Smallmouth Bass Habitat Use and Movement Patterns with Respect to Reservoir Thermal Structure

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Abstract: Temperature-sensing ultrasonic transmitters were implanted in adult smallmouth bass (*Micropterus dolomieu*) in thermally stratified Melton Hill Reservoir, Tennessee, to monitor daily summer movement. Based on energetic expectations and preferred temperatures, smallmouth bass were expected to inhabit areas with optimal temperatures except when food availability required them to move to areas of less-desired temperatures to feed. No significant changes in temperature or depth were observed during daily tracking sessions. Instead of demonstrating diel offshore/inshore movements, the fish remained in relatively warm (>28 C) water even though cooler water was available. While in warm shallow habitats, tagged fish were often associated with submerged or overhead cover. Smallmouth bass activity peaked in the afternoon and was minimal at night.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 49:240–249

Levels of preference and avoidance for many habitat variables have been described for several fish species. These characteristics supposedly describe the ideal habitat for a species. For example, previous studies suggest that ideal habitat qualities for lake-dwelling adult smallmouth bass are low turbidity, rock or gravel substrate, 21–26 C temperature, abundant cover (e.g., tree stumps, fallen trees, rock ledges, and boulders), and abundant food (e.g., small fish and crayfish) (Coble 1975, Coutant 1975, Miller 1975). Realistically, however, these ideal components are rarely found in the same place simultaneously. In any 1 habitat, some variables may be within this ideal or preferred range while others may occur only within a broader acceptable range. When different combinations of optimal and sub-optimal features are present, the mechanisms of habitat selection become more complex.

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[2] Managed by Lockheed Martin Energy Research, Inc. under contract No. DE-AC05-96OR22464 with the U.S. Department of Energy.

Fish usually prefer a narrow range of temperatures (Reynolds 1977) where physiological processes, such as digestion, assimilation of food, and growth, are most efficient (Crawshaw 1977, Jobling 1981). Coutant (1975) and Reynolds and Casterlin (1976) summarized several studies that attempted to determine the preferred temperature of smallmouth bass. Because of such complicating factors as acclimation temperature, season, age, physical health, geographic origin, and field vs. laboratory procedures, determination of a single preferred temperature for adult smallmouth bass is not meaningful (Reynolds 1977). Ferguson (1958) documented age- and size-related differences in temperature preference. Younger fish prefer higher temperatures than older ones, which probably explains much of the variation between temperature preferences determined in the laboratory (usually for juveniles) and those observed in the field (usually for adults). Taking these factors into consideration, I assumed the preferred temperature range to be approximately 21–26 C for adult smallmouth bass.

Habitat that meets the preferred temperature requirement of adult smallmouth bass during summer in most southeastern reservoirs often occurs in deeper, offshore areas. Prey, small sunfish (*Lepomis* spp.) and crayfish, typically concentrate in shallow, near-shore areas which often exceed 30 C in midsummer. During summer stratification, smallmouth bass that select their preferred temperature would probably be separated from their prey. If so, 3 alternatives exist for habitat selection. The choice of a single habitat for smallmouth bass means either residing inshore where food is available but basal metabolic rate is high due to high temperature, or residing offshore where energetic costs are low but food is less abundant. The third alternative would be to move between habitats on a regular basis. For maximum energy gain, smallmouth bass could move to the littoral zone to feed and then offshore to cooler waters to reduce metabolic costs. Diel movement patterns for the combined purpose of feeding and thermoregulation have been attributed to several fish species (Northcote et al. 1964, Narver 1970, Brett 1971, Janssen and Brandt 1980, DeMartini et al. 1985, Wurtsbaugh and Li 1985). Emery (1973) and Helfman (1981) observed smallmouth bass moving from shallow to deeper water at night where activity slowed and eventually stopped.

The primary objective of this study was to use temperature-sensing ultrasonic transmitters to determine if smallmouth bass in Melton Hill Reservoir, Tennessee, demonstrated offshore/inshore movement patterns consistent with the reservoir thermal structure and their preferred temperature. A secondary objective was to evaluate other characteristics of smallmouth bass movement such as temporal patterns.

I thank S. M. Adams and C. C. Coutant for their critical review of the manuscript and for field assistance, and the Environmental Sciences Division of Oak Ridge National Laboratory for equipment and facilities. I also thank the Graduate Program in Ecology at The University of Tennessee-Knoxville and Oak Ridge Associated Universities for graduate assistantship and fellowship support.

