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 glaucom);* deepwater cisco *(Coregonus johannae);* and blackfin cisco *(Coregonus nigripinnis) (Scott and Crossman 7973; 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 7979; 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 temperaturevalues 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 (time in minutes) = a + b (temperature in °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:

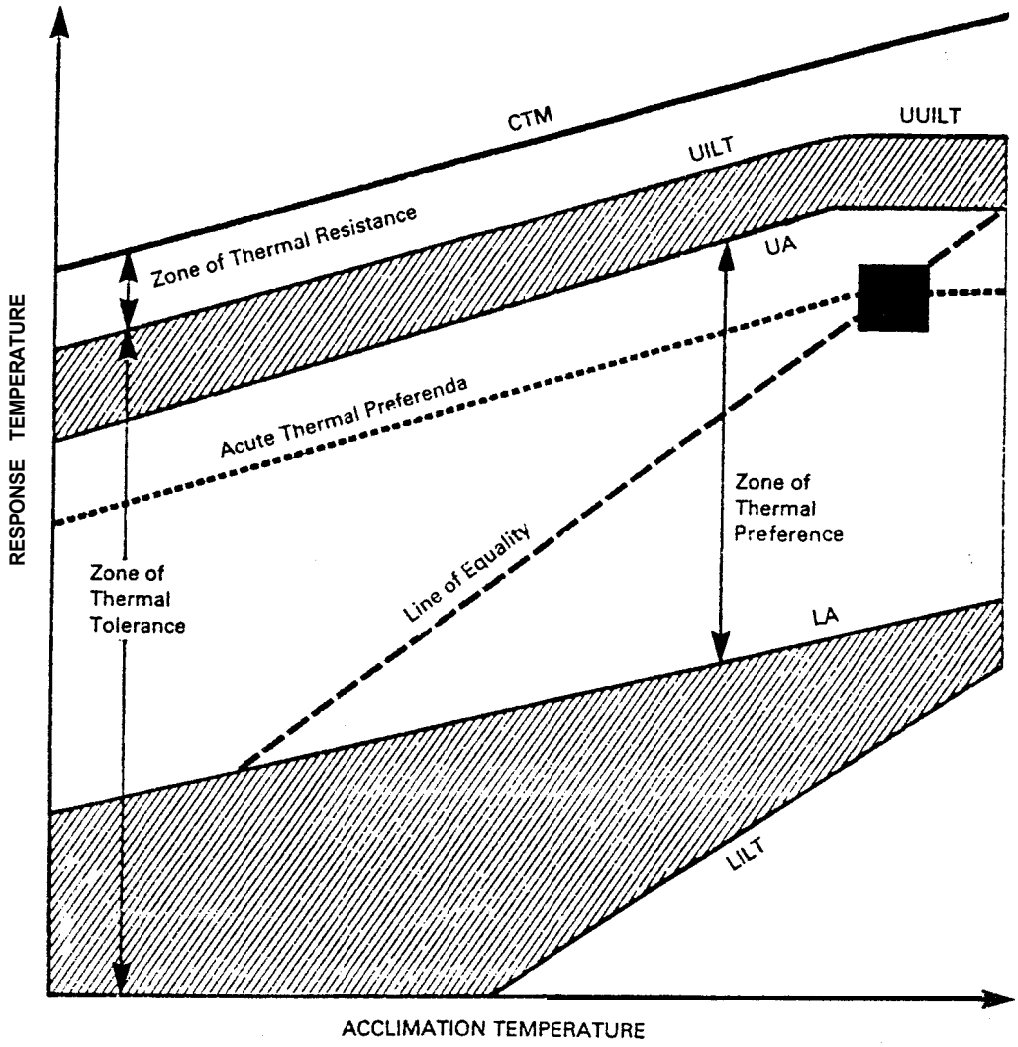
This is the test temperature a fish is exposed to in the laboratory in order to determine the time to mortality.

(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), Giatinna 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 (I(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 l(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 categoriesfound in thiscolumn 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 icthyoplankton (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 higherthan 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 behavioura! 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 salmons and trouts (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 Gift 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 Gift 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 Gift 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 Tolerances [1]	Preferred'	Growth [3]	Spawning and Development [4]
Petromyzontidae (Lampreys)	Petromyzon marinus	sea lamprey	X	X	X	X
Acipenseridae (Sturgeons)	Acipenser fulvescens	lake sturgeon				X
Lepisosteidae (Gars)	Lepisosteus oculatus	spotted gar*		X		
	Lepisosteus osseus	longnose gar		X	X	
Amiidae (Bowfin)	Amia calva	bowfin	X	X		X
Clupeidae (Herrings)	Alosa pseudoharengus	alewife	X	X	X	X
	Dorosoma cepedianum	gizzard shad	X	X	X	X
Salmonidae (Salmons, trouts whitefishes)	Oncorhynchus gorbuscha	pink salmon	X	X	X	X
	Oncorhynchus kisutch	coho salmon	X	X	X	X
	Oncorhynchus nerka	kokanee salmon	X	X	X	X
	Oncorhynchus tshawytscha	chinook salmon	X	X	X	X
	Salmo trutta	brown trout	X	X	X	X
	Salmo gairdneri	rainbow trout	X	X	X	X
	Salvelinus fontinalis	brook trout	X	X	x	X
	Salvelinus namaycush	lake trout	X	X	X	X
	Salvelinus fontinalis x S. namaycush	splake	X	X		X
	Coregonus alpenae	longjaw cisco				
	Coregonus artedii	cisco, lake herring	X	X	X	X
	Coregonus hoyi	bloater*	X	X		X
	Coregonus kiyi	kiyi*		X		X
	Coregonus reighardi	shortnose cisco*				X
	Coregonus zenithicus	shortjaw cisco				
	Coregonus clupea formis	lake whitefish	X	X	X	X
	Prosopium coulteri	pygmy whitefish*				
	Prosopium cylindraceum	round whitefish		X		X
Osmeridae (Smelts)	Osmerus mordax	rainbow smelt	X	X	X	X
Hiodontidae (Mooneyes)	Hiodon tergisus	mooneye		X		X

Table 1. - Continued

Family	Species	Common Name	Type of Temperature Data: Thermal Tolerances[1]	Preferred[2]	Growth[3]	Spawning and Development[4]
Umbridae (Mudminnows)	Umbra limi	central mud minnow	X	X		X
Esocidae (Pikes)	Esox americanus vermiculatus	grass pickerel*		X		X
	Esox lucius	northern pike	X	X	X	X
	Esox masquinongy	muskellunge	X	X	X	X
Cyprinidae (Minnows)	Campostoma anomalum	stoneroller*	X	X	X	X
	Chrosomus eos	northern redbelly dace	X	X		X
	Chrosomus neogaeus	finescale dace	X			X
	Couesius plumbeus	lake chub				X
	Cyprinus carpio	carp	X	X	X	X
	Exoglossum maxillingua	cutlips minnow		X		X
	Hybognathus hankinsoni	brassy minnow				X
	Hybognathus nuchalis	silvery minnow				X
	Hybopsis storeriana	silver chub				X
	Nocomis biguttatus	hornyhead chub				X
	Nocomis micropogon	river chub	X			X
	Notemigonus crysoleucas	golden shiner	X	X		X
	Notropis anogenus	pugnose shiner*		X		
	Notropis atherinoides	emerald shiner	X	X	X	X
	Notropis bifrenatus	bridle shiner				X
	Notropis cornutus	common shiner	X			X
	Notropis heterodon	blackchin shiner	X			
	Notropis heterolepis	blacknose shiner				
	Notropis hudsonius	spottail shiner	X	X	X	X
	Notropis rubellus	rosyface shiner	X	X	X	X
	Notropis spilopterus	spotfin shiner	X	X	X	X
	Notropis stramineus	sand shiner	X			
	Notropis umbratilis	redfin shiner				
	Notropis volucellus	mimic shiner				
	Pimephales notatus	bluntnose minnow	X	X	X	X
	Pimephales promelas	fathead minnow	X	X	X	X
	Rhinichthys atratulus	blacknose dace	X			X
	Rhinichthys cataractae	longnose dace	X	X	X	X
	Semotilus atromaculatus	creek chub	X			X
	Semotilus corporalis	fall fish		X		X
	Semotilus margarita	pearl dace				X
	Carassius auratus	gold fish	X	X	X	X
Castostomidae (Suckers)	Carpoides cyprinus	quillback	X	X		X
	Catostomus catostomus	longnose suckers	X	X		X
	Catostomus commersoni	white sucker	X	X	X	X
	Erimyzon sucetta	lake chubsucker*				X
	Hypentelium nigricans	northern hog sucker	X	X	X	X

