A BIOTELEMETRY STUDY OF THE MOVEMENTS OF THE WALLEYE IN CENTRAL HILLS RESERVOIR, TENNESSEE

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ABSTRACT

From July, 1974, through July, 1975 the movements of 29 walleye were monitored in Center Hill Reservoir, Tennessee, using ultrasonic telemetric techniques. Seasonally, monitored walleye were most active during the winter and least active during the summer and activity was not correlated with angler success. Diel activity varied from a nocturnal pattern during the summer, to crepuscular during the fall and winter, and no pattern was evident during the spring. Temperature preference was a range of 12°-18° C and the only bathymetric pattern established was that of a preference for the bottom, regardless of depth. However, oxygen was often limiting in the hypolimnetic zone. No patterns were established when the daily rates of movement of walleye were correlated with various environmental variables. Monitored walleye preferred to remain more than 30 meters offshore during all seasons of the year. Also preferences for certain type areas of the reservoir and bottoms were evident. Home ranges were established during winter and summer but not at other times of the year and "homing" to these ranges was exhibited as was "homing" to a previous spawning site.

The use of ultrasonic tracking devices to monitor the movements of fishes is a recently-developed technique. One of the earliest studies (Trefethen, 1956) employed this method to study the movements of salmon in the Columbia River system. More recently, many authors have adopted this technique in tracking both cold- and warmwater species, (Gaiduk, *et. al.*, 1971: Hasler *et. al.*, 1969; Johnson, 1960; Koo and Wilson, 1972; Leggett and Jones, 1971; Madison, *et al.*, 1972; McCleave and Horrall, 1970; Summerfelt, *et. al.*, 1972; and Ziebel, 1973).

Dendy (1945, 1946a, 1946b, 1948) published several studies on the behavior of walleye and other species with results based on extensive gill-netting from three TVA storage impoundments. The only research complete using ultrasonic telemetric techniques to describe the movement of walleye is that of Wrenn (1974) in a study of various fish species in relation to the discharge of heated effluents.

Data collection began in July, 1974 and continued through July, 1975 as part of a five-year research program sponsored jointly by the Tennessee Wildlife Resources Agency, the Tennessee Cooperative Fishery Research Unit, and the Biology Department of Tennessee Technological University. The program was initiated to develop a method of monitoring individual gamefishes in reservoirs in order to determine behavioral aspects that ultimately might aid both the fishery manager and the sportsman.

MATERIALS AND METHODS

Description of the Study Area

Center Hill Reservoir (Map 1) is a 8500 hectare U.S. Army Corps of Engineers flood control impoundment located on the edge of the Highland Rim in central Tennessee. The reservoir is 103 kilometers (km) long, drains 3506 square km., has 680 km of shoreline, and has an elevation of 197 meters (m) above mean sea level at power pool elevation.

Center Hill Reservoir can be classified as a warm monomictic lake according to the criteria established by Reid (1961). Very weak, if any, thermal stratification occurs in the winter but in the summer the lake exhibits marked horizontal thermal stratification. Characteristically, in late summer and early fall the reservoir has a critical drop in

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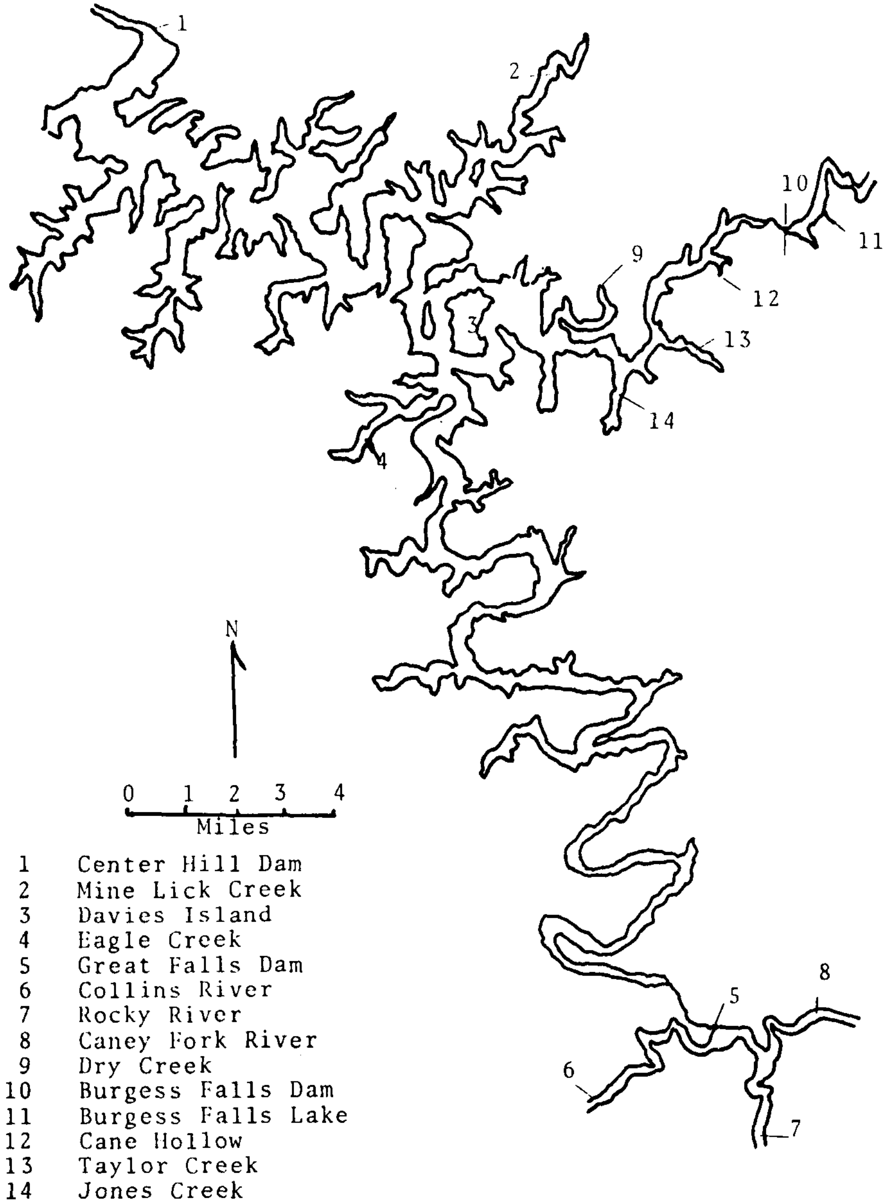