Methods

Melton Hill Reservoir is a 2,270-ha mesotrophic impoundment on the Clinch River in eastern Tennessee. Built in 1966, the reservoir has mean and maximum depths of about 6 and 21 m, mean residence time of 18 days, length of 71 km, and maximum width of about 0.6 km. The study area was in the middle of the reservoir (Clinch River miles 34–40). Hypolimnetic discharge of cold water from Norris Reservoir upstream affects the thermal stratification of Melton Hill Reservoir during summer. Because this discharged water becomes well oxygenated after release, Melton Hill Reservoir offers a range of well-oxygenated thermal habitat in summer.

Ultrasonic transmitters were cylindrical (65 mm long, 16 mm in diameter) and weighed 22.5 g in air (10.2 g in water) with an 85-mm tail and thermistor that extended out of the body of the fish to measure ambient water temperature. I calibrated transmitter signals at known temperatures in the laboratory. Expected transmitter life was about 1 year. I surgically implanted transmitters into the abdominal cavity of adult smallmouth bass (560–2,130 g, 368–542 mm) during spring and summer of 1986 and 1987. Smallmouth bass were collected by electrofishing, taken to the laboratory, and held for 1–3 days before and after implantation to monitor health and recovery. After surgery, I released each fish (6 each in 1986 and 1987) where originally captured.

I tracked fish with an underwater directional hydrophone connected to a sonic receiver (Smith-Root Model TA25). Signals were received at 71, 75, or 79 kHz with transmitters of the same frequency differentiated by individual pulse codes. Ambient temperature was determined by measured intervals between signal pulses. I tested transmitters at various depths to ensure that neither depth nor temperature stratification had noticeable effects on signal reception.

Searches were initiated where a fish was last located. I first surveyed 100–300 m upstream and downstream of the last successful location, and then, if necessary, enlarged the search area in both directions and along the opposite shore. Each day a fish was located was considered 1 fix. For example, 2 fish located on the same day were 2 fixes, whereas 1 fish located twice in 1 day was just 1 fix. Each located fish was usually monitored continuously for several hours. I estimated the fish's horizontal position relative to the shoreline by triangulation, and its depth by comparison to a vertical temperature profile measured near the location with a Hydrolab Surveyor-II temperature/dissolved oxygen meter. A fish's position and temperature were recorded at 5- to 10-minute intervals when the fish was stationary, but more often (every 1–3 minutes) when moving. I collected all tracking and limnological data at a distance (>25 m) sufficient to avoid disturbing the fish. The range of temperatures and depths occupied during the day were used to indicate movement in response to reservoir thermal structure.

Fish movement was recorded on maps; linear distance moved was estimated to the nearest 5 m with the use of shore markings every 50 m. Activity

Table 1. Information for 12 smallmouth bass tracked in Melton Hill Reservoir, Tennessee with ultrasonic transmitters. Measures of activity are included only for 4 fish tracked the most in 1987.

Date released	Last fix	*N* fixes	Total time tracked (minutes)	Total time moving (minutes)	Time moving (%)	Estimated rate of movement (m/minute)	Estimated daily movement (m)	Observed shoreline range (m)
09 May 86	06 Jun 86	1	7					
09 May 86	03 Jun 86	2	56					
09 May 86	13 Jun 86	4	129					
09 May 86	09 May 86	0	0					
20 Jun 86	20 Jun 86	0	0					
06 Aug 86	06 Mar 87	8	184					
26 Jun 87	05 Aug 87	10	798	296	37	4.7	2,527	840
12 Jun 87	13 Nov 87	15	2,881	1,073	37	6.5	3,477	1,680
13 Aug 87	07 Oct 87	7	1.996	288	14	7.5	1,555	1,510
12 Jun 87	26 Jun 87	4	30					
15 May 87	27 Aug 87	19	744	124	17	3.4	825	1,000
02 Jun 87	04 Jun 87	1	39					
Average			1,605	445	28	4.2	1,243	1,258

analysis was performed on those data collected from fish that were tracked >12 hours each (Table 1). Diel patterns of activity were determined by analyzing the proportion of time spent moving and the distance traveled for each hour of the day for each fish. The distance traveled/hour was estimated as the product of the proportion of each hour spent moving and the rate of movement (m/minute) during that hour times 60. Similarly, I estimated the distance traveled/day as the product of the proportion of the day spent moving and the rate of movement (m/minute) times 1,440.