Table 1. - Continued

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

Table 1. - Continued

Family	Species	Common Name	Type of Temperature Data: Thermal Tolerances[1]	Preferred[2]	Growth[3]	Spawning and Development[4]
Percidae (Perches)	Perca flavescens	yellow perch	X	X	X	X
	Stizostedion canadense	sauger	X	X	X	X
	Stizostedion vitreum	walleye	X	X	X	X
	Ammocrypta pellucida	eastern sand darter*		X		
	Etheostoma blennoides	greenside darter	X			
	Etheostoma caerulum	rainbow darter	X	X		X
	Etheostoma exile	Iowa darter		X		X
	Etheostoma flabellare	fantail darter	X			X
	Etheostoma microperca	least darter*				X
	Etheostoma nigrum	johnny darter	X	X		X
	Percina caprodes	log perch		X		X
	Percina copelandi	channel darter*				X
	Percina maculata	blackside darter				X
Sciaenidae (Drums)	Aplodinotus grunniens	freshwater drum	X	X	X	X
Cottidae (Sculpins)	Cottus bairdi	mottled sculpin	X	X		X
	Cottus cognatus	slimy sculpin	X	X		X
	Cottus ricei	Spoonhead sculpin				X
	Myoxocephalus quadricornis	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	Alosa pseudoharengus	Clupeidae
American Eel	Anguilla rostrata	Anguillidae
Banded Killifish	Fundulus diaphanus	Cyprinodontidae
Bigmouth Buffalo	Ictiobus cyprinellus	Castostomidae
Black Bullhead	Ictalurus melas	Ictaluridae
Black Crappie	Pomoxis nigromaculatus	Centrarchidae
Blackchin Shiner	Notropis heterodon	Cyprinidae
Blacknose Dace	Rhinichthys atratulus	Cyprinidae
Blackside Darter	Percina maculata	Percidae
Bloater	Coregonus hoyi	Salmonidae
Bluegill	Lepomis macrochirus	Centrarchidae
Bluntnose Minnow	Pimephales notatus	Cyprinidae
Bowfin	Amia calva	Amiidae
Brassy Minnow	Hybognathus hankinsoni	Cyprinidae
Bridle Shiner	Notropis bifrenatus	Cyprinidae
Brindled Madtom	Noturus miurus	Ictaluridae
Brook Silverside	Labbiddesthes sicculus	Atherinidae
Brook Stickleback	Culaea inconstans	Gasterosteidae
Brook Trout	Salvelinus fontinalis	Salmonidae
Brown Bullhead	Ictalurus nebulosus	Ictaluridae
Brown Trout	Salmo trutta	Salmonidae
Burbot	Lota lota	Gadidae
Carp	Cyprinus carpio	Cyprinidae
Central Mudminnow	Umbra limi	Umbridae
Channel Cat	Ictalurus punctatus	Ictaluridae
Channel Darter	Percina copelandi	Percidae
Chinook Salmon	Oncorhynchus tshawytscha	Salmonidae
Cisco, Lake Herring	Coregonus artedii	Salmonidae
Coho Salmon	Oncorhynchus kisutch	Salmonidae
Common Shiner	Notropis cornutus	Cyprinidae
Creek Chub	Semotilus atromaculatus	Cyprinidae
Cutlips Minnow	Exoglossum maxillingua	Cyprinidae
Deepwater Sculpin	Myoxocephalus quadricornis	Cottidae
Eastern Sand Darter	Ammocrypta pellucida	Percidae
Emerald Shiner	Notropis atherinoides	Cyprinidae
Fall Fish	Semotilus corporalis	Cyprinidae
Fantail Darter	Etheostoma flabellare	Percidae
Fathead Minnow	Pimephales promelas	Cyprinidae
Finescale Dace	Chrosomus neogaeus	Cyprinidae
Freshwater Drum	Aplodinotus grunniens	Sciaenidae
Gizzard Shad	Dorosoma cepedianum	Clupeidae
Golden Shiner	Notemigonus crysoleucas	Cyprinidae

TABLE 2 - Continued

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

TABLE 2 - Continued

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

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The authors are continually updating the document with plans to design a fish computer information database. Any comments, corrections or additional data and/or references are requested to be forwarded to the authors at Ontario Hydro.

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 Farenheit 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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
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
				> 29.5										Carlander 1969
prolarva	15120			28.5		17.5642	-0.4680	34	29				Great Lakes	Brown 1974
ammocoetes	5											29.5		Spotila et al 1979
	15											30		Spotila et al 1979
	25											31		Spotila et al 1979
				31.4										Spotila et al 1979

SPECIES: Petromyzon marinus (sea lamprey)

PREFERRED TEMPERATURES:

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

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
30-90 g; large	15						land locked	Farmer et al 1977
1O-30 g; small	20							Farmer et al 1977
						<3		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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp (a) Range 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 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								Scott and Crossman 1973
hatching (14d)			13.9-18.3							hatchery Cayuga L.. N.Y.	Scott and Crossman 1973
		18.3									Scott and Crossman 1973
swim-up		21.7									Scott and Crossman 1973
hatching			15.5-21								Carlander 1969
metamor-phosis		20-21	7-21							Lab	Cravens 1982
egg incubation	7.527	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	1O-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 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		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			34.5		29			Wabash R., Ind.	Coutant 1977a
YOY	Su			25.3				Lab	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 Limits Upper	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 (temp) 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)

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Tamp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
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 al 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 1376
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)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
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

THERMAL TOLERANCES:

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	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			> 2 0						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
				18.8				Cayuga L. N.Y.	Coutant 1977a
			22		8.0			L. Michigan	Coutant 1977a
adult	Sp			21.3				Lab	Coutant 1977a
					10				Brown 1974
	su		30	27.8-28.3					Brown 1974
adult				17.2		25	48h		McCauley 1981
young	su			17-19				L. Michigan	Talmage and Coutant 1980
				11-14				L. Michigan	Talmage and Coutant 1980
adult	F			11-16				L. Michigan	Talmage and Coutant 1980
				16-21					Wyman 1981
YOY				16-20				L. Michigan	Brandt et al 1980b
YOY				24-28				L. Michigan	Brandt et al 1980b
YOY		D		17-20				L. Michigan	Brandt et al 1980b
all sizes					3.0				Uziel 1980
	year		16	8-10	4			L. Michigan	Michaud 1981
subadult	F			12.3-14.5				L. Huron (27-40 m)	Argyle 1982
<140; adult	F			12.3-16.1				L. Huron (27-42 m)	Argyle 1982
YOY	su			31.3				Lab	Spotila et al 1979
adult	F			19.6				Lab	Spotila et al 1979
adult	w			12.0		1-3		Lab	Otto et al 1976
adult	SP			21		7-I 1		Lab	Otto et al 1976
adult	Su			19		1o-11		Lab	Otto et al 1976
adult	su			16		15-18		Lab	Otto et al 1976
adult	F			16		1o-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		1O-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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp.	Acclimation Time	Season	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
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
					o-o.5								L. Darnadelle, Ark	Talmage and Coutant 1980
			su	28.5								31.0	Mississippi R.	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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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
				1o-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			1o-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 Upper	Lower	Location	GROWTH TEMPERATURES: Reference
						18.3	L. Erie,	Brown 1974
		29.6-31.0		>37.5			White R., Wabash R. Ind.	Brown 1974
	16-18							Leidy and Jenkins 1977
			23.2					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 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	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
heal shock	W								+ 12/ + 16		Gt. Lakes power plant	Ellis 1964
spawning			1o-21.1									Brown 1974
hatch		22.2									Lake Erie	Brown 1974
cold shock	W 26								- 6			Brown 1974
heat shock	W						31.7				Sandusky R. Ohio	Brown 1974
heat shock	W						35.7					Brown 1974
spawning		22									L. Erie	Carlander 1969
cold shock	W 27								- 18			Coutant 1977b
cold shock	10							0	- 10			Edsall and Yocum 1972
cold shock	15							3.5	- 11.6			Edsall and Yocum 1972
cold shock	20							7.5	- 1 3			Edsall and Yocum 1972
cold shock	25							11	- 1 4			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	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Tamp	log time - a + b (temp) a	b	Data Limits Upper	Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: 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

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	Range	(a) YWAT	(b) ST Max	No Growth limits Upper	Lower	-acotion	GROWTH TEMPERATURES: Reference
	15.5							Jobling 1981
			18.3	21.7				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 Accli-mation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Man for Embryo Survival	Accli-motion Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
spawning		10	116									Scott and Crossman 1973
					> 7						Lab; L. Superior fish	Cravens et al 1983
				10	15							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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
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-l 30; juvenile	15											28.7	Lab (18C/h)	Becker and Genoway 1979
90-130; juvenile	20											35.1	Lab (18C/h)	Backer 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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				12-14				Lab	Scott and Crossman 1973
adult	SP			11.4				Lab	Coutant 1977a
adult				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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
	14.8						Lab	Jobling 1981
			18	24				EPA 1974
		14-17					Field in late summer	Brown 1974
	17						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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

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)		10.7									Calif.	Scott and Crossman 1973
(48d)		8.9									Calif.	Scott and Crossman 1973
heat shock	10					3 min			> 10		Lab (physiological stress)	Spotila et al 1979
				10	13							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)	Acclimation Temp	Acclimation Time	Season	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
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				1o-15					Scott and Crossman 1973
young				12-14					Scott and Crossman 1973
				10					Carlander 1969
				10.6-12.8				Horsetooth Res., Colo.	Coutant 1977a
			21					Okanagan R., Wash.	Coutant 1977a
small				14.5				Lab	Coutant 1977a

SPECIES: Oncorhynchus nerka (kokanee salmon)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: Reference
juvenile	15							Jobling 1981
					24	<0		Magnuson et al 1979
		5-15						Cravens et al 1983
			18.3	23				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) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
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)			13-5.1								Lab; decreasing temp.	Scott and Crossman 1973
spawning			7-12								Calif	Carlander 1969
							15.5					Carlander 1969
egg dev.							*13.5*	5.1			Lab	Beltz et al 1974
				8.5	12							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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Upper	Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				25.1										Scott and Crossman 1973
444; fry	5			21.5		9.3155	-0.3107	25	22.5				Lab, Wash.	Brown 1974
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)

PREFERRED TEMPERATURES:

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

SPECIES: Oncorhynchus tshawytscha [chinook salmon)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
	15.5							Jobling 1981
	<12						Lab . .	Cravens et al 1983
fingerling	14.4						Lab	Beltz et al 1974
			18.7	20				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 tshawytscha (chinook salmon)

SPAWNING AND DEVELOPMENT TEMPERATURES:

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	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
					10						Lab	Cravens et al 1983
egg dev.		11.1					14.9	5.1			Lab	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 (temp) a	b	Data Limits Upper	Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
													THERMAL TOLERANCES:	
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									Lab	Cherry et al 1977
				26.5										Jobling 1981
				26										Jobling 1981
				26.3										Jobling 1981
										30	0.55		Lab (loss of equilibrium)	Spotila et al 1979
										28	2		Lab (loss of equilibrium)	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	-O 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									Lab mean 24-h (TL50)	Hokanson et al 1977
150-200 FL;	10											28.5	Lab (Arizona; 0.02 C/min)	Lee and Rinne 1980
150-200 FL:	20											29.4	Lab (Arizona; 0.02 C/min)	Lee and Rinne 1980

SPECIES: Salmo gairdneri (rainbow trout)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
fry,									
fingerlings				13-15		10.6/12.7		Lab	Talmage and Coutant 1980
				121					Talmage and Coutant 1980
adult				18.9-21.7				Horsetooth Res., Colo.	Coutant 1977a
red									
fingerlings		D/N		22				Lab	Coutant 1977a
starved									
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)

GROWTH TEMPERATURES:

