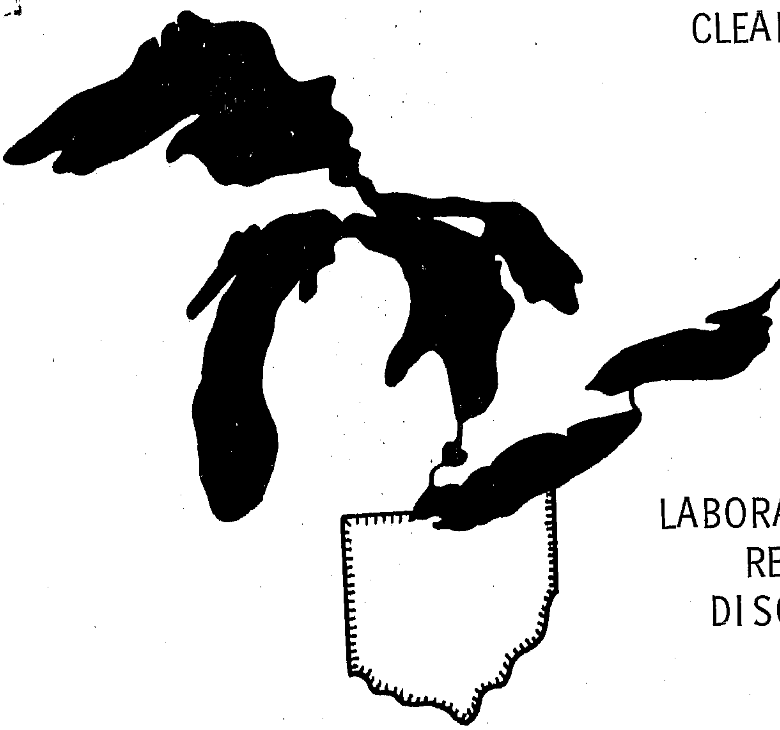
CLEAR TECHNICAL REPORT NO. 21



LABORATORY ESTIMATES OF FISH RESPONSE TO A HEATED DISCHARGE INTO LAKE ERIE WINTER

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Presented at

The Annual Meeting of the
Ohio Academy of Science
1973

CENTER FOR LAKE ERIE AREA RESEARCH
THE OHIO STATE UNIVERSITY
COLUMBUS, OHIO

1973

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INTRODUCTION

Since June 1971, The Ohio State University, in cooperation with the U.S. Fish and Wildlife Service and the Ohio Division of Wildlife, has been conducting experiments to determine the seasonal final temperature preferenda and the effects of sudden temperature changes on several species of fish that could come in contact with the thermal plume from the Davis-Besse Nuclear Power Station at Locust Point on Lake Erie. From this we hope to be able to predict, with some degree of accuracy, seasonal fish response, attraction or repulsion, to the thermal plume and to learn the potential for fish kills due to sudden temperature changes.

This paper will deal primarily with our results from the winter of 1972-1973. Results prior to June 1972 were reported by the developers of the gradient apparatus used in these experiments, Barans and Tubb (1973).

EQUIPMENT AND METHODOLOGY

Preference Testing

A horizontal temperature gradient approximately 24 m in length and 25 cm in depth was established within a wooden tank 9.72 m long, 79.0 cm wide, and 50 cm high (Barans, 1972). A system of alternating transverse baffles each 56 cm long, formed a series of 28 virtually identical compartments. This arrangement does not greatly restrict the movements of the fish. Filtered lake water was passed through 1/4 inch Tygon tubing at a rate of approximately 2 liters per minute into the cold end of the gradient. To lower the water temperature during spring, fall, and summer, the water was first routed through copper pipe in a cooling reservoir. Examinations of the water quality in the intake line and in the gradient 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 at the opposite end of the trough.

A Vicore 500 watt heater, ARC static switch relay, and corresponding Jumo thermoregulator maintained a relatively constant water temperature in the center of each compartment. By adjusting the thermal regulators a change of 0.5 – 1.0°C could be developed between compartments. Each season a different temperature range was established within the gradient. The gradient ranged from a low of several degrees below ambient lake temperature (late spring, summer and early fall) or slightly above ambient (winter), to a high of 15 – 28°C above ambient.

