ULTRASONIC TRACKING OF SMALLMOUTH BASS IN CENTER HILL RESERVOIR, TENNESSEE

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Abstract: Ultrasonic tracking was conducted on 11 smallmouth bass (*Micropterus dolomieui* Lacépède) in Center Hill Reservoir, TN from 24 May 1973 to 25 July 1974. Transmitters which had an average life of 30.4 days, were implanted in the body cavity and were a successful tool for studying fish movement and behavior. Factors observed were "homing" behavior of displaced fish, horizontal movement, distance ranged offshore, depth ranges, water temperature, and habitat preference. Also determined were correlations between fish movement and water temperature, barometric pressure, water turbidity, water levels, percentage cloud cover, solunar periods, and creel census data. The effects of noise and artificial light on smallmouth bass behavior were noted. Increased movement and activity were associated with water surface temperature between 11.1 and 23.9 C. Only surface temperature of the water was found to be significantly related to rate of fish movement. The mean horizontal distance moved per day was 345 m.

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Ultrasonic tracking of fishes to study their movements is a relatively new technique. Trefethen (1956) was one of the first to report the results of using ultrasonic equipment to study the movement of fish. He studied the movement of salmon in relation to Columbia River dams. His initial investigation laid the groundwork which provided fishery biologists with an additional tool to study fish behavior. Continued research has eliminated many of the early problems with the tracking equipment. Research has also developed smaller transmitters with more range, and with temperature-sensing mechanisms.

Several publications have reported the results of the study of movements of both coldwater and warmwater fish species using ultrasonic transmitters. Homing in cutthroat trout (*Salmo clarki*) was demonstrated by McCleave and Horrall (1970) in Yellowstone Lake. Johnson (1960) observed the movement of salmon at Bonneville Dam. Migratory movements of sockeye salmon (*Oncorhynchus nerka*) were determined by using ultrasonic transmitters in coastal British Columbia waters by Madison et al. (1972). Summerfelt et al. (1972) studied the movements, home range, and activity of the flathead catfish (*Pylodictis olivaris*) in Oklahoma. Movements and internal body temperature of channel catfish (*Ictalurus punctatus*) were observed by Ziebell (1973) using telemetry equipment. Hasler et al. (1969) studied open-water orientation of white bass (*Morone chrysops*) and Jones (1971) used ultrasonic transmitters to study net avoidance behavior of American shad (*Alsoa sapidissima*). Movement of striped bass (*M. saxatilis*) was studied by Koo and Wilson (1972) in the Chesapeake and Delaware Canal. Gaiduke et al. (1971) used ultrasonic transmitters to determine what depth pike, salmon, and sturgeon chose during daylight hours in Russia. An extensive bibliography on underwater telemetry has been provided by Stasko (1971a, 1971b, 1972a, 1972b, 1973a, 1973b).

Largemouth (*M. salmoides*) smallmouth, and spotted basses (*M. punctatus*) have been studied using ultrasonic transmitters to determine their movements. Peterson (1975) used ultrasonic transmitters to study the movements and behavior of largemouth and spotted basses in Center Hill Reservoir, TN. Lorio et al. (1973) studied the effects of water management practices on the movement of largemouth bass in Loakfoma Lake, MS. Smith (unpublished M.S. thesis, Clemson University) used ultrasonic transmitters to study movements and home ranges of largemouth bass in Keowee Reservoir prior to its receiving heated effluent from nuclear reactors. Movements of largemouth bass were studied by Clugston (1973) using temperature-sensing transmitters in 2 reservoirs receiving heated effluent. Wrenn (1974) studied movements of largemouth bass and smallmouth bass in relation to a heated effluent discharge into the Tennessee River and Cane Creek.

