TR-51

FEDERAL AID IN SPORT FISH RESTORATION

ANNUAL PERFORMANCE REPORT
Study II
June 1, 1975 - May 31, 1976

PROJECT F-41-R-7

ENVIRONMENTAL EVALUATION OF A NUCLEAR POWER PLANT ON LAKE ERIE

THE OHIO STATE UNIVERSITY
CENTER FOR LAKE ERIE AREA RESEARCH

July 1976

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STATE OF:	Ohio
PROJECT NO.:	F-41-R-7
PERIOD COVERED:	June 1, 1975 - May 31, 1976
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STUDY TITLE:	Laboratory Estimates of Fish Response to the Heated Discharge from the Davis-Besse Reactor, Lake Erie, Ohio
PREPARED BY:	Jeffrey M. Reutter Lynwood A. MacLean Charles [illegible]

Center for Lake Erie Area Research
The Ohio State University

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Prepared by: Jeffrey M. Reutter
Lynwood A. MacLean
Charles E. Herdendorf

Date Prepared: 31 July 1976

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ABSTRACT

The Davis-Besse Nuclear Power Station, currently under construction on the south shore of Lake Erie near Locust Point, will use water from the lake for cooling purposes. Based on thermal specifications for this plant, laboratory experiments were conducted to try to predict the effects of thermal effluents on the Lake Erie fishery resource. Over 2200 fish representing 29 of the 46 local species were tested to determine their seasonal final temperature preferenda. All final preferenda were above lake temperature dur-

ing fall, winter, and spring indicating attraction to thermal discharges during these seasons. Summer final preferenda were approximately equal to or slightly higher than lake temperature for all species tested indicating indifference or slight attraction to thermal plumes. Hot shock tests were conducted on 1873 fish of 41 species and cold shock tests were conducted on 893 fish of 34 species. Hot and cold shock results indicated that the absolute temperature to which fish were subjected was more important than the size of the temperature change. Therefore, summer hot shocks and winter cold shocks caused the greatest stress. The species most likely to be harmed by thermal effluents were Alosa pseudoharengus (alewife), Aplodinotus grunniens (freshwater drum), Dorosoma cepedianum (gizzard shad), and Morone chrysops (white bass).

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PROJECT STAFF

Charles E. Herdendorf - Principal Investigator

Jeffrey M. Reutter - Co-Principal Investigator

Lynwood A. MacLean - Investigator

Jo Ann Franks - Secretarial Services

Carolyn S. Jenkinson - Administration Assistant

Richard O. Moore, Jr. - Laboratory Technician

STUDY OBJECTIVE

To be able to specify the response of all species common to western Lake Erie to the heated discharge from the Davis-Besse nuclear power plant throughout the year.

JOB II-a
TEMPERATURE PREFERENCES OF LAKE ERIE FISH

Objectives

To be able to specify the seasonal temperature preferences of Lake Erie fish.

Procedures

Fish for these experiments were captured near F.T. Stone Laboratory on South Bass Island and at the northeast corner of North Bass Island with a fyke net, and south of Rattlesnake Island and at Locust Point by trawling (Fig. 1). Fish for winter testing were caught in November and early December and held in 420-l holding tanks in running, ambient temperature lake water until they were tested. During all other seasons fish were tested as soon as possible after capture, usually within 1 week. Fish were maintained and tested under actual seasonal photoperiods. Natural lighting from windows in the north and east walls was adequate for most observations.

Tests were conducted in a horizontal temperature gradient made from a wooden tank 8.7 m long, 79 cm wide, and 50 cm high (Barans and Tubb, 1973). A system of alternating transverse

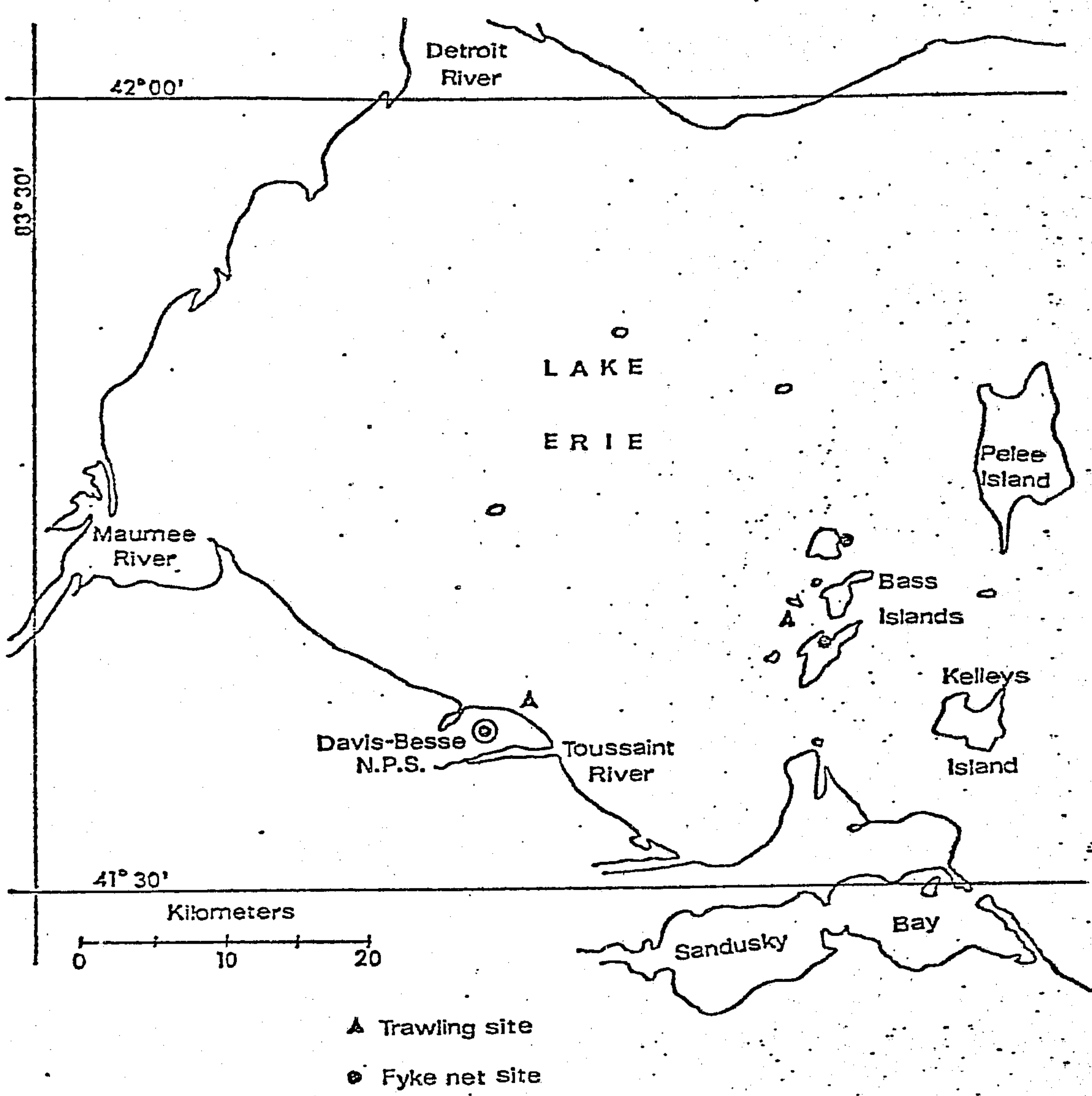

FIGURE 1. WESTERN LAKE ERIE SHOWING PLANT SITE AND LOCATIONS OF FISH CAPTURE FOR LABORATORY PREFERENCE AND SUDDEN TEMPERATURE CHANGE TESTING.

baffles each 56 cm long, formed a series of 28 virtually identical compartments. In effect, this arrangement increased the horizontal length of the tank to 24 m without greatly restricting the movements of the fish. Sand-filtered lake water was passed through 0.64 cm Tygon tubing at a rate of approximately 2 l/min into the cold end of the gradient. To lower the temperature during the spring, summer and fall, the water was first routed through copper pipe in a cooling reservoir. Examination of the water quality in the intake line and in the gradient tank indicated no significant increase in the level of copper in the water due to this cooling system. The water was then heated progressively higher in each of the 28 compartments as it flowed to a standpipe, 25 cm high, at the opposite end of the tank.

A Vycor 500 watt heater, ARC static switch relay, and corresponding Jumo thermoregulator maintained a constant water temperature in the center of each compartment. By adjusting the thermoregulators a change of 0.5 – 1.5°C could be developed between compartments. Each season a different temperature range was established within the gradient from a low of several degrees below lake temperature (late spring, summer, and early fall) or slightly above the lake temperature (winter), to a high of 15 – 28°C above lake temperature.

Aeration from three air stones in each compartment greatly reduced vertical temperature stratification and maintained dissolved oxygen at near saturation levels in all compartments (Barans and

Tubb, 1973). The water temperature at the center of alternate compartments was measured with probes from a YSI multi-channel telethermometer. By moving these probes temperatures could be ascertained for every compartment.

In order to acquaint the fish with the gradient apparatus, 24 hours prior to testing they were placed in an acclimation tank half as long as the gradient tank, with the same system of baffles as the gradient tank, but with no heaters or thermoregulators. The water temperature in the acclimation tank was maintained as close to lake temperature as possible (usually within 2°C of lake temperature). The fish were then placed in the gradient compartment with the temperature closest to lake temperature (normally within 0.5°C of lake temperature).

The number of fish per test varied from one for adult *Micropterus dolomieui* (Barans and Tubb, 1973) to 27 for *Notropis hudsonius*. The duration of the tests varied from 1-2 days in the summer to 3-4 days in winter. Barricades were used in late fall, winter, and early spring to keep fish from entering warm water too rapidly and being killed. The barricades were placed a minimum of 11.1°C (maximum plume temperature) above ambient and then gradually moved as the fish became acclimated to warmer water.

Fish location and behavior were observed at 2-hr intervals during daylight hours. The temperatures of the compartments containing fish, weighted by the number of fish in each, were used to calculate the mean temperature preference for each observation. When these mean temperature preferences were plotted graphically, the resulting curve could be divided into an acclimation period and a stationary preference period as shown in Figure 2. The acclimation period included the random swimming that often occurred upon entry into the tank and the rapid increase in preference temperature that occurred in late fall, winter, and early spring. The stationary preference period was that interval when individuals showed little or no change in their temperature preference for approximately 24 hrs. Observations during this period were used to calculate the final preferendum of each species. The final preferendum is that

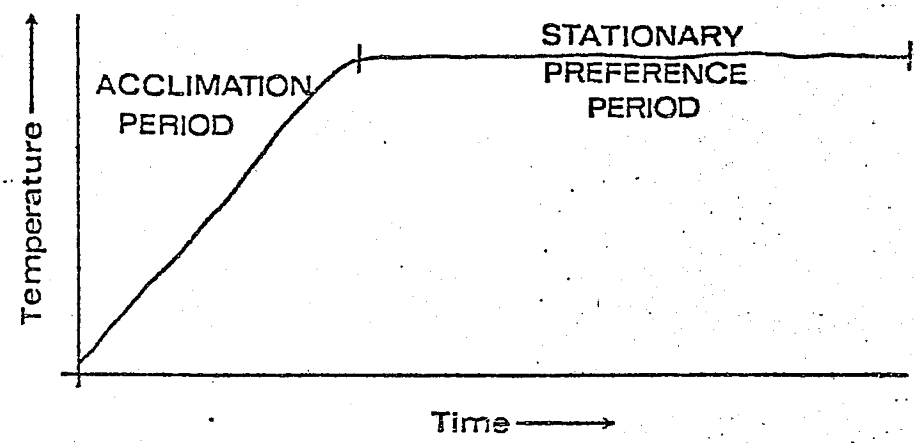

Figure 2. CHARACTERISTIC PLOT OF MEAN TEMPERATURE PREFERENCE FOR LAKE ERIE FISH AS OBSERVED AT PUT-IN-BAY, OHIO.

the mean temperature preference for each observation. When these mean temperature preferences were plotted graphically, the resulting curve could be divided into an acclimation period and a stationary preference period as shown in Figure 2. The acclimation period included the random swimming that often occurred upon entry into the tank and the rapid increase in preference temperature that occurred in late fall, winter, and early spring. The stationary preference period was that interval when individuals showed little or no change in their temperature preference for approximately 24 hrs. Observations during this period were used to calculate the final preferendum of each species. The final preferendum is that

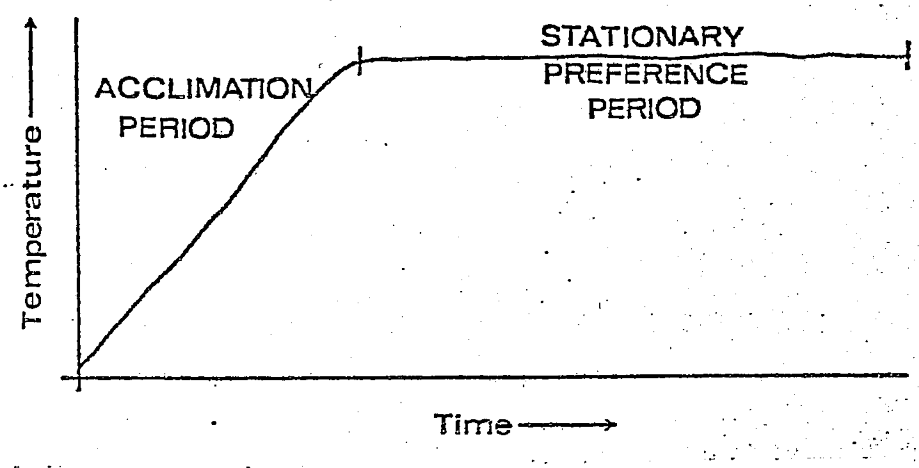

Figure 2. CHARACTERISTIC PLOT OF MEAN TEMPERATURE PREFERENCE FOR LAKE ERIE FISH AS OBSERVED AT PUT-IN-BAY, OHIO.

temperature range in which the fish will ultimately congregate in an infinite gradient (Fry, 1947). The present approach of calculating a "seasonal" final temperature preferendum for each species differs from the classical approach described by McCauley and Tait (1970) in that I have determined the final preferdum for each season rather than attempting to acclimate fish to unnatural temperatures during one season.

When a species was tested only once during a season all the readings taken from each observation during the stationary preference period were used to calculate the mean and the standard deviation in the final preferendum. This was impossible to do when a species was tested more than once during one season because the numbers of observations during the stationary preference periods were unequal resulting in a bias against the test with fewest observations. Therefore, the grand mean of the individual test means, weighted by the number of fish in each test, was used. In this case, the standard deviation presented is the standard deviation between the individual test means, again weighted by the number of fish in each test.

Ambient lake temperatures, as recorded in the holding tanks, range from approximately 1.0°C to 26.0°C. Based on the range of temperatures observed during the winter and summer months, results from tests starting at 5.5°C or lower were considered winter results, spring temperatures were 5.5°C to 20.0°C, summer temperatures were considered to be those of 20.0°C and above, and fall temperatures ranged from 20.0°C to 5.5°C.

Findings

Since 1971 data have been obtained from 2239 fish representing 29 of the 46 local species (Table 1). The remaining 17 species were not tested due to difficulty in obtaining sufficient numbers of individuals. A complete listing of individual test results is contained in Appendix A.

The final temperature preferenda of all fish tested were above lake temperature during fall, winter, and spring. Barricades were necessary during these seasons to keep fish from swimming into warm water too rapidly and being killed. All species tested displayed low thermal responsiveness during these seasons and would have exceeded their CTM, if barricades were not present. Summer preferenda were approximately equal to or slightly higher than lake temperature for all species tested.

Recommendations

This research should continue with additional effort to obtain results for species which have not been tested. The results of all tests should be key-punched to allow more sophisticated statistical analysis with computers and to determine where further testing is required or no longer necessary.

TABLE 1[illegible]

SUMMARY OF SEASONAL FINAL TEMPERATURE PREFERENDA OF LAKE ERIE FISH

Species, life stage, and season		No. tested	Length (mm) Mean	Length (mm) Range	Final preferendum °C	Standard deviation °C
Alosa pseudoharengus (alewife)						
AD[a]	Spring	11	166	150–175	21.3	1.5
Ambloplites rupestris (northern rockbass)						
AD	Winter	12	186	161–211	21.6	3.7[c]
	Spring	14	197	131–241	19.6	0.3
	Summer	12	192	148–217	20.2	2.6[c]
	Fall	8	166	123–209	22.2	0.8[c]
Aplodinotus grunniens (freshwater drum)						
YOY[b]	Summer	13	88	62–108	31.3	0.7
AD	Summer	47	182	132–287	26.5	1.7[c]
	Fall	3	299	292–308	26.2	5.7[b]
	Spring	2	369	355–383	18.8	2.0[b]
Carassius auratus (goldfish)						
AD	Winter	12	232	198–279	24.2	3.4
	Spring	13	264	205–330	25.0	0.8[c]
	Summer	33	261	175–345	27.0	1.6[c]
	Fall	5	266	237–295	26.4	1.3[c]
Carpiodes cyprinus (quillback carpsucker)						
AD	Fall	1	367		22.1	1.0
Catostomus commersoni (common white sucker)						
YOY	Winter	2	164	157–170	8.8	0.8
AD	Fall	3	222	146–310	22.4	1.7[c]

TABLE 1 CONT.

SUMMARY OF SEASONAL FINAL TEMPERATURE PREFERENDA OF LAKE ERIE FISH

Species, life stage, and season		No. tested	Length (mm) Mean	Length (mm) Range	Final preferendum °C	Standard deviation °C
Cyprinus carpino (carp)						
AD	Spring	21	268	204-337	27.4	2.1[c]
	Summer	9	184	145-225	29.7	2.3[c]
Dorosoma cepedianum (gizzard shad)						
AD	Summer	26	117	83-223	26.5	3.7[c]
	Fall	62	148	104-206	21.9	3.2[c]
Ictalurus melas (black bullhead)						
AD	Spring	4	214	208-221	23.8	1.3
I. natalis (yellow bullhead)						
AD	Summer	22	182	146-238	28.3	0.3[c]
	Fall	4	230	219-236	24.5	1.2
I. nebulosus (brown bullhead)						
AD	Winter	10	276	212-329	10.9	1.0[c]
	Spring	37	255	192-334	22.4	4.7[c]
	Summer	20	245	170-325	24.9	3.5[c]
	Fall	7	245	155-305	21.9	2.9[c]
I. punctatus (channel catfish)						
AD	Winter	1	398		10.6	0.3
	Summer	143	189	109-301	25.5	4.1[c]
	Fall	30	170	55-291	25.3	2.2[c]
Lepisosteus osseus (longnose gar)						
YOY	Summer	1	49		25.3	0.7
AD	Summer	1	239		33.1	1.3

TABLE 1 CONT.