Map 1. Map of Center Hill Reservoir, Tennessee

dissolved oxygen in the hypolimnion. Further discussion of this phenomenon in Center Hill can be found in the works by Austin (1974) and Gordon (1976).

Equipment

Two types of ultrasonic transmitters were used in this study. The model SR69 transmitter manufactured by Smith-Root, Inc. measured 88.9 mm in total length, 14.2 and 19.0 mm in diameter on the two ends, and weighed 29.5 g in water. These sonic tags transmitted at 74 kHz at a fixed pulse rate between 0.5 and 5.5 pulses per second. The other type of transmitter was designed by Mears and McDearman (1976). These cylindrical tags measured 85 mm in length, 15 mm in diameter, and weighed 27.5 g in water. They were designed to operate at frequencies between 60 and 90 kHz and contained a thermistor component that varied the pulse rate of the tag in direct relation to its temperature.

Sound waves emitted by a transmitter were received by a Smith-Root model SR70H hydrophone and amplified and made audible by a Smith-Root model TA60 receiver. The hydrophone was unidirectional and allowed determination of the direction of the transmitter. A Smith-Root PC74 pulse counter was used in conjunction with the receiver to digitally record the number of pulses over a period of time and thus determine the temperature of the transmitter. The use of the counter was later discontinued due to imprecision of the techniques involved and a timer developed by Mears and McDearman (1976) was used.

Capture and Tagging

Gill and trammel nets were generally the most effective methods used in capturing fish for use in the study. However, during late spring and early summer, a combination of gill netting and electrofishing at the mouths of major tributaries was very effective also.

Walleye were anesthetized and operated on in a 83 liter rectangular chamber containing a 75 mg/l solution of tricaine-methane-sulfonate (MS222). The use of MS222 was later terminated since it has been reported to influence both temperature selection and behavior of treated fishes (Goddard, *et. al.,* 1974). Fishes under operation were subdued by means of a cloth sling with the mid-ventral region slightly out of the water.

The total length of each experimental fish was measured in mm and an incision of two to three cm was made with a scalpel just dorso-lateral of the midline in the ventral abdominal region. An attempt was made to observe the sex organs after exposure of the coelom, however this was normally only successful with females. The scales at the line of incision were left intact and the placement slightly parasagittal to the midline was so the musculature in that area would provide a strong anchor for the sutures and facilitate rapid healing.

The transmitter was inserted anteriorly into the coelom. The incision was closed using a 000 atraumatic cutting needle trailing nonresorbable silk sutures. In most cases post-operative fishes were transported to the release site immediately following the operation. During the spring months, all transportation of fish, both pre- and post-operative, were made in a five mg/l solution of malachite green to prevent fungal infections.

Monitoring

A systematically chosen, monitoring (tracking) schedule comprised of 8-hour tracking shifts separated by 6-hour intervals, permitted tracking of walleye at all hours of the day and night. The length of time a fish was monitored in a shift was variable. Fishes were released and monitored from an aluminum outboard boat. Triangulation was used to locate fishes and, once located, the position of the fish was plotted on a 1:24000 scale map of the area, and the time and date recorded. Secchi disk readings, percent cloud cover (approximated to the nearest 10%), and weather conditions were recorded each time a fish was located. If the tag being monitored contained a thermistor and the water was thermally stratified, a pulse interval time was recorded and a temperature profile was taken using a Hydrolab model thermometer.

All fixes were later transfered to a master map assigned to each individual fish, and both the distance between successive fixes and the elapsed time were recorded. Average daily and hourly rates of movement could be calculated from these data. Also, type of reservoir bottom at each fix occurring within 25 m of shore were recorded for each of 19 walleye.

A Pearson correlation analysis was used to compare daily rates of movement for each fish with the selected variables: turbidity, percent cloud cover, water level, change in water level over the past 24 hours, amount of precipitation, barometric pressure, change in barometric pressure over the past 24 hours, weather conditions, and the elapsed time since release of the monitored fish.

RESULTS AND DISCUSSION

Activity

Eighteen walleye were chosen for analysis based upon the total time monitored (minimum of 10 days). The mean rates of movement ranged from 44.2 to 1179.3 m/day in June, 1975 and November, 1974 respectively and are illustrated for all months in Figure 1. November, December, January, and February were the months of highest levels of activity. Lowest activity was recorded in the spring and early summer months. Although fish monitored during September did not meet the 10 day minimum criteria for analysis, their activity was greater than that of the previous month and below that of October.

Monthly activity levels of the monitored fishes did not correlate directly with the success of walleye fishermen as determined by a sophisticated, statistically designed creel survey conducted by personnel of the Tennessee Wildlife Resources Agency (Figure 1).

