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Walleye Movement, Distribution, and Habitat Use in Laurel River Lake, Kentucky

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Abstract. Walleye movement, distribution, and habitat use in Laurel River Lake were determined by radio-tracking 35 walleye for 605 days (mean = 249 days) from March 1994 through November 1995. The goal of this study was to increase the angler utilization of walleye, a put-grow-take fishery in Laurel River Lake. Walleye movement (as measured in distance between weekly locations) was highest during the spring (median = 120 m/day) and lowest during the summer (median = 53 m/day). Maximum area encompassed by walleye varied from 33-1,547 ha, with 82% of walleye encompassing areas > 300 ha. Activity areas ranged from 2-590 ha with 75% of walleye utilizing areas < 300 ha. During the summer, most walleye confined their activities to specific areas of the lake and were often located in the same area during consecutive weeks. Walleye were widely distributed throughout the lake during each season, although only two walleye remained in the upper Laurel River arm during July and August, probably due to lack of coolwater habitat (< 25 °C) in that section. Walleye predominately utilized standing timber located only in the coves on an annual basis (54%) and even more (60%) in the summer. During summer stratification (June-August), walleye selected water temperatures averaging 23.0 °C for a mean depth of 6.1 m. Walleye gradually moved deeper as summer progressed, which coincided with an increase in the median depth of the thermocline. Walleye were most active at night, with mean peak movements occurring near dusk (2100-2200 h), at 0300-0400 h, and near dawn (0600-0700 h). Walleye typically moved out of the timbered coves at night and either traveled along the shoreline, suspended at the edge of timber near the mouth of the cove, or suspended in open water in the main lake. Walleye usually returned to the same cove by morning, although walleye occasionally returned to a nearby cove. A report on the findings of the study was provided to anglers in an "angler report" during the spring 1997. Walleye harvest and angler success are expected to increase in Laurel River Lake as anglers use this information.

INTRODUCTION

Several telemetry studies have been conducted on walleye; however, most have dealt with movements in river systems (Bahr 1977; McConville and Fossum 1981; Holzer and Von Ruden 1982; Kingery and Muncy 1988; Paragamian 1989), in northern lakes and reservoirs (Holt et al. 1977; Einhouse 1981; Hall 1982; Heidinger and Tetzlaff 1989), or midwestern reservoirs (Summers 1979, Prophet et al. 1989; Parks and Kraai 1991). Few studies have been conducted on deep, clear, southern reservoirs such as Laurel River Lake; therefore, little is known about the behavior of walleye in such systems. Ager (1976) tracked 29 walleye in Center Hill Reservoir, Tennessee; however, tracking times for individual fish were typically < 60 days because of equipment limitations. Shultz (1992) tracked 12 walleye in Dale Hollow Reservoir, Tennessee for over one year; however, his findings were general in scope.

A walleye population was established in Laurel River Lake upon impoundment in 1974, when two million walleye fry were stocked. Walleye fingerlings (~3.8 cm) have been stocked into Laurel River Lake annually since 1985 at a rate of 125 fish/ha. Natural reproduction has been documented the past three years (1994-1996); however, most of the walleye in the lake are the result of stocking. Gillnetting and electrofishing surveys indicate that the lake contains a good walleye population, but angler utilization has remained low. Results of a 1993 daytime creel survey on Laurel River Lake indicated that walleye comprised 13% of the total harvest by weight (0.47 kg/ha) and about 4% by number. Only 1.4% of the fishing trips to Laurel River Lake in 1993 was for walleye. Historically, most walleye have been caught incidently while fishing for other species. Most anglers attributed low fishing success to a general lack of walleye knowledge, specifically their habitat preferences and seasonal distribution.

The Kentucky Department of Fish & Wildlife Resource's conducted a walleye telemetry study on Laurel River Lake from March 1994 through November 1995. The goal of the study was to increase the utilization of walleye in Laurel River Lake by informing anglers on walleye movement patterns, habitat usage, and distribution within in the lake. The specific objectives of the Laurel River Lake telemetry study were to 1) determine the seasonal distribution of walleye, 2) determine the daily and seasonal movement patterns of walleye, and 3) determine the habitat usage (including temperature and depth selection) of walleye.