SUMMARY OF SEASONAL FINAL TEMPERATURE PREFERENDA OF LAKE ERIE FISH

Species, life stage, and season		No. tested	Length (mm)		Final preferendum °C	Standard deviation °C
			Mean	Range		
Lepomis gibbosus (pumpkinseed)						
AD	Spring	13	148	119–178	23.8	2.4
	Summer	25	163	95–168	27.7	1.1[c]
	Fall	2	162	158–165	25.3	3.3
L. macrochirus (bluegill)						
AD	Winter	20	129	89–144	27.4	0.4[c]
	Fall	2	138	105–171	29.8	1.5
Micropterus dolomieui (smallmouth bass)						
YOY[d]	Winter	13			18.0	
	Spring	4			19–24	
	Summer	19			31.0	
	Fall	2			24–27	
YOY	Summer	8	95	90–105	30.0	1.3
	Fall	6	111	97–141	26.6	2.2
AD[d]	Winter	2			12–13	
	Spring	4			15–16	
	Summer	2			30.0	
	Fall	4			21–23	
AD	Spring	3	238	217–268	27.0	2.4
	Summer	10	225	183–246	29.3	0.2[b]
M. salmoides (largemouth bass)						
AD	Fall	1	210		29.2	0.1
Minytrema melanops (spotted sucker)						
AD	Fall	1	363		8.3	1.7

TABLE 1 CONT.

SUMMARY OF SEASONAL FINAL TEMPERATURE PREFERENDA OF LAKE ERIE FISH

Species, life stage, and season		No. tested	Length (mm) Mean	Length (mm) Range	Final preferendum °C	Standard deviation °C
Morone chrysops (white bass)						
YOY[d]	Winter	18			10–13	
	Spring	15			16–18	
	Summer	23			31.0	
	Fall	55			28.0	
YOY	Summer	17	73	57–93	27.8	1.7
AD[d]	Winter	6			12–17	
	Spring	30			12–17	
	Summer	13			28–30	
	Fall	22			16–17	
AD	Winter	1	203		29.7	0.3
	Summer	6	147	131–167	31.8	0.5
	Fall	1	237		25.4	2.0
Notemigonus crysoleucas (golden shiner)						
AD	Winter	6	129	123–139	16.8	2.5
	Spring	8	194	162–241	23.7	2.9
	Summer	15	172	99–217	22.3	1.1[c]
	Fall	5	154	109–195	21.0	3.9
Notropis atherinoides (emerald shiner)						
YOY[d]	Winter	89			10–12	
	Spring	52			13–15	
	Summer	95			22–23	
	Fall	76			13–14	
AD[d]	Winter	40			5–6	
	Spring	40			16.0	
	Summer	27			22–24	
	Fall	33			15–17	
AD	Winter	55	93	75–110	8.3	2.1[c]

TABLE 1 CONT.

SUMMARY OF SEASONAL FINAL TEMPERATURE PREFERENDA OF LAKE ERIE FISH

Species, life stage, and season		No. tested	Length (mm)		Final preferendum °C	Standar deviatic °C
			Mean	Range		
N. hudsonius (spottail shiner)						
AD	Winter	25	110	102–125	9.0	1.6[c]
	Spring	27	116	105–140	14.3	1.5
Noturus flavus (stonecat madtom)						
AD	Winter	10	218	192–250	5.5	0.3[c]
	Fall	13	214	190–238	25.1	0.1[c]
Oncorhynchus kisutch (coho salmon)						
YOY	Summer	12	125	120–130	12.3	1.6
AD	Spring	5	150	140–160	11.4	4.0
	Fall	1	360		10.6	2.3
Osmerus mordax (rainbow smelt)						
AD	Winter	17	175	143–221	4.3	0.4[c]
Perca flavescens (yellow perch)						
YOY[d]	Winter	28			10–13	
	Spring	21			18.0	
	Summer	27			25–27	
	Fall	28			28.0	
AD[d]	Winter	27			7–12	
	Spring	27			13–16	
	Summer	13			27.0	
	Fall	38			22–25	
AD	Winter	33	201	140–288	14.1	0.8[c]
	Spring	5	257	232–283	21.2	0.7[c]
	Summer	61	179	131–210	20.9	3.4[c]
	Fall	24	197	170–246	20.8	6.3[c]

TABLE 1 CONT.

SUMMARY OF SEASONAL FINAL TEMPERATURE PREFERENDA OF LAKE ERIE FISH

Species, life stage, and season		No. tested	Length (mm)		Final preferendum °C	Standard deviation °C
			Mean	Range		
Pomoxis annularis (white crappie)						
AD	Winter	14	173	112-197	19.8	2.6[c]
	Spring	40	222	156-290	18.3	2.0[c]
	Summer	21	203	133-289	20.1	2.6[c]
	Fall	5	194	166-208	10.4	3.4
P. nigromaculatus (black crappie)						
AD	Winter	111	184	139-274	20.7	2.9[c]
	Spring	55	179	137-244	21.0	4.5[c]
	Summer	49	179	97-236	21.7	5.0[c]
	Fall	24	192	152-236	24.6	2.4[c]
Stizostedion v. vitreum (yellow walleye)						
YOY	Winter	1	128		27.1	1.7

Notes:
- a AD designates adult
- b YOY designates young-of-the-year
- c More than one test was conducted on this species
- d Tests conducted by Barans and Tubb (1973)

JOB II-b
EFFECTS OF SUDDEN TEMPERATURE CHANGES ON LAKE ERIE FISH

Objectives

To be able to specify the direct effects of sudden temperature changes and the critical thermal maxima of Lake Erie fish.

Procedures

Fish for this phase of the testing were captured by the same methods and in the same locations as those used in preference testing. Testing was accomplished using two 190-l aquaria equipped with a Jumo thermoregulator, ARC static switch relay, Vicore 500 watt heater, and 2 air stones.

To determine the effect of a hot shock (swimming into the plume) fish were transferred from ambient lake temperature to a 190-l aquarium, which was maintained 11.1°C above ambient, and observed for one hour. It was also deemed necessary to determine the Critical Thermal Maximum (C.T.M. - the temperature at which the fish loses locomotor control) of each species during each season. Consequently, when the 1-hr observation period was completed, the temperature was gradually increased to the C.T.M. of each fish, If the original shock temperature was above the C.T.M. of the fish, as was often the case in summer, the fish was removed after it lost swimming ability. It was then returned to ambient temperature, and observed to test survival. This was done to simulate a fish losing locomotor control in a plume and being forced to cooler water by a discharge current.

To determine the effect of a cold shock (a fish which had resided in the plume swimming out of the plume or simulation of a sudden plant shut-down), fish were maintained at a temperature 11.1°C above ambient in a 190-l aquarium for at least 24 hours. They were then transferred to a 420-l holding tank at ambient lake temperature and observed.

The above procedure allowed for the rapid testing of many specimens, however, species which were stressed by these cold shocks might not have been stressed if a hot shock had not preceeded the cold shock. Therefore, these "fragile" species were not subjected to hot shocks prior to their cold shocks. Instead, the temperature of their surroundings was gradually increased to the hot shock temperature prior to undergoing cold shock testing. To reduce the potential stress of handling these "fragile" fish, a siphon and pump system was developed to replace the warm water in the tank with ambient temperature water, thereby producing a cold shock without moving the fish. Loss o

Loss of stability, equilibrium, and swimming ability, and an increased respiration rate were used as indicators of stress (Bridges, 1971).

Findings

Hot shock data were obtained on 8 previously untested species and 2 hybrids during F-41-R-7. A total of 1873 fish representing 41 species and 3 hybrids have now been subjected to hot shocks since 1971. The highest observed CTM indicated the point above which hot shock temperatures were lethal (Table 2). Data on individual tests and test specimens are contained in Appendix B.

The most delicate species tested and the most likely to be harmed by a sudden temperature increase were Alosa pseudoharengus harengus and Dorosoma cepedianum. Both shad and alewife were very fragile, and could only be maintained in the holding tanks for short periods (usually 2-3 weeks maximum). Beyond this time the condition of the fish became questionable and shed doubt on the validity of the test results. Aplodinotus grunniens was also quite delicate and difficult to maintain and test. The other 30 species were tested and maintained easily.

The CTM of each species tested was well above the maximum plume temperature during late fall, winter, and early spring. The CTM of each species also increased as lake temperature increased, but not as rapidly. When the highest lake temperatures were reached in late spring, summer, and early fall (especially summer), the maximum expected plume temperature was above or very close to the CTM of every species tested.

TABLE 2

HIGHEST OBSERVED C.T.M. OF LAKE ERIE FISH SPECIES TESTED IN HOT SHOCK AT PUT-IN-BAY, OHIO

Species	C.T.M. (highest observed) °C	Ambient Temp. °C	Season of observation
Alosa pseudoharengus	30.2	18.2	spring
Ambloplites rupestris	36.0	23.5	summer
Amia calva	37.0	23.8	summer
Aplodinotus grunniens	34.0	21.2	summer
Carassius auratus	39.3	26.1	summer
Carpiodes cyprinus	37.2	23.3	summer
Catostomus commersoni	32.6	23.6	summer
Cyprinus carpio	39.0	23.3	summer
C. carpio × *Carassius auratus*	>25.3	9.3	fall
Dorosoma cepedianum	32.0	14.4	fall
Etheostoma blennioides	34.9	21.1	summer
Ichthyomyzon unicuspis	31.6	4.5	winter
Ictalurus melas	34.2	14.8	spring
I. natalis	36.4	22.2	summer
I. nebulosus	38.1	26.0	summer
I. punctatus	38.0	22.7	summer
Labidesthes sicculus	32.3	14.8	fall
Lepisosteus osseus	34.9	23.8	summer
Lepomis cyanellus	31.5	7.3	fall
L. cyanellus × *L. gibbosus*	32.7	9.0	fall
L. gibbosus	37.9	23.1	summer
L. gibbosus × *L. macrochirus*	39.1	21.3	summer
L. humilus	30.4	9.0	fall
L. macrochirus	38.3	22.8	summer
L. microlophus	37.4	22.7	summer
Micropterus dolomieui	38.5	24.6	summer
M. salmoides	>32.0	9.0	fall
Minytrema melanops	>31.1	20.0	summer
Morone chrysops	36.9	23.8	summer
Notemigonus crysoleucas	31.4	11.6	fall
Notropis atherinoides	28.6	7.8	spring
N. hudsonius	32.8	21.7	summer
N. spilopterus	30.4	9.0	fall
Noturus flavus	32.3	14.8	spring
Oncorhynchus kisutch	28.5	15.1	fall
Osmerus mordax	24.9	6.0	spring
Perca flavescens	35.0	22.0	summer
Percina caprodes	34.9	21.1	summer
Percopsis omiscomaycus	22.9	1.7	winter
Pimephales notatus	29.1	9.0	fall
Pomoxis annularis	34.7	22.6	summer
P. nigromaculatus	34.9	23.8	summer
Salmo gairdneri	>17.5	6.3	fall
Stizostedion v. vitreum	>34.4	23.3	summer

In a brief addition to the testing program, 69 fish survived from a total of 75 (92%) that were returned to ambient lake temperature after undergoing heat shocks which exceeded their CTM. Data of this type are somewhat subjective for they depend upon the amount of time the fish is held in the warm water. In all cases, the exposure time was longer than that which would occur at the Davis-Besse Nuclear Power Station due to the discharge velocity.

Cold shock data were obtained on 12 previously untested species during F-41-R-7. A total 893 fish representing 34 species have now been subjected to cold shocks since 1971 (Table 3). Stress was only evident in the test specimens during the winter when lake temperatures were the lowest. The greatest stress was shown when ambient lake temperatures was $1.0^{\circ}C$ of less. Above $3.0^{\circ}C$, stress was seldom evident in the test specimens. Of the species tested, *Dorosoma cepedianum* and *Morone chrysops* were stressed the most while stress often was not evident in *Cyprinus carpio*, the ictalurids, and *Osmerus mordax*. A complete listing of individual test results is contained in Appendix C.

Recommendations

This research should continue with emphasis on testing species which are likely to be harmed by sudden temperature changes. Additional tests should be performed with temperatures

TABLE 3

SUMMARY OF COLD SHOCK TESTS ON LAKE ERIE
FISH AT PUT-IN-BAY, OHIO

Species	Lowest Test Temp °C	Ambient °C	Lowest Safe Temp °C	Ambient Temp °C	Highest Lethal Temp °C
Ambloplites rupestris	1.3	12.4	1.3	---	---
Aplodinotus grunniens	0.6	11.8	0.6	11.8	0.6
Carassius auratus	1.5	12.5	1.5	24.0	3.0
Carpiodes cyprinus	14.9	26.0	14.9	---	---
Catostomus commersoni	0.5	11.6	0.5	---	---
Cyprinus carpio	0.8	11.9	0.8	---	---
Dorosoma cepedianum	0.1	13.0	0.1	19.0	8.0
Ichthyomyzon unicuspis	4.4	15.0	4.4	---	---
Ictalurus natalis	1.5	12.6	1.5	---	---
I. nebulosus	1.0	12.5	1.0	---	---
I. punctatus	0.9	12.0	0.9	---	---
Labidesthes sicculus	15.2	26.3	15.2	---	---
Lepisosteus osseus	23.1	34.9	23.1	---	---
Lepomis cyanellus	9.0	20.1	9.0	---	---
L. gibbosus	0.5	11.6	0.5	31.3	21.7
L. humilis	4.5	14.7	4.5	---	---
L. macrochirus	1.3	12.4	1.3	---	---
Micropterus dolomieui	1.0	12.0	1.0	---	---
M. salmoides	0.9	11.8	0.9	---	---
Minytrema melanops	20.2	31.1	20.2	---	---
Morone chrysops	0.2	11.3	0.2	12.8	0.8
Notemigonus crysoleucas	0.5	11.6	0.5	---	---
Notropis atherinoides	0.5	11.6	0.5	---	---
N. hudsonius	0.1	11.2	0.1	13.1	2.0
N. spilopterus	7.3	18.4	7.3	---	---
Noturus flavus	1.1	12.2	1.1	---	---
Oncorhynchus kisutch	2.1	13.4	2.1	---	---
Osmerus mordax	0.2	11.3	0.2	16.1	1.5
Perca flavescens	1.0	13.0	1.0	---	---
Percopsis omiscomaycus	0.5	11.6	0.5	---	---
Pimephales notatus	0.5	11.6	0.5	---	---
Pomoxis annularis	0.7	12.1	0.7	12.0	1.0
P. nigromaculatus	0.3	11.4	0.3	12.5	1.0
Stizostedion v. vitreum	1.2	12.3	1.2	---	---

changes greater than 11.1°C in an effort to justify limitations on the maximum temperature of thermal effluents.

STUDY ANALYSIS

Laboratory testing results indicated that the final preferendum varied with each season. The finding of a "seasonal" final preferendum was in agreement with the work of Brett (1946), Sullivan and Fisher (1953) and Hoar (1956) who found seasonal variations in lethal and preferred temperatures. Lustick (1965) found that the lethal temperatures for Culaea inconstans (brook stickleback) were higher in summer and lower in winter for all acclimation temperatures. Results of this type provide strong evidence to the importance of past thermal history and anticipatory thermoregulation in determining temperature preferences.

Assuming that past thermal history does play an important part in the temperature selection of fish (fish acclimated to warmer water prefer warmer water), the seasonal order of preference, from the highest to the lowest, would be summer, fall, spring, and winter. This was generally the case in these tests, but slight discrepancies did occur between spring and fall possibly due to the wide range of lake temperatures (5.5°C - 22.0°C) from which the final preferenda were calculated.

Low thermal responsiveness (swimming into warm water faster than they can acclimate to it and surpassing their CTM) was evident in all species during late fall, winter and early spring, but especially in winter. This was probably a laboratory artifact and would not occur in the wild. At Davis-Besse it could not occur as the winter CTM of all fish tested was well above maximum plume temperature.

Results indicated that all species tested would be attracted to thermal discharges during fall, winter, and spring. Again, in these seasons (especially winter) it was also observed that without the use of barricades all species tested would swim into warmer water too rapidly, surpass their Critical Thermal Maxima (CTM), and die. However, the CTM of these species during fall, winter, and spring was generally well above the maximum temperature of most thermal plumes in Lake Erie power plants. Results also indicated that during the summer, most of the species tested would be repelled by the higher plume temperatures, but could be attracted or indifferent to the periphery of thermal plumes.

When considering pollution tolerance, the ictalurids are high on the list of tolerant species. They also exhibited relatively high CTM's (Table 2). Therefore, it was surprising to see the lower winter preferenda of Ictalurus nebulosus (10.9°C) and Noturus flavus (5.5°C) (Table 1). The final preferendum of Noturus flavus was 5.2°C (5 fish) on 5 March 1973 and 5.8°C (5 fish) on 2 February 1974. Lake temperatures at these times were 3.1°C and 2.1°C, respectively. Similar results for Ictalurus nebulosus and *I. punctatus* indicate the possibility of a winter period during which these fish do not readily respond to thermal gradients.

Ferguson (1958) found that laboratory preference results, especially for warm water species, tended to yield higher values than field investigations, possibly because laboratory specimens were usually young individuals and field specimens were usually adults. Barans and Tubb (1973) studying *Micropterus dolomieui*, *Morone chysops*, *Notropis atherinoides*, and *Perca flavescens*, and McCauley and Read (1973) studying *Perca flavescens* found that young fish preferred higher temperatures than adults. My studies dealt mainly with adult fish because the apparatus was capable of testing them.

Sudden temperature change testing demonstrated that the temperature extremes to which the fish were subjected were more important than the 11.1°C temperature change. Therefore, summer heat shocks and winter cold shocks held the greatest potential for harm. Lustick (1965) felt that the failure of some coordinating mechanisms in the central nervous system and, secondarily, the breakdown of the osmoregulative mechanism were the causes of death due to sudden temperature changes. Powers (1976) felt that the Bohr Effect (reduction in the oxygen carrying capacity of the blood at high temperatures), and the resulting suffocation, also played an important role in death.