Aeration from three air stones in each compartment greatly reduced vertical temperature stratification and held dissolved oxygen at near saturation levels in all compartments. The water temperature at the center of every other compartment was measured with probes from a YSI multi-channel telothermometer. By moving these probes, temperatures could be obtained for every compartment.

Fish for these experiments were caught with a Fyke net near Stone Laboratory on South Bass Island. Fish for winter testing were caught in November and early December and held in 400-l holding tanks with a constant flow of lake water until ready for testing. During all other seasons fish were tested as soon as possible after capture. Fish were maintained and tested under normal seasonal photoperiods. Natural lighting from windows in the north and east walls was adequate for most observations.

In order to acquaint the fish with the gradient apparatus, 24 – 48 hours prior to testing they were placed in an acclimation tank half as long as the gradient and with the same system of baffles as the gradient, but with no heaters or thermoregulators. The water was maintained as close to ambient lake temperature as possible. The fish were then placed in the gradient compartment with the temperature closest to ambient. Fish location and behavior were observed at 2 hour intervals. The number of fish in each compartment and the temperature of that compartment were recorded and averaged to give a mean temperature preference for each observation.

The number of fish per test varied from one for large _Micropterus dolomieui_ (smallmouth bass) to 25 for _Notropis atherinoides_ (emerald shiner). The duration of the test varied from 1 – 2 days in summer to 3 – 4 days in winter. Barricades were necessary in late fall, winter and early spring to keep fish from entering warm water too rapidly and being killed. It was found that all species tested would exceed their Critical Thermal Maximum (C.T.M.), temperature at which the fish loses locomotor control, if barricades were not present. The barricades were gradually moved along as the fish became acclimated to warmer water. Fish were left in the gradient until the mean temperature preference had remained approximately constant for 24 hours.

Sudden Temperature Change Testing

Cold shock tests were conducted in a wire cage 18" x 15" x 24" lowered into a holding tank at ambient lake temperature. Fish were either taken directly from their preference compartments and placed into the cold shock cage or taken from a holding tank 11.0°C above ambient and placed into the cold shock cage. This was done to similate a plant shut-down. Fish were observed for at least 24 hours in cold shock since acclimation to cold water is slower than acclimation to warm water (Krenkel and Parker, 1969).

Hot shock tests were conducted in a 190 liter (50 gal.) glass aquarium equipped with two air stones, a Vicore 500 watt emersion heater, ARC static switch, and corresponding Jumo thermoregulator. The temperature in the tank was maintained 11.0°C above ambient. Theoretically this is the largest change that would occur in Lake Erie due to the heated discharge from the Davis-Besse Nuclear Power Station (Atomic Energy Commission, 1973).

Fish were taken directly from ambient lake water temperature and placed into the hot shock tank. This was done to simulate a fish entering the plume. They were observed for one hour, and, if normal at the end of this observation period, the heater was started and the water was warmed to the point where the fish lost locomotor control which is termed the C.T.M. of the fish. By varying the heaters and the number of heaters used the rate of temperature change could be varied, which has been reported to effect the C.T.M. (Burdick, 1969).

ANALYSIS OF RESULTS

Preference Testing

Barans and Tubb (1973) reported data on our first year of testing, June 1971 - May 1972. This paper will deal with our results from the winter of 1972-1973. Test results are shown diagramatically in Figure 1. As expected, all species tested preferred temperatures above ambient during the winter and therefore would be attracted to a warm thermal effluent. One must bear in mind that these are preliminary results and many more tests are needed to obtain the accuracy desired. The objective of this study was to obtain information on as many species as possible during a particular season of the year. However, the number of fish that can be tested in the winter is limited by the capacity of the holding tanks at our laboratory.

Sudden Thermal Change Testing

Cold shock results indicate that it is not so much the magnitude of the temperature change, but rather the absolute low temperature to which the fish is subjected that is important. Fish became more sensitive when shock temperature was below 5.0°C. In fact, in our tests no fish died from a cold shock with an absolute low temperature above 3.0°C.