STUDY AREA

Laurel River Lake is a 2,452-ha (maximum power pool) reservoir located in Laurel and Whitley counties, Kentucky. This lake is divided into two major arms, Laurel River and Craig's Creek, and has a mean depth of 21.9 m and a maximum depth of 76 m. Most of the watershed is forested (71%). The shoreline is relatively steep-sided and composed of mixtures of rock and sand with limited clay. Secchi disk readings are typically 2.5-4.0 m. The lake is highly dissected and contains numerous coves, most of which contain standing timber. A trophic gradient exists in Laurel River Lake ranging from oligotrophic in the lower lake and Craig's Creek arm (2,019 ha) to mesotrophic in the midregion of the lake (305 ha) to highly eutrophic in the headwaters (128 ha) of the Laurel River arm (Kentucky Division of Water 1984). Laurel River Lake is a warm, monomictic lake which is stratified between April-November. The upper Laurel River arm (uplake from Spruce Creek) experiences oxygen depletion (< 4 mg/l) in < 25 ^{0}C water during late summer. Most of the lake, however, maintains $\geq$ 4mg/l oxygen in < 25 C^0 water during summer stratification.

MATERIALS AND METHODS

Radio transmitters (48 MHZ) were surgically implanted into the body cavity of 47 walleye (26 females, 19 males, 2 undetermined sex) during March 1994 (28 transmitters) and December 1994 through March 1995 (19 transmitters; Table 1). Most walleye (45) were captured by electrofishing; 3 were captured by gillnets. Walleye were captured throughout the lake, including headwater, mid-lake, and lower lake areas. An effort was made to collect equal numbers of males and females from each area, although this was not always possible. Walleye weighing at least 1.1 kg were selected for tagging to keep the ratio of tag weight to fish's weight within the range recommended by Winter et al. (1978). Tagged male walleye ranged from 48.8- 67.3 cm and females ranged from 47.8-81.3 cm. Four sizes (ATS models 5, 5A, 6, and LTC30) of transmitters from Advanced Telemetry Systems, Isanti, Minnesota were used during the study. Transmitter life expectancy ranged from 225-450 days, depending upon the model, and each transmitter was equipped with an external whip antennae to increase reception range. Each transmitter operated on a unique frequency which allowed recognition of individual walleye. Forty-three of the 47 transmitters were temperature-sensitive. During lake thermal stratification, walleye's depth could be determined by comparing to a temperature profile of the lake at the walleye's location.

Surgical procedures occurred on the lakeshore following the collection of one to four walleye. Captured walleye were sedated in a 100 mg/l solution of tricaine methane sulfonate (MS-222), measured to the nearest 0.2 cm, and weighed to the nearest 0.4 kg. Walleye were then transferred to a hammock that consisted of seine netting draped over a metal frame. The walleye were placed ventral side up in the surgical hammock with their head and gills immersed in fresh lake water and their abdomen exposed. Surgical gloves were worn during the surgery. Surgical equipment was sterilized in a 25% Virosand^R solution and then rinsed in sterile water to prevent tissue irritation. The incision site was sprayed with a topical antiseptic (Betadine^R) and two to three rows of scales were removed from the incision area. A 2-cm incision was made (with scalpel) just lateral to the midline of the belly and was lengthened to 3-4 cm using surgical scissors. The whip antenna was first inserted into the incision and threaded out of the body cavity (about 3 cm posterior to the incision) through a hypodermic needle. The transmitter was then inserted anteriorly into the body cavity and the incision was closed with 3-0 (Dermalon^R) nonabsorbable surgical sutures. Typically, four to five sutures were required to close the incision. The surgical process typically lasted 5-8 minutes and the walleye were usually recovered from the anesthetic upon completion of the surgery. A Floy^R tag was inserted just behind the dorsal fin as an external marker to indicate a $20 reward for the transmitters. Walleye were released near the capture area immediately upon recovery from the anesthetic.