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The danger due to summer hot shocks should be minimal for the following reasons: final temperature preferenda results indicated that fish would avoid the hottest part of the plume, thus the only fish to encounter this area would be those which were drawn in or swam in from the shoreside of the discharge; and, due to the discharge velocity of 200 cm/sec, fish which were drawn into the plume and lost swimming ability would be carried to safer waters, where present results indicated approximately 90% would recover. The initial velocity for Davis-Besse Unit 1 at times could be as low as 113 cm/sec which would not carry fish to safer waters as rapidly as the 200 cm/sec current. Consequently, the fish would be subjected to the heat stress for a longer period of time.

Cold shock hazards occur when fish acclimated to the warm water of a plume swim out of the plume into ambient temperature water or if the plant shuts down, thus eliminating the plume. If the temperature change is great enough, or if ambient lake temperature is extremely low, fish experience a loss of swimming ability and, therefore, an inability to return to the plume. Agersborg (1930) observed this in the field with Dorosoma cepedianum. Even if a fish survived the shock, the stress could be severe enough to make it more susceptible to secondary fungal infections (Horning and Pearson, 1973). These secondary effects would be difficult to monitor since they are not immediately evident (often delayed up to several weeks).

Cold shock hazards could be greatly reduced by maintaining a discharge velocity high enough to keep the fish out of the hottest plume temperatures. This would have to be monitored closely for the use of additional dilution water to increase the discharge velocity would mean greater intake velocities and a greater possibility of entrainment and impingement.

Burst speeds of 10 body lengths (B.L.) per second and cruising speeds of 3-4 B.L./sec are generally accepted for fish (Bainbridge, 1958; Blaxter, 1969). These burst speeds can be maintained for only a period of seconds, but cruising speeds can be maintained for up to several hours (Bainbridge, 1960; Blaxter, 1969). Assuming this, a fish must be at least 20 cm long to attain the maximum discharge velocity of 200 cm/sec and 50-67 cm long to maintain position in the hottest section of the plume for any length of time. Moreover, this swimming ability decreases rapidly when the temperature is extremely high or low (Fry and Hart, 1947). Therefore, from swimming speed data alone, it would appear that no larvae or young-of-the-year fish and few adults could maintain position in the hottest section of the plume long enough to become acclimated and susceptible to cold shock dangers. (The actual length of time necessary for the fish to become acclimated to the plume temperature and lose acclimation to the colder ambient lake temperature was difficult to determine, but observations did indicate acclimation to warm water was faster than acclimation to cold water, and loss of acclimation to warm water was slower than to cold.) Thus it became evident that a high discharge velocity was desirable. Undoubtedly, a small number of fish will locate in the warmer water by finding places where the current is reduced, i.e., behind rocks in the rip-rap apron which will extend out 61 m in front of the discharge. This is not expected to be a significant factor.

In summary, large fish accumulations, possibly as great as 120 times that found in the unaffected contiguous vicinity (Robb and Herdendorf, 1975), are expected in the thermal plume in fall, winter, and spring. Summer populations will only be slightly larger than ambient. Romberg et al. (1974) found that although salmonids were attracted to thermal discharges, they did not reside in the discharge a long time and the discharge did not interrupt their normal migration patterns. If this holds true for the warm water species found at Locust Point, Study I results indicated that there were only 10 species of any numerical or commercial importance that would occur in the plume. The times at which these dominant species could be expected to be present in the largest numbers are as follows: Alosa pseudoharengus, July -- September; Aplodinotus grunniens, April -- September; Cyprinus carpio, June -- September Dorosoma cepedianum, June and July; Ictalurus punctatus, May --

August; Morone chrysops, June and July; Notropis atherinoides, abundant throughout the year; N. hudsonius, May; Perca flavescens, May -- September; and Stizostedion v. vitreum, May -- July. However, due to the high plume temperatures, only the species with the highest preferenda, Cyprinus carpio, Dorosoma cepedianum, and Ictalurus punctatus, will congregate in the plume in the summer.

Only the general location of fish within plumes can be predicted, for not only do the swimming speeds of the fish vary, but several authors found that fish did not remain at their seasonal final temperature preferenda. Instead, fish were found to behaviorally regulate their internal temperature at their seasonal final preferenda, but in so doing they spent brief periods at higher and lower temperatures (Neill and Magnuson, 1974; Spigarelli et al., 1974; McCauley and Huggins, 1976; Reynolds and Casterlin, 1976; Reynolds et al., 1976b). In addition, Reynolds et al., (1976a) observed fish to behaviorally regu-regulate a fever when "sick" which indicated the possibility of a higher percentage of diseased fish in thermal plumes. Indeed, Stauffer et al. (1974) found that the coefficient of condition of plume dwellers was significantly lower than non-plume residents which could indicate the presence of diseased fish.

Laboratory sudden temperature change results indicated that significant fish kills are unlikely. The species most likely to be harmed by thermal effluents were Alosa pseudoharengus, Aplodinotus grunniens, Dorosoma cepedianum, and Morone chrysops. These 4 species were all in the "top ten" at Locust Point. Personal observations of fish kills at other Lake Erie power plants indicated that Dorosoma cepedianum and Alosa pseudoharengus were the species most frequently killed, and these kills were generally associated with power plant intakes rather than discharges.

All fish drawn through the plant are expected to be killed (U.S. Nuclear Regulatory Commission, 1975). Traveling screening (6 mm mesh) at the pump intakes will prevent the entrainment of large fish. Again, based on observations at other power plants and their abundance in the area, Dorosoma cepedianum and Alosa pseudoharengus will be the species most likely to be impinged on these screens. Larvae of Dorosoma cepedianum, Notropis atherinoides, and Perca flavescens, due to their abundance in the ichthyoplankton samples from the vicinity, will be the most likely to be entrained with the cooling water and thereby killed within the plant.

STUDY RECOMMENDATIONS

Results indicate that winter plant shut-downs should be avoided. It is recommended that refueling and shut-downs for other reasons be completed during the period of May-July as fish are tolerant of cold shocks at this time and, this is the time that entrainment of ichthyoplankton will be greatest.

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APPENDIX A

RESULTS OF TEMPERATURE PREFERENCE TESTING

ON LAKE ERIE FISH AT PUT-IN-BAY, OHIO

TABLE 4

RESULTS OF PREFERENCE TESTING

Species Tested	Date	No. Tested	Length (mm)		Acclimation Temp °C	Preference Temp °C	Standard Deviation
			Mean	Range			
Alosa pseudoharengus	6-4-73	11	166	150-175	16.0	21.3	1.5
Ambloplites rupestris	10-4-72	5	157	123-209	19.4	22.8	3.0
A. rupestris	6-19-73	9	189	148-214	20.3	18.7	1.7
A. rupestris	1-15-74	6	192	179-211	3.0	25.1	3.1
A. rupestris	3-19-74	6	179	161-203	3.5	18.0	2.2
A. rupestris	6-11-74	3	202	178-217	20.0	24.5	1.1
A. rupestris	6-27-74	14	197	131-241	19.8	19.6	0.3
A. rupestris	11-12-75	3	181	174-188	12.8	21.2	0.8
Aplodinotus grunniens	8-12-72	8	153	132-170	22.0	27.2	1.7
A. grunniens	8-14-72	4	149	140-161	22.8	29.2	2.5
A. grunniens	8-19-72	9	166	153-182	22.7	27.2	3.3
A. grunniens	8-21-72	8	162	147-189	23.8	25.8	8.0
A. grunniens	10-26-72	1	292		13.7	19.6	1.6
A. grunniens	8-1-73	9	241	205-287	23.0	23.5	3.5
A. grunniens	8-18-73	9	198	181-225	23.8	27.6	2.5
A. grunniens	8-31-73	13	88	62-108	24.5	31.3	0.7
A. grunniens	10-3-75	2	302	296-308	15.2	29.5	1.5
A. grunniens	3-25-75	1	383		7.8	17.4	0.45
A. grunniens	4-18-76	1	355		12.2	20.2	0.70
Carassuis auratus	9-8-72	7	205	185-228	23.0	25.8	5.6
C. auratus	10-4-72	1	295		19.4	24.0	0.7
C. auratus	1-10-73	12	232	198-279	5.4	24.2	3.4
C. auratus	6-18-74	7	273	262-290	19.0	25.3	1.8
C. auratus	7-10-74	9	284	244-345	24.6	28.0	2.7
C. auratus	7-24-74	5	210	175-248	23.8	29.8	0.1

TABLE 4

RESULTS OF PREFERENCE TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Acclimation Temp °C	Preference Temp °C	Standard Deviation
Carassius auratus	7-29-74	8	302	283-316	24.2	25.2	4.8
C. auratus	8-8-74	4	293	249-342	23.2	26.9	0.8
C. auratus	9-29-75	4	259	237-286	17.2	27.0	2.1
C. auratus	4-2-76	3	322	309-330	7.6	23.6	1.50
C. auratus	5-23-76	3	246	205-279	14.8	25.5	1.39
Carpiodes cyprinus	10-4-72	1	367		19.4	22.1	1.0
Catostomus commersoni	10-8-72	2	260	210-310	19.0	23.4	4.8
C. commersoni	10-18-72	1	146		14.0	20.4	1.5
C. commersoni	12-23-75	2	164	157-160	1.4	8.8	0.8
Cyprinus carpio	3-22-73	4	313	265-337	7.9	25.2	1.1
C. carpio	7-27-73	6	175	145-200	22.9	31.2	0.3
C. carpio	8-20-73	3	201	156-225	24.2	26.6	3.3
C. carpio	6-12-74	5	255	244-264	19.5	30.9	0.9
C. carpio	7-1-74	12	259	204-337	20.0	26.6	3.7
Dorsoma cepedianum	10-26-72	24	149	117-185	13.7	22.1	2.9
D. cepedianum	11-19-73	15	120	104-133	9.0	20.2	1.8
D. cepedianum	11-21-73	10	156	132-190	8.0	17.2	2.9
D. cepedianum	7-2-74	5	207	175-223	20.8	19.0	3.8
D. cepedianum	8-12-75	6	116	94-138	24.8	28.6	0.3
D. cepedianum	8-13-75	15	88	83-93	25.2	28.1	0.0
D. cepedianum	10-23-75	8	156	123-172	15.2	28.3	1.1
D. cepianum	10-29-75	5	191	182-206	14.1	24.6	2.4
Ictalurus melas	5-7-76	4	214	208-221	11.8	23.8	1.26
Ictalurus natalis	8-31-72	10	182	146-238	24.0	28.0	3.7
I. natalis	9-19-72	12	182	146-238	23.0	28.5	1.5

TABLE 4

RESULTS OF PREFERENCE TESTING

Species Tested	Date	No. Tested	Length (mm)		Acclimation Temp °C	Preference Temp °C	Standard Deviation
			Mean	Range			
Ictalurus natalis	9-19-75	4	230	219-236	19.5	24.5	1.2
I. nebulosus	11-22-72	5	275	235-305	9.0	23.6	7.9
I. nebulosus	5-21-73	11	300	282-334	13.1	18.8	3.3
I. nebulosus	5-24-73	13	208	192-235	13.8	25.9	3.3
I. nebulosus	6-14-73	9	296	255-325	20.4	21.1	4.4
I. nebulosus	7-10-73	11	203	170-235	24.0	28.0	6.5
I. nebulosus	1-21-74	5	310	290-329	2.0	11.9	1.4
I. nebulosus	6-25-74	9	248	204-321	18.3	25.9	1.2
I. nebulosus	3-10-75	5	249	212-286	5.0	10.0	0.8
I. nebulosus	4-22-75	4	293	270-310	8.4	12.6	1.8
I. nebulosus	12-8-75	2	170	155-184	6.6	17.6	1.2
Ictalurus punctatus	8-29-72	9	127	109-228	23.4	29.8	7.3
I. punctatus	10-13-72	15	179	55-291	15.7	22.4	1.1
I. punctatus	10-18-72	15	161	61-265	14.0	27.8	1.6
I. punctatus	7-3-73	12	175	147-213	21.8	32.0	3.1
I. punctatus	7-5-73	8	183	168-205	22.5	26.4	4.5
I. punctatus	7-12-73	8	182	155-210	24.2	28.6	6.3
I. punctatus	7-18-73	12	175	150-198	23.0	30.4	5.0
I. punctatus	7-23-73	14	179	155-202	23.0	23.8	7.6
I. punctatus	7-24-73	10	180	162-202	29.7	25.5	6.2
I. punctatus	7-31-73	13	176	152-219	23.5	21.7	5.1
I. punctatus	9-18-73	12	197	180-217	20.0	20.6	10.5
I. punctatus	9-20-73	12	215	175-280	20.5*	25.5	7.0
I. punctatus	9-27-73	12	266	223-301	21.0	20.9	5.7

TABLE 4

RESULTS OF PREFERENCE TESTING

Species Tested	Date	No. Tested	Length (mm)		Acclimation Temp °C	Preference Temp °C	Standard Deviation
			Mean	Range			
Ictalurus punctatus	10-4-73	12	208	186-238	20.3**	20.2	7.2
I. punctatus	7-29-75	9	176	151-198	24.9	30.7	1.8
I. punctatus	2-10-76	1	398		2.2	10.6	0.3
Lepisosteus osseus	8-8-72	1	239		20.2	33.1	1.3
L. osseus	8-8-72	1	49		20.2	25.3	0.7
Lepomis gibbosus	9-13-72	9	129	95-168	22.6	26.7	4.3
L. gibbosus	7-18-74	6	137	108-160	23.9	29.6	3.4
L. gibbosus	7-22-74	10	149	132-166	23.2	27.5	5.3
L. gibbosus	6-20-75	13	148	119-178	18.6	23.8	2.4
L. gibbosus	11-19-75	2	162	158-165	11.0	25.3	3.3
L. macrochirus	2-15-73	10	120	89-135	4.9	27.0	2.1
L. macrochirus	2-20-73	10	137	130-144	4.0	27.8	0.5
L. macrochirus	10-6-75	2	138	105-171	14.9	29.8	1.5
Micropterus dolomieui	11-14-73	6	111	97-141	10.0	26.6	2.20
M. dolomieui	7-16-75	9	223	183-246	24.0	29.4	1.51
M. dolomieui	8-15-75	8	95	90-105	24.4	30.0	1.3
M. dolomieui	9-12-75	1	241		21.1	28.8	0.6
M. dolomieui	4-27-76	3	238	217-268	11.2	27.0	2.39
M. salmoides	9-16-75	1	210		18.9	29.2	0.1
Minytrema melanops	12-17-75	1	363		5.1	8.3	1.7
Morone chrysops	8-30-73	17	73	57-93	25.5	27.8	1.7
M. chrysops	6-25-75	6	147	131-167	23.9	31.8	0.52
M. chrysops	10-17-75	1	237		14.5	25.4	2.0
M. chrysops	1-6-76	1	203		2.4	29.7	0.3

TABLE 4

RESULTS OF PREFERENCE TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Acclimation Temp °C	Preference Temp °C	Standard Deviation
Notemigonus crysoleucas	9-6-72	2	184	168-217	22.5	23.7	0.6
N. crysoleucas	9-21-72	5	154	109-195	19.8	21.0	3.9
N. crysoleucas	9-26-72	5	140	99-176	21.0	20.8	6.2
N. crysoleucas	3-8-73	6	129	123-139	4.2	16.8	2.5
N. crysoleucas	6-11-73	8	194	162-241	19.6	23.7	2.9
N. crysoleucas	7-8-74	8	189	167-215	22.8	22.9	5.2
Notropis atherinoides	1-15-73	25	91	81-110	5.0	10.5	1.7
N. atherinoides	1-22-73	10	93	82-108	4.0	6.4	1.5
N. atherinoides	12-24-74	10	97	84-109	3.0	6.1	2.2
N. atherinoides	12-27-74	10	95	75-106	2.0	6.8	2.1
N. hudsonius	3-2-73	15	112	103-125	4.5	10.2	2.8
N. hudsonius	5-11-73	27	116	105-140	13.2	14.3	1.5
N. hudsonius	2-6-75	10	107	102-114	2.0	7.1	4.0
Noturus flavus	10-8-72	4	228	219-238	19.0	25.0	1.0
N. flavus	3-5-73	5	220	192-250	3.1	5.2	0.6
N. flavus	10-24-73	9	207	190-230	16.9	25.1	1.6
N. flavus	2-14-74	5	216	208-222	2.1	5.8	2.3
Oncorhynchus kisutch	3-14-73	5	150	140-160	11.0	11.4	4.0
O. kisutch	8-6-75	12	125	120-130	12-19***	12.3****	1.6
O. kisutch	11-6-75	1	360		13.8	10.6****	2.3
Osmerus mordax	12-12-75	9	175	143-221	4.8	4.6	0.8
O. mordax	1-15-76	8	175	165-188	2.5	3.9	4.1
Perca flavescens	11-30-72	11	191	171-220	6.1	14.5	4.1
P. flavescens	12-7-72	7	246	235-260	4.0	13.3	3.1

TABLE 4

RESULTS OF PREFERENCE TESTING

Species Tested	Date	No. Tested	Length (mm)		Acclimation Temp °C	Preference Temp °C	Standard Deviation
			Mean	Range			
Perca flavescens	12-18-72	10	199	188-212	3.0	16.1	4.0
P. flavescens	12-26-72	16	182	140-288	3.6	12.9	2.0
P. flavescens	8-26-73	10	191	175-203	23.5	22.7	3.4
P. flavescens	8-27-73	10	156	134-182	24.0	25.6	3.7
P. flavescens	8-29-73	4	183	166-202	25.0	13.9	1.3
P. flavescens	9-12-73	12	174	131-200	21.3	21.3	4.5
P. flavescens	9-14-73	12	181	162-195	21.2*** **	21.8	5.5
P. flavescens	10-2-73	13	189	177-210	20.2	16.6	5.6
P. flavescens	10-29-73	10	195	170-223	15.5	25.8	2.7
P. flavescens	9-24-75	3	225	185-246	17.4	28.5	1.4
P. flavescens	4-7-76	5	257	232-283	9.9	21.2	0.73
Pomoxis annularis	9-14-72	9	170	133-258	22.9	21.8	3.2
P. annularis	2-12-73	4	161	112-197	5.0	15.9	4.5
P. annularis	4-19-73	7	246	217-325	10.0	21.0	3.5
P. annularis	5-16-73	15	194	156-250	13.1	17.8	6.5
P. annularis	6-6-73	13	251	220-290	16.5	16.2	7.2
P. annularis	11-6-73	5	194	166-208	11.0	10.4	3.4
P. annularis	2-10-74	10	177	160-195	3.0	21.4	4.2
P. annularis	6-18-74	5	200	171-233	18.1	21.1	1.7
P. annularis	7-5-74	7	220	186-262	22.6	16.4	2.8
P. annularis	7-2-75	5	241	186-289	24.1	22.0	6.06
P. nigromaculatus	9-11-72	19	134	97-208	22.1	26.0	3.0
P. nigromaculatus	9-28-72	18	208	155-236	20.2	15.3	4.9
P. nigromaculatus	1-25-73	12	168	152-192	5.0	21.4	5.6

TABLE 4

RESULTS OF PREFERENCE TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Acclimation Temp °C	Preference Temp °C	Standard Deviation
Pomoxis nigromaculatus	2-8-73	8	176	139-230	3.0	15.8	3.1
P. nigromaculatus	4-16-73	10	210	165-244	10.0	18.6	2.8
P. nigromaculatus	4-23-73	7	200	165-232	11.3	18.2	3.6
P. nigromaculatus	5-14-73	12	170	152-208	13.1	14.9	4.1
P. nigromaculatus	5-18-73	13	157	137-165	12.1	26.3	3.0
P. nigromaculatus	6-2-73	13	175	143-229	15.5	24.6	4.8
P. nigromaculatus	10-9-73	12	211	191-231	20.7	24.6	4.2
P. nigromaculatus	12-6-73	12	168	152-181	7.5	22.2	1.2
P. nigromaculatus	12-17-73	12	172	162-165	1.8	21.3	2.9
P. nigromaculatus	12-20-73	12	165	142-181	2.0	24.2	2.3
P. nigromaculatus	1-2-74	10	240	215-274	1.2	23.5	4.6
P. nigromaculatus	1-7-74	12	178	155-193	2.3	22.7	3.5
P. nigromaculatus	1-28-74	10	173	155-184	4.0	18.8	6.7
P. nigromaculatus	2-21-74	10	169	160-175	2.4	18.7	6.3
P. nigromaculatus	3-4-74	10	222	210-246	3.8	14.7	3.2
P. nigromaculatus	3-11-74	10	160	148-177	5.0	21.8	6.4
P. nigromeculatus	11-1-74	12	216	193-236	13.8	26.9	1.0
P. nigromaculatus	1-10-75	5	232	215-245	2.4	23.0	2.6
Stizostedion v. vitreum	2-18-76	1	128		2.2	27.1	1.70

* Start compartment temperature 31.6°C

** Start compartment temperature 31.0°C

*** Fish transferred from Put-in-Bay Hatchery (13°C) to cold end of gradient (12-19°C). Barricade restraining fish removed after 24 hours.