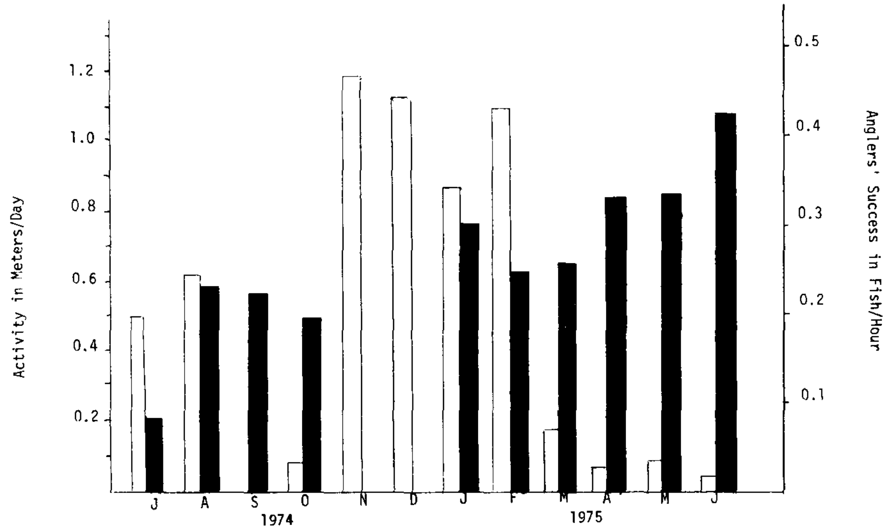

Figure 1. Monthly Activity (clear) of monitored Walleye in km per Day and Walleye-Anglers' Success (solid) in Fish per Hour.

This suggests walleye activity is not related to their vulnerability to anglers as Peterson (1975) reported to be true of black basses. Apparent lack of a positive relationship between walleye harvest by anglers and rate of movement of the fish may be attributed to changing behavioral patterns of the walleye associated with seasonal changes in water conditions.

Activity cycles of these same 18 fishes were examined individually and could be divided into three groups based on diel and seasonal activity levels. Walleye monitored from April through September were most active nocturnally, with peak activity occurring near midnight (Figure 2). This type of behavior is typical of negatively phototrophic fish (Moore, 1944) since these months characteristically have little cloud cover and long periods of daylight. Walleye monitored from October through December, a period dominated by substantial cloud cover and shorter days, displayed the greatest activity during early morning and evening (Figure 3). By contrast, walleye monitored from January through March exhibited no peak period of activity (Figure 4). This encompasses the spawning season of walleye in Center Hill and the activity of these fishes indicated that movement to the spawning grounds occurred continuously throughout the day and

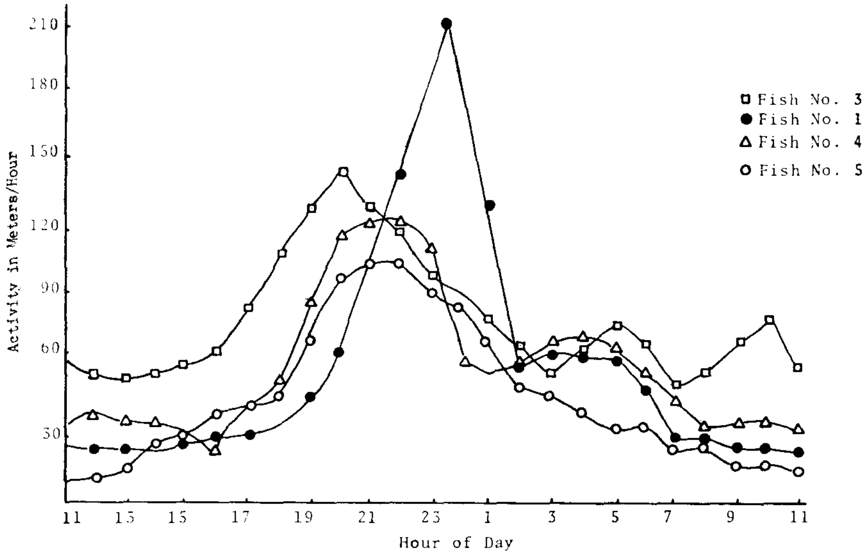

Figure 2. Daily Activity of 4 Walleye Between April and September in Center Hill Reservoir, Tennessee

night. Numerous other investigators have noted that spawning activity occurred almost wholly after dark (Crowe, 1962; Eschmeyer and Crowe, 1955; Priegel, 1968) and Muench (1966) found this to be true of Center Hill walleye. In addition, heavy cloud cover during this period and turbid water lessened light penetration and increased the likelihood of daytime movement.

Vertical Distribution and Temperature Preference

Nine fishes that contained thermistor-equipped transmitters were monitored between March and July, 1975 during a period when the water was thermally-stratified (Table 1). The range of temperatures available is the range between the minimum and maximum temperatures recorded in the thermal profiles taken during that monitoring period. Depths of fish below surface and distance above the bottom are rounded to the nearest whole meter. Both means and modes are shown for temperature, depth, and distance above the bottom selected by walleye, but the author believes that the modes more realistically represented the preferences.

Fish numbers 21, 22, 23, and 24 utilized all the available temperatures over a wide depth range, while the other fishes monitored later in the summer were probably limited to higher mean water temperatures and shallow depths due to oxygen depletion below the thermocline. Dendy (1946b) found that oxygen deficient density currents displaced walleye from their preferred temperature and depth in Norris Reservoir, Tennessee. Austin (1974) and Gordon (1976) describe hypolimnial oxygen depletion in Center Hill as extending upward as summer progressed to as shallow as 8.0 m below the surface by late August.

The unweighted mean of preferred temperatures was 18.2°C (±6.1). If the fishes monitored when oxygen may have been limiting in the cooler waters are excluded, (June and July) the mean was the 14.8°C (±3.3). Dendy (1946b), using information based upon gill netting results, concluded that 20 to 25°C was the preferred temperature range of walleye inhabiting Norris Reservoir. Although temperature range preference is not clearly defined in this study, the author believes that it is approximately 12°C to 18°C. Dendy's estimate was based upon fishes collected at peak activity, whereas these data were collected during all levels of activity. That walleye monitored simultaneously preferred similar temperatures indicated that temperature played an important role in habitat selection.