Black bass fishing pressure has greatly increased over the past several years through the formation of bass fishing clubs, thus creating another management problem for the fishery biologist. This study of the movement and the behavior of smallmouth bass provides more information for use by both the fishery biologist and the ardent bass fisherman. In this study we observed the "homing" behavior of displaced fish (telemetered fish released at sites other than capture site), horizontal movement, distance ranged

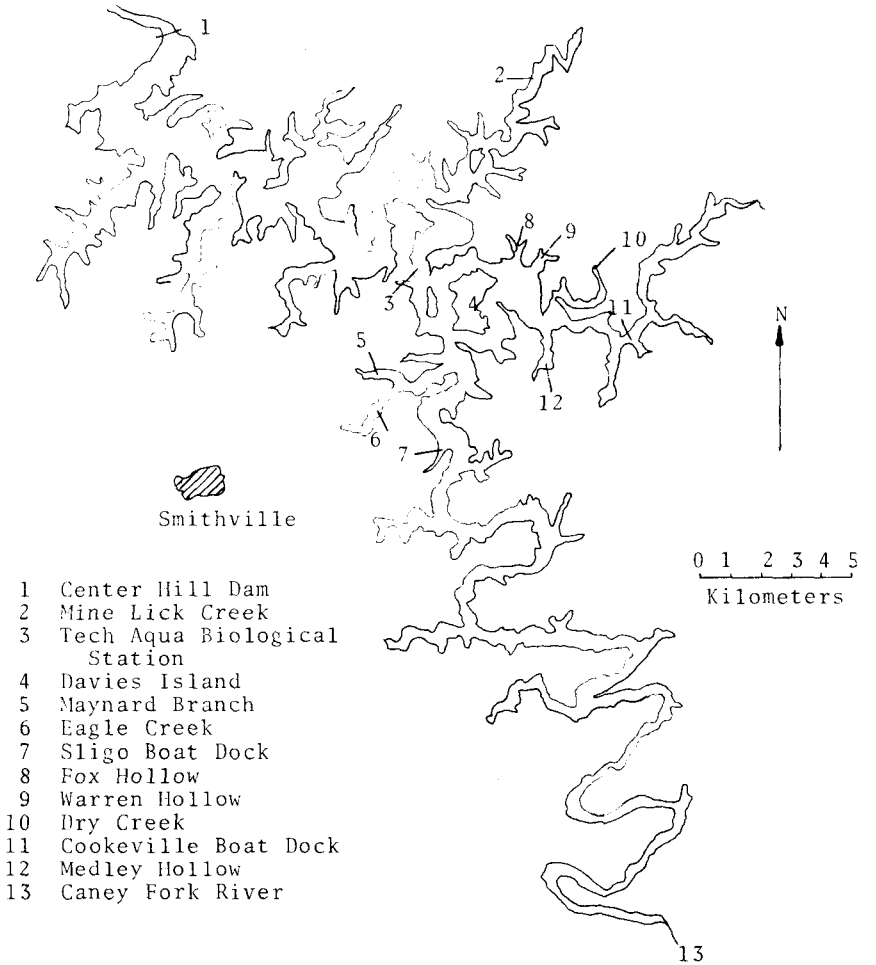

Figure 1. Map of Center Hill Reservoir, Tennessee

offshore, depth range, water temperature and habitat preference. Also determined were correlations between fish movement and water temperature, barometric pressure, water turbidity, water levels, percentage cloud cover, solunar periods, and creel census data. The effects of noise and artificial light on smallmouth bass behavior were noted.

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STUDY AREA

Center Hill Reservoir is an impoundment of the Caney Fork River, lying mainly in DeKalb County in middle Tennessee (Fig. 1). The reservoir at 209 m above MSL contains 9,332 ha. It was impounded by the U.S. Army Corps of Engineers in 1948. The reservoir has a drainage area of 5,631 km^2 and is 103 km long (Moss 1967).

Fig. 1. Map of Center Hill Reservoir, Tennessee.

The shore is composed of gravel, rubble, boulders, and limestone bluffs. Water depth increases rapidly to moderate depths and the bottom is sediment. Center Hill Reservoir is best described as being warm monomictic, tending toward eutrophication.