Our tests show that acclimation to high temperatures is fast and to low temperatures is slow, while loss of acclimation to high temperatures is slow and to low temperatures is fast. Fast acclimation to high temperatures and fast loss of acclimation to low temperatures is shown by the rapid temperature increases (up to 9.88°C/hr) we can use in our hot shock experiments without harming the fish and by the rapid choice of temperature preferenda (usually within 3 days). Slow acclimation to low temperatures and slow loss of acclimation to high temperatures is shown by the great deal of time it takes to get a fish that has acclimated to high temperatures in the gradient back down to lower ambient temperatures safely (Table 1, Nos. 7 and 19). In all tests fish appear more stressed by a sudden temperature change to to cold water than by the corresponding change to hot water, especially when the cold water is 3.0°C or below. We, therefore, feel that winter cold shocks are potentially more dangerous than winter hot shocks.

In many tests such as those on Lepomis macrochirus (bluegill) the same fish were used in more than one shock test. The first usually involved a large temperature change from the preference of the fish down to a temperature approximately 11.0°C above ambient. Then, after being held at this temperature for a period of time, the temperature was further reduced to ambient lake temperature. Further testing is necessary, for if the fish expired in the second shock, it is possible that it was still acclimated to its preference temperature. Therefore, tests of the same magnitude on fish that had been acclimated to a temperature no greater than 11.0°C above ambient are necessary. From these results it will be possible to determine whether it was the extremely low ambient lake temperatures or slow loss of acclimation to high temperatures and, therefore, a larger temperature change that killed the fish in tests such as nos. 6 and 7 on Table 1. Test no. 9 gives inconclusive results in this matter for ambient lake temperatures had risen to 2.6°C.

Our hot shock results on 18 species of Lake Erie fish indicate that with the possibility of one exception, no harm will come to these species by swimming into the thermal plume of the Davis-Besse Nuclear

Power Station during the winter. Table 2 lists some of our results. This is in agreement with the results of Nickum (1965) who found that an increase of 20.0°F (11.1°C) has little effect on fish as long as the fish's lethal limit is not exceeded. The one exception is Notropis atheriniodes (emerald shiner), 21.7% of which died during hot shock. Additional testing is necessary because the condition of the fish was questionable since some were dying in the holding tanks. Since the C.T.M. of the emerald shiner is approximately 24.1°C, the authors feel that a healthy specimen could survive the original shock.

Table 3 gives the ranking of the specimens tested by their C.T.M. We have again observed the fact that fish are more sensitive to a sudden temperature change in spring than winter as stated by Barans (1972). See the data for Notropis atherinoides (emerald shiner) and Perca flavescens (yellow perch) to verify this. One will notice that as ambient lake temperature increases in early spring the C.T.M. decreases.

We have noticed something quite interesting in our testing for the C.T.M. Burdick (1969) stated that fish can reach a much higher temperature when the temperature is increased at a rate of 1.0°F/hr. than when it is increased at 2.0°F/hr. After we had tested Perch at a rate of increase of approximately 4.0°C/hr., we tested them at a rate of 9.88°C/hr expecting the C.T.M. to be lowered. It was not. In fact, we found no change in the C.T.M. of Perch tested in winter when the temperature was raised from 1.00 – 9.88°C/hr. The C.T.M. was raised, however, when the temperature was increased at 0.12°C/hr. Therefore, Burdick's statement was correct, but there appears to be a break-off point above which a further increase in the rate on temperature increase has no effect. For Perch, in the winter, this break-off point appears to be between 0.12°C/hr. and 1.00°C/hr. Tests on more individuals and at different times of the year are needed to give our results greater accuracy.

Much work on hot shock is needed during the summer when an 11.0°C change above ambient lake temperatures will cause considerably more stress. During the summer, the greatest potential danger should come from a hot shock rather than a cold shock, as was noted in winter.