Because of the lack of more detailed information concerning conditions of turbidity, photoperiodicity, cloud cover, and temperature, oxygen, and food availability, depth selection by walleye is not definable in this study. However, in agreement with Haslbauer (1945), Regier, *et. al.*, (1969), and Dendy (1946a), most of the thermistor-equipped walleye preferred to stay on or within a meter of the bottom. The reason for two exceptions to this pattern is not clear. However, pelagic tendencies were more common at other times of the year.

Environmental and Life History Factors Affecting Behavior

An attempt was made to correlate daily activity of the 18 fishes monitored for at least 10 days, with mean daily values of various environmental conditions. Selected factors were water transparency, percent cloud cover, barometric pressure, change in barometric pressure, water level, change in water level, amount of precipitation, and moon phase.

No significant correlations were found when the data were pooled and analyzed by a Pearson correlation. When examined individually, activity of 13 (72.2%) of the fishes correlated with at least one variable but no one variable correlated with consistency and activity of five (27.8%) fishes showed no correlation.

Stepwise multiple regression analysis was performed on the 13 walleye having rates of movement correlated with some environmental factor. Coefficients of determination (R^2) for the formulas derived ranged from 17 to 94%. Nevertheless, no pattern in the components of the formulas existed and tends to indicate an individualistic behavior for walleye. Peterson (1975) found the same individualistic behavior in black basses. Certainly these and other factors influence walleye behavior but the relationship was apparently too complex to be revealed by the above statistical analyses.

Monitored walleye did not exhibit any avoidance of boats, noise, or direct light. Fishes were occasionally in water less than 3 m deep and could not be frightened away by disturbances directly above them.

Spawning was the life history factor which most affected behavior. Unfortunately, high water during the spawning season resulted in poor netting success and only four fish were successfully monitored.

On 7 February, 1975, a walleye of undetermined sex was captured near Davies Island in the main channel of the reservoir, implanted with a transmitter, and released. This fish was monitored 12 days and during this time exhibited behavior different from walleye tracked earlier. This fish moved over a very large area at a rapid rate. Just prior to the last signal obtained, the fish began a vigorous, non-stop, upstream movement of over 6.4 channel km that was interpreted by the author as initiation of a spawning migration.

On 15 February, 1975, a female walleye was released in the main channel near mid-reservoir. This fish was monitored for over 22 days and moved a mean distance of 3.3 km per day. It ranged over more area than any previously monitored walleye. On 3 March, 1975, this fish undertook a 20 km movement upstream which lasted four days and ended in the Fall Creek embayment. The fish remained in this area until 13 March, when heavy rains began and the water level of the reservoir rose more than 12 m in four days. The fish was never relocated. Information from gill netting indicated that the bulk of the spawning activity by walleye occured during the subsequent high water period.

A second female captured on 18 February, 1975, was held in a wire cage in the reservoir prior to implantation with a transmitter and released during the high water conditions on March 25. The individual was monitored for almost six days, and during this time moved from mid-reservoir to the spawning grounds at the headwaters of the lake, and began moving back down-lake. The mean rate of movement was more than 16.1 km per 24 hours and the fish was never located in the same place more than once. Whether this female spawned is unknown, but undoubtedly the movement could be considered a spawning migration.