METHODS AND MATERIALS

Capture and Transmitter Implantation

Smallmouth bass were collected from Center Hill Reservoir by electrofishing and by various methods of angling. Local bass fishermen were solicited to help collect fish, especially during the warmer months of the year when netting and electrofishing seemed to be less productive.

Fish in excellent condition were at first transported to the biology laboratory at Tennessee Technological University for transmitter implantation. Later the transmitters were implanted into the fish at the Tech Aqua Biological Station dock at Center Hill Reservoir, thus minimizing handling of the fish.

Surgical implantation of the transmitter into the coelom was used. This was similar to the method used by Summerfelt et al (1972) with flathead catfish, and also by Coutant (personal communication) with largemouth bass.

Electronic Tracking Equipment

Fish movements were determined by tagging bass with 3 types of omnidirectional ultrasonic transmitters (tags). Two of these types were manufactured by Smith-Root, Inc., of Vancouver, Washington. Type SR69 was 14.2 mm in diameter, 57.2 mm in length, and weighed 9.1 g in water. Type SR69A was 14.2 mm in diameter at one end, 19.0 mm in diameter at the other end, 88.9 mm in length, and weighed 29.5 g in water. These 2 types of tags had pulse rates that varied between 0.5 to 5.5 pulses per sec. for individual fish identification. They were received at 74 kHz $\pm$ 1 kHz. These transmitters were activated by soldering the battery lead wires together and sealing the end of the transmitter with paraffin prior to implantation in the fish.

The third type was a temperature-sensing transmitter manufactured by Meares and McDearman of the Department of Electrical Engineering of Tennessee Technological University. This type was similar to the transmitter developed by Rochelle and Coutant (1973). The transmitters were cylindrically shaped, approximately 13 mm in diameter and 57 mm long, and weighed 17.5 g in air. The temperature sensor was located inside the transmitter so that the fish's body temperature was recorded. Transmitters had varying frequencies so that individual fish could be identified. These transmitters were activated by soldering the lead wires together and sealing the end of the transmitter with silicone rubber, which was allowed to cure 24 hrs. Also, reference curves for these tags were calibrated in the laboratory by plotting tag temperature and time interval between signals in seconds, using the Smith-Root pulse counter.

Sound waves produced by the tag were received and amplified into audible signals by a Smith-Root SR-70-H hydrophone and TA-60 receiver. The hydrophone was undirectional which allowed the location of the fish to be determined accurately. A Smith-Root PC-74 pulse counter was used to distinguish pulse rates of individual transmitters and to record pulses per unit of time for the temperature-sensing transmitters. A dial on the pulse counter could be set to record seconds and tenths of seconds.

Tracking Procedure and Data Collected

Tagged bass were released close to the shore and tracked until they became stationary for approximately an hour. Tracking was conducted during various periods of each 24 hr day in an attempt to track a fish at least 84 randomly selected hours in a week. Fish were tracked regardless of weather to determine if inclement weather affected the movement of the fish. Bass were located by moving the tracking boat into the area where fish were suspected to be. The boat was stopped and the hydrophone lowered into the water and rotated until a signal was heard. Then the boat was moved to within approximately 15 m of the fish; the hydrophone was lowered and rotated again until the strongest signal could be detected. The fish was pinpointed by triangulation. In cases where a fish was not located at the site of its previous location, a search was made in the apparent direction of travel as suggested from previously recorded locations, or a systematic check was made in all possible directions.