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FIGURE 1

TEMPERATURE PREFENCES - WINTER

RANGE AND MEAN

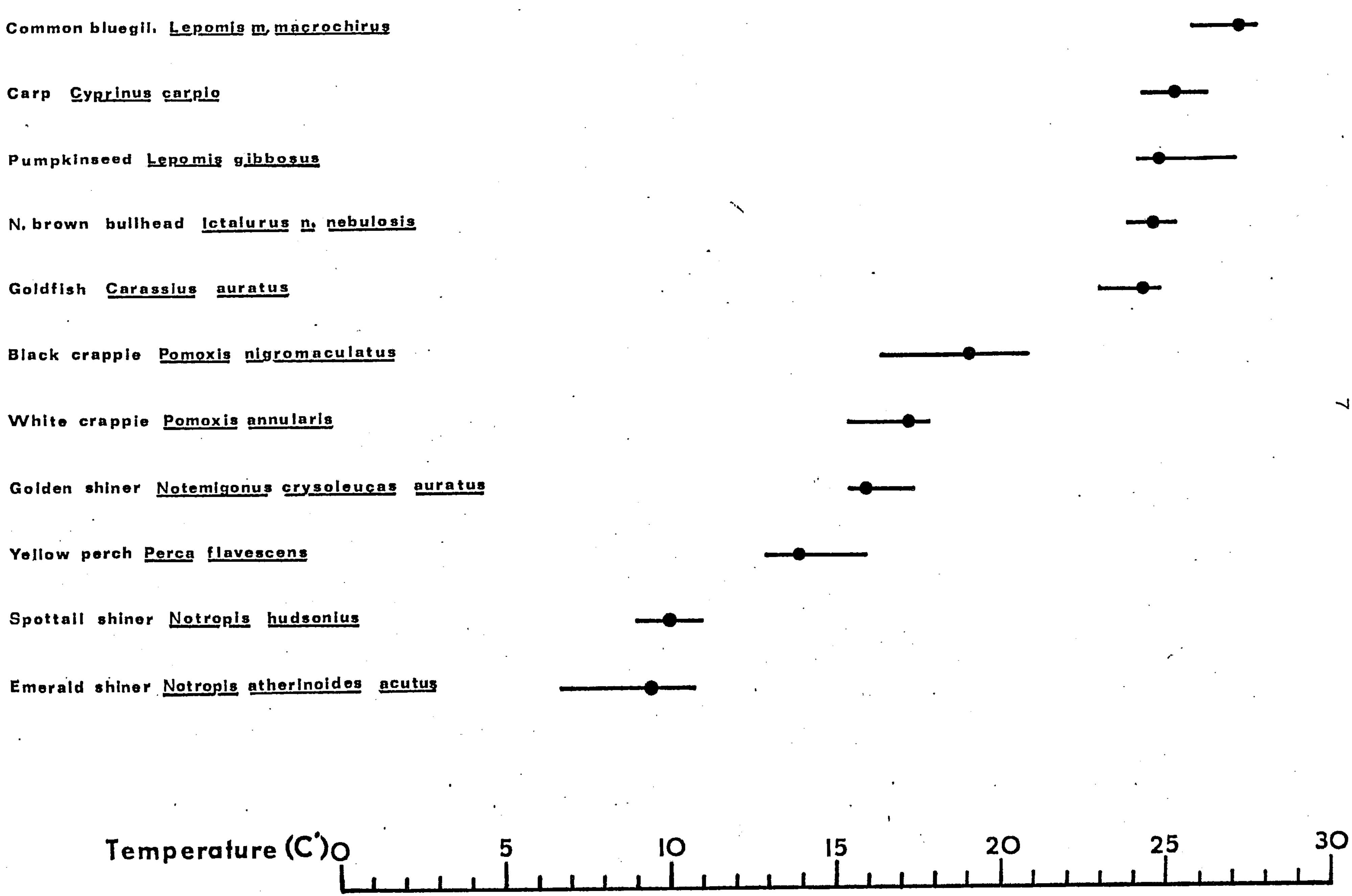

TABLE 1

COLD SHOCK EXPERIMENTS
Winter

	SPECIES	NO. IN TEST	LENGTH (CM) MEAN	RANGE	AMBIENT TEMP. C°	HELD AT AMBIENT	SHOCK TEMP. C°	COND. AFTER SHOCK
1.	*Carassuis auratus*	12	23.2	19.8-27.9	24.0°	56.0 hrs	3.0	12 EXPIRED
2.	*Cyprinus carpio*	2	29.6	26.5-32.7	20.0	100.0	5.0	NORMAL
3.	*C. carpio*	1	33.7		17.5	124.0	4.4	NORMAL
4.	*Ichthyomyzon unicupis*	1	30.5		15.0	28.0	4.4	NORMAL
5.	*Lepomis gibbosus*	6	12.9	11.3-16.2	25.0	33.0	6.5	NORMAL
6.	*Lepomis macrochirus*	10	12.0	8.9-13.5	27.0	40.0	12.0	NORMAL
7.	*L. macrochirus*	4	12.0	8.9-13.5	9.5	144.0	1.0	9 EXPIRED
8.	*L. macrochirus*	6	13.7	13.2-14.3	27.6	70.0	12.0	NORMAL
9.	*L. macrochirus*	4	13.7	13.2-14.3	12.0	242.0	2.6	NORMAL
10.	*Micropterus dolomieui*	2	18.9	18.8-19.0	12.0	56.0	1.0	NORMAL
11.	*Notropis atherinoides*	10	9.3	8.2-10.8	14.0	19.0	3.0	NORMAL
12.	*N. atherinoides*	24	9.1	8.1-11.0	15.6	17.0	3.9	NORMAL
13.	*Notropis hudsonius*	12	11.2	10.3-12.5	12.0	81.5	1.6	NORMAL
14.	*Perca flavescens*	4	20.5	18.0-22.0	16.0	70.0	5.0	NORMAL
15.	*P. flavescens*	7	24.6	23.5-26.0	17.0	50.0	3.0	NORMAL
16.	*P. flavescens*	10	19.9	18.8-21.2	21.2	40.0	3.0	NORMAL
17.	*P. flavescens*	16	18.2	14.0-21.8	15.0	40.0	4.0	NORMAL
18.	*Pomoxis annularis*	2	16.7	16.2-17.2	12.0	25.5	1.0	1 EXPIRED
19.	*P. nigromaculatus*	10	16.8	15.2-19.2	12.5	144.0	1.0	8 EXPIRED