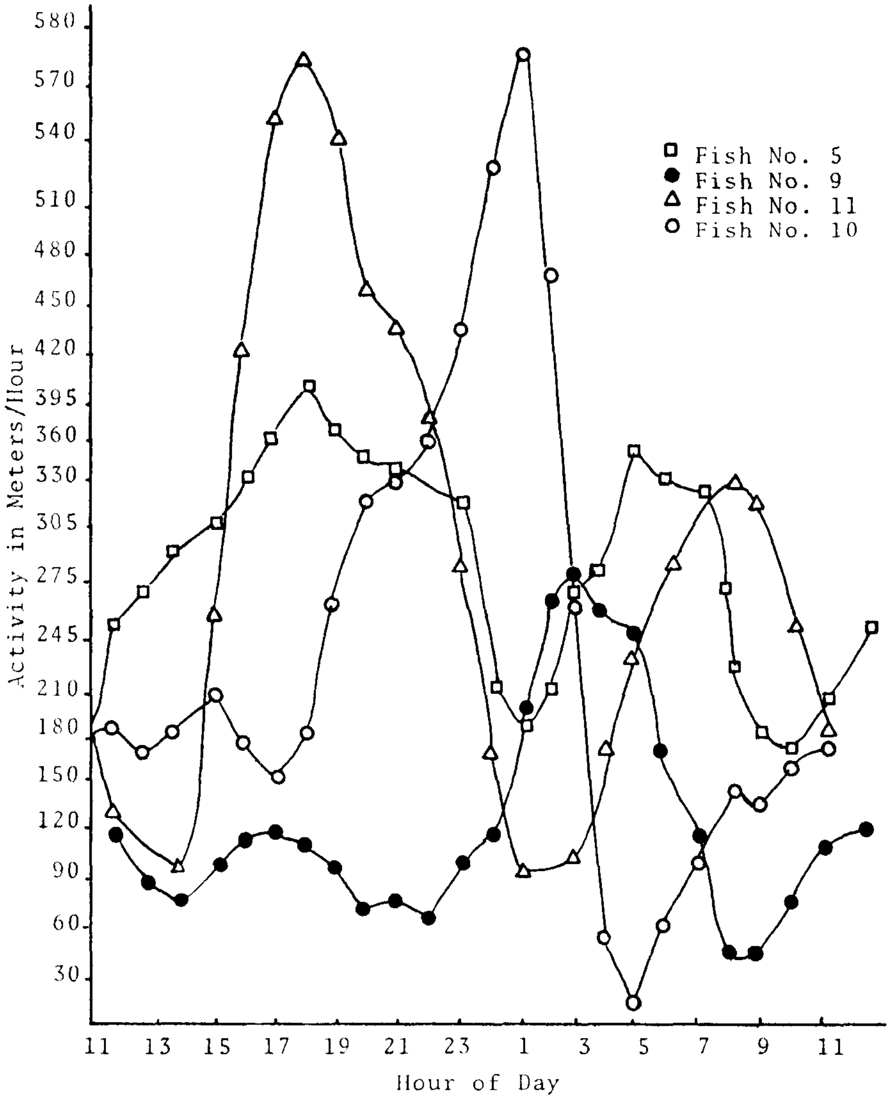

Figure 3. Daily Activity of 4 Walleye Between October and December in Center Hill Reservoir, Tennessee

Another female walleye was released on 30 October, 1974, and monitored through 29 December, 1974, in a section of the Falling Water River embayment of the lake. On 11 May, 1975, the fish was recaptured with a gill net in the same area. Eggs in an advanced stage of development were being absorbed, indicating that the fish probably had not spawned that season due to the physiological stress of the surgical procedure and the healing process.

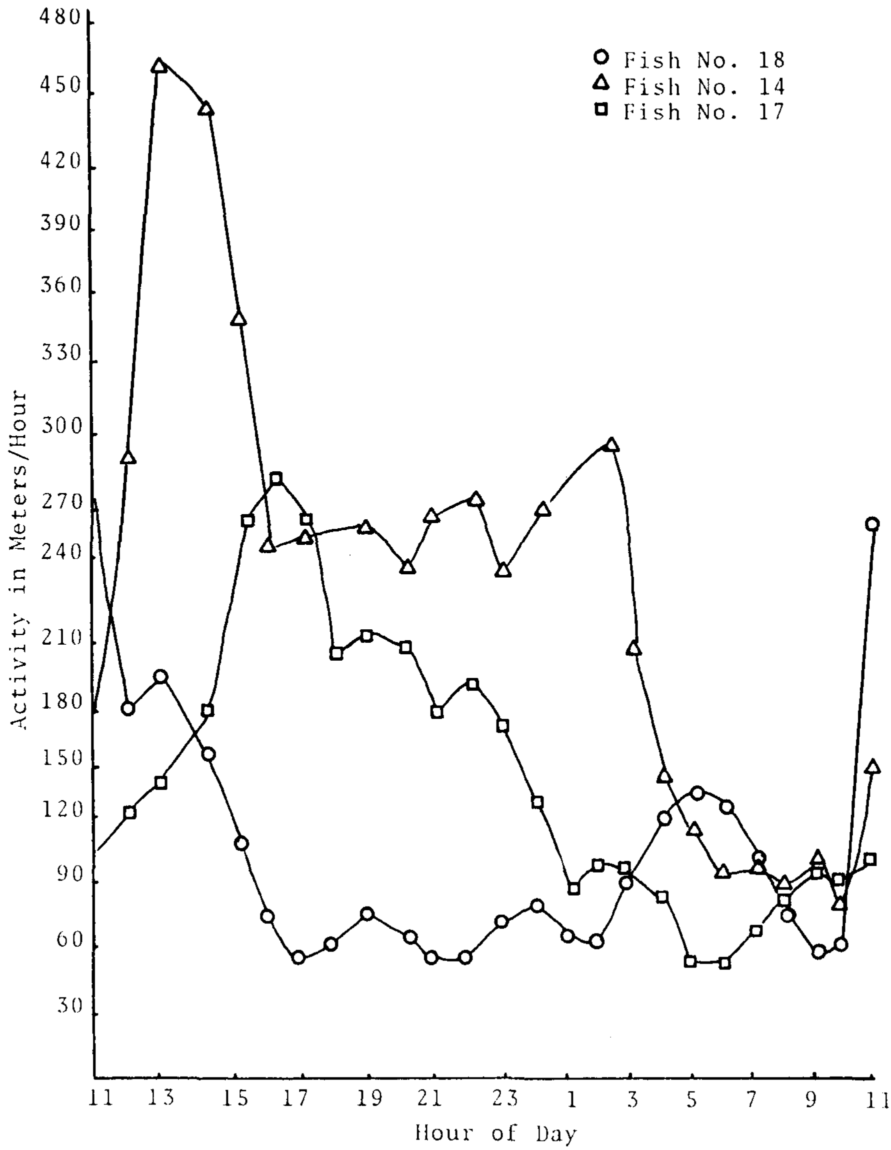

Figure 4. Daily Activity of 3 Walleye Between January and March in Center Hill Reservoir, Tennessee

Habitat Preference

Cover types were divided into five basic categories for the purpose of this analysis: sand or gravel, mud or clay, mixed rock and mud, rock, and brush or trees. The reservoir was divided into main channel, tributary channel, and tributary headwater areas, since walleye utilized these three areas at different times of the year and the composite of bottom types

Table 1. Summary of Temperature, Depth, and Distance Off the Bottom Recorded for 9 Walleye Monitored in Center Hill Reservoir, Tennessee