After a bass was located, its present position and route, if moving, were plotted on 1:10,000 scale maps. Because of water level fluctuation in the lake, graphical representation was not exact. Data collected when each fish was located were: date, time of day,

water surface temperature, Secchi disk reading, general atmospheric conditions, and percentage cloud cover. Wind direction and velocity were taken for the first 4 months of the investigation, but the high ridges surrounding the reservoir caused continuous fluctuations in wind direction and speed, therefore recording was discontinued. Barometric pressure was taken, but because of fluctuations in air temperature affecting the barometer this was also discontinued. Daily river bulletins were received from the U.S Army Corps of Engineers to determine water fluctuations. Barometric pressures, recorded every 6 hrs were furnished by the National Weather Service, Nashville, Tn. Oxygen-temperature profiles were taken once a month when the reservoir was not thermally stratified and twice a month when the reservoir was stratified. These profiles were measured with a YSI Oxygen-Temperature Meter (Model 54).

A Dietzen map measure was used to record on a map the distance the fish moved between fixes. The total assumed one-way distance traveled by each fish was measured from release site to the last position site. This measurement included areas of the shoreline which were located between the release site and the last position site even if the telemetered fish had not been detected by the tracker in this area.

A computer program, designed by J. Browning of the Computer Center of Tennessee Technological University and the investigators, was used to correlate fish movement with such variables as water temperature, barometric pressure, water turbidity, water levels, percentage cloud cover, and solunar periods.

RESULTS AND DISCUSSION

Literature concerning homing and movement of the smallmouth bass is limited. Larimore (1952) studied the homing behavior of smallmouth bass in Jordan Creek, Illinois. He found that smallmouth bass transferred and released in other parts of the stream showed an ability to return to their home pools from either upstream or downstream. Wrenn (1974) used ultrasonic temperature-sensing transmitters to study 6 smallmouth bass in relation to heated effluent. He reported 1 smallmouth bass, after being displaced from Pickwick Reservoir and released above a heated effluent discharge, moved downstream 4.5 km.

Homing is the ability of an animal to return, when displaced, to an area which may be considered its home range (Gerking 1959). Five of the fish were displaced. Of the 5, only 1 (Fish 8, Fig. 2) was known to have returned to its capture site.

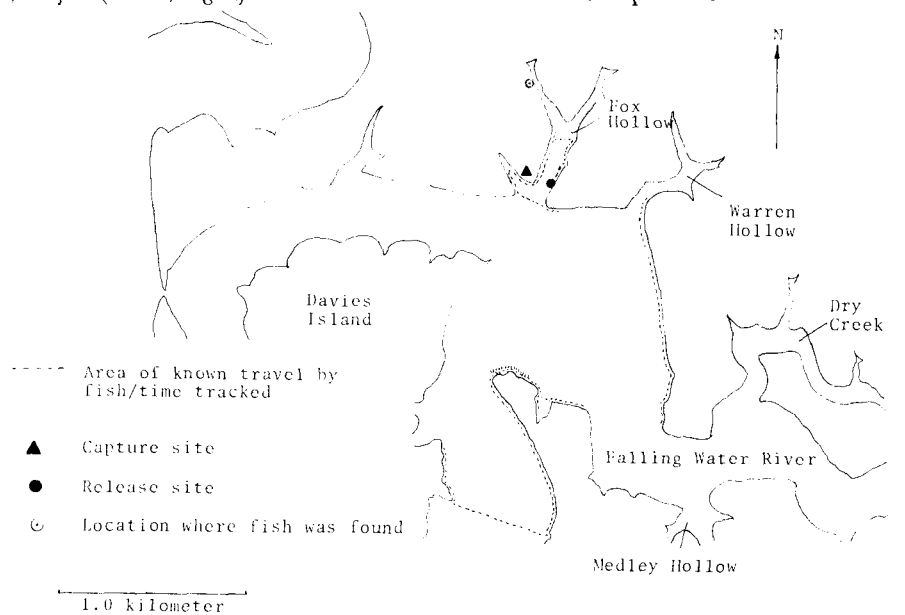

Fig. 2. Movement of smallmouth bass no. 8 as determined by ultrasonic telemetry from 23 December 1973 to 8 May 1974.