I located smallmouth bass tagged in 1986 on 11 of 19 days of tracking from 28 May to 29 October and 2 days in 1987 (Table 1). Because of equipment problems and loss of fish to anglers, data collected in 1986 were insufficient for detailed analysis.

Tracking in 1987 resulted in 56 fixes during 40 days of tracking from 18 May to 13 November (Table 1); no fish were found on 3 of those days. Fish were tracked during all hours of the day, but only 1 fish tracked on 1 occasion accounted for the time between 2300 and 0600 hours (Fig. 1). The length of time individual fish were tracked over the course of a day ranged from 5 minutes to 20 hours. Transmitters in at least 3 fish strayed from calibration by mid-summer as indicated by calculated temperatures that greatly exceeded ambient temperatures. Transmitters appeared to lose calibration gradually, and the data collected through July were considered accurate. This malfunction prevented determination of the exact temperature and depth of these fish after July, though their location could still be estimated.

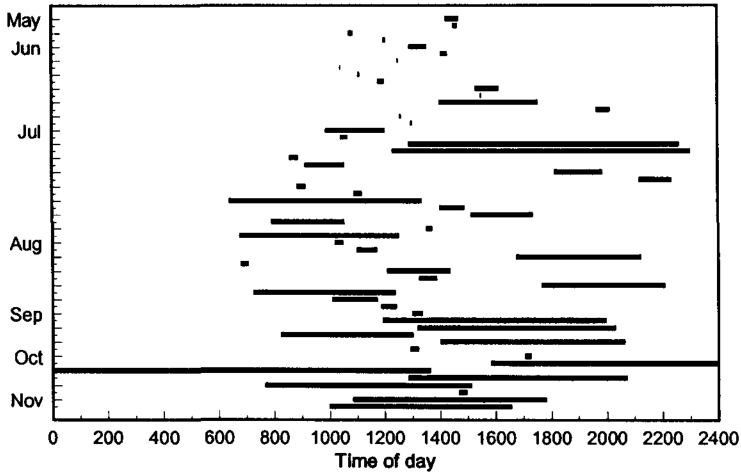

Figure 1. Length of time (hours) individual smallmouth bass were tracked in Melton Hill Reservoir, Tennessee, 1987.

Results

Limnological data collected during the study indicate summer temperatures in Melton Hill Reservoir regularly exceeded the preferred temperature of smallmouth bass (i.e., >26 C; Fig. 2). The 24-C isotherm which represents the middle of the preferred range was normally deeper than 3 m during much of the summer (Fig. 2). Temperatures were abnormally cool in the reservoir from mid-July through August 1987 compared to 1986 when temperatures were more typical. Several months of lower than average rainfall and hotter than normal air temperatures during August 1987 raised demand for electrical power and increased hydropower generation at the upstream reservoir and at Melton Hill Reservoir. The result was a greater than normal influx of cold hypolimnetic water in the study area at the hottest time of the year, and inshore surface temperature did not reach the levels expected during the hottest part of the summer. For this reason, only data collected before 17 July 1987 was included in the temperature selection analysis.

From June to mid-July 1987, I made 22 fixes on 6 fish. No significant changes in temperature or depth were observed during daily tracking sessions and, therefore, there was no indication of diel movements in response to the reservoir thermal structure. Temperatures occupied by fish were usually within 1 C of the maximum temperature available (Fig. 3), and comparison of these occupied temperatures to temperature profiles taken on those days indicated that all of the fish were in the top 1.5 m of the water column. Occupied temperatures sometimes exceeded the recorded maximum available temperature, probably a result of using offshore temperature profiles to estimate inshore temperatures. Temperature profiles measured at different distances from the shore on