**** Fish usually in compartment 1, lowest temperature, may prefer temperatures lower than those offered in preference tanks or may be rheotactic response as fish were usually observed headed into current that flowed into compartment 1.

***** Start compartment temperature 30.0°C

APPENDIX B

RESULTS OF HOT SHOCK TESTING

ON LAKE ERIE FISH AT PUT-IN-BAY, OHIO

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/ hr.	Critical Thermal Maximum
Alosa pseudoharengus	6-5-73	5	171	160-195	16.5	27.5	1 expired		
A. pseudoharengus	6-6-73	5	164	150-173	16.5	27.5	2 expired	1.7	27.9
A. pseudoharengus	6-7-73	9	164	147-177	16.3	27.3	stressed	2.2	28.5
A. pseudoharengus	6-25-74	2	181	175-187	18.2	29.3	stressed	3.6	30.2
A. pseudoharengus	7-5-74	2	165	162-168	21.7	32.8	1*		
A. pseudoharengus	6-25-75	5	153	139-185	23.8	34.9	2*		
A. pseudoharengus	10-29-75	2	127		12.4	23.5	3*		
Ambloplites rupestris	7-72	1			27.1	35.1	normal		
A. rupestris	3-14-73	1	203		2.9	13.6	normal	3.1	24.5
A. rupestris	3-30-73	1	133		5.6	16.6	normal	4.5	24.8
A. rupestris	4-25-73	1	189		10.5	21.8	normal	3.3	27.0
A. rupestris	6-1-73	1	206		14.6	25.5	normal	3.4	31.2
A. rupestris	1-22-74	1	515		1.9	13.0	normal	4.0	25.8
A. rupestris	7-19-74	3	179	147-205	23.5	34.6	4*	2.8	36.0
A. rupestris	7-24-74	1	172		22.8	33.8	normal		
A. rupestris	8-1-74	1	214		23.9	35.0	5*		
A. rupestris	8-7-74	1	99		23.1	34.2	normal		
A. rupestris	1-29-75	1	171		1.8	12.9	normal		
A. rupestris	6-25-75	3	184	160-208	23.8	34.9	6*		
A. rupestris	7-10-75	1	230		26.0	37.1	7*		
A. rupestris	7-29-75	1	234		25.8	36.9	8*		
A. rupestris	8-26-75	1	96		24.0	35.1	normal		
A. rupestris	9-18-75	2	175	171-179	18.5	29.6	normal	4.16	34.8
A. rupestris	10-17-75	2	154	123-184	14.1	25.2	normal		

TABLE 54

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Ambloplites rupestris	2-20-76	3	63	57-66	1.2	12.3	normal	3.68	25.6
A. rupestris	3-17-76	3	155	124-171	2.4	13.5	normal		
A. rupestris	3-20-76	2	171	162-179	2.3	13.5	normal	3.90	24.9
A. rupestris	4-14-76	2	191	168-214	8.2	19.4	normal		
A. rupestris	5-26-76	3	169	166-174	14.8	26.1	normal	2.86	31.9
Amia calva	5-17-73	1	379		12.0	23.2	normal	2.6	29.0
A. calva	8-14-73	1	410		24.4	35.5	9*	2.6	29.0
A. calva	1-29-74	1	515		1.9	13.0	normal	4.0	25.8
A. calva	7-18-74	1	540		23.8	34.9	stressed	2.8	37.0
Aplodinotus grunniens	8-72	3		130-190	18.9	30.5	expired		
A. grunniens	11-72	1	290		9.0	24.1	stressed		
A. grunniens	7-2-73	3	105	102-111	21.2	32.3	10*		
A. grunniens	7-2-73	3	200	180-212	21.2	32.3	normal	2.0	34.0
A. grunniens	8-21-73	4	160	140-180	23.2	34.2	11*		
A. grunniens	8-28-73	3	219	195-247	24.0	35.1	12*		
A. grunniens	8-28-73	5	90	80-107	24.0	35.1	13*		
A. grunniens	8-30-73	6	92	71-111	25.6	36.7	14*		
A. grunniens	8-30-73	5	185	158-211	25.6	36.7	15*		
A. grunniens	8-30-73	7	96	82-106	25.6	36.2	16*		
A. grunniens	12-31-73	2	236	225-248	0.8	11.8	normal		
A. grunniens	12-31-73	1	269		0.8	11.9	normal	4.1	25.2
A. grunniens	6-25-74	2	265	240-291	18.2	29.3	17*		
A. grunniens	6-24-75	1	427		22.6	33.7	18*		
A. grunniens	7-8-75	1	302		26.2	37.3	19*		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
<u>Aplodinotus grunniens</u>	7-29-75	2	290	268-312	25.8	36.9	20*		
<u>A. grunniens</u>	10-2-75	1	287		15.0	26.1	normal	4.23	33.5
<u>A. grunniens</u>	10-2-75	1	342		15.0	26.1	normal		
<u>A. grunniens</u>	10-17-75	2	248	214-281	14.1	25.2	normal		
<u>A. grunniens</u>	1-16-76	1	178		0.4	11.5	normal		
<u>A. grunniens</u>	5-4-76	1	349		10.0	21.0	normal	3.27	28.8
<u>A. grunniens</u>	5-25-76	1	292		14.6	25.5	normal	2.73	29.5
<u>Carassius auratus</u>	11-72	1	204		9.0	24.1	normal		
<u>C. auratus</u>	11-72	1	183		9.3	15.3	normal		
<u>C. auratus</u>	2-8-73	2	110	110-119	3.2	13.8	normal	7.5	29.2
<u>C. auratus</u>	4-20-73	1	249		8.7	19.7	normal	3.7	27.7
<u>C. auratus</u>	6-1-73	1	255		14.6	25.5	normal	3.2	34.0
<u>C. auratus</u>	8-30-73	1	302		25.6	34.3	normal		
<u>C. auratus</u>	9-12-73	2	151	145-156	22.0	33.0	normal		
<u>C. auratus</u>	6-20-74	3	286	258-307	17.7	28.8	normal		
<u>C. auratus</u>	8-1-74	2	301	296-305	23.9	35.0	normal		
<u>C. auratus</u>	8-8-74	1	293		23.0	34.1	normal		
<u>C. auratus</u>	1-14-75	1	209		1.5	12.6	normal		
<u>C. auratus</u>	7-8-75	1	296		26.2	37.3	stressed	2.67	39.3
<u>C. auratus</u>	7-10-75	1	235		26.0	37.1	stressed	2.03	39.3
<u>C. auratus</u>	11-3-75	2	158	157-158	11.6	22.7	normal	3.19	35.2
<u>C. auratus</u>	2-23-76	2	258	250-266	1.2	14.0	normal	3.42	29.1
<u>C. auratus</u>	3-26-76	3	247	239-252	5.2	16.3	normal	3.11	32.1
<u>Carpiodes cyprinus</u>	12-4-72	1	363		3.2	14.3	normal	3.3	28.2

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Carpiodes cyprinus	7-24-73	3	47	43-52	23.3	34.4	normal	2.1	37.2
C. cyprinus	7-24-73	4	50	42-56	23.3	34.3	normal		
C. cyprinus	7-8-75	2	323	276-370	26.2	37.2	21*		
C. cyprinus	7-11-75	1	381		24.9	36.0	stressed	1.67	37.2
C. cyprinus	10-6-75	1	144		14.8	26.0	normal		
C. cyprinus	10-22-75	3	128	126-132	13.0	24.1	normal	3.71	34.5
Catostomus commersoni	10-72-72	1	210		14.3	29.9	stressed		
C. commersoni	1-22-73	1	145		3.0	14.0	normal	3.6	25.4
C. commersoni	6-12-74	1	470		19.0	30.0	stressed	4.8	31.6
C. commersoni	6-12-74	1	420		19.0	30.0	22*		
C. commersoni	10-3-75	2	138	136-140	14.1	25.2	normal		
C. commersoni	10-21-75	2	156	143-169	12.5	23.6	normal	3.75	32.6
C. commersoni	11-13-75	2	183	157-208	11.0	22.1	normal		
C. commersoni	12-4-76	2	165	155-174	3.5	14.6	normal		
C. commersoni	2-23-76	4	153	135-178	1.2	12.3	normal	3.98	24.3
C. commersoni	3-22-76	5	160	143-179	2.6	13.7	normal		
C. commersoni	4-14-76	3	160	150-167	8.2	19.5	normal		
C. commersoni	4-22-76	4	159	140-174	10.0	21.1	normal	3.05	30.3
C. commersoni	4-26-76	1	394		9.6	20.7	normal		
C. commersoni	5-26-76	2	162	160-163	15.2	26.3	normal	3.31	32.4
Cyprinus carpio × Carassius auratus	11-72	1	282		9.0	24.1	normal		
C. carpio × Carassius auratus	11-72	1	228		9.3	25.3	normal		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Cyprinus carpio	12-5-72	1	355		3.8	14.8	normal	3.4	30.5
C. carpio	2-7-73	1	422		1.0	12.5	normal	3.7	26.5
C. carpio	2-12-73	1	362		1.1	11.1	normal	3.5	29.0
C. carpio	4-9-73	1	364		6.0	17.0	normal	3.4	30.5
C. carpio	4-19-73	1	370		8.3	18.7	normal	3.6	28.3
C. carpio	6-25-73	1	270		22.2	32.8	normal		
C. carpio	7-24-73	1	63		23.3	34.4	normal	2.0	39.0
C. carpio	7-24-73	2	62	53-71	23.3	34.3	normal		
C. carpio	9-6-73	3	190	180-200	25.2	36.1	normal		
C. carpio	1-10-74	1	380		1.5	12.5	normal	3.4	22.8
C. carpio	2-27-74	1	326		1.3	11.9	normal		
C. carpio	3-7-74	1	470		4.2	14.2	normal	4.2	31.0
C. carpio	7-3-74	4	305	279-327	20.2	31.3	normal	3.2	37.7
C. carpio	7-9-74	2	262	241-283	22.7	33.8	normal		
C. carpio	8-8-74	3	305	255-352	23.0	34.1	normal		
C. carpio	8-8-74	1	292		23.0	34.1	normal		
C. carpio	11-19-74	1	367		8.0	19.1	normal		
C. carpio	12-20-74	1	350		1.9	13.0	normal		
C. carpio	3-7-75	1	330		0.9	12.0	normal		
C. carpio	4-11-75	1	336		3.5	14.6	normal		
C. carpio	4-23-75	1	395		7.0	18.1	normal		
C. carpio	3-18-76	1	122		2.1	13.4	normal	3.47	24.9
C. carpio	5-26-76	1	121		15.2	26.3	normal	3.31	34.4
Dorosoma cepedianum	9-26-73	1	217		20.9	32.0	23*		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Dorosoma cepedianum	10-17-73	2	175	175-175	15.9	27.0	normal		
D. cepedianum	10-17-73	3	160	152-167	15.9	27.3	normal	4.7	31.7
D. cepedianum	10-24-73	2	163	150-175	15.9	27.0	normal	3.7	30.2
D. cepedianum	11-13-73	5	129	112-143	7.5	18.6	normal	3.9	26.1
D. cepedianum	11-14-73	4	121	112-127	8.1	19.2	normal	3.9	26.6
D. cepedianum	11-14-73	2	160	157-163	8.1	19.2	normal		
D. cepedianum	11-19-73	3	149	145-155	7.0	18.0	normal		
D. cepedianum	11-20-73	1	168		7.7	18.8	normal	2.8	25.7
D. cepedianum	11-21-73	6	131	120-142	7.7	18.8	1 expired		
D. cepedianum	11-21-73	1	205		7.7	18.8	normal	3.6	21.5
D. cepedianum	12-19-73	5	134	120-151	0.9	12.0	normal		
D. cepedianum	12-24-73	3	129	115-156	0.8	11.8	1 expired		
D. cepedianum	6-17-74	1	199		18.7	29.8	24*		
D. cepedianum	6-25-74	1	212		18.2	29.3	25*		
D. cepedianum	6-25-74	1	183		18.2	29.3	26*		
D. cepedianum	7-19-74	2	213	198-228	23.5	34.6	27*		
D. cepedianum	10-31-74	1	303		12.3	23.4	28*		
D. cepedianum	11-18-74	10	151	135-178	7.0	18.0	29*		
D. cepedianum	12-2-74	11	127	96-169	3.0	14.1	normal		
D. cepedianum	12-26-74	2	125	121-129	2.0	13.1	30*		
D. cepedianum	6-24-75	1	449		22.6	33.7	31*		
D. cepedianum	8-12-75	10	90	86-101	25.0	36.1	32*		
D. cepedianum	8-12-75	10	105	86-125	25.0	36.1	33*		
D. cepedianum	8-26-75	5	94	87-101	24.0	35.1	34*		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/ hr.	Critical Thermal Maximum
Dorosoma cepedianum	8-26-75	5	94	85-109	24.0	35.1	35*		
D. cepedianum	10-7-75	2	168	161-175	14.9	26.0	normal		
D. cepedianum	10-7-75	2	117	111-123	14.9	26.0	normal		
D. cepedianum	10-16-75	8	113	96-135	14.8	25.9	normal		
D. cepedianum	10-16-75	9	102	96-108	14.4	25.5	normal		
D. cepedianum	10-17-75	8	110	96-122	14.4	25.5	normal	3.77	32.0
D. cepedianum	10-29-75	8	107	93-120	12.4	23.5	normal	3.66	29.6
D. cepedianum	10-30-75	6	141	133-149	11.2	22.3	normal		
D. cepedianum	11-4-75	8	185	173-197	11.9	23.0	normal		
D. cepedianum	11-4-75	8	99	89-104	11.9	23.0	normal		
D. cepedianum	11-5-75	6	110	105-117	11.9	23.0	normal		
D. cepedianum	11-5-75	6	104	95-115	11.9	23.0	normal		
D. cepedianum	11-7-75	6	106	96-113	12.7	23.8	normal		
D. cepedianum	11-7-75	6	147	132-161	12.7	23.8	normal		
D. cepedianum	12-5-75	6	128	121-133	4.1	15.2	36*		
D. cepedianum	12-12-75	7	128	108-162	3.2	14.3	37*		
D. cepedianum	12-18-75	4	136	119-155	2.4	13.5	normal	2.57	24.2
D. cepedianum	12-31-75	3	113	108-119	1.4	12.5	38*		
D. cepedianum	1-28-76	2	160	154-166	1.5	12.6	39*		
Etheostoma blennioides	9-29-75	1	61		21.1	32.2	normal	4.05	34.9
Ictalurus melas	4-16-76	2	221	215-226	9.2	20.7	normal		
I. melas	4-22-76	2	222	204-239	10.0	21.1	normal	3.31	32.4
I. melas	5-26-76	3	218	192-236	14.8	26.0	normal	3.07	34.2
Ictalurus natalis	9-72	7	183	146-248	19.7	35.0	expired		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Ictalurus natalis	8-5-74	1	257		22.2	33.3	normal	2.3	36.4
I. natalis	10-28-75	2	227	224-229	12.4	23.5	normal	2.86	33.4
I. natalis	1-26-76	1	151		1.5	12.6	normal		
I. natalis	2-11-76	2	146	143-148	0.5	11.6	normal	3.47	27.2
I. natalis	4-21-76	2	158	128-188	12.3	23.4	normal	2.98	30.6
I. natalis	5-26-76	1	223		14.8	26.0	normal	3.07	34.4
I. nebulosus	9-72	3	169	144-193	19.7	35.0	normal		
I. nebulosus	3-5-73	1	185		1.2	12.2	normal	7.2	27.9
I. nebulosus	5-24-73	3	241	233-251	13.2	24.3	normal	3.1	31.8
I. nebulosus	5-30-73	3	318	305-340	14.5	25.5	normal	3.5	31.0
I. nebulosus	6-4-73	4	214	194-230	16.0	27.1	normal	3.2	33.5
I. nebulosus	7-13-73	7	15		22.5	33.6	normal		
I. nebulosus	7-23-73	3	206	187-223	23.0	34.1	normal	3.3	37.4
I. nebulosus	8-29-73	1	287		25.0	36.0	40*		
I. nebulosus	11-21-74	2	322	320-323	1.0	12.1	normal	3.9	27.7
I. nebulosus	7-2-74	1	251		20.0	31.1	normal	3.0	35.6
I. nebulosus	8-7-74	1	230		23.1	34.2	normal	2.6	37.5
I. nebulosus	8-8-74	1	182		23.0	34.1	normal	2.5	37.8
I. nebulosus	12-26-74	3	175	152-192	1.0	12.1	41*		
I. nebulosus	1-31-75	1	297		1.4	12.5	normal		
I. nebulosus	3-13-75	1	244		0.8	11.9	normal		
I. nebulosus	4-10-75	3	247	227-265	3.4	14.6	normal		
I. nebulosus	4-11-75	2	250	243-256	3.5	14.9	normal		
I. nebulosus	4-14-75	2	183	177-188	5.0	16.0	normal		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Ictalurus nebulosus	7-10-75	2	215	215-215	26.0	37.1	normal	2.00	38.1
I. nebulosus	9-17-75	2	274	271-278	18.5	29.6	normal	3.65	37.3
I. nebulosus	10-24-75	2	243	226-260	13.5	24.6	normal		
I. nebulosus	10-28-75	2	248	231-265	12.4	23.5	normal	3.01	33.4
I. nebulosus	10-29-75	2	248	246-249	12.4	23.5	normal		
I. nebulosus	1-26-76	1	208		1.5	12.6	normal		
I. nebulosus	2-19-76	5	245	221-287	1.1	12.2	stressed		
I. nebulosus	3-2-76	4	246	206-285	2.8	18.0	stressed		
I. nebulosus	4-15-76	4	256	237-272	8.5	19.7	normal		
I. nebulosus	5-7-76	4	260	231-274	10.6	25.3	normal		
I. punctatus	10-72	12	165	55-291	14.3	29.2	stressed		
I. punctatus	10-72	5	165	55-291	20.9	34.9	expired		
I. punctatus	11-72	4	240		9.3	25.3	normal		
I. punctatus	7-5-73	2	225	210-240	22.5	33.6	normal		
I. punctatus	7-5-73	3	164	155-173	22.5	33.5	normal	2.7	36.2
I. punctatus	7-30-73	1	387		23.2	34.3	normal	2.3	37.2
I. punctatus	7-30-73	2	273	265-280	23.2	34.3	42*		
I. punctatus	8-28-73	2	278	240-315	24.0	34.4	43*		
I. punctatus	9-18-73	2	352	333-370	20.7	31.7	normal		
I. punctatus	10-2-73	3	173	145-205	20.1	31.0	normal		
I. punctatus	12-17-73	2	242	230-253	0.8	11.9	normal		
I. punctatus	12-21-73	1	375		1.0	12.0	normal	4.5	25.5
I. punctatus	12-21-73	2	244	240-248	1.0	12.1	normal		
I. punctatus	12-24-73	1	310		0.8	11.8	normal	4.3	26.8