DAYTIME TRACKING

Walleye were tracked by boat during daylight hours from March 1994 through November 1995. The tracking boat was equipped with a 4-element Yagi antennae connected to a programmable, scanning receiver (Challenger Model 2000; Advanced Telemetry Systems) that cycled through the transmitter frequencies. Tracking was usually conducted 1-2 times per week in an effort to locate each walleye at least once per week. Each time a walleye was located, the following information was recorded at each fix: area type (cove, shoreline, point, open water, submerged hump), cover type (standing timber, rock/sand, fallen tree, suspended, and other), water temperature at walleye depth (based on transmitter temperature), water depth at walleye location, distance from shore, distance from edge of timber (if the walleye was located in standing timber), and water clarity determined by secchi disk. During thermal stratification, walleye depth (to the nearest 0.1 m) and DO level at walleye depth were determined by comparing the temperature reading from the transmitter (based on pulse rate) to a temperature and oxygen profile recorded at the walleye's location. Correlation analysis was used to test the relation between water transparency and walleye depth. Temperature selection data was analyzed for differences between lake regions by the Wilcoxon rank sum test (Rosner 1986).

Location was plotted on a grid system (50 m X 50 m) overlaid on the lake (1:24,000), and movement distances (m/day) were determined by dividing the distance between weekly locations by the number of elapsed days. This movement rate is an underestimate since walleye can move extensively and return to the same place; however, it is useful for comparing monthly and seasonal movements. Median values were used for movement data, water depth at walleye location, distance from shore, and distance to the edge of timber to reduce the effect of outliers. Movement data and distance to edge of timber were analyzed for differences between seasons by the Kruskal-Wallis test (Rosner 1986).

Maximum area encompassed and size of activity areas, calculated by the minimum area polygon method (Winter 1977), were determined for walleye tracked > 180 days. Maximum area encompassed was the area enclosed by all fixes for each walleye. Activity area (home area) was defined as an area normally traversed by walleye during the monitoring period, excluding wanderings, movements between activity areas, and spawning movements. Certain areas within the activity areas that received heavy daytime use were termed "rest areas" (Pitlo 1978). Correlation analysis was used to test the relation between activity area size and size of tagged fish, number of days tracked, and number of fixes.

24 - HOUR TRACKING

Daily activity patterns were determined by continuous 24-hour tracking of individual walleye. During these tracks, two or three walleye were selected and located approximately once per hour during a 24-hour period to determine their activity patterns. Tracking typically began about mid-day and continued for 24 hours. Total distance traveled over 24 hours and hourly movement rates were determined for each walleye during these tracks. Seasonal differences between total distance traveled within 24 hours were examined by the Kruskal-Wallis test (Rosner 1986).

RESULTS

Limited tracking was accomplished on 41 of the 47 tagged walleye; six walleye were not located after release. Six of the remaining 41 walleye died or expelled their tags, thereby reducing the study cohort to 35 fish. Seven of these walleye were caught by anglers during the study period. Thirty-one walleye were tracked 100+ days, 24 were tracked for 200+ days, and 10 walleye were tracked at least 300 days. A total of 886 daytime fixes on 35 walleye was made during the study period.

Twenty-four hour tracking sessions were conducted on eleven separate occasions. Twenty-seven tracks on 17 walleye were conducted during these sessions. Most 24-hour tracking sessions were during the summer (15 tracks), followed by the fall (7 tracks) and spring (5 tracks). No 24 - hour tracks were conducted during the winter period. Of the 17 walleye tracked, 11 were tracked once, 2 were tracked on two separate occasions, and 4 were tracked on three separate occasions.

DISTRIBUTION AND MOVEMENT

Walleye were widely distributed throughout the lake during the spring (March-May), including the headwaters of the major tributaries (Figure 1). Movement of walleye measured in m/day between locations was highest during the spring season (median = 120 m/day). Several walleye made long distance migrations, traveling over much of the lake. Walleye tagged in the headwaters of the two major arms typically traveled the greatest distances; most returned to the main lake after spawning in the headwaters. The highest monthly movement rate for the year occurred in April (Figure 2), primarily due to spawning movement. In April, walleye were rarely located in the same area for consecutive weeks. By mid-May, most movement rates decreased and walleye were often located in the same area in consecutive weeks.