The smallmouth bass on a daily basis had individual habits. Of the 11 fish tracked in the study, the daily average distance moved varied from 15 to 1,208 m. The daily distance moved of these individual fish changed throughout the study.

The average horizontal distance moved per day for 11 telemetered smallmouth bass for the total elapsed days was 345 m. These bass ranged between 2.2 to 15.5 m offshore; however we believe that the smallmouth bass on a yearly basis, ranged between 1.5 to 4.8 m offshore. Depth range for 3 smallmouth bass containing temperature-sensing tags varied from 0.3 to 9.7 when the water was thermally stratified. Nikolsky (1963) reported that most fishes' body temperature are 0.5 to 1.0 C above ambient water temperature. Considering the body temperature-water temperature difference suggested by him, 1.0 C was subtracted from all body temperature readings to determine ambient water temperature. This was done by Clugston (1973) and also in the present study to determine depth and water temperature encountered by the fish.

Although most smallmouth bass moved after dark, the majority of their movements occurred during the daylight hours. Emery (1973) compared day and night habits of freshwater fish in Ontario Lake by SCUBA observations. He found that any movement of smallmouth bass which occurred during the night was unusual. In this study, smallmouth bass were observed to move mostly when the surface temperature was between 11.1 to 23.9 C. In general, smallmouth bass tracked in winter and in summer were less active than those tracked during spring and fall. Munther (1970) observed movement and distribution of smallmouth bass in the Middle Snake River with aid of SCUBA. He found that there was no significant seasonal variation in numbers of fish moving in different seasons, although there seemed to be slightly more movement in spring and less in summer when compared to the mean movement.

During the middle of July 1973, through the middle of October 1973, the dissolved oxygen in Center Hill Reservoir decreased below 5.0 ppm at depths between 4.5 m in August and 8.5 m in October. On no occasion was a smallmouth bass known to move below 5.5 m during these months. Known minimum water temperature encountered by the telemetered smallmouth bass was 9.0 C in December 1973. In July 1974, the maximum temperature encountered was 30.0 C. Barans and Tubb (1973) reported the maximum summer water temperature preference of 31 C for this species. Two smallmouth bass tracked by Wrenn (1974) moved into a heated effluent pool of 33 C during summer conditions.

The effect of noise on 6 smallmouth bass was noted to determine whether it caused the fish to move from its site. Noise was defined as any fisherman's normal activities, such as operating a gasoline or electric motor near the fish, dropping an object in the boat, and casting lures near the fish. Of the 6 fish tested, none responded by movement away from the noise. Lorio et al (1973) found that neither a gasoline nor an electric motor caused a tagged largemouth bass to move away from its resting place.

The effect of artifical light at night on 5 smallmouth bass was observed to determine if this caused the fish to move from their locations. The fish were tested by shining a 200,000 candle power, handheld light in the vicinity of the fish. None seemed to be affected.

Based upon data from a creel census conducted in 1973-74 by the Tennessee Wildlife Resources Agency at Center Hill Reservoir, a comparison between periods of major movements of smallmouth bass tagged with ultrasonic transmitters and the number of smallmouth bass caught per hour in the 12 study months was made (Fig. 3). Major movements of tagged fish occurred when surface temperature of the reservoir was between 11.1 to 23.9 C, which occurred during October through December 1973, and February through May 1974. A major movement is defined as the increased distance traveled by a fish while moving to new locations plus increased activity within a home area. This was the same definition used by Lorio et al. (1973) while tracking largemouth bass. The creel census indicated that most fish were caught during these major movement periods. Thus, bass activity and fisherman success seem to be related.

A computer program was used to determine if correlations existed between fish movement per hour and such variables as water surface temperature, barometric pressure, water turbidity, water levels, solunar periods, and percentage cloud cover. No r value less than $\pm$ 0.147 ($p < .01$) was considered to be significant. Only water surface temperature was found to be significantly related to fish movement per hr.