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/ hr.	Critical Thermal Maximum
Ictalurus punctatus	1-24-74	2	276	244-308	1.0	12.0	normal	4.3	22-24
I. punctatus	6-18-74	1	165		17.5	28.5	normal	3.2	38.0
I. punctatus	8-5-74	1	162		22.2	33.3	normal		
I. punctatus	11-1-74	1	215		12.3	23.4	normal		
I. punctatus	7-10-75	5	182	166-208	26.0	37.1	44*		
I. punctatus	7-11-75	4	284	255-335	24.9	36.0	stressed	2.20	37.7
I. punctatus	7-28-75	1			24.9	35.0	normal		
I. punctatus	8-28-75	1	282		23.9	35.0	normal		
I. punctatus	11-24-75	1	338		7.3	18.4	normal	3.08	31.8
I. punctatus	4-16-76	1	345		9.2	20.7	normal		
Ichthyomyzon unicuspis	1-18-73	1	305		4.5	15.5	normal	9.9	31.6
Labidesthes sicculus	10-14-75	9	71	62-75	15.2	26.3	normal		
L. sicculus	10-16-75	8	72	56-83	14.8	25.9	normal	3.50	32.3
Lepisosteus osseus	6-25-75	2	649	616-681	23.8	34.9	stressed		
Lepomis cyanellus	11-18-75	1	128		9.0	20.1	normal		
L. cyanellus	11-24-75	1	147		7.3	18.4	normal	3.00	31.5
L. cyanellus × L. gibbosus	11-21-75	1	165		9.0	20.1	normal	2.88	32.7
L. gibbosus	8-72	4		146-178	22.5	34.8	expired		
L. gibbosus	10-72	3	100		20.9	34.9	expired		
L. gibbosus	6-28-73	5	150	136-181	21.0	32.2	stressed	3.0	34.2
L. gibbosus	6-10-74	1	151		20.5	31.5	normal	3.9	36.0
L. gibbosus	6-11-74	1	196		19.5	30.5	slight stress		
L. gibbosus	7-3-74	3	158	142-164	20.2	31.3	normal		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Lepomis gibbosus	7-8-74	3	161	147-185	22.2	33.3	normal	3.3	36.9
L. gibbosus	8-7-74	2	157	153-160	23.1	34.2	normal	2.6	37.5
L. gibbosus	8-8-74	1	147		23.0	34.1	normal		
L. gibbosus	6-26-75	2	141	126-155	23.1	34.2	normal	3.16	37.9
L. gibbosus	7-16-75	2	178	177-178	23.8	34.9	normal		
L. gibbosus	10-20-75	3	130	112-155	12.8	23.9	normal	2.96	33.8
L. gibbosus	11-14-75	5	57	51-63	9.9	21.0	normal		
L. gibbosus	11-18-75	2	139	122-155	9.0	20.1	normal		
L. gibbosus	12-10-75	2	141	113-168	4.1	15.2	normal	3.60	29.9
L. gibbosus	2-20-76	4	66	62-69	1.2	12.3	normal	3.68	24.4
L. gibbosus	2-27-76	2	137	111-162	2.1	13.2	normal	4.48	26.6
L. gibbosus	3-23-76	6	57	51-63	4.5	14.7	normal		
L. gibbosus	5-26-76	3	154	149-160	15.3	26.4	normal		
L. gibbosus × *L. macrochirus*	9-11-75	5	52	45-60	21.3	32.4	normal	0.79	39.1
L. humilis	3-30-73	1	156		5.6	16.6	normal	4.5	26.0
L. humilis	11-20-75	4	47	44-49	9.0	20.1	normal	3.14	30.4
L. humilis	11-25-75	4	46	41-48	7.0	18.1	normal		
L. humilis	2-20-76	4	68	65-73	1.2	12.3	normal	3.68	25.2
L. humilis	3-22-76	6	55	43-69	2.6	13.7	normal		
L. humilis	3-25-76	3	61	46-72	4.6	16.1	normal	3.19	25.4
L. humilis	4-7-76	3	54	44-72	7.9	19.0	normal	3.14	26.5
L. macrochirus	6-26-73	1	154		21.3	32.4	45*		
L. macrochirus	7-6-73	1	155		22.5	33.5	normal	2.5	36.0

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Lepomis macrochirus	8-29-73	1	205		24.8	34.3	46*		
L. macrochirus	6-11-74	1	196		19.5	30.5	normal	3.4	34.8
L. macrochirus	6-19-74	1	163		17.5	28.7	normal	3.7	35.0
L. macrochirus	7-8-74	2	156	149-163	22.2	33.3	normal		
L. macrochirus	7-17-74	2	159	139-178	23.3	34.4	slight stress		
L. macrochirus	7-24-74	1	168		22.8	33.8	normal	2.6	38.3
L. macrochirus	7-8-75	3	207	172-224	26.2	37.3	47*		
L. macrochirus	7-24-75	1	150		24.0	35.1	stressed	4.50	38.1
L. macrochirus	7-30-75	1	143		24.7	35.8	stressed		
L. macrochirus	8-13-75	4	153	145-165	24.7	35.8	stressed		
L. macrochirus	8-28-75	1	121		23.9	35.0	normal		
L. macrochirus	10-31-75	2	142	127-156	10.8	21.9	normal		
L. macrochirus	11-20-75	6	54	50-59	9.0	20.1	normal	3.14	30.8
L. macrochirus	1-8-76	2	163	149-176	1.0	12.1	normal	3.88	27.3
L. macrochirus	2-20-76	4	61	55-72	1.2	12.3	normal		
L. macrochirus	2-27-76	2	140	125-154	2.1	13.2	normal	4.48	21.4
L. macrochirus	3-23-76	4	118	80-175	4.5	14.7	normal		
L. macrochirus	4-12-76	6	50	36-65	7.2	19.4	normal		
L. macrochirus	4-26-76	3	167	151-175	9.6	20.7	normal		
L. macrochirus	5-26-76	2	165	154-175	14.8	26.1	normal	2.86	31.9
L. microlophus	7-9-74	1	175		22.7	33.8	normal	3.3	37.4
Micropterus dolomieui	3-29-73	2	189	188-190	4.8	16.0	normal	4.0	28.0
M. dolomieui	6-25-73	1	292		22.2	32.2	48*		
M. dolomieui	8-28-73	1	216		24.1	35.2	49 *		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Micropterus dolomieui	1-17-74	1	151		23.3	34.4	slight stress	2.4	36.3
M. dolomieui	7-31-74	1	223		23.9	34.9	slight stress	2.6	36.2
M. dolomieui	6-25-75	1	343		23.8	34.9	50*		
M. dolomieui	7-15-75	2	320	305-335	23.8	34.9	51*	2.36	36.0
M. dolomieui	7-16-75	1	190		23.8	34.9	52*		
M. dolomieui	7-17-75	4	237	230-245	24.2	35.3	53*		
M. dolomieui	7-17-75	4	235	220-252	24.2	35.3	54*		
M. dolomieui	7-18-75	4	223	216-230	24.0	24.0	a*	3.25	37.8
M. dolomieui	7-21-75	4	245	230-273	24.1	24.1	a*	7.68	37.4
M. dolomieui	7-22-75	4	256	238-281	24.7	30.2	normal	4.34	37.5
M. dolomieui	7-23-75	4	235	215-254	25.2	36.3	55*		
M. dolomieui	7-24-75	4	213	192-250	24.6	30.0	normal	3.64	38.5
M. dolomieui	7-30-75	2	154	134-174	24.7	35.8	56*		
M. dolomieui	8-5-75	2	315	305-325	25.9	37.0	57*		
M. dolomieui	8-11-75	3	96	86-102	24.4	35.5	58*	2.40	37.8
M. dolomieui	8-12-75	11	95	85-105	25.0	36.1	59*		
M. dolomieui	9-24-75	10	83	75-91	16.8	27.8	normal	4.09	36.3
M. dolomieui	9-26-75	12	86	75-116	16.1	27.2	normal		
M. dolomieui	10-21-75	1	251		12.5	23.6	normal	3.21	32.8
M. dolomieui	10-24-75	1	259		13.5	24.6	normal		
M. dolomieui	12-8-75	1	211		3.5	14.6	normal	3.51	28.4
M. dolomieui	12-12-175	1	182		3.2	14.3	normal		
M. dolomieui	2-25-76	2	256	251-260	1.4	12.5	normal		
M. dolomieui	3-20-76	2	235	211-259	22.3	13.5	normal	4.24	24.7

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Micropterus dolomieui	3-25-76	2	123	110-135	4.6	16.1	normal	3.74	26.6
M. dolomieui	4-6-76	2	225	210-239	6.9	18.0	normal	3.85	26.2
M. dolomieui	4-23-76	2	240	232-248	10.4	21.5	normal		
M. dolomieui	5-26-76	5	236	220-249	15.2	26.3	normal	3.33	30.5
M. dolomieui	5-26-76	4	260	257-263	15.3	26.3	normal		
M. salmoides	1-7-74	1	280		0.7	12.0	normal		
M. salmoides[b]*	1-15-74	1	341		0.9	12.0	normal	6.0	18.0
M. salmoides	11-21-75	1	80		9.0	20.1	normal	2.87	32.0
M. salmoides	2-4-76	1	79		1.5	12.6	normal		
M. salmoides	3-25-76	1	78		4.6	16.1	normal	3.74	25.4
M. salmoides	4-9-76	1	234		7.7	19.3	normal		
M. salmoides	5-4-76	1	233		10.0	21.2	normal	3.47	29.0
Minytrema melanops	7-2-74	1	255		20.0	31.1	normal		
Morone chrysops	6-1-73	1	135		14.6	25.5	normal	3.3	29.6
M. chrysops	8-1-73	1	240		23.3	34.4	60*		
M. chrysops	8-29-73	5	67	60-72	25.0	36.0	61*		
M. chrysops	1-14-74	1	135		0.8	11.9	normal		
M. chrysops	6-25-74	1	285		18.2	29.3	slight stress	4.5	32.9
M. dhrysops	7-5-74	1	134		21.7	32.8	slight stress	2.7	35.3
M. chrysops	7-18-74	1	181		23.8	34.9	62*		
M. chrysops	7-31-74	1	170		23.9	34.9	63*		
M. chrysops	11-19-74	5	111	109-132	7.5	18.6	normal		
M. chrysops	2-5-75	1	104		1.0	12.1	normal		
M. chrysops	6-26-75	2	148	143-152	23.1	34.2	64*		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Morone chrysops	7-15-75	2	186	181-191	23.8	34.9	stressed	2.55	36.9
M. chrysops	8-11-75	4	201	180-223	24.1	35.2	65*	3.2	36.8
M. chrysops	8-11-75	2	98	85-110	24.1	35.2	66*		
M. chrysops	8-28-76	1	222		23.9	35.0	67*		
M. chrysops	10-6-75	5	129	116-145	14.8	26.0	normal		
M. chrysops	10-20-76	3	217	212-222	12.8	23.9	normal	2.36	31.5
M. chrysops	11-10-75	1	213		13.1	24.2	normal		
M. chrysops	12-8-75	1	227		3.5	14.6	normal	3.85	23.4
M. chrysops	12-19-75	3	139	123-158	1.2	12.3	normal		
M. chrysops	12-23-75	1	174		0.3	11.4	68*		
M. chrysops	1-7-76	1	151		0.7	11.8	normal	3.73	23.0
M. chrysops	4-8-76	2	138	123-152	8.0	19.2	normal		
M. chrysops	5-25-76	1	270		14.6	25.6	normal	3.13	30.5
Notemigonus crysoleucus	10-72	5	140	99-176	19.6	34.4	expired		
N. crysoleucus	12-8-72	3	183	173-201	2.0	13.0	normal	3.5	26.2
N. crysoleucus	5-31-73	2	212	204-220	14.4	25.5	normal	3.3	30.5
N. crysoleucus	3-22-74	2	157	150-164	2.9	13.9	normal		
N. crysoleucus	6-17-74	1	205		18.7	29.8	stressed		
N. crysoleucus	10-9-75	3	135	132-138	15.1	26.2	normal		
N. crysoleucus	11-3-75	2	122	113-130	11.6	22.7	normal	3.37	31.4
N. crysoleucus	11-22-75	3	79	65-89	8.7	19.8	normal		
N. crysoleucus	1-5-76	1	131		1.5	12.6	normal	3.25	27.5
N. crysoleucus	1-9-76	1	182		0.5	11.6	normal		
N. crysoleucus	3-18-76	1	118		2.1	13.4	normal	3.49	25.7

