J. Great Lakes Res. 23(4):468–471
Internat. Assoc. Great Lakes Res., 1997

NOTE

The Effect of Temperature on Growth of Juvenile Bloater

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ABSTRACT. *The bloater (*Coregonus hoyi*), which feeds mainly on invertebrates and in turn is eaten by lake trout (*Salvelinus namaycush*) and burbot (*Lota lota*), is a major trophic integrator in coldwater ecosystems in the upper Great Lakes. To better understand their thermal niche and habitat distribution, we acclimated groups of yearling bloater to 3, 5, 10, 15, 20, or 25°C and then fed them* ad libitum *for 35 days. Bloater increased in length and weight at all of the test temperatures and at the end of the study were heaviest and longest at 15–20°C. The specific growth rate was highest at 20°C and progressively lower at 15, 25, 10, 5, and 3°C. A curve fitted to the specific growth rate data indicated that the optimum temperature for growth was 18.6°C. Our results are in agreement with other published information on the thermal ecology of juvenile bloater.*

INDEX WORDS: *Bloater, optimum temperature, fish, growth.*

INTRODUCTION

The bloater (*Coregonus hoyi*) is one of a group of ciscoes that was historically abundant in the Great Lakes (Scott and Crossman 1973). These fish, which fed mainly on invertebrates and in turn were a major food of lake trout (*Salvelinus namaycush*) and burbot (*Lota lota*), were the major trophic integrator between the top and the bottom of the food chain in Great Lakes coldwater ecosystems. Overfishing and predation by exotic fishes (Smith 1968), probably followed by introgressive mating of the remnant stocks (Baily and Smith 1981), caused extinction of several species of deepwater ciscoes. The bloater is now the dominant surviving member of the group (Baily and Smith 1981) and in Lake Michigan where it is abundant (Rudstam *et al.* 1994) is still a major item in the diet of lake trout and burbot (Fratt *et al.* 1997).

We performed this study to describe the optimum temperature for growth of yearling bloater. Knowledge of the optimum temperature for growth of a fish species can be used with free-ranging populations to predict or explain distribution and habitat use (Crowder and Crawford 1984, Edsall *et al.* 1993), estimate potential commercial yield (Christie and Regier 1988), and develop energetics models and estimate forage requirements (Stewart *et al.* 1983, Binkowski and Rudstam 1994, Rudstam *et al.* 1994).

METHODS

Bloater used in this study were reared from eggs taken from spawners captured in February in Lake Michigan, 7–8 km east of Kenosha, Wisconsin. The eggs were artificially fertilized in the field and taken to the laboratory where they were incubated in flowing water at 5 to 6°C until they hatched. The young bloater were held in the laboratory at temperatures that varied seasonally from about 10°C in summer to about 8°C in late February of their 2nd year of life. In late February, yearling bloater from

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this laboratory stock were placed in groups of 100 in 12, 30-L fiberglass test tanks at 10°C; they were held for 1 week at 10°C, and then acclimated over 2 weeks to test temperatures of 3, 5, 10, 15, 20, or 25°C. Two tanks of fish were acclimated to each test temperature. Each test tank was equipped with a thermostatically controlled heater that maintained acclimation and test temperatures within 0.1°C of the desired temperature. Temperature was measured daily to the nearest 0.1°C in each test tank and thermostats were adjusted as needed to reach or maintain the desired temperature. Water temperature during the 2-week acclimation period was raised or lowered at different rates in each tank (maximum rates of change varied from about +1.0 to −0.5°C · day^{-1}), so that all test groups reached their final acclimation temperature (i.e., test temperature) on the same day. A water flow of about 1.0 L · min^{-1} was maintained in each tank and continuous aeration was provided by compressed air released through an air stone. Dissolved oxygen was measured with a YSI model 54-A oxygen meter[1]; three measurements were made in each tank at 3 to 5°C and seven in each tank at 20 and 25°C. The level of dissolved oxygen was maintained at 82 to 92% of saturation at 3 to 10°C and 72 to 86% at 15 to 25°C during the study. Test fish were fed *ad libitum* six times daily during the study with floating cubes of plankton frozen in water, live *Artemia naupli*, and commercial trout food (Oregon Moist and Purina trout chow). Mortality was recorded daily.

Eighty-nine fish from the stock tank that provided the test fish were anesthetized, measured individually (total length) to the nearest millimeter, and weighed as a group to the nearest 0.01 g, midway through the acclimation period (i.e., 1 week before the final acclimation or test temperatures were reached). We had planned to measure and weigh each group of test fish at the end of the acclimation period, but high handling mortality among the 89 fish we weighed and measured from the stock tank caused us to alter the study design. Instead we used the lengths and weights of the stock sample to represent the fish in the test tanks at the start of the study. All surviving fish in the test tanks were measured and weighed individually on day 35 when the study ended.

RESULTS AND DISCUSSION

Survival was 84 to 98% for fish at 3 to 15°C, 75 and 80% at 20°C, and 24 and 37% at 25°C (Table 1). Markedly lower survival is to be expected at temperatures close to the ultimate upper lethal temperature (UULT)—"the temperature beyond which no increase in lethal temperature results from further increase in acclimation temperature"(Fry *et al.* 1946). The UULT for yearling bloaters is 26.7°C (Edsall *et al.* 1970). A similar decrease in survival at temperatures approaching the UULT was demonstrated for larval lake herring (*C. artedi*) by McCormick *et al.*(1971).