Walleye typically had the most restricted distribution during the summer (June-August), although they were still distributed throughout most of the lake (Figure 3). Only two walleye (#130 & #210) inhabited the upper Laurel River arm (near Mill Creek) during midsummer. All other walleye remained downlake from Spruce Creek. During the summer, most walleye established an "activity area" and stayed in the same general area of the lake, often in the same location for several consecutive weeks. Similarly, the movement rate of walleye during the summer was lower than any other season (median = 53 m/day). Walleye movement was significantly lower (Kruskal-Wallis test, $P < 0.05$,) during the summer than during the spring and winter. June had the lowest median movement rate of any month (Figure 2).

Walleye were widely distributed throughout the lake during the fall (September-November; Figure 4). Walleye movement increased (median = 93 m/day) during declining water temperatures in the fall as they began to frequent more areas of the lake. October was the beginning of this trend, as indicated by the higher movement rates (Figure 2). Some walleye moved back to the heads of some of the major tributaries while others remained in the main lake. Individual movement rates were highly variable; the highest rate (5,798 m/day) noted by one walleye occurred in November. The two walleye that remained near Mill Creek all summer moved to near Corbin City Dam in late fall.

Walleye were widely distributed throughout the lake in the winter months (December-February), including the headwaters of the two major arms, Laurel River and Craig's Creek (Figure 5). Movement rates were typically high during the winter months (median = 105 m/day; Figure 2). Most walleye were not located in the same area in consecutive weeks.

MAXIMUM AREA ENCOMPASSED; ACTIVITY AREA

Maximum area encompassed and size of activity areas were calculated for the 27 walleye that were tracked > 180 days. Maximum area encompased ranged from 33-1,547 ha; 82 % of the walleye encompased areas > 300 ha (Table 1). Activity areas were established by early June and ranged in size from 2-590 ha, with most (75%) < 300 ha. Most walleye (67%) utilized a single activity area; 33% utilized two or more areas. Within the activity areas, walleye were typically found in 1-3 smaller daytime resting areas usually within timbered coves. Five walleye (#'s 130, 210, 750, 830, 990), however, did not appear to use specific daytime rest areas. These fish were typically located in a different resting area each day, although they were still within a relatively confined activity area. Activity area size was not significantly correlated with length of period tracked ($r = 0.30$; $P = 0.12$) or number of contacts ($r = 0.16$; $P = 0.16$). However, there was a significant positive correlation between activity area size and weight of fish ($r = 0.53$; $P = 0.004$), suggesting that larger fish utilized larger activity areas.

Walleye typically maintained activity areas through the warmwater months (June-September). During the fall, some walleye abandoned their summertime activity areas and became more nomadic. Unfortunately, many of the tags began to fail during October and November 1994 when walleye were utilizing larger areas of the lake; therefore, limited data was available for the winter period. Walleye were behaving similarly in October and November 1995, when the study was concluded. It remains unknown whether these fish were truly nomadic or simply establishing larger late fall-winter activity areas.

Relationships between spawning sites and activity areas were mixed. Walleye that were tagged near the Laurel River Dam during the spawning season established activity areas that included their tagging site. Contrarily, some walleye that were tagged in the two headwater areas during the spawning season established activity areas downlake from their tagging sites. These walleye were in the headwater areas only during the spawning season. Other walleye tagged in the headwaters remained near their tagging sites the entire time they were tracked and established activity areas that included their tagging site. Walleye tagged in the mid-upper portions of the Laurel River and Craig's Creek arms also displayed varying patterns, with some fish establishing activity areas inclusive of their tagging site while others established activity areas in other parts of the lake.