Fish No.	*Months Monitored*	*Available Temp. (°C)*	*Temperature of Fish (°C)*		*Depth of Fish (m)*		*Distance Off Bottom (m)*	
			Mean	*Mode*	*Mean*	*Mode*	*Mean*	*Mode*
3	Aug-Sept	24.0-29.0	25.3	25.6	6.2	8.0	1.5	0
21	March	11.3-14.5	12.1	12.0	12.7	11.0	0	0
22	April	11.0-14.5	12.8	12.6	4.7	0	8.4	13.0
23	April	11.4-17.8	12.0	12.5	5.2	6.0	1.2	0
24	May	13.8-21.5	15.9	12.3	7.8	11.5	4.2	0
25	May-June	14.4-34.0	23.7	23.8	2.9	2.0	1.5	0
26	May-June	14.8-29.9	14.7	13.9	13.2	14.0	0	0
28	June	12.5-29.0	24.9	24.9	4.1	4.0	13.2	5.0
29	June-July	14.8-31.5	26.9	26.4	2.4	2.0	2.1	0
X			18.7	18.2	6.6	6.5	3.6	2.0
			±5.8	±6.1	±3.1	±4.1	±3.4	±3.1

Table 2. Utilization of Cover Types in Percentage of Occurrences and Availability of Cover Types in Percentages of Shoreline in Three Areas of Center Hill Reservoir, Tennessee

	(5) Main Channel		*(11) Tributary Channel*		*(3) Tributary Headwaters*		*(19) All Areas Combined*	
	Util.	*Avail.*	*Util.*	*Avail.*	*Util.*	*Avail.*	*Util.*	*Avail.*
Sand or Gravel	2.5	14.6	11.7	6.6	5.6	5.8	8.6	8.6
Clay or Mud	13.8	9.0	8.7	11.5	1.0	10.6	9.7	10.7
Rock and Mud	60.0	32.4	27.1	35.1	33.3	52.9	43.0	37.2
Rock	11.3	42.3	43.1	45.2	50.0	7.7	34.2	38.5
Brush	12.4	1.7	1.0	23.1	11.1	23.1	4.5	5.0

Number of fish in parentheses.

was different between these areas. For all fixes within 25 m of the shore, determined for 19 walleyes, bottom types were identified and compared with the occurrence or availability of the 5 different bottom types in that area of the reservoir (Table 2).

Walleyes were monitored in main channel areas of the reservoir during the early spring and autumn months. It was found that when the walleye were within 25 m of shore, they selected mixed rock and mud and brushy bottoms to a significantly greater degree ($p = 0.05$) than they were available in that area of the reservoir.

Telemetered walleye were found in channel areas of major tributaries during the winter months. No preference in bottom type seemed to be expressed by these fish.

During the summer months monitored walleyes were found in headwaters of tributary embayments and rock bottoms were preferred. Of the three above designated areas, this was the only one which the monitored fish were found within 25 m of shore more than 50% of the time.

The fixes of 18 fishes which were monitored for at least 10 days were examined on the basis of shoreline exposure. Locations were considered to be facing either north, south, east, west, or exposed to all headings (open water). Analysis of the data with a chi-squared test revealed no significant difference ($p = 0.05$) in the preference of shore exposure either seasonally or annually from that of random distribution.

Thirteen of the eighteen fishes preferred open-water rather than areas adjacent to the shoreline. The utilization of open water could account for the apparent lack of a relationship between rates of movement and angler success. Most walleye anglers fish within 20 to 40 m of shore and, as demonstrated, during most of the year over 50% of the monitored walleyes bathymetric distribution was farther offshore.

Home Range

Home range has been defined by many authors as an area which is regularly traversed by an animal in its normal activities of food-gathering, mating, and caring for the young. This definition regards the time over which home range is defined to be that from one mating season to the next. For most species of temperature regions, this would encompass one year.

In a reservoir, various barriers to movement limit the size of a home range. Based upon the above definition, many authors (Crowe, 1962; Eschmeyer & Crowe, 1955; Olson and Scidmore, 1962; Priegel, 1968; Regier, *et. al.,* 1969) have concluded from mark-recapture studies that an individual walleye may well utilize an entire lake or reservoir over an annual period, however, isolated populations of walleyes have been found in many of the Great Lakes (Eschmeyer, 1950). These same authors and others have also found from mark-recapture studies that walleye return to the same spawning site year after year.

In this study, monitored walleye displayed two distinct behavioral patterns. Some fish wandered over the reservoir at varying rates following release, never utilizing any particular area repeatedly, while others would remain within a limited area. Occasionally this area would be abandoned and the fish would roam over a large area or re-establish another limited range. Based on movements recorded during this study, individual walleye utilize large portions of, if not the entire, reservoir during a 12-month period.

Homing could not be demonstrated if one considers the entire reservoir as the home range. Therefore, in this study, the definition of home range was modified to include only that area which is traversed repeatedly over the monitoring period. No attempt was made to define the home range in three dimensional terms although the vertical limits of home range are possibly very distinct.

Table 3. Summary of Home Ranges and Home Behavior of 9 Walleye Monitored in Center Hill Reservoir, Tennessee

Fish No.	*Months Monitored*	*Size of Range (hectares)*	*Comments Regarding Homing**
1	July-Aug	11.8	1, 4, 5, 7
3	Aug-Sept	22.0	1, 4, 7
9	Oct-Nov-Dec	47.7	1, 4, 6, 7
10	Nov-Dec	73.3	1, 3, 5, 8
11	Nov	75.6	1, 3, 8
12	Nov-Dec	29.5	2, 3, 7
13	Dec-Jan-Feb	58.5	1, 3, 8
25	May-June	33.7	1, 3, 8
29	June-July	13.7	1, 3, 8

*1 Initially captured within eventual home range.
2 Initially captured outside eventual home range.
3 Displaced from capture site when released.
4 Non-displaced from capture site when released.
5 Recaptured within home range.
6 Recaptured outside home range.
7 Release site within eventual home range.
8 Release site outside eventual home range.