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/ hr.	Critical Thermal Maximum
Notemigonus crysoleucus	4-7-76	3	143	96-205	7.9	19.0	normal	3.20	27.9
N. crysoleucus	4-23-76	4	165	109-218	10.4	21.5	normal		
Notropis atherinoides	2-13-73	6	90	80-97	1.1	12.1	1 expired	3.6	24.0
N. atherinoides	2-28-73	5	97	91-105	1.5	12.5	1 expired	7.3	24.3
N. atherinoides	3-1-73	7	91	83-105	1.0	12.0	normal	8.5	24.0
N. atherinoides	3-8-73	5	90	82-96	2.6	13.6	3 expired	7.6	20.5
N. atherinoides	5-2-73	10	30	28-35	10.4	21.6	normal	4.4	27.7
N. atherinoides	5-3-73	14	40	35-45	10.5	21.5	normal	3.2	26.6
N. atherinoides	1-21-75	5	110	105-118	1.5	12.6	normal		
N. atherinoides	1-23-75	5	106	104-110	1.8	12.9	normal		
N. atherinoides	4-21-75	3	105	99-111	5.6	16.7	normal		
N. atherinoides	4-24-75	3	50	47-52	7.7	18.8	normal		
N. atherinoides	4-28-75	3	50		7.8	18.9	normal		
N. atherinoides	4-28-75	3	48	45-52	7.8	18.9	normal	8.4	28.6
N. atherinoides	11-22-75	3	60	55-64	8.7	19.8	normal		
N. atherinoides	12-15-75	10	80	51-101	5.7	16.8	normal	3.35	27.3
N. atherinoides	2-26-76	9	91	81-114	2.4	13.5	normal	3.57	24.7
N. hudsonius	4-11-73	5	121	109-129	6.0	16.6	normal	4.1	27.6
N. hudsonius	4-12-73	7	123	111-138	5.6	16.7	normal	4.0	27.0
N. hudsonius	4-13-73	8	115	107-121	5.8	16.8	normal	3.9	27.0
N. hudsonius	5-1-73	10	110	97-125	10.0	21.5	normal	3.8	27.9
N. hudsonius	3-22-74	1	124		2.9	13.9	normal		
N. hudsonius (fry)	6-28-74	30-40	1		18.8	29.8	69*		
N. hudsonius	7-5-74	2	124	118-130	21.7	32.8	70*		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Notropis hudsonius	12-2-74	31	109	98-120	3.0	14.1	normal		
N. hudsonius	1-2-75	10	113	102-129	0.8	12.0	normal		
N. hudsonius	1-16-75	5	121	114-128	0.8	11.9	normal		
N. hudsonius	1-23-75	5	118	110-134	1.0	12.1	normal		
N. hudsonius	2-3-75	3	105	102-110	2.2	13.3	normal		
N. hudsonius	3-6-75	3	113	110-116	0.9	12.0	normal		
N. hudsonius	4-7-75	3	117	108-130	2.4	13.5	normal		
N. hudsonius	4-23-75	3	107	105-109	7.0	18.1	normal	6.0	29.2
N. husdonius	4-24-75	3	117	114-123	7.7	18.8	normal		
N. hudsonius	4-28-75	3			7.8	18.9	normal		
N. hudsonius	10-23-75	8	135	102-217	13.6	24.7	normal	3.85	32.1
N. hudsonius	10-29-75	8	110	100-118	12.4	23.5	normal		
N. hudsonius	11-22-75	4	77	66-89	8.7	19.8	normal		
N. hudsonius	2-26-76	9	114	108-121	2.4	13.5	normal	3.51	25.0
N. spilopterus	11-19-75	4	69	66-72	9.0	20.1	normal	2.87	30.4
N. spilopterus	11-22-75	4	78	74-82	8.7	19.8	normal		
N. spilopterus	3-18-76	1	84		2.1	13.4	normal	3.49	24.6
N. spilopterus	3-25-76	1	80		4.6	16.1	normal	3.19	25.9
Noturus flavus	12-12-72	1	195		1.6	12.8	normal	3.7	26.0
N. flavus	12-12-72	1	210		1.6	12.8	normal	3.3	29.0
N. flavus	10-3-75	2	197	165-229	14.1	25.2	normal		
N. flavus	10-22-75	1	213		13.0	24.1	normal	3.40	32.2
N. flavus	11-10-75	2	221	219-222	11.0	22.1	stressed		
N. flavus	12-5-75	2	209	202-216	4.1	15.2	normal		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/ hr.	Critical Thermal Maximum
Noturus flavus	12-11-75	2	259	243-275	3.5	14.6	normal	3.35	27.1
N. flavus	2-17-76	5	208	183-228	0.7	11.8	normal		
N. flavus	3-3-76	5	216	202-226	3.8	18.0	stressed		
N. flavus	3-26-76	3	219	186-265	5.2	16.7	normal	3.44	28.9
N. flavus	4-6-76	3	219	189-247	6.9	18.0	normal	3.61	27.7
N. flavus	4-15-76	2	210	199-220	8.5	19.6	normal		
N. flavus	5-26-76	2	206	196-216	14.8	26.0	normal	3.07	32.3
Oncorhychus kisutch	6-6-75	6	88	81-90	19.8	31.0	71*		
O. kisutch	7-2-75	7	110		12.5	13.0	a*	4.37	27.2
O. kisutch	7-2-75	3	103	99-106	12.5	23.6	stressed	4.08	27.0
O. kisutch	7-3-75	5	107	93-114	12.5	12.5	a*	6.80	27.8
O. kisutch	7-3-75	4	103	88-113	12.5	23.6	stressed	4.92	27.8
O. kisutch	10-15-75	2	129	120-137	15.1	26.2	normal	4.26	28.5
O. kisutch	12-11-75	2	138	133-142	3.5	14.6	normal		
O. kisutch	12-11-75	2	119	116-122	3.5	14.6	normal		
O. kisutch	1-29-76	2	139	138-140	1.2	12.3	normal		
O. kisutch	2-6-76	2	162	144-179	0.5	11.6	normal	3.51	24.7
O. kisutch	3-17-76	2	139	117-161	2.4	13.5	normal		
O. kisutch	4-8-76	3	134	125-139	8.0	19.2	normal		
Osmerus mordax	4-10-73	1	147		6.0	17.1	normal	3.9	24.9
O. mordax	11-25-74	6	154	125-179	6.3	17.5	normal		
O. mordax	12-30-74	1	173		1.1	12.2	normal	2.7	23.5
O. mordax	12-10-75	3	249	200-287	4.1	15.2	normal	3.58	24.0
O. mordax	12-15-75	5	179	146-206	5.7	16.8	normal	3.67	23.4

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Osmerus mordax	12-18-75	4	162	146-174	2.4	13.5	normal	2.63	21.9
O. mordax	12-19-75	8	169	155-185	1.2	12.3	normal		
O. mordax	1-3-76	4	167	164-170	1.5	12.6	normal	3.93	24.0
O. mordax	1-13-76	7	161	136-194	1.0	12.1	normal		
O. mordax	1-15-76	6	169	158-185	1.1	16.1	normal		
O. mordax	1-16-76	6	170	141-202	1.2	21.2	72*		
O. mordax	1-20-76	4	164	137-176	1.4	18.9	stressed		
O. mordax	1-26-76	4	176	162-184	0.4	19.0	normal		
O. mordax	2-3-76	3	173	168-179	1.5	12.6	normal	3.29	23.1
O. mordax	2-11-76	5	171	164-187	1.9	20.0	73*		
O. mordax	2-13-76	6	174	128-188	1.4	11.4	a*	6.62	24.0
O. mordax	4-5-76	3	180	172-194	6.6	17.7	normal	3.44	24.9
Perca flavescens	1-2-73	4	195	176-217	1.0	12.2	normal	3.8	26.0
P. flavescens	1-3-73	1	260		1.0	12.7	normal	3.5	25.0
P. flavescens	1-4-73	3	245	237-260	1.5	12.5	normal	3.6	25.4
P. flavescens	1-5-73	3	242	235-255	1.0	12.1	normal	3.6	26.0
P. flavescens	1-11-73	3	205	199-214	1.6	12.7	normal	9.0	26.0
P. flavescens	1-16-73	4	201	196-205	1.5	12.6	normal	9.9	26.4
P. flavescens	1-17-73	2	197	196-197	1.5	12.5	normal	2.1	25.3
P. flavescens	2-6-73	3	184	173-191	1.0	12.0	normal	0.1	29.7
P. flavescens	2-14-73	3	204	201-209	1.1	12.0	normal	7.0	25.7
P. flavescens	3-6-73	2	182	179-185	1.6	12.6	normal	7.8	24.3
P. flavescens	3-7-73	2	173	172-178	2.2	13.2	normal	7.6	24.0
P. flavescens	3-8-73	3	163	142-185	2.6	13.6	normal	6.3	23.5
P. flavescens	4-24-73	2	248	230-265	9.0	19.8	normal	4.0	25.8

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/ hr.	Critical Thermal Maximum
Perca flavescens	5-28-73	4	203	190-215	13.8	25.0	normal	3.7	29.7
P. flavescens	6-25-73	2	185	178-192	22.2	32.9	74*		
P. flavescens	7-6-73	2	175	163-186	22.7	33.7	75*		
P. flavescens	8-21-73	3	187	185-190	23.2	34.3	76*		
P. flavescens	8-22-73	3	178	142-205	21.5	32.0	normal	2.4	33.3
P. flavescens	8-28-73	1	131		24.0	35.0	77*		
P. flavescens	8-30-73	6	78	70-85	25.6	36.7	78*		
P. flavescens	9-6-73	1	152		25.2	36.2	79*		
P. flavescens	9-12-73	3	182	165-195	22.0	33.3	normal	3.4	35.0
P. flavescens	9-17-73	4		176-191	19.9	31.0	stressed	4.4	31.9
P. flavescens	9-19-73	3	144	141-147	20.2	31.3	normal	2.3	32.8
P. flavescens	1-21-74	3	266	245-284	1.0	12.1	normal		
P. flavescens	1-24-74	3	237	230-250	1.0	12.0	normal		
P. flavescens	3-1-74	1	327		1.0	12.3	normal	4.3	23.0
P. flevescens	3-7-74	3	250	242-257	3.2	14.0	normal		
P. flavescens	3-13-74	3	250	240-260	1,8	12.9	normal	4.4	24.0
P. flavescens	6-11-74	1	173		19.5	30.5	stressed	2.7	32.5
P. flavescens	6-19-74	2	225	244-205	17.5	28.6	normal		
P. flavescens	7-5-74	1	236		21.7	32.7	80*		
P. flavescens	7-17-74	2	196	189-203	23.3	34.4	81*		
P. flavescens	7-17-74	1	136		23.3	34.4	82*		
P. flavescens	7-18-74	2	184	172-195	23.8	34.9	83*		
P. flavescens	7-19-74	2	246	220-272	23.5	34.6	84*		
P. flavescens	8-1-74	1	245		23.9	35.0	85*		
P. flavescens	1-14-75	1	236		1.5	12.6	normal	3.6	24.0

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Perca flavescens	7-24-75	6	195	170-221	24.6	35.7	86*		
P. flavescens	7-30-75	2	164	160-167	24.7	35.8	87*		
P. flavescens	8-26-75	1	83		24.0	35.1	88*		
P. flavescens	9-26-75	4	102	93-114	16.1	27.2	normal	4.24	32.5
P. flavescens	10-9-75	5	102	97-107	15.1	26.2	normal		
P. flavescens	10-23-75	3	211	200-217	13.6	24.7	normal	3.19	31.0
P. flavescens	10-31-75	2	237	227-246	10.8	21.9	normal		
P. flavescens	11-14-75	5	99	91-107	9.9	21.0	normal		
P. flavescens	12-4-75	3	99	93-108	3.5	14.6	normal		
P. flavescens	12-23-75	2	111	106-115	0.3	11.4	normal		
P. flavescens	2-26-76	4	236	199-269	1.9	13.0	normal	4.05	24.0
P. flavescens	4-5-76	4	212	200-219	6.6	17.7	normal	3.23	25.2
P. flavescens	5-5-76	6	219	194-233	10.3	21.6	normal	2.46	28.5
P. flavescens	5-7-76	7	120	106-143	10.6	25.4	89*		
P. flavescens	5-25-76	9	229	205-254	15.0	26.1	normal	3.19	30.2
P. flavescens	5-26-76	4	192	176-209	15.3	26.4	normal		
Percina caprodes	9-29-75	1	55		21.1	32.2	normal	4.05	34.9
Percopsis omiscomaycus	12-15-72	2	101	89-113	1.7	12.8	normal	4.0	22.9
P. omiscomaycus	1-15-76	1	108		0.5	11.6	normal		
Pimephales notatus	4-3-73	3	93	92-94	6.0	17.0	normal	4.0	27.8
P. notatus	2-4-75	1	96		1.0	12.1	normal		
P. notatus	11-19-75	3	70	67-74	9.0	20.1	normal	3.55	29.1
P. notatus	11-22-75	3	65	62-68	8.7	19.8	normal		
P. notatus	3-18-76	3	881	73-89	2.1	13.4	normal	3.49	26.2
P. notatus	4-12-76	6	40	28-52	7.2	19.2	normal		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Pomoxis annularis	10-72	3		102-125	20.9	34.9	expired		
P. annularis	2-6-73	2	255	249-260	5.0	16.0	normal	3.5	33.0
P. annularis	5-16-73	5	221	205-233	12.1	23.1	normal	2.9	27.0
P. annularis	6-26-73	4	186	166-219	21.3	32.4	90*	4.0	23.5
P. annularis	8-14-73	2	143	131-155	24.4	35.5	91*		
P. annularis	10-23-73	3	212	205-223	15.7	26.8	normal	3.5	30.3
P. annularis	1-10-74	2	295	293-297	10.7	12.0	normal	4.0	23.5
P. annularis	1-29-74	3	185	184-187	1.3	12.4	normal		
P. annularis	2-12-74	3	234	215-244	1.0	12.0	normal		
P. annularis	2-13-74	3	196	193-200	0.9	12.0	normal	4.5	24.0
P. annularis	2-13-74	3	168	153-180	1.0	12.1	normal		
P. annularis	2-14-74	3	109	97-130	1.0	12.0	normal	4.5	22.7
P. annularis	2-14-74	2	95	90-100	1.0	12.0	normal		
P. annularis	7-5-74	4	134	101-167	21.7	32.8	92*		
P. annularis	7-17-74	2	229	210-248	23.3	34.4	93*		
P. annularis	11-13-74	3	170		10.0	21.5	94*		
P. annularis	11-16-74	2	174	166-183	6.8	17.9	stressed		
P. annularis	4-21-75	2	257	255-259	1.5	12.6	normal		
P. annularis	3-13-75	1			0.8	11.9	normal		
P. annularis	6-12-75	4	201	189-208	18.8	20.1	a*	3.88	32.7
P. annularis	6-12-75	4	188	171-199	18.9	30.0	normal	3.60	33.1
P. annularis	6-13-75	4	198	192-211	19.0	25.0	normal	3.80	33.3
P. annularis	6-16-75	4	187	170-193	18.9	22.2	a*	1.63	34.0
P. annularis	6-24-75	3	207	194-213	22.6	28.5	normal	1.25	34.7
P. annularis	6-25-75	4	204	187-218	23.9	35.0	95*		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/hr.	Critical Thermal Maximum
Pomoxis annularis	7-28-75	4	196	182-207	24.9	35.0	96*		
P. annularis	7-29-75	2	197	191-202	24.8	35.9	97*		
P. annularis	8-6-75	3	211	191-226	24.0	35.1	98*		
P. annularis	9-30-75	5	201	185-219	16.2	27.3	normal	3.73	32.2
P. annularis	9-30-75	6	238	212-253	16.2	27.3	normal		
P. annularis	10-27-75	8	164	146-184	12.8	23.9	normal	3.17	31.1
P. annularis	10-27-75	8	201	192-214	12.8	23.9	normal	2.74	30.8
P. annularis	12-8-75	1	254		3.5	14.6	normal		
P. annularis	12-8-75	3	162	159-164	3.5	14.6	normal		
P. annularis	12-17-75	8	87	77-101	3.8	14.9	normal	2.59	26.5
P. annularis	1-21-76	3	85	86-87	0.4	11.5	normal	2.61	21.6
P. annularis	1-22-76	6	79	73-93	0.3	11.4	normal		
P. annularis	1-29-76	3	179	169-193	1.0	12.1	normal	3.73	23.9
P. annularis	2-9-76	4	201	180-249	0.5	11.6	99*		
P. annularis	5-5-76	8	181	167-196	10.3	21.5	normal	3.08	28.4
P. annularis	5-6-76	6	184	165-198	11.4	25.5	normal		
P. nigromaculatus	11-72	7	173	165-187	9.0	24.1	normal		
P. nigromaculatus	11-72	3	202	182-222	9.3	25.3	normal		
P. nigromaculatus	12-20-72	3	93	91-95	3.4	14.4	normal	3.7	24.3
P. nigromaculatus	12-20-72	2	67	62-71	3.4	14.4	normal	4.0	23.1
P. nigromaculatus	1-3-73	2	186	174-198	1.0	12.7	normal	3.7	22.4
P. nigromaculatus	1-25-73	1	160		3.0	14.0	normal	3.7	19.5
P. nigromaculatus	1-31-73	2	174	174-175	3.5	15.0	normal	3.6	23.4
P. nigromaculatus	2-1-73	2	158	155-161	2.8	13.8	normal	3.9	23.5

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Temperature °C Ambient	Temperature °C Shock	Results	Temp °C Increase/hr.	Critical Thermal Maximum
Pomoxis nigromaculatus	2-5-73	5	165	162-172	11.3			2.9	33.5
P. nigromaculatus	5-14-73	1	397		12.1	23.5	stressed	3.6	29.0
P. nigromaculatus	5-15-73	3	230	227-234	12.5	26.6	normal	3.3	28.0
P. nigromaculatus	6-28-73	5	202	157-259	21.0	32.1	100*		
P. nigromaculatus	7-31-73	3	191	185-197	23.5	34.5	101*		
P. nigromaculatus	10-5-73	5	171	160-179	19.0	30.0	102*		
P. nigromaculatus	10-5-73	5	174	147-190	19.0	30.0	normal		
P. nigromaculatus	10-23-73	2	168	162-173	15.7	26.8	normal		
P. nigromaculatus	12-22-73	3	198	190-210	1.0	12.1	normal		
P. nigromaculatus	3-12-74	3	216	210-223	2.8	13.9	normal		
P. nigromaculatus	6-20-74	4	205	181-224	17.7	28.8	normal	4.1	33.2
P. nigromaculatus	7-1-74	1	224		20.0	31.1	normal	3.1	33.9
P. nigromaculatus	7-12-74	4	164	144-184	22.8	33.8	103*		
P. nigromaculatus	7-17-74	4	194	185-206	23.3	34.4	104*	2.8	34.4-35.8
P. nigromaculatus	7-18-75	5	193	183-209	23.8	34.9	105*		
P. nigromaculatus	10-31-74	3	166	163-170	12.3	23.4	normal		
P. nigromaculatus	11-1-74	3	206	197-215	12.3	23.4	normal		
P. nigromaculatus	2-4-75	3	187	173-199	1.0	12.1	normal		
P. nigromaculatus	2-5-75	3	163	149-179	1.0	12.1	normal		
P. nigromaculatus	3-5-75	1	198		1.0	12.0	normal		
P. nigromaculatus	4-10-75	2	205	203-207	3.5	14.6	106*		
P. nigromaculatus	4-14-75	3	175	167-185	5.0	16.0	normal		
P. nigromaculatus	4-21-75	2	170	159-182	5.6	16.6	normal		
P. nigromaculatus	7-25-75	3	212	201-220	24.7	35.8	107*		
P. nigromaculatus	7-25-75	3	191	178-203	24.7	35.8	108*		

TABLE 5

RESULTS OF HOT SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Temperature °C		Results	Temp °C Increase/ hr.	Critical Thermal Maximum
			Mean	Range	Ambient	Shock			
Pomoxis nigromaculatus	7-28-75	2	186	171-200	24.9	35.0	109*		
P. nigromaculatus	7-29-75	3	178	163-198	24.8	35.9	110*		
P. nigromaculatus	7-29-75	2	238	210-265	24.8	35.9	111*		
P. nigromaculatus	7-30-75	1	217		24.7	35.8	112*		
P. nigromaculatus	8-6-75	3	211	186-236	24.0	35.1	113*		
P. nigromaculatus	9-30-75	5	212	194-223	16.2	27.3	normal	3.03	32.5
P. nigromaculatus	9-30-75	6	222	193-248	16.2	27.3	normal		
P. nigromaculatus	12-8-75	1	261		3.5	14.6	normal		
P. nigromaculatus	12-8-75	3	140	133-149	3.5	14.6	normal		
P. nigromaculatus	12-17-75	8	76	70-84	3.8	14.9	normal	2.40	24.3
P. nigromaculatus	1-21-76	4	80	76-83	0.4	11.5	normal	2.61	23.8
P. nigromaculatus	1-22-76	4	79	76-82	0.3	11.4	normal		
P. nigromaculatus	1-29-76	3	170	140-197	1.0	12.1	normal	3.73	23.5
P. nigromaculatus	2-9-76	4	169	147-203	0.5	11.6	stressed		
P. nigromaculatus	3-1-76	4	199	187-229	3.2	15.2	stressed	3.83	21.9
P. nigromaculatus	3-2-76	6	200	154-233	3.2	14.3	stressed		
P. nigromaculatus	3-4-76	5	197	180-219	3.8	20.2	114*		
P. nigromaculatus	5-6-76	6	180	145-204	11.4	25.5	normal		
P. nigromaculatus	5-25-76	6	220	200-244	15.0	26.1	normal	3.33	30.4
Salmo gairdneri	11-25-74	1	406		6.3	17.5	normal		
Stizostedion v. vitreum	7-31-73	3	265	245-276	23.5	34.5	115*		
S. v. vitreum	8-1-73	1	284		23.3	34.4	116*		
S. v. vitreum	2-2-76	1	181		1.2	12.3	normal		
S. v. vitreum	4-11-76	1	182		7.4	19.3	normal		
S. v. vitreum	4-21-76	1	183		12.3	23.4	normal	3.97	33.0
S. v. vitreum	5-25-76	1	218		14.6	25.6	normal	3.13	30.4
S. v. vitreum	5-26-76	1	184		15.2	26.3	normal	3.31	30.6

TABLE 5 CONT.