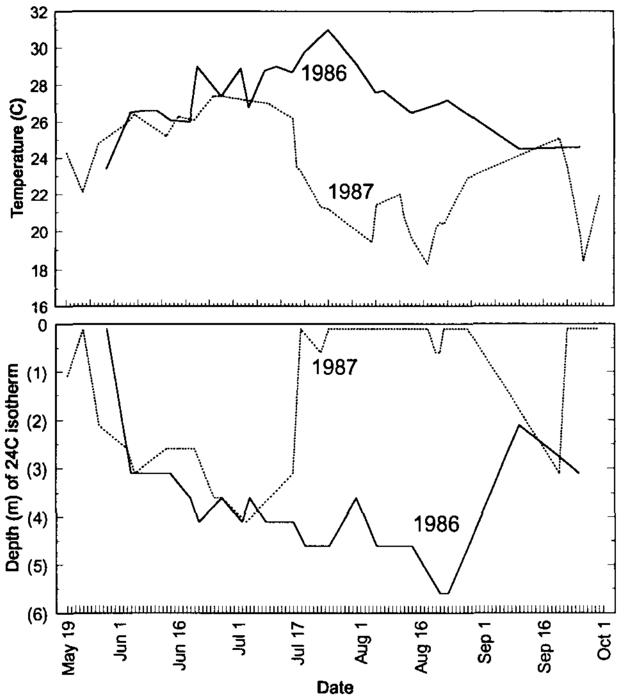

Figure 2. Summer temperatures at 1 m depth (upper panel) and the depth of the 24-C isotherm (lower panel) in Melton Hill Reservoir, Tennessee.

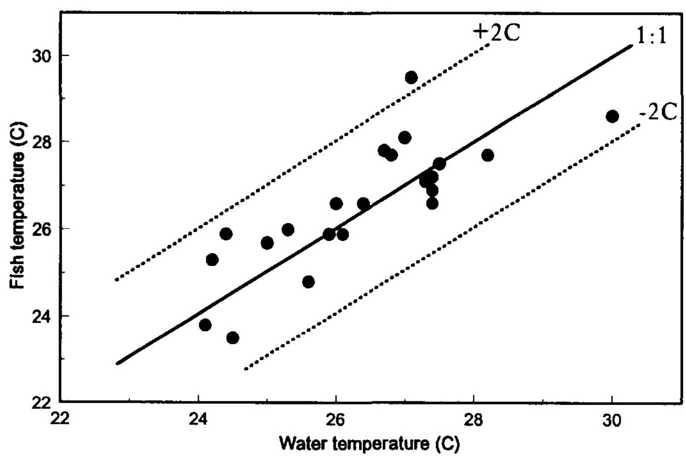

Figure 3. Relation between temperatures occupied by 6 smallmouth bass and maximum available temperatures in Melton Hill Reservoir, Tennessee, during the first month (summer 1987) after their release.

the same day and at the same time indicated that near-surface temperatures inshore differ from temperatures collected 10–100 m from shore at the same depth by up to 1.7 C. Tracked fish (including those monitored after calibration strayed) were within 3 m of the surface and 5 m of the shore most of the time regardless of the inshore temperature. The 1986 tracking, though limited, resulted in similar observations; fish were usually found in the littoral zone, even when inshore water temperatures exceeded 28 C.

When smallmouth bass were not moving, they often were associated with structures visible from the surface, including fallen trees, submerged logs, boulders, overhanging bushes, and man-made fish attractors. Except for crossings of small embayments, smallmouth bass were not found in the open water of the main channel.

Activity was analyzed for 4 fish with which I had direct tracking contact for a total of 107 hours. The proportion of the time that fish were mobile and

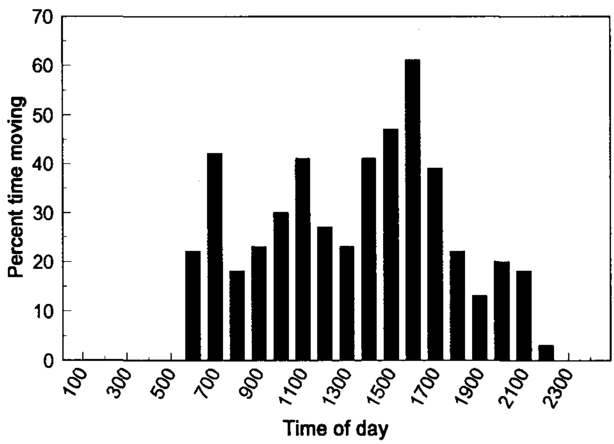

Figure 4. Average percent of each hour of the day that 4 smallmouth bass were moving, Melton Hill Reservoir, Tennessee.