Delineating the boundaries of such a home range based upon observations of individual fishes involved was difficult. An area selected entirely objectively did not realistically represent the actual area utilized. A method similar to that used by Burt (1943) was used in which a line was drawn subjectively around points of repeated occurrences which excluded as far as possible those areas which were not known to be utilized by the fish during that period. This method allowed the author to draw boundaries according to his personal knowledge of the movement and behavior of each individual subject.

By the above definition, nine of the 29 fishes monitored were determined to have established a home range during the time they were monitored (Table 3). However, when only the 18 fish monitored for more than 10 consecutive days were considered, 50% established home ranges. The remaining nine walleye were monitored during the spring and autumn months and no home ranges were established during these seasons.

With one exception, the home ranges utilized during the winter months were at least twice the size of those utilized during the summer. This is a further indication of increased activity and the seasonal pelagic behavior previously discussed.

Eight of the fishes were captured within eventually established home ranges and all were either released at or they returned to these areas. The behavior of the six walleye displaced from their capture site and their subsequent return to the capture site and establishment of home range, and the tendency for non-displaced fish to remain within a home range indicates that walleye can and do orient and return to home areas. Whether or not the walleye utilize these same home areas year after year could not be established in this study but this investigator questions the concept in light of the nomadic movement over the reservoir during much of the year.

A male walleye was captured near Great Fall Hydro Plant at the reservoir's headwaters on the Caney Fork River on January 11, 1975, and released that same day approximately 60 km away in the lake's headwaters on the Falling Water River. The fish was flowing milt at capture and ripe females were also present in the area. Over the 23.5-day monitoring period, some downstream movement did occur but not enough to consider the fish to be returning to the capture site. On March 15, 1976, the fish was recaptured by an angler in the general vicinity of the original capture site. Evidently the fish had again returned to the spawning site of the previous year. No ripe walleye were ever collected by this investigator in any area of the lake other than that immediately down-lake from the Great Falls facility, and the author believes that this is the primary spawning ground for Center Hill walleye. Muench (1966) mentioned other areas in Center Hill Reservoir as possible sites, but confirmed only this area.

SUMMARY

From July, 1974 through July, 1975, a study of the behavior and movement of sonar-tagged walleye was conducted on Center Hill Reservoir, Tennessee. The major objectives were to observe the behavior and movement of individual fish and determine traits of the population which might aid in the management of the walleye in a reservoir situation.

A total of 29 tagged walleye were released and monitored in Center Hill. Monitored walleye were most active, based on rates of movement, during the months of November through February. Monthly activity levels were not correlated with walleye-angler's success, apparently due to changes in habitat preference during peak months of activity which reduced their vulnerability.

Diel activity varied seasonally. During summer months walleye were most active nocturnally. During fall and winter a more crepuscular pattern was evident. During the spring there was no apparent daily cycle of activity.

Data on temperature and depth of the fish was obtained for only 9 of 18 walleye containing thermistor-equipped transmitters. Depth and temperature selection was often limited by hypolimnetic oxygen depletion. Based on the fish with the widest range of temperatures available to them, the preferred range appeared to be 12-18°C. Seven of these nine walleye preferred to remain within 2 m or less of the bottom and no pattern was established that would indicate preference for any particular depth. There is considerable

evidence in the literature, substantiated somewhat by data from this study, that light penetration is a significant factor governing both depth and temperature selection.

An attempt was made to correlate daily rates of movement of 18 walleye with selected environmental variables: water transparency, percent cloud cover, barometric pressure, water level, amount of precipitation and moon phase. No pattern was established either by correlation or multiple regression analyses. This does not indicate that environmental variables do not influence activity but only that the relationship apparently was too complex to be revealed in this study.

Movement patterns of monitored walleye indicated that spawning migrations to the headwaters of the Caney Fork River began as early as January and continued into March. Rates of movement to the spawning grounds varied from approximately 3.2 to 16.1 km per day. Apparently, some fish migrate continuously until they reach the spawning grounds while others make periodic stops along the way. The dispersal from the spawning grounds by walleye occurred at a slower rate than did the migration to them.

Monitored walleye remained more than 30 m offshore over 60% of the time. During winter and spring this percentage was often over 80 for several fish. Fishes monitored did show seasonal preferences for various areas of the reservoir. During the summer months monitored walleye occurred most often in shallow tributary headwaters and when found near shore, showed a preference for rock banks. During fall and early winter, walleye occupied the channel areas of major tributaries and showed no particular cover type preference. During the late winter and early spring the tracked walleye were found most often in areas on the main channel of the reservoir and migrated to the spawning grounds along this channel. When they were found along shore during this period, these fish seemed to prefer banks of mixed rock and mud or brushy cover.

In this study, home range was defined as an area which was traversed by the walleye repeatedly during the monitoring period and the boundaries were subjectively delineated by the author. Nine of 18 fish monitored for more than 10 days established a home range. Home range was apparently only utilized during the summer and early winter. The sizes of the home ranges were greater in winter than in summer. Data indicated that walleye displaced from their home range would return to it and furthermore that walleye returned to the same spawning area year after year.

Of the 29 walleye monitored, five either died after a period of monitoring or lost the transmitter, one died and was recovered, three were recaptured with gill nets during the course of the study, four were recaptured by anglers and the fate of 16 was not determined.

LITERATURE CITED

Austin, R. E. 1974. The effects of a hypolimnial discharge on two-story reservoirs. M.S. Thesis. Tennessee Technological University, Cookeville, TN. 39p.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. J. Mamm. 24: 346-352.

Crowe, W. E. 1962. Homing behavior in walleyes. Trans. Am. Fish. Soc. 91 (4): 350-354.

Dendy, J. S. 1945. Fish distribution, Norris Reservoir, Tennessee, 1943. II. Depth distribution of fish in relation to environmental factors, Norris Reservoir. Rep. Reelfoot Lake Biol. Sta., Vol. 9, pp. 114-135.