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

SPECIES: Salmo gairdneri (rainbow trout)

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			1o-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)
				9	13							EPA 1974
spawning		6-8	0.3-10								Bothwells Ck, Ont.	Brown 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-l 8.9										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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
50-100FL; young	12-24			23									Lab	Cherry et al 1977
				26.4										Jobling 1981
adult	14-18											25	Lab (death point)	Spotila et al 1979
adult	26											26	Lab (death point)	Spotila et al 1979
fry	5-6											22.5	Lab (death point)	Spotila et al 1979
fry	20											23	Lab (death point)	Spotila et al 1979
newly hatched fry	6			22		12.7756	-0.4010	28	20				Lab; England	Brown 1974
				24.7									Lab	Brown 1974
	23			25.3								28.3	N.Y. (limiting temp)	Brown 1974
										26.8	1440		Lab	Brown 1974
										27.8	720		Lab	Brown 1974
150-200TL;	10											29	Lab (Arizona; 0.02 c/min)	Lee and Rinne 1980
	20											30	Lab (Arizona; 0.02 c/min)	Lee and Rinne 1980

SPECIES: Salmo trutta (brown trout)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				18.3-23.9					Scott and Crossman 1973
				12				L. Oredon, France	Coutant 1977a
			20					Lab	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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
	10							Jobling 1981
	15.5							Jobling 1981
	12							Jobling 1981
	12.8							Jobling 1981
juvenile	12.6							McCauley and Casselman 1980
		7-19						Brown 1974
					<29.1	5		Brown 1974
			19.1	21				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: Salmo trutta (brown trout)

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			6.7-8.9								S.E. Ontario	Scott and Crossman 1973
				12.8								Brown 1974
incubation (34-148d)			1.9-11.2				27				Lab	Brown 1974
embryo							15					Cravens et al 1983
spawning			4-l 1								streams SW Ontario	Witzel and MacCrimmon 1983
				7.5	11.2							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: Salvelinus fontinalis (brook trout)

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
50-I00FL; 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				12.7									Lab, Ontario	Brown 1974
newly hatched	12			20.4									Lab, Ontario	Brown 1974
swim-up	12			24.3								24.5	Lab, Ontario	Brown 1974
												25.3	Lab, ($UUILT_{50}$)	Brown 1974
larvae				20.1										Houston 1982
juvenile	13			24									Lab	Houston 1982
	16			24.9									Lab	Houston 1982
	19			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; young			15	13.7	6	12		Lab (rising water temps)	Cherry et al 1977
50-100FL; young			18	15.2	9	15		Lab (rising water temps)	Cherry et al 1977
50-100FL; young			21	17.2	15	18		Lab (rising water temps)	Cherry et al 1977
50-100FL; young			24	18.3	15	21		Lab (rising water temps)	Cherry et al 1977
50-100FL; young			26	19.0	18	24		Lab (rising water temps)	Cherry et al 1977
50-100FL; young				15.5				Lab (rising water temps)	Cherry et al 1977
				14					Jobling 1981
fry				10		4		Lab	Brown 1974
			21		7			Lakes N.S.	Brown 1974
fry				9-I 1.5		10.6-12.7		Lab	Talmage and Coutant 1980
fingerlings				17.5		12.1		Lab	Talmage and Coutant 1980

SPECIES: Salvelinus fontinalis (brook trout)

GROWTH TEMPERATURES:

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

SPAWNING AND DEVELOPMENT TEMPERATURES:

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
hatching (50-100d)			1 o-5									Scott and Crossman 1973
eggs							11.7					Scott and Crossman 1973
				9	13							EPA 1974
spawning		10.7									Minn.	Brown 1974
spawning			2.2-11.7									Brown 1974
incubation (15-28d)			1.5-14.8								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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
				25.1										Spotila et al 1979
27.7/82.8g; 1-2 yr	a			22.7		14.4820	-0.5	142	26	23			Hatcheries, Ont.	Brown 1974
	15			23.5		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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				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
yearling			15	11.7				Lab	Coutant 1977a
young			14	11.5				Lab	Coutant 1977a
adult				11.8				L. Michigan	Coutant 1977a
				12					Spotila et al 1979
YOY			17.2		5.6			L. Superior	Brown 1974
1-2 yrs			11.7		3.9			L. Superior	Brown 1974
juvenile	SU			7.2-12.1				L. Michigan	Brown 1974
			15.5		a			field	Brown 1974
			18.2	7.2-12.8				L. Ontario	Brown 1974
			>14	14	<1			Point Beach, L. Michigan	Michaud 1981
fry				9-11.5		10.6-12.7		Lab	Talmage and Coutant 1980
fingerlings									
adult			14		4	1-17		L. Michigan	Cravens et al 1983
YOY			15	7-14				L. Superior	Peck 1982

SPECIES: Salvelinus namaycush (lake trout)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: Reference
yearling	11.7							Leidy and Jenkins 1977
1-2 yrs	16.5							Leidy and Jenkins 1977
		4-18					Lake Louisa, Ont.; Cayuga L., N.Y.	Leidy and Jenkins 1977
			19.4	21.5				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 (a) Range	MWAT	(b) ST Max for Embryo Survival	Accli-mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal ST	(d) Median Lethal Final	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
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	8.8						14.8		+ 6		Lab	Wyman 1981
spawning			11-14								L. Simcoe, Ontario	Brown 1974
				a.9								Brown 1974
incubation (50-162d)			1.8-10								Lab	Brown 1974
					<10							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
					14.4							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: Salvelinus fontinalis x S. namaycush (splake)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
	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
				13.1				Jack and Sproule L., Ont.	Coutant 1977a
young				12				Lab	Coutant 1977a
fry				9-11.5		10.6-12.7		Lab	Talmage and Coutant 1980

SPECIES: Salvelinus fontinalis x S. namaycush (splake)

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 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									+10		Lab (fall spawned)	Griffiths 1978
spawning		7.8										Griffiths 1980
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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
				26									Lab	Scott and Crossman 1973
				19.8										Jobling 1981
				26.2										Jobling 1981
larvae				19.7									Lab (Mich.)	Brown 1974
juvenile	2	8wk		21.7		16.51X-0.6689		23		19			Lab (Mich.)	Brown 1974
juvenile	5	4wk		24.2		10.2799-0.3645		24		20			Lab (Mich.)	Brown 1974
juvenile	IO	2wk		26.2		12.4993-0.4098		28		24			Lab (Mich.)	Brown 1974
juvenile	20	2wk		25.7		17.2967-0.5333		30		26			Lab (Mich.)	Brown 1974
juvenile	25	3wk				15.1204-0.4493		30		25			Lab (Mich.)	Brown 1974
juvenile	2	8wk			<0.3			1.5		0.3			lab (Mich.)	Brown 1974
juvenile	5	4wk			to.5					0.5			Lab (Mich.)	Brown 1974
juvenile	10	2 wk			3.0	2.7355	0.3381	3		0.5			Lab (Mich.)	Brown 1974
juvenile	20	2wk			4.7	2.5090	0.2685	4.5		0.5			Lab (Mich.)	Brown 1974
juvenile	25	3wk			9.7	1.7154	0.1652	9.5		0.5				

SPECIES: Coregonus artedii (cisco, lake herring)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
			15.5	13				L. Superior	Carlander 1969
			17-20					L. Nippissing, Ontario	Carlander 1969
			20	10				L. Nippissing, Ontario	Coutant 1977a
large				7.2				Cayuga L., N.Y.	Coutant 1977a
large				13-18					Spotila et al 1979
larval	SP			9-14				Atikokan GS preop., Ont.	Haymes 1984

SPECIES: Coregonus artedii (cisco, lake herring)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: Reference
	18.1							Jobling 1981
			17	25				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) 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	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
spawning		3.3	3.3-5								Wisc.	Scott and Crossman 1973
incubation (92d)		5.6									Lab	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
					≤7							Spotila et al 1979
				3	8							EPA 1974
incubation		6									Lab	Cravens 1981
cold shock 7									- 6			
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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
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	l-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

SPECIES: Coregonus hoyi (bloater)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
larval			4.8					L. Michigan	Scott and Crossman 1973
			>11.4	3.8-7	>1.5			L. Michigan	Carlander 1969
large	su		IO		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 (a) Range	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 (a) Range	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	Temp (a) Range	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			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	Season	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
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				12.7				Lab	Coutant 1977a
juvenile				17				South Bay, Lake Huron Ontario	Coutant 1977a
larvae									
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
				11.9				Moosehead L., Me.	Coutant 1977a
4.2-7.2g; fingerling				10				Lab	Spotila et al 1979
1.1-1.7g; young				17				Lab	Spotila et al 1979
larval				4				L. Erie, L. Ontario (surface water temp)	Brown 1974
YOY				17					
larval	Sp		14		8			Atikokan GS, (preop.)	Haymes 1984
			12	4	0			Point Beach, L. Michigan	Michaud 1981
adult				<9		o-13		L. Michigan	Cravens et al 1983
larval	SP			6.9-9.5				L. Opeongo, Ontario	Ihssen et al 1981
larval	SP			3.5-15				L. Simcoe, Ontario	Ihssen et al 1981
larval	SP			4-12				Bay of Quinte, L. Ontario	Ihssen et al 1981
larval	SP			4.5-9				South Bay, L. Huron	Ihssen et al 1981

SPECIES: Coregonus clupeaformis (lake whitefish)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: 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 (a) Range	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.	Carlander 1969
incubation (120-140d)			0.5-1.7								field	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

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 ΔT	(d) Median Lethal Final	Location	Reference
heat shock									i-31		Lab (simulated entrain)	Dunstall 1978
entrainment							28.9				Lab (simulated entrain)	Dunstall 1978
hatching			2.8-6.7								L. Superior	Dunstall 1978
hatching		4	4-8								L. Ontario	Dunstall 1978
heat shock	6								+25		Lab (untempered)	Dunstall 1978 (d)
spawning			0.5-10									Dunford 1980
egg									+6		Lab (+ ambient)	Griffiths 1980
				7	10							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 embryosurvival (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: Prosopium cylindraceum (round whitefish)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				17.5				Moosehead L. Me.	Coutant 1977a
	W			3-5.8				L. Ont. near Pickering GS	Carey 1982
	F			2.1-3.6				L. Ont. near Pickering GS	Carey 1984