Bloater increased in length and weight at all of the test temperatures (Table 1). At the end of the study bloater were heaviest and longest at 15 to 20°C. The length-to-weight ratio was identical in each pair of tanks at a given temperature and increased from 0.002 at 3°C to 0.007 at 20°C and then fell to 0.003 at 25°C (Table 1). Thus, fish were largest and most robust at 20°C. The specific growth rate was highest at 20°C and progressively lower at 15, 25, 10, 5, and 3°C (Table 1). A curve fitted by spline function (SlideWrite for Windows, Version 4) to the specific growth rate data indicated that the optimum temperature for growth in weight at *ad libitum* feeding was about 18.6°C (Fig. 1) and that the fundamental thermal niche (FTN)—"the optimum temperature (+1 and −3°C) for growth in weight" (Christie and Regier 1988)—was about 15.6 to 19.6°C. A growth optimum of 18.6°C indicates yearling bloater are temperate stenotherms (Hokanson 1977), as are other coregonines, trout, and salmon.

There are no published estimates of the optimum temperature for growth or FTN for bloater, but Crowder and Crawford (1984) showed that yearling bloater (80 to 145 mm, fork length) in Lake Michigan in late August to early September were caught at 3 to 18°C and were most abundant at 11 to 14°C. Yearlings smaller than 100 mm were represented only in catches made at 15 to 18°C and the smallest individuals occurred only at 17 to 18°C. The catches of yearlings at temperatures lower than 15°C were dominated by progressively larger individuals. The yearlings Crowder and Crawford (1984) caught at 17 to 18°C were most similar in size to yearlings we tested in the present study, which lends support to our finding of a growth optimum at 18.6°C, and thus, a FTN at 15.6 to 19.6°C for bloater of this size. Further support for our finding was provided by Binkowski and Rudstam

1 Mention of trade names or manufacturers does not imply U.S. government endorsement of a commercial product.

TABLE 1. Survival and growth of groups of 100 yearling bloater fed **ad libitum** *at different constant temperatures for 35 days. Mean wet weight and mean total length of 89 fish at the start of the study was 59.0 mm and 0.113 g.*

Nominal temperature (C)	Survival (%)	Total length (mm) at end of study Mean	SD	Wet weight (g) at end of study Mean	SD	Weight to length ratio	Specific growth rate
3	91	64.5	7.1	0.145	0.051	0.002	
	92	63.3	5.8	0.133	0.041	0.002	0.61
5	98	66.7	7.5	0.168	0.061	0.003	
	97	66.6	7.4	0.166	0.061	0.003	1.15
10	89	79.2	7.5	0.309	0.098	0.004	
	94	79.2	8.0	0.309	0.115	0.004	2.96
15	84	88.6	8.0	0.515	0.149	0.006	
	90	90.5	8.8	0.531	0.181	0.006	4.51
20	80	91.3	8.8	0.589	0.186	0.007	
	75	94.3	7.4	0.640	0.158	0.007	4.98
25	37	70.5	7.7	0.231	0.094	0.003	
	24	70.8	6.4	0.210	0.062	0.003	1.97

Specific growth rate (Ricker 1979) = (log e W2 – log e W1)/(t2 - t1) × 100, where W2 = the mean wet weight at the start of the study (t1 = day 1) and W2 = the weighted mean wet weight at the end of the study (t2 = day 35) for paired groups of fish held at the same constant temperatures.

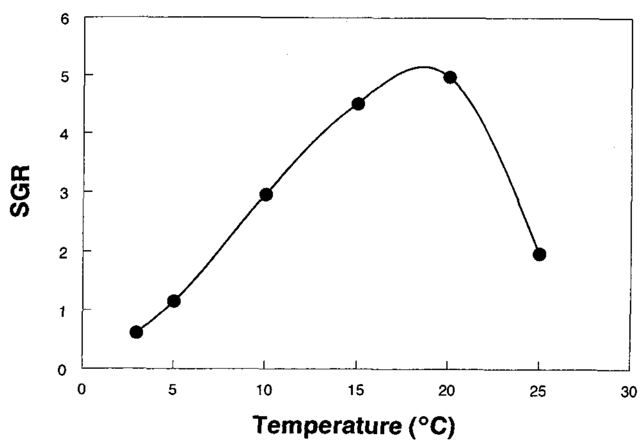

FIG. 1. Specific growth rate (SGR) of yearling bloater fed **ad libitum** *at various constant temperatures for 35 days.*

(1994), who determined that the optimum temperature for food consumption for bloater—which is generally close to the optimum temperature for growth in fishes (Jobling 1981)—was about 17°C.

The ontogenetic differences in thermal (and depth) niche use by bloater observed by Crowder and Crawford (1984) suggest that the optimum temperature for growth of adult bloater is substantially different from that of younger cohorts. However, alternative explanations based on diel vertical migration of adults into warmer water, or on spatial-temporal differences in the availability of invertebrates that are the major food of adult bloater, are perhaps equally valid. Laboratory study of the optimum temperature for growth of adult bloater, perhaps coupled with stable isotope analysis of the scales of juvenile and adult bloater, could further advance our understanding of thermal habitat use and energetics of this important forage species.

ACKNOWLEDGMENTS

This is contribution 993 of the Great Lakes Science Center, 1451 Green Road, Ann Arbor, Michigan 48105.

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