20.	*P. nigromaculatus*	2	15.8	15.5-16.1	13.0	24.0	2.0	NORMAL
21.	*P. nigromaculatus*	5	19.0	17.2-23.0	15.0	71.5	4.0	NORMAL

TABLE 2

HOT SHOCK EXPERIMENTS
Winter

SPECIES TESTED	NO. IN TEST	LENGTH (CM) MEAN	RANGE	TEMP. C° AMBIENT	SHOCK	COND. AFTER SHOCK	TEMP. INC. AFTER SHOCK C°/HR	CRITICAL THERMAL MAX. C°
Ambloplites r. rupestris	1	20.3		2.9	13.6	NORMAL	3.11	24.5
A. r. rupestris	1	13.3		5.6	16.6	NORMAL	4.48	24.8
Carassuis auratus	2	11.0	10.0-11.9	3.2	13.8	NORMAL	7.40	29.2
Carpiodes cyprinus	1	36.3		3.2	14.3	NORMAL	3.30	28.2
Catostomus c. commersoni	1	14.5		3.0	14.0	NORMAL	3.61	25.4
Cyprinus carpio	1	35.5		3.8	14.8	NORMAL	3.36	30.5
C. carpio	1	38.0		1.5	12.5	BETTER	3.43	22.8
C. carpio	1	42.2		1.0	12.5	NORMAL	3.73	29.0
C. carpio	1	36.2		1.1	11.1	NORMAL	3.46	29.2
C. carpio	1	36.4		6.0	17.0	NORMAL	3.38	30.5
Ichthyomyzon unicuspis	1	30.5		4.5	15.5	NORMAL	9.94	31.6
Ictalurus nebulosis	1	18.5		1.2	12.2	NORMAL	7.23	27.9
Lepomis humilis	1	15.6		5.6	16.6	NORMAL	26.0	4.52
Micropterus dolomieui	2	18.9	18.8-19.0	4.8	16.0	NORMAL	4.00	28.0
Notemigonus crysoleucas	3	18.3	17.3-20.1	2.0	13.0	NORMAL	3.46	26.2
Notropis atherinoides	7	9.1	8.3-10.5	1.0	12.0	NORMAL	8.47	24.0
N. atherinoides	6	9.0	8.0- 9.7	1.1	12.1	1 EXPIRED	3.57	24.0
N. atherinoides	5	9.0	8.2- 9.6	2.6	13.6	3 EXPIRED	7.56	20.5
N. atherinoides	5	9.7	9.1-10.5	1.5	12.5	1 EXPIRED	7.27	24.3
Noturus flavus	1	19.5		1.6	12.8	NORMAL	3.69	26.6
N. flavus	1	21.0		1.6	12.8	NORMAL	3.28	29.0