SPECIES: Prosopium cylindraceum (round whitefish)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Tamp	Optimum Temp (a) Temp	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		4.5									L. Superior	Scott and Crossman 1973
hatching (140d)		2.2										Scott and Crossman 1973
spawning		≤3									L. Ontario	Carey 1982
egg survival		1-5										Gowans 1982
spawning		3	2-4.4								L. Ontario	Dunford 1980
incubation		1-2										Dunford 1980
incubation (37-168d)			1.7-10		<10							Griffiths 1980
egg									+6		Lab (above ambient)	Griffiths 1980
egg									4.8		Lab (above ambient-TL50)	Griffiths 1980
				3	5							This study

SPECIES: Osmerus mordax (rainbow smelt)

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
													THERMAL TOLERANCES:	
	<10		W	19										Ellis 1984
	<6			>24										Ellis 1984
	15											28.5		Ellis 1984
										22	51			Ellis 1984
	6									21	736			Ellis 1984
	5.3-6.2		SP							23	12		Lab (April 13)	McCauley 1981
										22	51			McCauley 1981
										21	736			McCauley 1981
										20	1630			McCauley 1981
	5.7-6.2		SP							24	13		Lab (April 20)	McCauley 1981
										23	30			McCauley 1981
										22	88			McCauley 1981
										27	854			McCauley 1981
	6		SP									24.9	Lab	Reutter and Herdendorf 1976
150-210:	10.2-15			21.5-28.5									Lab	Brown 1974
adult	17				8.5									Houston 1982
			W	19						37	<1			Teleki 1976
			SP	18.9										McCauley 1981
adult	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
				6.6-8.3				Cayuga L., N.Y.	Coutant 1977a
			14		6			L. Michigan	Coutant 1977a
				12.8				L. Champlain, N.Y.	Coutant 1977a
			20						Ellis 1984
				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		O-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
	su			14.1-16				L. Michigan	Tin and Jude 1983
adult		N	15.5	7-8				L. Erie	Heist and Swenson 1983
	su	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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp Range	(al 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
avoidance of delta-T									+10.5		Field (summer)	Ellis 1984
spawning			2.2-14.5								L. Superior	Brown 1974
spawning run			3.9-5.6									Brown 1974
spawning		10									L. Erie	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
				13.6								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			27		22			Wabash R., Ind.	Coutant 1977a
larval	SU			22				Upper Mississippi R., Wisc.	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									Assiniboine R., Man.	Talmage 1978
				11.5	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: Umbra limi (central mudminnow)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
													Shallow pond. Mich.	Beltz et al 1974

SPECIES: Umbra limi (central mudminnow)

PREFERRED TEMPERATURES:

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

SPECIES: Umbra limi (central mudminnow)

SPAWNING AND DEVELOPMENT TEMPERATURES:

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									Scott and Crossman 1973
				13	15.6							This study

SPECIES: Esox americanus vermiculatus (grass pickerel)

PREFERRED TEMPERATURES:

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

SPECIES: Esox americanus vermiculatus (grass pickerel)

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		7.2-11.7		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)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a -t b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
subadult				29.4	0.1								Lab	Casselman 1978
				30										Casselman 1978
	30			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-saclarvae	14-15	24h		31										Cravens et al 1983
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

SPECIES: Esox lucius (northern pike)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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
				23-24				Lab	McCauley and Casselman 1980
fry				9.9-l 1.1					Spotila et al 1979
			22	16.0	12.9			Connecticut R., Conn. (mean occurrence)	Marcy 1976a

SPECIES: Esox lucius (northern pike)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	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
			23.1	30				This study
larval	18-25.6				23.9			Brown 1974
juvenile and subadult	19-21							McCauley and Casselman 1980
			28	30				EPA 1974
larvae	21	18-26						EPA 1974
juvenile	26							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)

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 ΔT	(d) Median Lethal Final	Location	Reference
cold shock	21.8 12							4.9	-16.9		L. Wabamun, Alta.	Casselman 1978 DeMontalembert et al 1978
spawning			9.4-l 4.4								Ont.	Brown 1974
spawning			6.7-7.8								L. Simcoe, Ont.	Brown 1974
spawning			4.4-l 1.1								Canada	Scott and Crossman 1973
incubation			2.2-16.6								Wis. Lake	Brown 1974
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
				12	19							EPA 1974
spawning			4-19									EPA 1974
incubation and hatch		12	7-19									EPA 1974
spawning		<10									Niagara R. tributaries (N.Y.)	Talmage and Coutant 1979
hatching		20.8			<26.7		29.7					Cravens et al 1983
hatch		6.4-17.7	5.8-21				24.2					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 = a + b (temp) a	b	Data Limits Upper	Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
≥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

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
				>25.5				Stony L., Ontario	Minor and Crossman 1978
	sp/su			14				L. St. Clair	Haas 1978
small				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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
fingerling	24-26.6				>30			Jobling 1981 Carlander 1969
			28.4	32				This study
						10	Niagara R., N.Y.	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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp (a) Range	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		>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-I 5									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) a	b	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
				26.8				Lab	Coutant 1977a
adult			33	29	24			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)	Cherry et al 1977
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) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: Reference
	26.6123							Jobling 1981
			27	30				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	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	SPAWNING AND DEVELOPMENT TEMPERATURES: 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			>24.3						Lab (Missouri)	Carmichael 1983
				22.5	27							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: Chrosomus eos (northern redbelly dace)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
	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)

PREFERRED TEMPERATURES:

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

SPECIES: Chrosomus eos (northern redbelly dace)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp (a) Range	MWAT	(b) ST Max for Embryo Survival	Acclimation lime	(c) Lethal Limit Upper	(c) Lethal Limit Lower	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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
	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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	lb) 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		>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, fess 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	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning migration		14/19									Lac Saugay, Que. (tributary/lake)	Scott and Crossman 1973
				19								This study
spawning onset		4									Montreal R., Sask	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	Season	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
	20			31-34									Lab	Spotila et al 1979
	26			35.7										Spotila et al 1979
small												38-39		Spotila et al 1979
large				35-36										Spotila et al 1979
	23.3		su									39.0	Lab	Spotila et al 1979
					0.7									Leidy and Jenkins 1977(a)
eggs				31-35										Brown 1974
	26.3											40.6		Brown 1974(b)
eggs	25			35						25	1 0		Lab	Jinks et al 1981
larval	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	2 9	24				LabCoutant 1977a
				29					Jobling 1981
				25-30					Wyman 1981
	su			26-34				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) MWAT	(lb) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: 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									Scott and Crossman 1973
				21	26							EPA 1974
		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 Entrainment	Talmage and Coutant 1980
hatching		23.4	11-32									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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
			18.3		C			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)

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		<15										Brown 1974
spawning			17-21.5									Brown 1974
				19	21.5							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 hankinsoni (brassy minnow)

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 AND DEVELOPMENT TEMPERATURES:	
spawning			1O-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)

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 AND DEVELOPMENT TEMPERATURES:	
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 ihornyhead 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	Id) 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	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	fog time = a + b (temp) a	b	Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance 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			19-28								Illinois	Carlander 1969
nest building			11.9-20.6									Brown 1974
nest building			19.4-27.8								Illinois	
				23.5	28							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: Notemigonus crysoleucas (golden shiner)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
												30.5	Lab	Reutter & Herdendorf 1976
adult	14.4		SP										Lab (Ohio, Ont., Fla.)	Brown 1974
adult	10			29.3		42.7095	-1.3507	30.5	29.5				Lab (Ohio, Ont.. Fla.)	Brown 1974
adult	15			30.5	1.5	30.2861	-0.8933	32.5	31				Lab (Ohio, Ont., Fla.)	Brown 1974
adult	20			31.8	4.0	31.0275	-0.8722	34.5	32				Lab (Ohio, Ont., Fla.)	Brown 1974
adult	25			33.2	7.0	34.2505	-0.9226	36	34				Lab (Ohio, Ont., Fla.)	Brown 1974
adult	30			34.7	11.2	26.3829	-0.6615	37.5	35				Lab (May 28)	Spotila et al 1979
			SP	30.3									Lab (June 17)	Spotila et al 1979
			su	31.8									Lab (June 28)	Spotila et al 1979
			su	33.5									Lab (July 8)	Spotila et al 1979
3.49 in;	22		su	33.4									Lab (July 28)	Spotila et al 1979
			SU	33.2									Lab (Aug 91	Spotila et al 1979
			su	32.8									Lab (Aug 26)	Spotila et al 1979
			su	31.6									Lab (Sep 8)	Spotila et al 1979
			F	30.4									Lab (Ont)	Carlander 1969
	17.1-17.5			31-31.6									Lab (Ont.)	Carlander 1969
	21				3.4								Lab (Ont.)	Carlander 1969
	22.8			32.7	3.4								Lab (Ont)	Carlander 1969
	25-26			33.2									Field	Carlander 1969
				27-35								39.5	Lab (temp incr 0.75C/d)	Brown 1974
70-80;	22											40	Lab (temp incr 0.75C/d)	Brown 1974
	22												Lab	Brown 1974
	0			26.7							35	100	Lab (Algonquin Pk., Ont.)	Brown 1974
	25			35							30.5	30	Lab (Algonquin Pk., Ont.)	Brown 1974
	10										32.5	15	Lab (Algonquin Pk., Ont.)	Brown 1974
	15										35	>1000	Lab (Algonquin Pk., Ont.)	Brown 1974
	30										33	800	Lab (Algonquin Pk., Ont.)	Brown 1974
	20												Heated discharge, Delaware R.. Penn.	Brown 1974
	25-26.1			36									Michigan lake mortality	Leidy and Jenkins 1977
				38								40		Hutchison 1976
												33		Hutchison 1976
	10											35		Hutchison 1976
	15											36		Hutchison 1976
	20											38		Hutchison 1976
	25											39		Beltz et al 1974
	30													
	22			40										

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 Upper	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		20										Scott and Crossman 1973
spawning		20-21									N.Y. ponds	Carlander 1969
hatching (1st)		20									Ponds, Alab.	Carlander 1969
							>33-35				Field	Carlander 1969
spawning			15.6-21									Brown 1974
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									Lab (gonad regression)	Talmage and Coutant 1978
				20	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: Notropis anogenus (pugnose shiner)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				15-18				Rondeau Harbour, L. Erie	McAllister et al 1385