RESULTS OF HOT SHOCK TESTING

Notes:

a* C.T.M. was initiated from ambient without a prior hot shock.
b* Fish in poor condition
1* Test terminated after 6 minutes; fish died upon cooling
2* All fish removed in less than 1 minute; none recovered upon cooling
3* 1 fish removed after 25 minutes and 1 fish removed after 35 minutes; both fish appeared to have recovered upon cooling but were found dead the next day
4* 1 fish removed after 8 minutes; fish died upon cooling. Two fish remained normal throughout test period.
5* Test terminated after 40 minutes; fish died upon cooling
6* All fish removed after 1 hour observation period; 1 recovered upon cooling
7* Fish in poor condition; test terminated after 8 minutes; fish dead before cooling initiated
8* Test terminated after 15 minutes; fish dead before cooling initiated
9* Test terminated after 15 minutes; fish lived upon cooling
10* Test terminated after 6 minutes; fish lived upon cooling
11* Test terminated after 9 minutes; fish lived upon cooling
12* Test terminated after 7.3 minutes; fish lived upon cooling
13* Test terminated after 4.5 minutes; fish lived upon cooling
14* Test terminated after 1.3 minutes; 1 died upon cooling
15* Test terminated after 3.4 minutes; 1 died upon cooling
16* Test terminated after 1.5 minutes; fish lived upon cooling
17* Normal after 1 hour; fish dead after 19 hours
18* Test terminated after 19 minutes; fish died upon cooling
19* Test terminated after 7 minutes; fish died upon cooling
20* Test terminated after 10 minutes; both fish recovered upon cooling
21* Test terminated after 13 minutes; both fish lived upon cooling

TABLE 5 CONT.

RESULTS OF HOT SHOCK TESTING

22*	Normal after 1 hour; dead after 20.5 hours
23*	Test terminated after 24 minutes; fish died upon cooling
24*	Test terminated after 25 minutes; fish died upon cooling
25*	Test terminated after 15 minutes; fish died upon cooling
26*	Test terminated after 40 minutes; fish died upon cooling
27*	Test terminated after 10 minutes; 1 fish died upon cooling
28*	Normal after 1 hour; dead after 16 hours
29*	1 fish stressed; others normal after 1 hour; 1 fish dead after 23.75 hours
30*	1 fish stressed and 1 normal after 1 hour; 1 fish dead after 2.75 hours
31*	Test terminated after 11 minutes; fish lived upon cooling
32*	Test terminated after 2 minutes
33*	Test terminated after 5 minutes; 5 lived and 5 died upon cooling
34*	1 fish removed after 18 minutes; 2 after 20 minutes, 1 after 22 minutes, and 1 after 30 minutes; 2 fish died and 3 fish recovered upon cooling
35*	All fish removed after 18 to 30 minutes; 2 fish died and 3 lived upon cooling.
36*	2 fish were heavily stressed for several hours but recovered and were held for cold shock
37*	All fish were seriously stressed; 2 died before end of 24 hours holding period for cold shock.
38*	2 fish stressed and 1 normal after 1 hour; all died within 19 hours
39*	Both fish immediately went into stress and died between 6 and 12 hours after start of test.
40*	Test terminated after 20 minutes; fish lived upon cooling
41*	1 fish stressed; 2 fish normal after 55 minutes
42*	Normal after 1 hour, dead after 24 hours
43*	Normal after 8 hours, dead after 24 hours
44*	1 fish removed at each of following times: 5 min., 15 min., 17 min., 25 min., 40 min.; 4 fish lived and 1 died upon cooling
45*	Normal after 3 hours, dead after 19 hours
46*	Normal after 8 hours, dead after 24 hours

TABLE 5 CONT.

RESULTS OF HOT SHOCK TESTING

47*	1 fish removed after 23 minutes, 2 after 30 minutes; 1 fish lived and 2 died upon cooling
48*	Normal after 1 hour, dead after 5 hours
49*	Test terminated after 20 minutes; fish died upon cooling
50*	Test terminated after 23 minutes; fish died upon cooling
51*	1 fish removed after 35 minutes; died upon cooling. Other fish stressed.
52*	Test terminated after 55 minutes; fish died upon cooling
53*	1 fish removed after 35 minutes, 1 after 38 minutes, and 1 after 50 minutes; 2 fish recovered and 1 died upon cooling; last fish found dead after 18 hours.
54*	1 fish removed after 30 minutes and 1 after 60 minutes; last 2 fish found dead after 90 minutes.
55*	3 fish removed after 16 minutes and 1 after 50 minutes; 1 fish recovered and 3 died upon cooling
56*	1 fish died between 30 and 60 minutes; other fish stressed
57*	Test terminated after 15 minutes; both fish died upon cooling. 2 fish stressed
58*	1 fish removed after 1 minute and died upon cooling; other 2 fish stressed but retained for C.T.M. testing
59*	Test terminated after 30 minutes; 5 fish died and 6 recovered upon cooling
60*	Stressed after 1.25 hours, dead after 2.75 hours
61*	Test terminated after 30 seconds; fish lived upon cooling
62*	Test terminated after 15 minutes; fish died upon cooling
63*	Stressed after 1 hour; dead after 8,25 hours
64*	Test terminated after 50 minutes; 1 died upon cooling
65*	1 fish removed after 10 minutes and 1 after 26 minutes; other 2 fish slightly stressed but retained for C.T.M. testing; all 4 fish recovered upon cooling at end of tests.
66*	1 fish removed after 30 seconds and recovered upon cooling; 1 fish found dead after 5 hours
67*	Fish removed after 6 hours and recovered upon cooling
68*	Fish went into shock while being transferred to testing tank but recovered when place in hot shock

TABLE 5 CONT.

RESULTS OF HOT SHOCK TESTING

69*	Most fish dead after 5 minutes; only a few survived for 1 hour
70*	One fish removed after 20 minutes; test terminated after 55 minutes; both fish died upon cooling
71*	Test terminated after 1 minute; all fish died upon cooling
72*	All fish died within 2 hours
73*	All fish stressed; 2 dead after 1 hour, 3 normal after 3 hours
74*	Test terminated after 10 minutes; fish lived upon cooling
75*	Test terminated after 5 minutes; 1 died upon cooling
76*	Test terminated after 5 minutes; fish lived upon cooling
77*	Test terminated after 6 minutes; fish lived upon cooling
78*	Test terminated after 1 minute; fish lived upon cooling
79*	Test terminated after 2 minutes; fish lived upon cooling
80*	Test terminated after 10 minutes; fish died upon cooling
81*	1 fish removed after 30 minutes; test terminated after 50 minutes; both fish died upon cooling
82*	Test terminated after 30 minutes; fish died upon cooling
83*	1 fish removed after 23 minutes; test terminated after 38 minutes; 1 fish died upon cooling
84*	Test terminated after 17 minutes; 1 fish died upon cooling
85*	Test terminated after 15 minutes; fish died upon cooling
86*	4 fish removed after 3 minutes and 2 after 4 minutes; all fish recovered upon cooling
87*	1 fish removed after 6 minutes and 1 after 10 minutes; both fish recovered upon cooling
88*	Fish removed after 40 minutes and recovered upon cooling
89*	1 fish removed after 2 minutes, recovered upon cooling; 1 fish found dead after 28 hours; one found dead after 82 hours.
90*	Test terminated after 8 minutes; 1 died upon cooling
91*	Test terminated after 4 minutes; fish lived upon cooling
92*	Test terminated after 1 hour; 1 fish died upon cooling; 3 fish held for cold shock found dead after 17.25 hours
93*	1 fish removed after 10 minutes; test terminated after 45 minutes; 1 fish died upon cooling

TABLE 5 CONT.

RESULTS OF HOT SHOCK TESTING

94*	1 fish removed after 5 minutes; fish died upon cooling; 2 fish normal
95*	Test terminated after 25 minutes; 1 fish died upon cooling
96*	2 fish removed after 5 minutes, 1 after 15 minutes and 1 after 20 minutes; all fish recovered upon cooling
97*	Both fish removed after 3 minutes and recovered upon cooling
98*	1 fish removed after 16 minutes and 1 after 35 minutes; both fish recovered upon cooling; last fish found dead after 19 hours
99*	All fish heavily stressed for first 30 minutes; 1 died and 3 recovered
100*	Test terminated after 7 minutes; fish lived upon cooling
101*	Test terminated after 7.5 minutes; fish lived upon cooling
102*	Normal after 24 hours, 2 dead after 68 hours
103*	1 fish removed after 10 minutes; 1 fish removed after 55 minutes; 1 fish removed after 60 minutes; all fish recovered upon cooling; 1 fish stressed after test and found dead after 70 hours
104*	1 fish removed after 55 minutes; 1 fish removed after 60 minutes; 1 fish died upon cooling; 2 fish stressed at end of test
105*	2 fish removed after 20 minutes; 1 fish removed after 32 minutes; 2 fish removed after 45 minutes; all fish lived upon cooling
106*	1 fish stressed and 1 normal after 1 hour test; 1 fish dead after 6 hours
107*	1 fish removed after 6 minutes and 2 after 10 minutes; all fish recovered upon cooling
108*	All fish removed after 7 minutes and recovered upon cooling
109*	1 fish found dead after 5-1/2 hours; other fish stressed but held for cold shock testing
110*	All fish removed after 5 minutes and recovered upon cooling
111*	1 fish removed after 5 minutes and 1 after 10 minutes; 1 lived and 1 died upon cooling
112*	Fish removed after 15 minutes and recovered upon cooling
113*	All fish normal after 1 hour but found dead after 18 hours
114*	All fish heavily stressed for several hours; 3 died and 2 recovered within 24 hours
115*	Test terminated after 5 minutes; fish lived upon cooling
116*	Test terminated after 5 minutes; fish lived upon cooling

APPENDIX C

RESULTS OF COLD SHOCK TESTING

ON LAKE ERIE FISH AT PUT-IN-BAY, OHIO

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
Ambloplites rupestris	7-25-74	1	172		33.8	24.0	23.0	normal
A. rupestris	8-8-74	1	99		34.2	24.3	23.0	normal
A. rupestris	1-31-75	1	171		12.9	46.3	1.4	normal
A. rupestris	8-28-75	1	96		35.1	40.0	24.0	normal
A. rupestris	10-20-75	1	123		23.9	66.0	12.8	normal
A. rupestris	12-31-75	1	168		12.1	160.0	1.2	normal
A. rupestris[a]	2-25-76	2	172	168-175	12.4	24.0	1.3	normal
A. rupestris	3-18-76	3	155	124-171	13.4	25.0	2.1	normal
A. rupestris	4-15-76	2	191	168-214	19.7	24.0	8.5	normal
Aplodinotus grunniens	1-2-74	2	236	225-248	11.8	54.0	0.6	1 expired
A. grunniens	6-26-74	1	291		29.3	24.0	19.1	normal
A. grunniens	10-20-75	2	248	214-281	23.9	66.0	12.8	normal
A. grunniens[a;b]	1-6-76	1	340		12.5	36.0	1.0	1*
A. grunniens[b]	1-20-76	1	178		11.7	94.0	0.6	stressed
Carassious auratus	1-14-73	12	232	198-279	24.0	56.0	3.0	12 expired
C. auratus	8-31-73	1	302		34.3	24.5	25.0	normal
C. auratus	9-13-73	2	151	145-156	33.1	24.8	21.8	normal
C. auratus	6-21-74	3	286	258-307	28.8	28.0	17.6	normal
C. auratus	8-2-74	2	301	296-305	35.0	25.0	23.8	normal
C. auratus	1-15-75	1	209		12.5	24.3	1.5	normal
Carpiodes cyprinus	7-27-73	4	50	42-56	34.3	67.0	23.1	normal
C. cyprinus	10-7-75	1	144		26.0	24.0	14.9	normal

TABLE #6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
			Mean	Range				
Catostomus commersoni	10-6-75	1	140		26.0	68.0	14.8	normal
C. commersoni	11-14-75	1	208		22.1	24.0	11.0	normal
C. commersoni	12-5-75	2	165	155-174	14.6	25.0	3.4	normal
C. commersoni[a]	2-3-76	3	158	146-177	11.6	62.0	0.5	normal
C. commersoni	3-23-76	5	160	143-179	14.7	29.0	4.5	normal
C. commersoni	4-15-76	3	160	150-167	19.6	24.0	8.5	normal
C. commersoni	4-27-76	1	394		20.7	24.0	10.1	normal
Cyprinus carpio	3-27-73	2	296	265-327	20.0	100.0	5.0	normal
C. carpio	3-28-73	1	337		17.5	28.0	4.4	normal
C. carpio	6-25-73	1	270		33.4	48.0	21.5	normal
C. carpio	7-27-73	2	62	53-71	34.3	67.0	23.1	normal
C. carpio	2-28-74	1	326		12.0	31.5	0.9	normal
C. carpio	7-12-74	2	262	241-283	33.8	71.0	22.8	normal
C. carpio	11-25-74	1	367		17.5	138.0	6.3	normal
C. carpio	12-23-74	1	350		14.0	72.5	2.9	normal
C. carpio	3-10-75	1	330		11.9	78.0	0.8	normal
C. carpio	4-14-75	1	336		14.6	69.8	5.0	normal
C. carpio	4-28-75	1	395		18.8	116.5	7.0	normal
Dorosoma cepedianum	10-18-73	2	175	175-175	27.0	24.0	15.5	normal
D. cepedianum	10-24-73	2	168	162-173	26.8	24.0	15.9	normal
D. cepedianum	11-19-73	2	160	157-163	19.3	117.5	8.0	normal

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
Dorosoma cepedianum	11-21-73	3	149	145-155	18.0	119.0	7.7	normal
D. cepedianum	11-26-73	2	137	132-142	18.8	119.5	7.6	normal
D. cepedianum	12-21-73	5	134	120-151	12.1	56.5	1.0	stressed
D. cepedianum	12-26-73	2	129	115-156	13.0	53.0	0.1	stressed
D. cepedianum	11-19-74	9	151	135-178	19.0	28.0	8.0	4 expired
D. cepedianum	12-3-74	11	127	96-169	14.6	24.0	3.4	2*
D. cepedianum	12-30-74	1	129		11.4	94.3	3.0	expired
D. cepedianum	10-8-75	2	168	161-175	26.8	24.0	15.7	normal
D. cepedianum	10-8-75	2	117	111-123	26.8	24.0	15.7	normal
D. cepedianum	10-17-75	9	102	96-108	25.2	25.0	14.1	normal
D. cepedianum	10-31-75	6	141	133-149	22.3	24.0	11.2	normal
D. cepedianum	11-5-75	8	185	173-197	23.0	26.0	11.9	normal
D. cepedianum	11-5-75	7	99	89-104	23.0	26.0	11.9	normal
D. cepedianum	11-6-75	6	110	105-117	23.0	24.0	11.9	normal
D. cepedianum	11-6-75	6	104	95-115	23.0	24.0	11.9	normal
D. cepedianum	11-8-75	6	106	96-113	23.8	26.0	12.7	normal
D. cepedianum	11-8-75	6	147	132-161	23.8	26.0	12.7	normal
D. cepedianum	12-8-75	6	128	121-133	14.9	66.0	3.5	3*
D. cepedianum	12-15-75	5	122	108-134	14.7	72.0	3.6	normal
D. cepedianum[a,b]	1-3-76	2	155	148-162	9.0	26.0	1.5	4*
D. cepedianum[a,b]	1-29-76	3	129	122-136	12.6	24.0	1.2	5*
D. cepedianum[a,b]	1-30-76	1	151		12.6	28.0	1.5	normal

TABLE 6

TABLE
RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
			Mean	Range				
Ichthyomyzon unicuspis	12-4-72	1	305		15.0	28.0	4.4	normal
Ictalurus melas	4-19-76	2	221	215-226	23.0	71.0	12.0	normal
I. natalis	1-28-76	1	151		12.6	48.0	1.5	normal
I. nebulosus	7-72	3			31.0		23.5	normal
I. nebulosus	7-15-76	3	25		34.0	53.0	23.0	normal
I. nebulosus	12-31-74	3	175	152-192	12.0	113.0	1.0	normal
I. nebulosus	2-3-75	1	297		12.5	74.5	1.0	normal
I. nebulosus	3-17-75	1	24.4		11.9	95.2	1.0	normal
I. nebulosus	4-11-75	3	247	227-265	14.6	24.0	3.5	normal
I. nebulosus	4-14-75	2	25.0	243-256	14.9	68.5	5.0	normal
I. nebulosus	4-21-75	2	183	177-188	16.1	167.1	5.6	normal
I. nebulosus	10-27-75	2	243	226-260	24.6	72.0	12.8	normal
I. nebulosus	10-30-75	2	248	246-249	23.5	25.0	11.2	normal
I. nebulosus	1-28-76	1	208		12.6	48.0	1.5	normal
I. nebulosus	2-21-76	5	245	221-287	12.2	45.0	1.1	normal
I. nebulosus	4-16-76	4	256	237-272	20.7	29.0	9.2	normal
I. nebulosus	5-14-76	4	260	231-274	25.9	168.0	13.0	normal
I. punctatus	7-72	1			34.0		23.5	normal
I. punctatus	7-7-73	2	225	210-240	34.6	48.0	23.5	normal
I. punctatus	9-19-73	2	352	333-370	31.7	24.0	20.2	normal
I. punctatus	10-4-73	3	173	145-205	31.0	44.0	20.1	normal
I. punctatus	12-19-73	2	242	230-253	12.0	44.0	0.9	normal