HABITAT USAGE

Coves were the dominant area type utilized by walleye during the study. Cove use was very similar among seasons (Figure 6), with walleye found in coves in more than 62% of the daytime locations. Use of points was highest in the fall; shoreline use was highest during the winter and spring. Walleye began using submerged humps in July and continued their use through the fall, with heaviest use in October (7.5%). Walleye were rarely suspended over deep water during the daytime.

Standing timber, confined to coves, was the dominant cover type used by walleye during the daytime. Standing timber comprises only about 6% of the surface area of Laurel River Lake, yet over one-half (54%) of the walleye were located in standing timber during the daytime. Use of standing timber was similar between sexes: male walleye were found in standing timber 56% of the time while females used standing timber 51% of the time. Standing timber was the dominant cover type used by 19 of the 31 (62%) walleye that were tracked more than 10 times. Standing timber use was highest during the summer (Figure 7), particularly in June and July (Figure 8). Although standing timber was the dominant cover type, the relative position of walleye within the cove varied among seasons. Walleye were located farther back in the standing timber (as measured in distance to outer edge of timber) during the spring (median = 73 m) than in the summer (median = 44 m) and fall (median = 41 m) (Kruskal-Wallis test, $P < 0.05$).

DEPTH AND DISTANCE FROM SHORE; TEMPERATURES OCCUPIED

Tagged walleye were usually located in water < 10 m deep and within 30 m of shore (Figure 9). Walleye were typically shallowest and nearest to shore during the winter and spring. They exhibited a general trend of inhabiting deeper water from spring through summer. During late September, when surface water temperatures cooled, most walleye moved toward the shore into < 8 m of water while a few remained offshore in 8-12 m water. Although the general trend during the fall was movement into shallower water, depths of individual fish varied widely and walleye did not appear to concentrate at a particular depth.

During summer stratification (June-August), exact depth of the walleye was determined during 263 observations. Mean depth from all combined observations was 6.1 m (mean range 4.2-7.6 m) during thermal stratification. Walleye gradually moved deeper as summer progressed. Mean depth was 4.5 m (mean range 2.8-6.7 m) in June ($N = 72$), 6.2 m (mean range 3.8-7.9 m) in July ($N = 91$), and 7.1 m (mean range 4.0 - 8.3 m) in August ($N = 101$). Walleye depth was weakly but significantly correlated ($r = 0.25$; $P < 0.001$) with water clarity, suggesting that water clarity played a role in depth selection. Walleye inhabiting timber were slightly shallower (mean depth = 5.9 m) than other walleye (mean depth = 6.2 m); however, this difference was not statistically significant (Wilcoxon rank sum test, $P = 0.12$).

Although the mean depth occupied by walleye increased during the summer months, mean temperature occupied remained nearly identical (Figure 10). Mean temperature occupied during summer stratification (June-August) was 23.0 °C (mean range 19.4-26.3 °C; N = 271 observations), with 77% of the walleye mean temperatures between 21-25 °C (Table 2). Walleye in the upper portion of the Laurel River arm (upstream from mouth of Spruce Creek) occupied significantly (Wilcoxon rank sum test, $P < 0.05$) warmer water (mean = 25.7 °C; N = 23) during the summer than walleye downlake from that location (mean = 22.8 °C; N = 246). The low DO levels (< 4 mg/l) in the thermocline in the upper Laurel River arm probably contributed to this temperature differential since walleye were rarely (4.2%) located in water with $\leq$ 4 mg/l DO during the summer.

DIEL ACTIVITY -24-HOUR TRACKS

Walleye were most active at night, with maximum movement rate between 2000-0800 h for 85% of the walleye. A tri-modal pattern of movement occurred, with peaks just after sunset (2100-2200 h), at 0300-0400 h and again at dawn (0600-0700 h), with maximum movement at 0300 h. Mean nighttime movement rates were usually > 100 m/h while daytime rates were < 50 m/h (Figure 11). The peak mean movement rate was highest during the spring (396 m/h), occuring at 0200 h, followed by the fall (198 m/h) at 0400 h, and summer (174 m/h) at 2200 h.