SPECIES: Notropis atherinoides (emerald shiner)

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 a	b	Upper	Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	7.8		SP									28.6	Lab	Reutter and Herdendorf 1376
0-1.9 g; juvenile (<1 yr)	5			23.3		20.3532	-0.7959						Lab (Chippewa Ck, Ont.)	Brown 1374
	10			26.7		36.5023	-1.2736						Lab (Chippewa Ck, Ont.)	Brown 1374
	15			28.9	1.6	47.4849	-1.5441						Lab (Chippewa Ck, Ont.)	Brown 1374
	20			30.7	5.2	33.4714	-0.9858						Lab (Chippewa Ck, Ont.)	Brown 1974
	25			30.7	8.0	26.7036	-0.7337						Lab (Chippewa Ck, Ont.)	Brown 1374
												34.3	Lab	Ellis 1384
				35.2									Lab	Ellis 1384
	20									32	60		Lab	Ellis 1384
	5			23									Lab	Carlander 1369
	10			27									Lab	Carlander 1963
	15			28.9	1.6								Lab	Carlander 1963
	20			31	5-5.2								Lab	Carlander 1363
												30.7	(ultimate upper lethal)	Carlander 1369
	20									33	30			Ellis 1984
	25									34	35			Brown 1374
				27-28										Brown 1374
	5									24	175			Brown 1974
	10									27	150			Brown 1974
	15									29.5	70			Brown 1374
YOY				35.2								34.3		Talmage 1378
	20-25			32.6										Talmage 1978

SPECIES: Notropis atherinoides ([emerald shiner)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
adult	w			8.3				Lab	Reutter and Herdendorf 1976
YOY	w			1o-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						Spotila et al 1979
			>31.1					White R., Ind. heated discharge	Brown 1974
			42		6			Field occurrence	Ellis 1984
				27.8125.1					Jobling 1981
				25				L. Simcoe, Ont.	Brown 1974
	su			25				L. Simcoe, Ont.	EPA 1974
	w			27				Ohio R.	EPA 1974

SPECIES: Notropis atherinoides (emerald shiner)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum "C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
	24-28.9							Spotila et al 1979
	27							Jobling 1981
YOY						21	L. Erie	Carlander 1969
juvenile	29	24-31						Brown 1974
			30	31				EPA 1974
YOY	28.9	19-29			29	<19	Lab (Minn.)	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	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		24										Scott and Crossman 1973
spawning			20-27									Brown 1974
hatch (24h)		23.9									L. Erie	Brown 1974
				23	27							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	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning			14-27								N.H.	Carlander 1969
				20.5	27							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)	Acclimation Temp.	Acclimation Time	Season	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)	THERMAL TOLERANCES: Location	Reference
				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;	25-26		Su	32										Carlander 1969
adult	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	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 Final	Location	Reference
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			15-25.5									Brown 1974
initial spawning			13-15.6								Cayuga L., N.Y.	Brown 1974
spawning		20	18.9-21.1								Big Sandy L., Minn.	Brown 1974
spawning			<28									Brown 1974
initial spawning			18								S. Michigan	Brown 1974
spawning		17.8									Central N.Y.	Brown 1974
				20	28							This study
inshore migration			12-l 5.5									Dodson and Young 1917
spawning			13.5-18									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	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
													Pond Michigan	Beltz et al 1974

SPECIES: Notropis hudsonius (spottail shiner)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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)	THERMAL TOLERANCES: Location	Reference
adult	21.7		su									32.8	Lab	Reutter and Herdendorf 1976
				>35									Field (active)	Carlander 1969
	7.2		W	30.6									Lab (0.6-1.1C/h)	Brown 1974
	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
13-36; 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
				II-16				L. Michigan	Brandt et al 1980
		D/N		17-20				L. Michigan	Brandt et al 1980
				9				Lab	Reutter and Herdendorf 1976
adult	w			14.3				Lab	Reutter and Herdendorf 1976
	SP			14					Spotila et al 1979
			>22		13			L. Michigan	Coutant 1977a
large								Delaware R., Penn.	Brown 1974
			>35						
110-116; adult				13.9		15		(6% salinity) estuary heated discharge into Delaware R., Penn.	Brown 1974
	SU		<40						Brown 1974
				10.2					Houston 1982
adult	w			17-20				L. Michigan	Talmage and Coutant 1980
		D		19-20	15			L. Michigan	Crowder et al 1981
	F	N		17-18	11			L. Michigan	Crowder et al 1981
	F								
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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
Young						18	L. Erie	Carlander 1969
					>35		Delaware R., Penn.	Brown *1974*
YOY						*10*	Lower Red L., Minn.	Brown *1974*
Young	*27.3*	*22.8-32.7*			*34*	*<20*	Lab (N.Y.)	Kellogg and Gift 1983
			30	*32.7*				This study
	>26						Clear L., Iowa	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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp (a) Range	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		20									L. Erie	Carlander 1969
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	Mansfield 1984
			15-20								Great Lakes	Mansfield 1984
heat shock							*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)

THERMAL TOLERANCES:

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

SPECIES: Notropis rubellus (rosyface shiner)

PREFERRED TEMPERATURES:

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

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum "C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	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	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			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										Brown 1974
				24.5	28							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 spilopterus (spotfin shiner)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	12-36			36									Lab	Cherry et al 1977

SPECIES: Notropis spilopterus (spotfin shiner)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
adult			35	29.5	26			Lab	Coutant 1977a
adult				29.4				Lab	Jobling 1981
			>31.1					White R., heated discharge, Ind.	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 Irking water temperatures)	Cherry et al 1977
				31					

SPECIES: Notropis spilopterus (spotfin shiner)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	No Growth Limits Lower	Location	Reference
	28.6/29.2							Jobling 1981
			31.3	35				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 (a) Range	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.

SPECIES: Notropis stramineus (sand shiner)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a -- b	Data Limits Upper	Data Limits 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 = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
adult	6.0		SP									27.8	Lab	Reutter and Herdendorf 1976
	15											31.9	Lab (N.Y.)	Spotila et al 1979
												34.8	Lab (1C/h)	Spotila et al 1979
	12-30			32									Lab	Cherry et al 1977
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
o-2 g; adult (1 yr)	25			33.3	7.5	50.8212	-1.4181	35	34	35	21		Etobicoke Ck., Ont.	Brown 1974
										38	>120		S. Michigan pond	Brown 1974
17-23; young adult				38									S. Michigan pond (one fish)	Brown 1974

SPECIES: Pimephales notatus (bluntnose minnow)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				23-29.5				Field	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 l977
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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	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 temperaturesas defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Pimephales promelas (fathead minnow)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
				33.2										Jobling 1981
	10			28										Carlander 1969
	20			31.7	2									Carlander 1969
	21				21									Carlander 1969
	25-6			32.3										Carlander 1969
	30			33	10.5									Carlander 1969
2-3.9 g;														
adult (1 yr)	10			28.2		60.7782-2.000		30	29.5				Don R., Thornhill, Ont.	Brown 1974
	20			31.7		6.9970-0.1560		33	28.5				Don R., Thornhill, Ont.	Brown 1974
	30			33.2		41.3696-1.1317		36	34				Don R., Thornhill, Ont.	Brown 1974
larval	21			- 3	4					34	>5760		Lab	Jinks et al 1981
												33-34	Lab	Madness & Hutchison 1980

SPECIES: Pimephales promelas (fathead minnow)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				28.5				Lab	Coutant 1977a
adult			32	29	25			Lab	Coutant 1977a
<74;			28	23.4				Lab	Coutant 1977a
50-100FL;				26.6				Lab	Jobling 1981
50-100FL			18	19.5	9	12		Lab (rising temperatures)	Cherry et al 1977
50-100FL			24	21.2	12	15		Lab (rising temperatures)	Cherry et al 1977
50.100FL			24	20.9	15	18		Lab (rising temperatures)	Cherry et al 1977
50.100FL			27	22	15	21		Lab (rising temperatures)	Cherry et al 1977
50.100FL			30	25.4	21	24		Lab (rising temperatures)	Cherry et al 1977
50-100FL			33	27.6	21	27		Lab (rising temperatures)	Cherry et al 1977
50-100FL			32	28.7	24	30		Lab (rising temperatures)	Cherry et al 1977
50-100FL				22.6				Lab	Beltz et al 1974

SPECIES: Pimephales promelas (fathead minnow)

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

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	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
spawning			15.6-17.8								Lake, Que. (minimum temp)	Scott and Crossman 1973
hatching (5d)		25										Scott and Crossman 1973
spawning onset	SP	15.6										Carlander 1969
spawning cessation	F		15.6-18.4									Carlander 1969
spawning	Su	>27										Carlander 1969
spawning			15.6-28.9								Outdoor exptal pool, Penn.	Gale and Buynak 1982
spawning		<23.5	<32								Lab	Beltz et al 1974
				23	28							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 Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
	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/l6 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 Lethal 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									N.Y.	
				21	22.2							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	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (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			1o-19.7				heated discharge into Delaware R., Penn.	Brown 1974
95-l 34;	S	P		*8-14*	*5.2*			L. Michigan (nearshore occurrence)	Brazo et al *1978*
51-104;	su			*1o-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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	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)

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	(4) Median Lethal Final	Location	Reference
spawning		11.7									Nicola R., B.C.	Scott and Crossman *1973*
hatching (7-10d)		15.6									Manitoba	Scott and Crossman 1973
spawning migration	Sp	> 8									L. Michigan	Brazo et al *1978*
spawning			14-19								L. Michigan	Brazo et al *1978*
spawning		15									L. Winnipeg	Brazo et al 1978
				15	20							This study
spawning			*15.5-20*								L. Winnipeg	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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (tamp) a	b	Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
	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									Lab (Delaware R; 2F/h)	Brown 1974
												32.3	Lab (Savannah R., 4C/h)	McFarlane et al 1976

SPECIES: Semotilus atromaculatus (creek chub)

SPAWNING AND DEVELOPMENT TEMPERATURES:

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

PREFERRED TEMPERATURES:

