b	Upper	Lower					
adult	21.2 29-35			32.8								34.0	Lab	Reutter and Herdendorf 1976 Houston 1982
YOY			su	32.8					32.8	2880				Jinks et al 1981

SPECIES: Aplodinotus grunniens [freshwater drum]

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
large				22.2				Norris Res., Tenn		Coutant 1977a
large			30		22			Wabash R., Ind.		Coutant 1977a
small		D		29.5-30.3				L. Monona, Wis.		Coutant 1977a
small		N		27.529				L. Monona, Wis.		Coutant 1977a
YOY	su			31.3				Lab		Coutant 1977a
adult	su			26.5				Lab		Coutant 1977a
adult	F			19.6				Lab		Coutant 1977a
				21.1-26.1				Lewis and Clark L., S.D. (CUE)		Brown 1974
				22				thermal discharge, Ohio R.		Brown 1974
				29-31				thermal discharge, Wabash R., Ind.		Brown 1974
	F			22-30				J.M. Stuart GS, Ohio R., Ohio		Yoder and Gammon 1976
	Wi			6-11				J.M. Stuart GS, Ohio R., Ohio		Yoder and Gammon 1976
5-10; larvae	Su			20-28				Missouri R., Nebr. (CUE)		Cada and Hergenrader 1980

SPECIES: Aplodinotus grunniens (freshwater drum)

Size or Age (mm)	Optimum °C	Range	(b) ST Max		No Growth Limits		Location	GROWTH TEMPERATURES:	
			(a) MWAT	Max	Upper	Lower		Reference	
	22					14.4	L. Erie		Brown 1974
			25.6	33		18.3	L. Erie		Brown 1974
									This study

(a) MWAT (maximum weekly average temperature for growth) = optimum + 1/3 (upper incipient lethal temperature - optimum temp for growth)

(b) Maximum temperature for short-term exposure during growth season to protect against lethal effects.

SPECIES: Aplodinotus grunniens (freshwater drum)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival		(c) Lethal Limit Upper	(c) Lethal Limit Lower		(d) Median Lethal AT	(d) Median Lethal Final	Location	Reference
					Acclimation Time								
spawning		21	18-22.2									Wis.	Brown 1974
spawning			18.0-24.5									Lewis and Clark L., S.D.	Brown 1974
hatching (36-22h)			21-25										Brown 1974
hatching		23.9										L. Erie	Brown 1974
heat shock	W						35.6					winter thermal discharge, Sandusky R.	Brown 1974
spawning				21	26								EPA 1974
incubation		21	19-24										EPA 1974
and hatch			22-26										EPA 1974
cold shock	27							9	- 18				Coutant 1977b

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Cottus bairdii* (mottled sculpin)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Sea-son	THERMAL TOLERANCES:										Reference	
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits		Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location		
						Upper	Lower								
15													30.9		Spotila et al 1979

SPECIES: *Cottus bairdii* (mottled sculpin)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:		Reference
								Location		
				16.5 16.7				S. Ontario streams		Coutant 1977a Wyman 1981

SPECIES: *Cottus bairdii* (mottled sculpin)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	SPAWNING AND DEVELOPMENT TEMPERATURES:						Reference
							(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location		
spawning hatching (21-28d)		12.8	5.0 - 16.1 7.8-17.3									Lab	Brown 1974 Brown 1974
spawning cold shock	18.7	10							7	-11.7		Field, N.Y. L. Huron, (Seiche)	Scott and Crossman 1973 Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for Spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Cottus cognatus* (slimy sculpin)

Size or Age (mm)	Accli- mation Temp	Accli- mation Time	Sea- son	THERMAL TOLERANCES:											
				Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)		Data Limits		Expo- sure Temp	Resis- tance Time (Min)	Critical Thermal (Max)	Location	Reference	
						a	b	Upper	Lower						
40-1 00				26.5									Lab, L. Mich.	Otto and Rice 1977	
70-80	5		SP	18.5	<1								22.7	Lab, L. Mich.	Otto and Rice 1977
70-80	10		SP	22.5	<1								24.8	Lab, L. Mich.	Otto and Rice 1977
70-80	15		SP	23.5	3.5								26.3	Lab, L. Mich.	Otto and Rice 1977
70-80	20		SP										29.4	Lab, L. Mich.	Otto and Rice 1977
80-100	5		w										24	Lab, L. Mich.	Otto and Rice 1977
80-1 00	10		w										25.1	Lab, L. Mich.	Otto and Rice 1977
80-1 00	15		w										27.3	Lab, L. Mich.	Otto and Rice 1977
80-100	20		w										29.4	Lab, L. Mich.	Otto and Rice 1977
40-100	5								19	305				Lab, L. Mich.	Otto and Rice 1977
40-100	5								22	25				Lab, L. Mich.	Otto and Rice 1977
40-100	10								23	8800				Lab, L. Mich.	Otto and Rice 1977
40-100	10								26	8				Lab, L. Mich.	Otto and Rice 1977
40-100	15								24	3000				Lab, L. Mich.	Otto and Rice 1977
40-100	15								27	35				Lab, L. Mich.	Otto and Rice 1977
40-100	20			25											Talmage 1978

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SPECIES: *Cottus cognatus* (slimy sculpin)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
large			6		4			L. Michigan	Coutant 1977a
				6-8				L. Michigan	Brandt et al 1980
	F	N		4-6				L. Michigan	Brandt et al 1980
			15.2	9		5		Lab	Otto and Rice 1977
			21.5	12		15		Lab	Otto and Rice 1977
				10				L a b	Otto and Rice 1977
			16			10		Lab	Otto and Rice 1977
				13		20			Talmage 1978

SPECIES: *Cottus cognatus* (slimy sculpin)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		5									Cayuga L., N.Y.	Scott and Crossman 1973
spawning		10									Trib. Fall Ck., N.Y.	Scott and Crossman 1973
spawning		8									Montreal, R., Sask.	Scott and Crossman 1973
40-100 mm; 5 heat							22		+17		Lab	Otto and Rice 1977
shock	10						26		+16		Lab	Otto and Rice 1977
shock	15						27		+12		Lab	Otto and Rice 1977
cold shock	15							2.5	-12.5		Lab	Otto and Rice 1977
				8.	1	0						This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

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SPECIES: *Cottus ricei* (Spoonhead sculpin)

SPAWNING AND DEVELOPMENT TEMPERATURES:												
Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		4.5		4.5							Pemichangan L., Quebec	Scott and Crossman 1973 This study

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: *Myoxocephalus quadricornis* (deepwater sculpin)

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	PREFERRED TEMPERATURES:	
								Location	Reference
large			4.5 10		4			L. Michigan Field	Coutant 1977a
	F	N		<5				L. Michigan (bottom trawl)	Coutant 1977a Brandt et al 1980
9-18TL		N		2-10				L. Michigan	Mansfield et al 1983
9-18TL	SP	N		2-6				L. Michigan	Mansfield et al 1983

SPECIES: *Myoxocephalus quadricornis* (deepwater sculpin)

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median AT	(d) Median Lethal Final	Location	Reference
incubation (97d)		1.5										Mansfield et al 1983

(a) MWAT = maximum weekly average temperature during month of peak spawning, less than or equal to optimum, or middle of range of spawning temperatures.

(b) Short-term (24h) maximum temperature for successful embryo survival (incubation temp) or maximum temperature for spawning.

(c) Not incipient lethal temperatures as defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

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