Mean distance traveled over 24 hours for all walleye was 1,750 m (range 0-3,910 m). A declining trend of total distance traveled from the spring (mean = 2,660 m; range 1,170-3,910 m) to summer (mean = 1,590 m; range 820-3,580 m) and fall (mean = 1,450 m; range 0-2,980 m) tended toward significance (Kruskal-Wallis test, $P = 0.10$). Although distance traveled over 24 hours varied widely among individual walleye, mean distance traveled over 24 hours during the warmwater months (June-September) was similar (Figure 12).

DISCUSSION

Walleye utilized most major sections of Laurel River Lake throughout the year, with some limited distribution during the summer months. Walleye that were tagged in the headwater portions of the lake during the spawning season typically frequented a larger portion of the lake than fish tagged in the lower lake near the dam. Similar wide range use by walleye has been reported for Center Hill Reservoir, Tennessee (Ager 1976), Lake Okoboji, Iowa (Pitlo 1978), and Chautauqua Lake, New York (Einhouse 1981). Only two walleye remained in the upper Laurel River arm during midsummer. These two walleye typically remained in 25-27 °C water temperatures which exceeded their preferred temperatures of 20.6-23.2 °C but below their reported lethal temperature of 31.6 °C (Hokanson 1977).

Annual walleye movement patterns in Laurel River Lake were similar to patterns reported in the literature, with highest movement during the coolwater seasons (fall-winter-spring). Spawning migrations accounted for much of the movement documented in late March and April, as most walleye tagged in the two headwaters during March returned to the main lake within weeks of tagging. A few walleye, however, appeared to be year-round residents of the upper arms of Laurel River and Craig's Creek; they remained near their tagging sites the entire time they were tracked. Walleye tagged in the lower lake near Laurel River dam typically remained near their tagging sites and exhibited more modest movements than headwater fish. Data from this study suggest that the walleye population in Laurel River Lake is composed of two discrete spawning groups: headwater spawners and main-lake spawners. These groups are segregated only during the spawning season; they intermingled during other times of the year. Walleye did not appear to make mass migrations to the headwaters during the spawning season. Instead, it seemed some walleye chose to spawn on the riprap of the Laurel River Dam or on rocky banks in the lower lake while others made the migration to one of the headwaters. Several walleye were documented returning to these areas in consecutive years. Food availability may have also influenced movements of Laurel River Lake walleye. Both Ney (1978) and Holt et al. (1977) found walleye more active in the spring and fall, possibly due to lower food availability. Similarly, in Laurel River Lake, the primary prey (gizzard and threadfin shad) abundance is highest in the summer when walleye movement was lowest.

Laurel River Lake walleye displayed characteristic nighttime movement patterns generally associated with feeding. Ryder (1977) noted that most feeding by walleye in clear lakes is either crepuscular or nocturnal. Laurel River Lake walleye were typically found inactive in timbered coves during the daytime. Movement typically began at dark (2100-2200 h) as walleye exited the standing timber and either traveled along the shoreline or suspended near the mouth of the cove or in open water. Suspended walleye were often marked with schools of baitfish (presumably shad). Walleye also commonly suspended within the timber at night, especially in late summer. Walleye tended to suspend in open water more during late summer and fall than during the spring, possibly due to the greater availability of shad during the summer and early fall. Mean movement rates remained high during the night, with peaks near 0200-0300 h and dawn (0600-0700 h); the dawn peak often coincided with walleye returning to the coves. Other investigators have reported similar findings, with reported peak activity occurring near dusk and dawn (Carlander and Cleary 1949; Fossum 1975; Kelso 1978; Holt et al. 1977; Pitlo 1976; Einhouse 1981; McConville and Fossum 1981). Bahr (1977) reported four distinct modes of activity–at 0230 h, 1630 h, 1130 h, and 1830 h, with the maximum movement peak occurring after midnight (at 0230 h) as in Laurel River Lake.