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

SPECIES: Semotilus corporalis (fall fish)

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
nest building		12									Brome L., Que.	Scott and Crossman 1973
spawning		16.6									Brome L., Que.	Scott and Crossman 1973
				16.6	28							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)

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	(4) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		17.2									Pentwater R., Mich.	Scott and Crossman 1983
spawning		18.3									Pine Ck., Mich.	Scott and Crossman 1983
				17.2	>18.3							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)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time - a + b (temp) a	b	Data Limits Upper	Lower Temp	Expo-sure	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
				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
Juvenile	19				1.0									Houston 1982
	24				5.0									Houston 1982
	38				15.5									Houston 1982
	I-2			28								41		Houston 1982
	9.3		F									>25.3	Lab	Reutter and Herdendorf 1976(a)
	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
larval	21-23			39.3									Lab	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				L a b	Coutant 1977a
adult	su			27.0				Lab	Coutant 1977a
adult	F			24.0				Lab	Coutant 1977a
medium				27.9				Lab	Coutant 1977a
				29.7			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: Carassiusauratus (goldfish)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
Juvenile	25							Jobing 1981
	28.1		30.4	32				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)

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	(4) Lethal Limit Lower	Median Lethal ΔT	(d) Median Lethal Final	Location	Reference
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									Talmage and Coutant 1978
				24	29.5							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	Season	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
	23.3											37.2	Lab	Spotila et al 1979

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	F			22.1				Lab	Coutant 1977a
large			34.5		27.0			Wabash, R., Ind.	Coutant 1977a
	su			26.32				J.M. Stuart, GS, Ohio R., Ind.	Yoder and Gammon 1976
	W			1O-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 (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			19-28								Four Mile Ck., Ohio	Talmage 1978
				23.5	28							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 temperaturesas defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Catostomus catostomus (longnose sucker)

THERMAL TOLERANCES:

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
44 9;	14			26.5										Scott and Crossman 1973
44 9;	11.5			27										Carlander 1969

SPECIES: Catostomus catostomus (longnose sucker)

PREFERRED TEMPERATURES:

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

SPECIES: Catostomus catostomus (longnose sucker)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp (a) Range	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 run		5									B.C.	Scott and Crossman 1973
hatching (8-11d)			1o-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)

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time -- a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	THERMAL TOLERANCES: Critical Thermal (Max)	Location	Reference
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
Juvenile												35.1-36.1		Brown 1974
				31.4									Nova Scotia R.	Brown 1974
				30-33.3									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
	21.2	7d		>28.2	4.8								Lab	McCormick et al 1977
swim-up	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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
				20.6				Wisconsin lakes	Coutant 1977a
				18.3				Moosehead L. Me.	Coutant 1977a
large				18.9-21.1				Horse tooth Res., Colo	Coutant 1977a
adult	F			22.4				Lab	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
			31.2						McCormick et al 1977
adult				19-21				Oswego or Pickering GS 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. (mean field occurrence)	Marcy 1976a
Larval			30					Jack L., Ont.	Corbett and Powles 1983

SPECIES: Catostomus commersoni (white sucker)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max far Embryo Survival	Acclimation Time	(c) Lethal Limit Upper	(4) Lethal Limit Lower	Median Lethal AT	(4) Median Lethal Final	Location	Reference
spawning		10	4-18	10	21							EPA 1974
incubation/ hatch		15	8-21									EPA 1974
spawning			1o-20									Brown 1974
heat shock	12								20	32	Lab	Moore 1979(d)
incubation/ hatch	6.2-42.1	15.2	9-17.2				24.1	6.2			Lab	McCormick et al 1977
spawning		17.8	27.2		<24.1							McCormick et al 1977
cold shock	16							0	-16		Lab	Edsall and Yocum 1972
cold shock	20							3	-17		Lab	Edsall and Yocum 1972
cold shock	25							6	-19		Lab	Edsall and Yocum 1972
cold shock	33-34							10	-13		Sandusky, R. (L. Erie)	Coutant 1977b
cold shock	27							2	-25		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		23.4	12.2-24								Connecticut R., Conn.	Marcy 1976b
larval dev.		23.8	14.0-24								Connecticut R., Conn.	Marcy 1976b
spawning migration		211.8	3-16.5								Jack L., Ont.	Corbett and Powles 1983
spawning		16.8	10-16.9-k								Jack L., Ont.	Corbett and Powles 1983
larval dev. (9-11 mm TL)			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 (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
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.

SPECIES: Hypentelium nigricans (northern hog sucker)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower Temp	Exposure	Resistance 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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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)

GROWTH TEMPERATURES:

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

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			>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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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)

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		15.5-18.3										Scott and Crossman 1973
spawning			14.4-26.7									Carlander 1969
				17	27							EPA 1974
spawning		17										EPA 1974
hatching			14-27									EPA 1974
				17	26.7							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: Minytrema melanops (spotted sucker)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
	20		SU									>31	Lab	Reutter and Herdendorf 1976

SPECIES: Minytrema melanops (spotted sucker)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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)

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			15-17.8								Oklahoma	Scott and Crossman 1973
				16.4	17.8							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 (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		13.3										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
			37.2						Scott and Crossman 1973
large			26		22			Wabash R., Ind. (Moxostoma sp.)	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 (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		11									Iowa	Scott and Crossman 1973
spawning		16									Big Rock Ck, III.	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)

THERMAL TOLERANCES:

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

SPECIES: Ictalurus melas (black bullhead)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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)

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										Scott and Crossman 1973
				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: Ictalurus natalis (yellow bullhead)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
	22.2		su									36.4		Spotila et al 1979

SPECIES: Ictalurus natalis (yellow bullhead)

PREFERRED TEMPERATURES:

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

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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)	THERMAL TOLERANCES: Location	Reference
				36. l										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
	I5			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	-O-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

THERMAL TOLERANCES:

Size or Age (mm)	Accli-mation Temp.	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
larval	25			38.2						38.2	IO		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	IO		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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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-l 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-l 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)

GROWTH TEMPERATURES:

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

SPAWNING AND DEVELOPMENT TEMPERATURES:

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		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 iincubation 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	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
	15			30.3	*0*									Carlander 1969
	20			32.8	2.5									Carlander 1969
	25			33.5	6.0									Carlander 1969
				35										Carlander 1969
												33.5		Carlander 1969
44-57d; juvenile	26			36.6		34.7119	-0.8816	39	36.6				Hatchery, Ark.	Brown 1974
44-57d; juvenile	30			37.8		32.1736	-0.7811	40.6	37.4					Brown 1974
44-57d; juvenile	34			38.0		26.4204	-0.6149	42	38					Brown 1974
	12											34.5		Spotila et al 1979
	16											34.2		Spotila et al 1979
	20											35.5		Spotila et al 1979
	24											37.7		Spotila et al 1979
	28											39.2		Spotila et al 1979
	32											41.0		Spotila et al 1979
	22.7		*su*									38.0		Spotila et al 1979
				36.1										Jobling 1981
				36.4										Jobling 1981
11.5 mo; juvenile	25			35.5		34.5554	-0.8854	37.5	35.5				Hatchery, Ark.	Brown 1974
11.5 mo; juvenile	30			37		17.7125	-0.4058	40	37.5				Hatchery, Ark.	Brown 1974
11.5 mo; juvenile	35			38		28.3031	-0.6554	41	38				Hatchery, Ark.	Brown 1974
adult	15			30.4	0	34.7829	-1.0637	31.5	30.5				Put-in-Bay, Ohio + Fla	Brown 1974
adult	20			32.8	0	39.4967	-1.1234	34	33				Put-in-Bay, Ohio + Fla	Brown 1974
adult	25			33.5	0	46.2155	-1.2899	35	44				Put-in-Bay, Ohio + Fla	Brown 1974
	7.2			32.8							32.8	60		Brown 1974
	11.			35							35	60		Brown 1974

SPECIES: Ictalurus punctatus (channel cat)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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		I2			Spotila et al 1979
				21.7		15			Spotila et al 1979
				22.9		I8			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		I2			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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
	29							Jobling 1981
	30							Jobling 1981
	28-30							Jobling 1981
larvae	29/31	21-34			36			Brown 1974
juvenile	28/32	18.3-34			>34	15.6		Brown 1974
			32	36				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)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp (al Range	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		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		27	21-29									EPA 1974
hatch			18-29									EPA 1974
wintering			5-15									Yoder and Gammon 1976
cold shock									-6/-10		Lab	Coutant et al 1976
heat shock									+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	Season	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
	I.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 Lethal AT	(d) Median Lethal Final	Location	Reference
spawning		27.8										Scott and Crossman 1973
				27.8								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)

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
												38	Shallow Michigan pond.	Beltz et al 1974

SPECIES: Noturus miurus (brindled madtom)

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	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
spawning		25.6									Michigan	Scott and Crossman 1973
				25.6								This study
spawning			25-27								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						Carlander 1969
				16.7		6-30		Maryland	Cravens 1961
			33	20.5	11.9			Connecticut Yankee GS discharge, Conn. Ft., Conn.	Marcy 1976a

SPECIES: Anguilla rostrata (american eel)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: 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 for Embryo Survival	Acclimation Time	(c) Lethal Limit UPPer	(c) Lethal Limit Lower	Median Lethal AT	(d) Median Lethal Final	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
spawning		17.									Ocean	Scott and Crossman 1973
				17	35							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 Tamp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
adult	15			27.5 ≥38.3									Lab Field	Brown 1974 Leidy and Jenkins 1977
adult	25			34.5 26.5										Houston 1982 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) Median Lethal Final	Location	Reference
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)

THERMAL TOLERANCES:

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time - a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	-Critical Thermal (Max)	Location	Reference
				23.3										Scott and Crossman 1973

SPECIES: Lota lota (burbot)

PREFERRED TEMPERATURES:

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

SPECIES: Lota lota (burbot)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
	15.6-18.3							Scott and Crossman 1973
			20	24				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)		o-1.5										Mansfield et al 1983
hatching		<8-10										Mansfield et al 1983
				1.2	1.7							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: Labiddesthes 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) a	b	Data Limits Upper	Data Limits 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 temperaturesas defined by Fry et al (1946).

(d) Simulated larval entrainment temperatures.