Sites where smallmouth bass were sedentary included bushes, trees, and rocky banks. Of the 11 tagged bass, 7 were known to have crossed 30.5 m or more of open water. However, the majority of movement occurred along the shoreline. Lewis and Flickinger

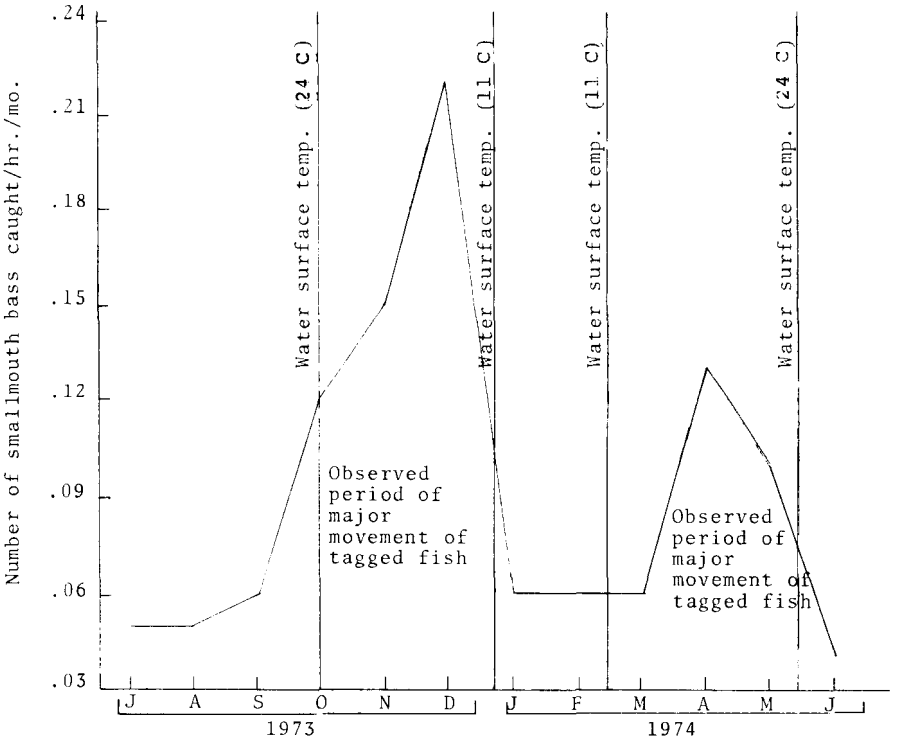

Fig. 3. Comparison between observed major movement periods of smallmouth bass tagged with ultrasonic transmitters and the number of smallmouth bass caught per hour per month from Center Hill Reservoir, Tennessee.

(1967) reported no case of a largemouth bass in a 3.2 ha pond moving along the shoreline to a home area. They concluded that bass probably swam directly across open water. Smith (unpublished M.S. thesis, Clemson University) observed only 1 largemouth swimming straight line courses across open water. Peterson (1975) also noted that telemetered largemouth bass crossed open water.

Ultrasonic tracking proved to be a successful method for studying movement and behavior of smallmouth bass in Center Hill Reservoir. Ultrasonic transmitters had an average life of 30.4 days. Two of the fish that received transmitters and were released in Center Hill Reservoir died. Their death was believed to have been caused by a fungus infection due to improper handling. None of the remaining fish seemed adversely affected by the transmitters. All fish tagged moved laterally and vertically throughout the study. The investigators believe that the transmitters had little effect on their behavior. Clugston (1974) also thought that transmitters had little influence on behavior, because the largemouth he tracked moved freely and fed. Peterson (1975), as did Lorio et al. (1973), observed ultrasonic tagged bass feeding in a holding trough and assumed behavior to be normal. Bass were observed by Smith (unpublished M.S. thesis, Clemson University) in a holding trough after transmitters were surgically placed in the body cavity. He noted normal swimming with no loss of stability or buoyancy.

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