_______________. 1946a. Water temperature and spring fishing, Norris Reservoir, Tennessee. Rep. Reelfoot Lake Biol. Sta. Vol. 10, pp. 89-93.

_______________. 1946b. Further studies of depth distribution of fish, Norris Reservoir, Tennessee. Rep. Reelfoot Lake Biol. Sta., Vol. 10, pp. 94-104.

_______________. 1948. Predicting depth distribution of fish in three TVA storage-type reservoirs. Trans. Am. Fish. Soc. (1945). 75: 65-71.

Eschmeyer, P. H. 1950. The life history of the walleye, *Stizotedion vitreum vitreum* (Mitchill), in Michigan. Michigan Dept. Cons., Inst. Fish. Res., Bull. No. 3, 99p.

Eschmeyer, P. H., and W. R. Crowe. 1955. The movement and recovery of tagged walleyes in Michigan, 1929-1953. Michigan Dept. of Con. Miscellaneous Pub. No. 3. 32p.

Gaiduk, V.V., L. K. Malinin, and A. G. Poddubnyi. 1971. Determination of the swimming depth of fishes during the hours of daylight. J. Ichthyology 11 (1): 140-143.

Goddard, C. I., J. W. Lilley, and J. S. Tait. 1974. Effects of MS-222 anesthetization on temperature selection in lake trout, *Salvelinus namaycus* J. Fish. Res. Board Can. 31: 100-103.

Gordon, J. A. 1976. Water quality in Center Hill Reservoir. Final report to Corps of Engineers, Nashville, TN. 160pp.

Haslbauer, O. F. 1945. Fish distribution, Norris Reservoir, Tennessee, 1943, III. Relation of the bottom to fish distribution, Norris Reservoir. Rep. Reelfoot Lake Biol. Sta., Bol. 9, pp. 135-138.

Hasler, A. D., E. S. Gardella, R. M. Horrall, and H. F. Henderson. 1969. Openwater orientation of white bass, *Roccus chrysops*, as determined by ultrasonic tracking methods. Jour. Fish. Res. Bd. Can. 26(3): 2173-2192.

Johnson, J. H. 1960. Sonic tracking of adult salmon at Bonneville Dam, 1957. U.S. Fish Wildlife Serv. Bull. 176: 471-485.

Koo, T. S. Y., and J. S. Wilson. 1972. Sonic tracking of striped bass in the Chesapeake and Delaware Canal. Trans. Amer. Fish. Soc. 101(3): 453-462.

Leggett, W. C., and R. A. Jones. 1971. Net avoidance behavior in American shad (*Alosa sapidissima*) as observed by ultrasonic tracking techniques. J. Fish. Res. Bd. Canada, 28(8): 1167-1171.

Madison, D. M., R. M. Horrall, A. B. Stasko, and A. D. Hasler. 1972. Migratory movements of adult sockeye salmon (*Oncorhynchus nerka*) in coastal British Columbia as revealed by ultrasonic tracking. J. Fish. Res. Bd. Canada, 27(4): 715-730.

McCleave, J. D., and R. M. Horrall. 1970. Ultrasonic tracking of homing cut-throat trout (*Salmo clarki*) Yellowstone Lake. J. Fish. Res. Bd. Canada, 27(4): 715-730.

Mears, G. T., and J. R. McDearman. 1976. Ultrasonic fish tagging system development, January 1, 1974-June 30, 1975. Project # 2-219-R-1: Completion Rpt. TWRA & NOAA & TTU. 11p.

Moore, G. A. 1944. The retinae of two North American teleosts with special reference to their tapeta licida. J. Comp. Neur., Vol. 80, No. 3, pp. 369-379.

Muench, K. A. 1966. Certain aspects of the life history of the walleye, *Stizostedion vitreum vitreum* in Center Hill Reservoir, Tennessee. M. S. Thesis. Tennessee Technological University, Cookeville, TN. 40p.

Olson. D., and W. J. Scidmore. 1962. Homing behavior in spawning walleyes. Trans. Amer. Fish. Soc. 91(4): 355-361.

Peterson, D. C. 1975. Ultrasonic tracking of three species of black basses, *Micropterus* spp., in Center Hill Reservoir, Tennessee. M.S. Thesis. Tennessee Technological University, Cookeville, TN. 43p.

Priegel, G. A. 1968. The movement, rate of exploitation and homing behavior of walleyes in Lake Winnebago and connecting waters, Wisconsin, as determined by tagging. Trans. Wis. Acad. Sci., Arts Letters 56: 207-223.

Regier, H. A., V. C. Applegate, and R. A. Ryder. 1969. The ecology and management of the walleye in Western Lake Erie. Great Lakes Fish. Comm., Tech. Rep. 15, 101p.

Reid, G. K. 1961. Ecology of inland waters and estuaries. Van Nostrand Reinhold Co. New York, 375p.

Summerfelt, R. G., L. Hart, and P. R. Turner. 1972. Flathead catfish movements. Natl. Marine Fish. Serv., U. S. Dept. of Commerce, P. L. 8—309, Completion Rept. for Okla. Proj. 4-60-R. Multilithed. 76p.

Trefethen, P. S. 1956. Sonic equipment for tracking individual fish. U. S. Wildlife Serv., Spec. Sci. Rept. Fish. 179: 11p.

Wrenn, W. B. 1974. Fisheries studies in relation to a long heated discharge channel (Colbert Steam Plant, Tennessee River). Ph. D. Dissertation, Virginia Polytechnic Institute. 104.

Ziebell, C. D. 1973. Ultrasonic transmitters for tracking channel catfish. Prog. Fish-Cult. 35(1): 28-32.