TABLE 2

HOT SHOCK EXPERIMENTS
Continued

SPECIES TESTED	NO. IN TEST	LENGTH (CM) MEAN	RANGE	TEMP. C° AMBIENT	SHOCK	COND. AFTER SHOCK	TEMP. INC. AFTER SHOCK C°/HR	CRITICAL THERMAL MAX. C°
Perca flavescens	4	19.5	17.6-21.7	1.0	12.2	NORMAL	3.83	26.9
P. flavescens	1	26.0		1.0	12.7	NORMAL	3.51	25.0
P. flavescens	3	24.5	23.7-26.0	1.5	12.5	NORMAL	3.53	25.4
P. flavescens	3	24.2	23.5-25.5	1.0	12.1	NORMAL	3.36	26.0
P. flavescens	3	20.5	19.9-21.4	1.6	12.7	NORMAL	9.00	26.00
P. flavescens	4	20.1	19.6-20.5	1.5	12.6	NORMAL	9.88	26.4
P. flavescens	2	19.65	19.6-19.7	1.5	12.5	NORMAL	2.05	25.3
P. flavescens	3	18.4	17.3-19.1	1.0	12.0	NORMAL	0.12	29.7
P. flavescens	3	20.4	20.1-20.9	1.1	12.0	NORMAL	1.00	25.7
P. flavescens	2	18.2	17.9-18.5	1.6	12.6	NORMAL	7.80	24.3
P. flavescens	2	17.25	17.2-17.3	2.2	13.2	NORMAL	7.60	24.0
P. flavescens	3	16.3	14.2-18.5	2.6	13.6	NORMAL	6.27	23.5
Percopsis omiscomaycas	2	10.1	8.9-11.3	1.7	12.8	NORMAL	3.96	22.9
Pimephales notatus	3	9.3	9.2- 9.4	6.0	17.0	NORMAL	4.04	27.8
Pomoxis annularis	2	25.5	24.9-26.0	5.0	16.0	NORMAL	3.50	23.0
Pomoxis nigromaculatus	3	9.3	9.1- 9.5	3.4	14.4	NORMAL	3.68	24.3
P. nigromaculatus	2	6.65	6.2- 7.1	3.4	14.4	NORMAL	3.99	23.1
P. nigromaculatus	2	18.6	17.4-19.8	1.0	12.7	NORMAL	3.68	22.4
P. nigromaculatus	2	17.45	17.4-17.5	3.5	15.0	NORMAL	3.62	23.4
P. nigromaculatus	2	15.8	15.5-16.1	2.8	13.8	NORMAL	3.88	23.5
P. nigromaculatus	5	16.5	16.2-17.2	11.3	11.3		2.86	33.5
P. nigromaculatus	1	16.0		3.0	14.0	NORMAL	3.67	19.5

TABLE 3

CRITICAL THERMAL MAXIMUMS

WINTER

	SPECIES	C.T.M. (°C)
1.	*Ichthyomyzon unicuspis*	31.6
2.	*Cyprinus carpio*	29.8
3.	*Carassius auratus*	29.2
4.	*Carpiodes cyprinus*	28.2
5.	*Micropterus dolomieui*	28.0
6.	*Ictalurus nebulosis*	27.9
7.	*Noturus flavis*	27.8
8.	*Pimephales notatus*	27.8
9.	*Notemigonus crysoleucas*	26.2
10.	*Lepomis humilis*	26.0
11.	*Perca flavescens*	25.8
12.	*Catostomus c. commersonii*	25.4
13.	*Osmerus eperlanus*	24.9
14.	*Ambloplites rupestris*	24.7
15.	*Notropis atherinoides*	23.7
16.	*Pomoxis nigromaculatus*	23.4
17.	*Pomoxis annularis*	23.0
18.	*Percopsis omiscomaycus*	22.9