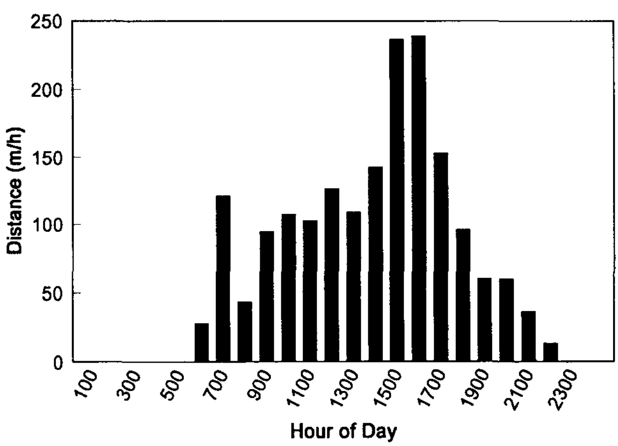

Figure 5. Average estimated distance moved/hour by 4 smallmouth bass in Melton Hill Reservoir, Tennessee, 1987.

the estimated distance traveled both peaked in the afternoon and were minimal at night (Figs. 4 and 5). Smallmouth bass were mobile about 6.7 hours/day, that is, 28% of a 24-hour day and 42% of the daylight and twilight hours (roughly 0530 to 2130 hours), assuming movement at dark was minimal. The average rate of movement for all smallmouth bass was 4.2 m/minute. Estimates of distance moved ranged from 825 to 3,477 m/day (Table 1).

Discussion

Smallmouth bass in Melton Hill Reservoir did not exhibit diel offshore/inshore movements among different habitats in response to temperature. Instead, they were usually near shore and in shallow (<2m depth) water where temperatures sometimes exceeded 28 C. Though their studies were not designed to detect diel movement patterns, Peterson and Myhr (1977) and Hubert and Lackey (1980) also observed smallmouth bass at relatively high temperatures (>30 C) in Tennessee reservoirs. One possible explanation for these observations is that simple thermoregulation may not necessarily be the most energetically efficient behavior. Although energetic costs could be reduced by thermoregulatory behavior, food consumption may be maximized by residing in the warmer, inshore habitats where prey is abundant. Although food conversion efficiency may not be maximized by constant residence in warm water, growth could be.

A second possible explanation for the observed results is that bioenergetic efficiency (i.e., growth maximization) may not be a primary factor in habitat selection by adult smallmouth bass. Other habitat variables such as cover may provide benefits that outweigh growth maximization. Smallmouth bass use of cover was similar to that observed in other studies in large lakes, reservoirs, rivers, and streams (Emery 1973, Peterson and Myhr 1977, Hubert and Lackey 1980, Todd and Rabeni 1989). Various types of cover have also proven attractive to smallmouth bass in laboratory experiments (Haines and Butler 1969, Sechnick et al. 1986). A laboratory study performed in conjunction with this field study determined that smallmouth bass would incur the increased metabolic costs and other associated physiological stresses of high temperature (>29.5 C) in order to utilize cover Bevelhimer (1996). These experiments also determined that activity levels were reduced when fish resided at high temperatures, offsetting to some extent the increased basal metabolic costs. Although the use of cover by adult smallmouth bass is well documented, the benefits are uncertain but could include predator avoidance, nest site territoriality, and predatory effectiveness.

A secondary objective of this study was to evaluate other characteristics of smallmouth bass movements. The observed daily activity patterns were similar to those reported by other investigators. Smallmouth bass are less active at night (Munther 1970, Emery 1973, Helfman 1981, Gerber and Haynes 1988, Bevelhimer 1996), except for males when nest guarding (Hinch and Collins 1991).

Although many smallmouth bass anglers are successful at night (Weathers and Bain 1992), this does not mean the fish are actively moving during this time. As in this study, Gerber and Haynes (1988) found smallmouth bass activity was highest in the afternoon, while Emery (1973) described a crepuscular pattern of activity.

Observations in the field provide data on the ultimate choice of habitat by an organism given a limited selection of available habitats. However, one should not assume that habitat use implies a preference for 1 (or even a few) associated habitat variable(s). In this case, smallmouth bass were found at temperatures which exceeded 28 C, most likely as a result of their primary preference for some other variable such as food or cover. The companion laboratory experiments (Bevelhimer 1996) demonstrated the relative importance of some factors involved in habitat selection by smallmouth bass; both cover and food affected the ultimate thermal exposure in experiments where a range of temperatures were available. This study demonstrates that energetic efficiency with regard to thermal habitat selection is not always a primary driving force and may be secondary to other survival benefits.

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