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
			Mean	Range				
Ictalurus punctatus	12-22-73	2	244	240-248	12.1	21.0	1.0	normal
I. punctatus	8-7-74	1	162		33.3	41.5	23.1	normal
I. punctatus	7-29-75	1	250		35.0	24.0	24.9	normal
Labidesthes sicculus	10-15-75	9	71	62-75	26.3	24.0	15.2	normal
Lepisosteus osseus	6-26-75	2	649	616-681	34.9	25.0	23.1	normal
Lepomis cyanellus	11-19-75	1	128		20.1	24.0	9.0	normal
L. gibbosus	4-6-73	6	129	113-162	25.0	33.0	6.5	normal
L. gibbosus	7-5-74	3	158	142-164	31.3	48.0	21.7	1 expired
L. gibbosus	7-17-75	2	178	177-178	34.9	29.0	24.2	normal
L. gibbosus	11-17-75	5	57	51-63	21.0	64.0	9.2	normal
L. gibbosus	11-19-75	2	139	122-155	20.1	24.0	9.0	normal
L. gibbosus[a]	2-3-76	3	59	58-61	11.6	62.0	0.5	6*
L. gibbosus	3-25-76	6	57	51-63	16.1	43.0	4.8	normal
L. gibbosus	5-27-76	3	154	149-160	26.4	28.0	16.8	normal
L. humilis	11-26-75	4	46	41-48	18.1	25.0	7.0	normal
L. humilis	3-23-76	6	55	43-69	14.7	29.0	4.5	normal
L. macrochirus	2-20-73	10	120	89-135	27.0	40.0	12.0	normal
L. macrochirus	2-26-73	4	120	89-135	9.5	144.0	1.0	4 expired
L. macrochirus	2-26-73	6	137	132-143	27.6	70.0	12.0	normal
L. macrochirus	3-8-73	4	137	132-143	12.0	242.0	2.6	normal
L. macrochirus	7-9-74	2	156	149-163	33.3	24.0	22.7	normal

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
Lepomis macrochirus	7-18-74	2	159	139-178	34.4	24.0	23.8	normal
L. macrochirus	7-31-75	1	143		35.8	24.0	24.4	normal
L. macrochirus	8-14-75	2	151	145-157	35.8	25.0	24.8	normal
L. macrochirus	8-30-75	1	121		35.0	24.0	23.9	normal
L. macrochirus	11-1-75	2	142	127-156	21.9	24.0	10.8	normal
L. macrochirus[a]	2-25-76	2	147	114-179	12.4	24.0	1.3	stressed
L. macrochirus	3-25-76	4	118	80-175	15.6	43.0	4.8	normal
L. macrochirus	4-14-76	6	50	36-65	19.3	40.0	8.2	normal
L. macrochirus	4-27-76	3	167	151-175	20.7	27.0	10.1	normal
Micropterus dolomieui	3-2-73	2	189	188-190	12.0	56.0	1.0	normal
M. dolomieui	9-29-75	12	86	75-116	27.5	58.0	16.4	normal
M. dolomieui	10-27-75	1	259		24.6	72.0	12.8	normal
M. dolomieui	12-13-75	1	182		14.3	24.0	3.2	normal
M. dolomieui	2-26-76	1	251		14.0	24.0	1.9	stressed
M. dolomieui	4-26-76	2	240	232-248	21.5	70.0	9.6	normal
M. dolomieui	5-27-76	4	260	257-263	26.3	28.0	16.8	normal
M. salmoides	1-8-74	1	280		11.8	24.0	0.9	normal
M. salmoides	2-6-76	1	79		12.6	48.0	1.5	stressed
M. salmoides	4-12-76	1	234		19.2	73.0	7.2	normal
Minytrema melanops	7-3-74	1	255		31.1	24.0	20.2	normal
Morone chrysops	1-15-74	1	135		13.5	24.0	0.9	normal

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
Morone chrysops	11-25-74	5	118	109-132	17.5	141.3	6.3	normal
M. chrysops	2-11-75	1	104		12.8	138.7	0.8	expired
M. chrysops	10-7-75	5	129	116-145	26.0	24.0	14.9	normal
M. chrysops	11-11-75	1	213		24.2	27.0	13.1	normal
M. chrysops	12-22-75	3	139	123-158	11.3	73.0	0.2	7*
M. chrysops[b]	12-31-75	1	174		11.4	195.0	1.2	8*
M. chrysops[a,b]	1-12-76	1	159		7.0	42.0	0.5	normal
M. chrysops[a,b]	1-14-76	1	153		9.5	29.0	1.0	normal
M. chrysops	4-9-76	2	138	123-152	19.3	29.0	7.7	normal
Notemigonus crysoleucas	9-72	5	154	107-197	28.2		12.1	normal
N. crysoleucas	3-27-74	2	157	150-164	14.0	125.0	3.0	normal
N. crysoleucas	6-18-74	1	205		29.8	24.0	17.5	normal
N. crysoleucas	10-10-75	1	132		26.2	31.0	15.1	normal
N. crysoleucas	11-24-75	3	79	65-89	18.4	48.0	7.3	normal
N. crysoleucas	1-12-76	1	182		11.6	72.0	0.5	normal
N. crysoleucas	4-26-76	4	165	109-218	21.5	70.0	9.6	normal
Notropis atherinoides	1-18-73	24	91	81-110	15.6	17.0	3.9	normal
N. atherinoides	1-24-73	10	93	82-108	14.0	19.0	3.0	normal
N. atherinoides	1-22-75	5	110	105-118	12.5	24.3	0.9	normal
N. atherinoides	1-29-75	3	106	104-110	12.9	142.3	1.8	normal
N. atherinoides	4-23-75	3	105	99-111	18.1	48.3	7.0	normal
N. atherinoides	4-29-75	3	50		18.9	24.0	7.7	normal
N. atherinoides	11-24-75	3	60	55-64	18.4	48.0	7.3	normal
N. atherinoides[a,b]	2-10-76	5	94	87-98	11.6	36.0	0.5	normal
N. atherinoides[a,b]	2-25-76	9	87	69-97	15.0	24.0	1.8	stressed

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
			Mean	Range				
Notropis hudsonius	3-5-73	12	112	103-125	12.0	81.5	1.6	normal
N. hudsonius	5-4-73	7	115	106-122	21.5	72.0	11.5	normal
N. hudsonius	3-27-74	1	124		14.0	125.0	3.0	normal
N. hudsonius	12-18-74	5	107	100-113	11.2	408.0	0.1-0.5	2 expired
N. hudsonius	12-19-74	5	110	104-120	11.2	409.0	0.1-0.5	normal
N. hudsonius	12-20-74	5	107	98-113	11.1	428.0	0.0-0.5	normal
N. hudsonius	12-23-74	5	109	103-120	14.0	502.3	2.9	normal
N. hudsonius	12-26-74	6	109	100-117	13.1	574.0	2.0	2 expired
N. hudsonius	1-3-75	5	114	108-118	12.0	24.7	1.0	normal
N. hudsonius	1-3-75	5	112	102-129	12.0	25.7	1.0	normal
N. hudsonius	1-20-75	5	121	114-128	11.9	100.0	0.8	normal
N. hudsonius	1-28-75	5	118	110-134	12.1	118.3	1.0	normal
N. hudsonius	2-4-75	3	105	102-110	13.4	25.3	1.5	normal
N. hudsonius	3-12-75	3	113	110-116	12.5	147.8	1.1	normal
N. hudsonius	4-10-75	3	117	108-130	14.6	72.0	3.5	normal
N. hudsonius	4-24-75	3	107	105-109	18.8	24.1	7.7	normal
N. hudsonius	4-29-75	3			18.9	24.0	7.7	normal
N. hudsonius	10-30-75	8	110	100-118	23.5	29.0	11.2	normal
N. hudsonius	11-24-75	4	77	66-89	18.4	48.0	7.3	normal
N. hudsonius[a,b]	2-10-76	5	110	104-117	11.6	36.0	0.5	normal
N. hudsonius[a,b]	2-25-76	9	91	68-116	15.0	24.0	1.8	stressed

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
Notropis spilopterus	11-24-75	4	78	74-82	18.4	48.0	7.3	normal
Noturus flavus	10-6-75	2	197	165-229	26.0	68.0	14.8	normal
N. flavus	11-14-75	1	222		22.1	96.0	9.7	normal
N. flavus	12-8-75	2	209	202-216	15.0	66.0	3.5	normal
N. flavus	2-19-76	5	208	183-228	12.2	47.0	1.1	normal
N. flavus	3-4-76	5	216	202-226	18.0	24.0	3.8	normal
N. flavus	4-16-76	2	210	199-220	20.7	28.0	9.2	normal
Oncorhynchus kisutch	12-12-75	2	119	116-122	14.6	24.0	3.5	normal
O. kisutch	3-18-76	2	139	117-161	13.4	25.0	2.1	normal
O. kisutch	4-9-76	3	134	125-139	19.3	29.0	7.7	normal
Osmerus mordax	12-22-75	6	170	155-185	11.3	73.0	0.2	9*
O. mordax	1-14-76	7	161	136-194	12.1	28.0	1.0	normal
O. mordax	1-16-76	6	169	158-185	16.1	24.0	1.5	10*
O. mordax	1-22-76	3	160	137-175	19.0	48.0	1.5	11*
O. mordax[b]	1-27-76	4	176	162-184	19.0	24.0	0.4	12*
O. mordax[a]	2-6-76	4	188	178-200	17.3	25.0	0.9	normal
O. mordax[b]	2-13-76	3	172	164-187	19.5	46.0	1.2	13*
O. mordax[a,b]	2-19-76	5	171	162-186	17.2	24.0	1.0	normal
Perca flavescens	12-5-72	4	205	180-220	16.0	70.0	5.0	normal
P. flavescens	12-12-72	7	246	235-260	17.0	50.0	3.0	normal
P. flavescens	12-21-72	10	199	188-212	21.2	40.0	3.0	normal

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm)		Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
			Mean	Range				
Perca flavescens	12-29-72	16	182	140-218	15.0	40.0	4.0	normal
P. flavescens	1-22-74	3	266	245-284	13.0	25.0	1.0	normal
P. flavescens	1-25-74	3	237	230-250	12.1	26.8	1.2	normal
P. flavescens	3-11-74	3	250	242-257	13.9	96.0	2.8	normal
P. flavescens	6-20-74	2	225	205-244	28.7	24.0	17.8	normal
P. flavescens	10-10-75	5	102	97-107	26.2	31.0	15.1	normal
P. flavescens	11-1-75	2	237	227-246	21.9	25.0	10.8	normal
P. flavescens	11-17-75	5	99	91-107	21.0	64.0	9.2	normal
P. flavescens	12-5-75	3	99	93-108	14.5	25.0	3.4	normal
P. flavescens	12-31-75	2	111	106-115	11.4	197.0	1.2	normal
P. flavescens	5-14-76	4	126	113-143	27.7	168.0	13.0	normal
P. flavescens	5-27-76	4	192	176-209	26.4	28.0	16.8	normal
Percopsis omiscomaycus	1-16-76	1	108		11.6	24.0	0.5	normal
Pimephales notatus	2-5-75	1	96		12.1	24.5	1.0	normal
P. notatus	11-24-75	2	64	62-65	18.4	48.0	7.3	normal
P. notatus[a,b]	2-10-76	3	94	89-97	11.6	36.0	0.5	normal
P. notatus	4-14-76	6	40	28-52	19.2	40.0	8.2	normal
Pomoxis annularis	2-15-73	2	167	162-172	12.0	25.5	1.0	1 expired
P. annularis	4-23-73	6	231	217-255	20.5	58.0	9.3	normal
P. annularis	1-31-74	3	185	184-187	13.5	48.0	2.0	normal
P. annularis	2-13-74	3	234	215-244	12.5	28.5	1.0	normal
P. annularis	2-14-74	3	168	153-180	12.0	23.0	1.0	normal

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
Pomoxis annularis (YOY)	2-15-74	2	95	90-100	11.8	26.5	1.0	normal
P. annularis	11-18-74	2	174	166-183	18.0	47.3	7.0	normal
P. annularis	1-22-75	2	257	255-259	12.5	27.3	1.8	normal
P. annularis	3-17-75	1			12.0	95.0	1.0	expired
P. annularis	10-1-75	6	238	212-253	28.0	24.0	16.9	normal
P. annularis	12-9-75	1	254		14.6	24.0	4.0	normal
P. annularis	12-9-75	3	162	159-164	14.6	24.0	4.0	normal
P. annularis a,b	1-8-76	3	164	161-170	12.1	26.0	0.7	normal
P. annularis	1-23-76	6	79	73-93	11.4	27.0	0.3	14*
P. annularis	2-10-76	3	204	180-249	11.6	24.0	0.5	15*
P. annularis a,b	2-17-76	2	194	179-209	13.8	41.0	1.4	normal
P. annularis	5-7-76	6	184	165-198	25.4	24.0	10.6	normal
P. nigromaculatus	1-30-73	10	168	152-192	12.5	144.0	1.0	8 expired
P. nigromaculatus	2-27-73	2	158	155-161	13.0	24.0	2.0	normal
P. nigromaculatus	2-12-73	5	190	172-230	15.0	71.5	4.0	normal
P. nigromaculatus	4-19-73	10	210	165-244	19.0	54.0	8.3	normal
P. nigromaculatus	4-25-73	5	200	165-232	19.0	50.0	8.5	normal
P. nigromaculatus	6-4-73	7	178	155-229	26.6	40.0	16.0	normal
P. nigromaculatus	10-8-73	3	177	175-179	30.0	68.0	19.0	normal
P. nigromaculatus	12-24-73	3	198	190-210	11.8	45.4	0.8	stressed
P. nigromaculatus	3-13-74	3	216	210-223	14.0	24.0	22.9	normal

TABLE 6

RESULTS OF COLD SHOCK TESTING

Species Tested	Date	No. Tested	Length (mm) Mean	Length (mm) Range	Ambient Temp °C	Time in Ambient	Shock Temp °C	Results
Pomoxis nigromaculatus	11-1-74	3	206	197-215	23.4	23.0	12.3	normal
P. nigromaculatus	11-12-74	3			22.5	260.5	11.0	normal
P. nigromaculatus	11-15-74	2	174	166-183	21.1	45.0	7.5	normal
P. nigromaculatus	2-5-75	3	187	173-199	12.5	24.3	1.0	normal
P. nigromaculatus	2-11-75	3	163	149-179	12.2	137.5	0.8	normal
P. nigromaculatus	3-7-75	1	198		12.0	44.5	0.9	normal
P. nigromaculatus	4-11-75	1	207		14.9	24.0	3.5	normal
P. nigromaculatus	4-21-75	3	175	167-185	16.0	163.1	5.6	normal
P. nigromaculatus	4-23-75	1	159		16.6	39.8	7.0	normal
P. nigromaculatus	7-29-75	1	171		35.0	24.0	24.9	normal
P. nigromaculatus	10-1-75	6	222	193-248	28.0	24.0	16.9	normal
P. nigromaculatus	12-9-75	1	261		14.6	24.0	4.0	normal
P. nigromaculatus	12-9-75	3	140	133-149	14.6	24.0	400	normal
P. nigromaculatus	1-23-76	4	79	76-82	11.4	27.0	0.3	16*
P. nigromaculatus	2-10-76	4	169	147-203	11.6	24.0	0.5	stressed
P. nigromaculatus[a,b]	2-17-76	2	259	250-268	13.8	41.0	1.4	normal
P. nigromaculatus	3-3-76	6	200	154-233	13.8	24.0	2.6	normal
P. nigromaculatus	3-5-76	2	183	180-185	20.2	24.0	4.0	17*
P. nigromaculatus	5-7-75	6	180	145-204	25.3	24.0	10.6	normal
Salmo gairdneri	12-2-74	1	406		14.1	171.3	3.0	normal
Stizostedion v. vitreum	2-4-76	1	181		12.3	48.0	1.2	normal
S. v. vitreum	4-12-76	1	182		19.4	28.0	7.2	normal

TABLE 6 CONT.

RESULTS OF COLD SHOCK TESTING

Notes:

a No hot shock proceeded cold shock. Fish were acclimated to warmer water by placing them in aquaria at ambient lake temperature and allowing tank to slowly warm to room temperature. The final acclimation temperature was achieved and maintained through the use of a thermoregulator and one heater.

b To reduce handling stress cold shocks were initiated in the aquaria rather than transferring fish to holding tanks maintained at lake temperature. This was achieved by lowering the water level in the aquaria to approximately 1/5 normal level by use of a siphon, and the pumping in of cold water. Thus the aquaria reached lake (shock) temperature withing 15 to 20 minutes.

1* Fish in stress after 1/2 hour but regained normal activity after 7 hours
2* 1 fish died; had been seriously stressed in hot shock
3* Both fish stressed at end of first hour and died within 24 hours
4* All fish stressed by end of 1 hour and dead by end of 24 hours
5* 1 expired after 19.5 hours; 10 expired after 69 hours
6* 1 fish stressed for 5 hours before recovering; other 2 were normal
7* Fish were in extreme stress for 4 to 5 hours but eventually resumed normal activity
8* Fish began to lose equilibrium after 15 minutes; problem continued for 3 days until fish died
9* 1 fish died; others were only slightly stressed
10* 4 fish stressed after 1/2 hour; after 1 hour 5 fish normal and 1 severely stressed (later died)
11* All fish severely stressed after 1/2 hour; 2 recovered and 1 died
12* All fish heavily stressed after 2 hours; 3 recovered and 1 died
13* All fish stressed after 2 hours; 1 recovered and 2 died
14* All fish severely stressed for several hours; 2 eventually died
15* All fish stressed for 1 hour; 2 died and 1 recovered after 7 hours
16* All fish severely stressed for several hours; 1 eventually died
17* Both fish heavily stressed for several hours but had regained normal activity after 24 hours
18* 1 fish stressed; 2 fish normal

Prepared by: Jeffrey M. Reutter
Research Associate
Center for Lake Erie
Area Research

Lynwood A. MacLean
Research Associate
Center for Lake Erie
Area Research

Date: July 30, 1976

Approved by: Charles E. Herdendorf
Project Leader

Date: July 30, 1976

Approved by: ____________________
Supervisor
Lake Erie Fisheries
Research Unit

Approved by: ____________________
Supervisor
Fish Management
Section

Date: ____________________

Approved by: ____________________
Federal Aid Coordinator

Date: ____________________