SPECIES: Gasterosteus aculeatus (three spine 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) a	b	Data Limits Upper	Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
				28.5										Jobling 1981
	19			25.8										Houston 1982
37 mm	19			25.8		19.3491	-9.5940	32	26				Columbia R., Oregon	Brown 1974
				26										Talmage 1978
					-0.7									Carlander 1969(a)

(a) fatal body temperature

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
				7.5-10					Jobling 1981
				16-18					Jobling 1981
				12-16					Wyman 1981
adult				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)

GROWTH TEMPERATURES:

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

SPAWNING AND DEVELOPMENT TEMPERATURES:

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
hatching (7d)		19										Scott and Grossman 1973
spawning			5-20									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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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)

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 AT	Median Lethal	(d) Median Lethal Final	Location	Reference
eggs		19-24	16-26									Carlander 1969
				21	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 *(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)	Accli-mation Temp.	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: 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
	F	N		7-8				L. Michigan	Crowder et al 1981

SPECIES: Percopsis omiscomaycus (trout perch)

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: 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 Lethal 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)

THERMAL TOLERANCES:

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
				32.4-34							24-336h	35.6-36.4		Ellis 1964
larvae				33-36							10			Talmage and Coutant 1979
	8			27	8									Talmage 1978
	26			35										Talmage 1978
larvae	15			35.6							10		Lab	Jinks et al 1981
				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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
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) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: Reference
27.5	28.5	26.3-31.7			34		Lab, Hudson R. N.Y.	Kellogg and Gift 1983
			30.6	33				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 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	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
spawning			11-15								Bay of Quinte, L. Ont	Scott and Crossman 1973
hatch			15-20									Scott and Crossman 1973
hatch	8-26	14.1/17.6										Cravens et al 1983
eggs	18				18		24		6			Wyman 1981
cold shock	20							2	-18			Talmage 1978
spawning		15.6-19.4	12-22.2	17	25						Lab	Morgan II and Rasin, Jr. 1982
hatch		14.1	10-24								Lab	Morgan II and Rasin. Jr. 1982
embryo		17.6	10-24								Lab	Morgan II and Rasin, Jr. 1982
spawning			8.9-27								Connecticut R.	Marcy 1976b
eggs		19.0-20.9									Connecticut R.	Marcy 1976b
heat shock							28					Marcy 1976b
heat shock	27								t 8.5		Lab	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)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
larvae	14-26			30-32							24h			Ellis 1984
YOY				33.5							48h			Ellis 1984
	21.7											35.3	Lab	Reutter & Herdendorf 1976
larvae	14			31.7	12.8								Lab	McCormick 1978
	18			30.8										McCormick 1978
	20			32.0										McCormick 1978
	26			30.6										McCormick 1978
	14-26			31.3										McCormick 1978
YOY				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			1o-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)

GROWTH TEMPERATURES:

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

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp (a) Range	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			12-24	19	24							EPA 1974
incubation/ hatch		16-17										EPA 1974
hatch		23.9									L. Erie	Brown 1974
spawning			14.4-21.1								L. Erie	Scott and Crossman 1973
cold shock	w 27							9	-18		Little-Three Mile Ck. Ohio A.	Coutant 1977b
eggs	19		18-26		26		30.2	10			Lab	McCormick 1978
			11-23.9									McCormick 1978
spawning		14.7-16.3									Lewis & Clark L. (S.D.)	Talmage & Coutant 1978
spawning			13-26								L. Mendota. Wis.	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	Season	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
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)

GROWTH TEMPERATURES:

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

(a) MWAT (maximumweekly 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: Ambloplites rupestris (rock 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		20.5-21									Lab	Brown 1974
survival							38				Michigan pond	Brown 1974
spawning		15.6-21.1										Scott and Crossman 1973
			20.5-26									Carlander 1977
				21	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) rnaximum 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	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
														Brown 1974
														Brown 1974
												>36	White R., Ind.	Carlander 1977
													Field study	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						Brown 1974
				15.9		6			Carlander 1977
				22.7		15			Carlander 1977
				30.6		30			Carlander 1977
				26.8					Beltz et al 1974
<74;			30	27.3	24			Lab	Coutant 1977a
adult			33	30.6	23			Lab	Coutant 1977a
small			30.3	28.2	26.5			Lab	Coutant 1977a

SPECIES: Lepomis cyanellus (green sunfish)

GROWTH TEMPERATURES:

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

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			15.6-28									Brown 1974
spawning	16.7						21.1					Brown 1974
heat shock	F/W/SU								>11.1			Brown 1974
spawning			20-24									Carlander 1977
hatching		29.1										Carlander 1977
				21.8	28							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)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	THERMAL TOLERANCES: Critical Thermal (Max)	Location	Reference
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*
												>35.6	Lab	Carlander *1977*
	25.26			34.5									Lab	Carlander *1977*
	25			24.5										Leidy and Jenkins 1977
				36.6										Jobling 1981
				34.8										Jobling 1981
	30				8.5									Schneider and et al 1975
	25				5									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	Range	(a) MWAT	W ST Max	No Growth Limits Upper	Lower	Location	Reference
	25							Carlander 1977
underyearling	30							Jobling 1981
						13	Gt. lakes	Griffiths 1978
						5		Spotila et al 1979
			29.3	36				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	(al 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			20-29								Lake, N.Y.	Brown 1974
		28									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	-1O	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								-1O	6.3	Lab	Scheider and Becker et at *1975*
cold shock	30							8.5	- 18	12	Lab	Scheider and Becker et al 1975
cold shock	30								- 1 o	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	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Exposure Temp	Resistance Time (Min)	THERMAL TOLERANCES: Critical Thermal (Max)	Location	Reference
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-l 00	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

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
a d u l t				31		26			Cravens 1982
juvenile				31.2		25			Talmage and Coutant 1978
juvenile			33.1		29.5	25			Talmage and Coutant 1978
				31				Lab	Talmage and Coutant 1980
50-100; <1 yr	Su			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		33.6					Thermal discharge White R., Ind.	Brown 1974
			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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
						13	Gt. Lakes	Griffiths 1978
						16-20	Indiana Lakes	Evans 1984
	30	20-36						Talmage and Coutant 1978
	30							Cravens 1981
juvenile	30-31							Talmage and Coutant 1980
juvenile	30.1							McCauley and Casselman 1980
subadult	29-30							McCauley and Casselman 1980
	31							McCauley and Casselman 1980
		24-34		32.2				Brown 1974
adult	24-27	16-30						Brown 1974
			29	32				EPA 1974
					26.7	1o-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)

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			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
				25	34							EPA 1974
spawning		25										EPA 1974
hatching		22-24	22-34									EPA 1974
cold shock	25								-1o		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	Season	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
>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 Lethal 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 dolomieui (smallmouth bass)

Size or Age (mm)	Accli-mation Temp	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a - b	Data Limits Upper	Data Limits Lower	Expo-sure Temp	Resis-tance Time (Min)	THERMAL TOLERANCES: Critical Thermal (Max)	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 dolomieui (smallmouth bass)

Size or Age (mm)	Season	Day or Night	PREFERRED TEMPERATURES: Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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
juvenile				28-29				Lab	Shuter et al 1980
		D		30.1				Lab	Talmage and Coutant 1979
		N		26.6				Lab	Talmage and Coutant 1979
50-100;≤1yr				30.3				Lab	Cherry et al 1977
50-100;&lyr			27		15	18		Lab	Cherry et al 1977
50-100;≤1yr			30		18	21		Lab	Cherry et al 1977
50-100;*lyr			33		21	24		Lab	Cherry et al 1977
50.100;*lyr			33		24	27		Lab	Cherry et al 1977
50-100;≤1yr			33		24	30		Lab	Cherry et al 1977
50-100;≤1yr			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 dolomieui (smallmouth bass)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
YOY	28	14-31.5			35	7	Lab and field (Baie du Dore, L. Huron)	Shuter et al 1980
juvenile			29					EPA 1974
juvenile/adult			32/33	35		10-12	Tennessee R.. (outdoor exptal channels), Alab.	Wrenn 1990
15-35SL; fry	25-26						Lab	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 dolomieui (smallmouth bass)

SPAWNING AND DEVELOPMENT TEMPERATURES:

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		18	15-17								Baie du Dore. L. Huron	Shuter et al 1980
				17	26						Tennessee R., Ala. (outdoor expt. channel)	Wrenn 1984
					25							EPA 1974
egg/larval devel.		21	13-26				30	10			Lab and field (Baie du Dore, L. Huron)	Shuter et al 1980
w	19						29	17				Brown 1974
egg	16.1						23.1		+7			Brown 1974
heat shock	20								+17	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)

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Exposure Tamp	Resistance Time (Min)	Critical Thermal (Max)	THERMAL TOLERANCES: Location	Reference
	12			36										Cherry et al 1982
juvenile	20			33	5									EPA 1974
	25			35	7									EPA 1974
	30			36	11									EPA 1974
	35			36										EPA 1974
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
	20				5.5								Put-in-Bay, Ohio	Brown 1974
	30				11.8								Put-in-Bay, Ohio	Brown 1974
under yearling	30			36.4		36.0620	X1.9055	38.5	37				Knoxville, Tenn.	Brown 1974
	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
	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
adult	0.7		W									>12.0	Lab	Reutter and Herdendorf 1976
				36.7/389										Carlander 1977
	20-21			28.9										Spotila et al 1979
eggs				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	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: Reference
juvenile	25							McCauley and Casselman 1980
subadult	26-28							McCauley and Casselman 1980
			32	34				EPA 1974
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)

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	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
				21	27							EPA 1974
spawning		15.6-21	12-20								field	Carlander 1977
hatching		20	13-26									EPA 1974
eggs							32.5					Brown 1974
spawning				23.9								Brown 1974
					29-32						Lab (Wis., Minn.)	EPA 1978
embryo devel.	20						32.1				Lab	Cravens 1982
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			1O-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)

THERMAL TOLERANCES:

