BODY TEMPERATURE CHANGE OF BLUEGILL SUNFISH SUBJECTED TO THERMAL SHOCK

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A MAJOR PROBLEM in the assessment of the effects of heated effluents on fish distribution is the determination of residency time of the fish in the thermal plumes. Gross [2] stated that "it is possible to estimate a fish's residence time in heated effluents through comparing its internal temperature with the ambient and discharge temperatures." Spigarelli [4] also indicated that an examination of body temperatures was a reasonable method to determine residency time. This investigation was initiated to determine the feasibility of using such a technique to analyze transiency and residency of fish in a heated effluent located on the New River at Glen Lyn, Virginia, and was designed to test Gross' [2] and Spigarelli's et al. [4] hypothesis.

MATERIALS AND METHODS

Appalachian Power Company's fossil fuel plant at Glen Lyn, Virginia, discharged heated water approximately 7.8° C (14° F) above ambient river temperatures [5]. Comparable conditions were established in aquariums in order to determine if body temperature analysis would be useful in evaluating fish residence time in thermal plumes.

Body temperature was measured with a temperature sensitive radio transmitter (length = 14.2 mm; diameter = 8.5 mm; weight = 1.5 g) inserted into a fish. Insertion into the body cavity by means of an incision proved to be unsatisfactory as there was some direct contact between the transmitter and the water. Therefore, the transmitter was inserted through the mouth and into the stomach. Following this, the fish were placed in an aquarium for 24 hours to check the condition of the fish and to permit the establishment of temperature equilibrium between internal temperature and surrounding water.

The body temperature monitoring apparatus consisted of a strip recorder, timer, temperature sensitive transmitter, and transistor radio. Impulses sent by the transmitter were picked up on an unused AM band, and recorded on the strip chart. Impulse frequency was related to temperature. A timer was used to mark 1-second, 10-second, and 1-minute intervals. By using both the timer and strip chart, the change in frequency, and therefore the change in body temperature could be calculated. The transmitter markedly reduced lag time in information generation.

Fish acclimated at one temperature were immediately exposed to another temperature, and the time required for the internal body temperature to reach equilibrium with the new environmental temperature was recorded. Eight bluegills were exposed to each of four different experimental conditions: (1) Acclimation temperature +5.5° C (10° F); (2) acclimation temperature +8.3° C (15° F); (3) ac-

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climation temperature +11.1° C (20° F); and (4) acclimation temperature −11.1° C (20° F). Three fish were then killed and exposed to acclimation temperature +11.1° C, and to acclimation temperature −11.1° C. Length, weight, and condition factor ($K = W/L^3 \times 10^2$) were compared against time to reach equilibrium with environmental temperature, using a Spearman's rank correlation procedure [*1*].

RESULTS AND DISCUSSION

The results indicated that the internal body temperature of the bluegill sunfish reached thermal equilibrium too rapidly to be of practical use in determining residency time (table 1). The Spearman's rank correlation coefficient indicated that there was no significant correlation when length, weight, or condition factor was compared against the time for the body temperature to reach equilibrium with the surrounding water. The results of the Spearman's rank correlation test for one experimental condition for the live fish [acclimation temperature to acclimation temperature +11.1° C] are given in table 2. In all cases, it took longer for dead fish to reach thermal equilibrium with the environment than it did when they were alive. The probable reason for this is the heat transfer by the counter-current exchange system of the gills [*3*]. Although its primary function is thought to be the enhancement of gas exchange, it must also act as an excellent heat exchanger when blood is flowing through the gills of a live fish. Therefore, factors which influence blood flow rate, such as feeding and swimming activity, may affect the rate of heat transfer. These data do not support the hypothesis proposed by Gross [*2*] and Spigarelli et al. [*4*] who stated that heating rates "are somewhat dependent on size in thick-bodied fish." Our data suggest that differences in body temperature and ambient water temperature are of little value in determining residency time in a thermal plume.

Table 2.—Spearman's rank correlation coefficient for the fish exposed to acclimation temperature to acclimation temperature +11.1°C (20° F)

[Number in parenthesis denotes probability r under $HO{:}RHO = 0$ ($N = 8$)]

	Weight	Length	Time	Condition factor
Weight	1.0 (0)			
Length	.98 (0)	1.0 (0)		
Time	−.27 (0.53)	−2.46 (0.56)	1.0 (0)	
Condition factor	.47 (0.23)	.32 (0.56)	−.22 (0.61)	1.0 (0)

It is interesting to note that in experiments with both the live and dead fish, it took longer for the internal body temperature to reach equilibrium when body temperature was higher than environmental temperature than when it was lower.

CONCLUSIONS

1. The lack of significant correlation between length, weight, and condition factors, and time to reach equilibrium with environmental temperature suggested that heating rates are not dependent solely upon the weight or body thickness of the fish.

Table 1.—The time, expressed in seconds, for internal body temperature to reach thermal equilibrium

Weight (g)	Length (mm)	Condition factor	Acc. to Acc. + 10 (sec) 5.5°C (10°F)	Acc. to Acc. + 15 (sec) 7.8°C (15°F)	Acc. to Acc. + 20 (sec) 11.1°C (20°F)	Acc. to Acc. − 20 (sec) 11.1°C (20°F)	Acc. to Acc. + 20[1] 11.1°C (20°F)	Acc. to Acc. − 20[1] 11.1°C (20°F)
236.6	22.5	2.08	360	480	450	540	—	—
115.6	18.0	1.98	360	390	420	570	—	—
124.1	18.5	1.96	300	390	420	450	—	—
124.5	19.0	1.82	300	390	510	510	—	—
131.4	18.5	2.07	360	330	510	540	—	—
138.0	19.0	2.01	330	390	480	540	630	810
109.0	17.5	2.03	330	390	510	570	660	810
108.4	18.0	1.86	360	390	510	480	660	780

[1]Denotes dead fish.

2. The difference in time to reach equilibrium with environmental temperature between live fish and dead fish suggested that blood flow rate may be an important factor in determining heat exchange.

3. More time was required for the fish to reach equilibrium with environmental temperatures when exposed to temperatures below acclimation, than when exposed to temperatures above acclimation.

4. This study indicates that it may be inaccurate to base residency time of the fish in the plume on the relationship of its internal temperature with the ambient and discharge temperature as suggested by Gross [2] and Spigarelli et al. [4] since the time to temperature equilibrium is influenced by the activity of the fish via its rate of blood flow.

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