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

SPECIES: Pomoxis annularis (white crappie)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
large			27		22			Wabash R., Ind.	Coutant 1977a
adult	W			19.8				Lab	Coutant 1977a
adult	SP			18.3				Lab	Coutant 1977a
adult	F			10.4				Lab	Coutant 1977a
adult	su			19.4				Lab	Reutter and Herdendorf 1976
	SU		31		26			Ohio R.	Yoder and Gammon 1976
	F		26		18				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)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
juvenile	25		27					EPA 1974
				32.2				Brown 1974
					27	15.6		Carlander 1977
	27-28.5						Ohio R.	Yoder and Gammon 1976
		5-30						O'Brien et al 1984

(a) MWAT (maximum weekly averagetemperature 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)

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	sp/su	16-20	14-23									EPA 1974
spawning		18-20										EPA 1974
				18	23							EPA 1974
hatching			18.3-20									Carlander 1977
spawning		14-16										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	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a -- b	Data Limits Upper	Data Limits Lower	Exposure Temp	Resistance Time (Min)	Critical Thermal (Max)	Location	Reference
juvenile	29			<33								Lab (UUILT)	EPA 1974
	7.2	1°C/h		28.9								Lab	Brown 1974
adult	23.8		su								34.9	Lab	Reutter and Herdendorf 1976
				34									Carlander 1977
				32.5									Leidy and Jenkins 1977
>200TL			su	26-28								Hayes Centre L., Neb. (observed)	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	su		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)

GROWTH TEM

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
juvenile	22-25		27	32.2	30	11		EPA 1974 Brown 1974 Brown 1974
<76TL;		27-29				6.5	L. Monona, Wis. Ontario	Carlander 1977 Ellison 1984
>200TL;	9-17	9-25			26 27		Hayes Center State Lake, Neb. 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 Accli-mation Temp	Optimum Temp	Temp Range	(a) MWAT	(b) ST Max for Embryo Surviva	Accli-mation	(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)	Accli-mation Temp.	Accli-mation Time	Sea-son	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
													THERMAL TOLERANCES:	
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
young	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

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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			1o-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

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
small			30.5					L. Monona, Wis.	Brown 1974
underyear-lings	W			13		1			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	Brapdt 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				Pokegamma Res., Minn.	Cravens 1981
	Wi			6.3				near thermal outfall, Minn.	Cravens 1981
adult	F			7-8, 11-17				L. Michigan	Talmage and Coutant 1980
				14-19				Wickett L., Manitoulin Isl., Ont.	Talmage and Coutant 1980
60 g				20.2		20		Lab	Talmage and Coutant 1980
newly hatched larvae				24.3		20			Talmage and Coutant 1980
				24.2		23			Talmage and Coutant 1979
				21.7		25			Talmage and Coutant 1979
8-11	SP		>29	12-16				Keowee Res., S.C.	Clugston et al 1978
adult	su			18-21					Clugston et al 1978
juvenile	su			20-24					Clugston et al 1978

SPECIES: Perca flavescens (yellow perch)

GROWTH TEMPERATURES:

Size or Age (mm)	Optimum °C	Range	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	Reference
			22	29				EPA 1974
adult		13-20				12.513		EPA 1974
juvenile	22.5							McCauley and Casselman 1980
	23							Smagula and Adelman 1982
juvenile		20-23.3						Leidy and Jenkins 1977
adult		17.6-20.1						Leidy and Jenkins 1977
	24.2							Leidy and Jenkins 1977
5.2-23.7 g	23							Jobling 1981
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)

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		12	7-15	12	20							EPA 1974
incubation/ hatch		1o-20	7-20									EPA 1974
wintering		<6	4-11									Brown 1974
spawning		7.8-l 2.2	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 Accli-mation Temp	Optimum Temp	Temp (a) Range	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
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/ larvae	7								+17		Lab; simulated onshore discharge	Crippen and Fahmy 1981
heat shock/ larvae	7								+21.6		Lab; simulated tempering discharge	Crippen and Fahmy 1981
heat shock/ larvae	7								+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.	Thorpe 1977
			7.2-l 1								Wisc.	Clugston et al 1978
heat shock (larval)	7.6-15.8								> + 15		Lab; simulated once-through cooling	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	Season	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	25.8		F	30.4										Hokanson 1977
larval				20.9	6.0									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)

GROWTH TEMPERATURES:

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

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			4-14.4								N. Dak., Tenn.	Hokanson 1977
spawning		9-15										Hokanson 1977
incubation		12-15										Hokanson 1977
spawning		9	S-12									Smith and Koenst 1975
				10	21							EPA 1974
spawning		10	6-14								Norris Res., Tenn	EPA 1974
incubation/ hatch		12-15	1O-16									EPA 1974
spawning			3.0-I 1 1									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	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp)	Data Limits Upper	Data Limits Lower	Expo-sure Temp	Resis-tance Time (Min)	THERMAL TOLERANCES: Critical Thermal (Max)	Location	Reference
115; juvenile	25.8		F	31.6									Hokanson 1977
larval				19.2	6.0								Hokanson 1977
115; juvenile	8.0			27								Lab	Smith and Koenst 1975
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: Location	Reference
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	(a) MWAT	(b) ST Max	No Growth Limits Upper	Lower	Location	GROWTH TEMPERATURES: Reference
			25	31				This study
					27			Cheshire and Steel 1972
age 0		12-28				12	West Blue Lake. Man.	Kelso and Ward 1972
85	22.1				29			Hokanson 1977
65	25.2							Hokanson 1977
1.81-2.00 g	22	19-25						Smith and Koenst 1975
				32-33			outdoor experimental channels, Alabama	Talmage and Coutant 1980
	22.6							Casselman 1978
<35; fry	15				20	10	Lab	Nickum 1978
4 2 5 ; fingerling	22				27		Lab	Nickum 1978

(a) MWAT (maximum weekly average temperature for growth) = optimum t 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	Median Lethal AT	(d) Median Lethal Final	Location	Reference
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
				8.9	15.6							This study
spawning		7.1-9.9										Spotila et al 1979
incubation		10.5-15.5	5-19				20				Lab	Griffiths 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: Ammocrypta pellucida (eastern sand darter)

PREFERRED TEMPERATURES:

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

SPECIES: Etheostoma blennoides (greenside darter)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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											32.2	Lab (N.Y.)	Kowalski et al 1978

SPECIES: Etheostoma caeruleum (rainbow darter)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	Upper Incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a -t b (temp) a -- b	Data	Limits 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 Lethal AT	(d) Median Lethal Final	Location	Reference
hatching (IId)		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)

PREFERRED TEMPERATURES:

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

SPECIES: Etheostoma exile (Iowa darter)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Acclimation Temp	Optimum Temp	Temp Range	(a) (at 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)	Accli-mation Tamp	Accli-mation Time	Sea-son	Upper incip. Lethal Temp	Lower Incip. Lethal Temp	log time = a + b (temp) a	b	Data Limits Upper	Lower	Expo-sure Temp	Resis-tance Time (Min)	Critical Thermal (Max)	Location	Reference
	15											32.1	Lab, N.Y.	Kowalski et al 1978

SPECIES: Etheostoma flabellare /fantail darter)

SPAWNING AND DEVELOPMENT TEMPERATURES:

Event	Season and/or Accli-mation Temp	Optimum Temp	Temp (a) Range	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
hatching		21.1										Scott and Crossman 1973
spawning			18.9-24.4								N.Y.	Brown 1974
spawning			7-15								N.Y.	Cooper 1979
migration												
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 Accli-mation Temp	Optimum Temp	Temp (a) Range	MWAT	(b) ST Max for Embryo Survival	Accli-mation Time	(c) Lethal Limit Upper	(c) Lethal Limit Lower	Median Lethal AT	Median Lethal Final	Location	Reference
hatching		18-20										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 nigrum (johnny darter)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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		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)

PREFERRED TEMPERATURES:

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

SPECIES: Etheostoma nigrum (johnny 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 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)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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)

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
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)

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	SPAWNING AND DEVELOPMENT TEMPERATURES: 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 a) (1946).
(d) Simulated larval entrainment temperatures.

SPECIES: Percina maculata (blackside darter)

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	SPAWNING AND DEVELOPMENT TEMPERATURES: 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)

THERMAL TOLERANCES:

Sire or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
adult	21.2											34.0	Lab	Reutter and Herdendorf 1976
	29-35			32.8										Houston 1982
YOY			su	32.8						32.8	2880			Jinks et al 1981

SPECIES: Aplodinotus grunniens [freshwater drum)

PREFERRED TEMPERATURES:

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

GROWTH TEMPERATURES:

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

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	18922.2								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
				21	26							EPA 1974
spawning		21	19-24									EPA 1974
incubation 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)

												THERMAL TOLERANCES:	
Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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											30.9		Spotila et al 1979

SPECIES: Cottus bairdii (mottled sculpin)

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

SPECIES: Cottus bairdii (mottled 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		12.8	5.0 - 16.1								Lab	Brown 1974
hatching (21-28d)			7.8-17.3									Brown 1974
spawning		10									Field, N.Y.	Scott and Crossman 1973
cold shock	18.7								7	-11.7	L. Huron, (Seiche)	Scott and Crossman 1973
				10	16.1							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)

THERMAL TOLERANCES:

Size or Age (mm)	Acclimation Temp	Acclimation Time	Season	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
40-l 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-l 00	10		w									25.1	Lab, L. Mich.	Otto and Rice *1977*
80-l 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

SPECIES: Cottus cognatus (slimy sculpin)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	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)

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	SPAWNING AND DEVELOPMENT TEMPERATURES: 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; heat shock	5					*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.

SPECIES: Cottus ricei (Spoonhead 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 Lethal AT	(d) Median Lethal Final	SPAWNING AND DEVELOPMENT TEMPERATURES: Location	Reference
spawning		4.5								Pemichangan L., Quebec	Scott and Crossman 1973
			4.5								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 entrainmenttemperatures.

SPECIES: Myoxocephalus quadricornis (deepwater sculpin)

PREFERRED TEMPERATURES:

Size or Age (mm)	Season	Day or Night	Upper Avoidance	Final Preferendum	Lower Avoidance	Acclimation Temperature	Acclimation Time	Location	Reference
large			4.5		4			L. Michigan	Coutant 1977a
			10					Field	Coutant *1977a*
	F	N		< 5				L. Michigan (bottom trawl)	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)

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
incubation (97d)		1.5										Mansfield et al 1983

(a) MWAT = maximurn 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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