Laurel River Lake walleye appeared to use the timbered coves as daytime rest areas; they typically returned to the same cove or a nearby cove after foraging at night. Similarly, Pitlo (1978) noted that study fish in West Lake Okoboji, Iowa were usually found stationary in smaller rest areas during the daytime period and moved toward or within a larger foraging area during the nighttime period. West Lake Okoboji walleye tended to make nightly, daily, or two-day excursions out of the rest area and then returned. Utilization of smaller rest areas within activity areas has also been noted by Einhouse (1981) and Prophet et al. (1989).

Laurel River Lake walleye typically remained at similar depths throughout the 24-hour monitoring periods. Some reports suggest that walleye move into shallow water at night to feed (Carlander and Cleary 1949; Scott and Crossman 1973). Other studies found no difference in daily depth distribution (Einhouse 1981; Hall 1982; Prophet et al. 1989). Interestingly, four walleye in Laurel

River Lake moved 3-5 m deeper during the night for periods ranging from 1-6 hours, possibly to forage. Walleye in Laurel River Lake feed primarily on shad during the year; however, rainbow trout are stocked annually in Laurel River Lake and some walleye may move deeper at night into cooler water to feed on trout. Rawson (1956) found that in Lac La Rounge, Saskatchewan, walleye were most often caught in deep water when ciscoes, the most abundant food item of walleye, were numerous in the 15-20 m depths. Similarly, Eschmeyer (1950) found that Michigan walleye were generally located at the depth of their forage. In nearby Dale Hollow Lake, Tennessee, Schultz (1992) found that the mean depth of walleye captured in vertical gillnets was deeper than that for walleye implanted with transmitters. He suggested that different sampling times (gillnets at night, transmitters during the day) accounted for the difference. Dale Hollow Lake walleye may have been moving deeper at night to feed on alewives.

Walleye depth distribution in Laurel River Lake varied seasonally and was influenced by water temperature, oxygen concentrations, and possibly water clarity. Walleye moved deeper during the summer months as the thermocline moved deeper except for the two "outlier" walleye in the Laurel River arm headwaters. These two walleye were limited to shallow depths because of oxygen depletion in the thermocline; they typically occupied the coolest water that contained > 4.0 mg/l DO. Fitz and Holbrook (1978) found that as the thermocline increased in median depth during the period of stratification (May-August), there was a corresponding increase in walleye depth in Norris Reservoir, Tennessee. Also, Dendy (1948), using gillnets in three Tennessee reservoirs, found that as summer progressed, walleye distributed themselves in deeper water unless forced to remain shallow by oxygen depletion. Similarly, Ager (1976) suggested that hypolimnetic oxygen depletion limited the depth selection of walleye in Center Hill Reservoir,Tennessee. Light penetration may have influenced walleye depth selection in Laurel River Lake. Ryder (1977) stated that in clear lakes, light is most important variable affecting depth distribution. Kelso (1976) agreed with Ryder's contention that light rather than temperature regulate depth in walleye; however, these findings were in northern water bodies where epilimnetic water temperatures remained cool (< 23.0 ^{0}C). Ryder (1977) stated that walleye may optimize daytime light levels by using some form of cover to reduce light intensities. Pitlo (1978) found that walleye in Lake Okoboji, Iowa used rooted aquatic vegetation to reduce light intensities. Likewise, Laurel River Lake walleye may have used timber to reduce light intensities—walleye inhabiting timber were slightly shallower than other walleye. The variables affecting walleye depth distribution in Laurel River Lake were interrelated. During the summer, walleye depth was positively correlated to water clarity; however, the more turbid locations were typically in the upper Laurel River arm, which lacked coolwater habitat. Therefore, walleye in the upper Laurel River arm would have remained shallow in this area regardless of water clarity.

Mean temperatures occupied by walleye during the summer in Laurel River Lake were similar to findings in nearby reservoirs. Schultz (1992) reported that the mean temperature occupied during summer stratification by walleye in Dale Hollow Lake, Tennessee was 23.9 ^{0}C. Similarly, four of the five walleye tracked during the warmwater months (May-September) in Center Hill Reservoir, Tennessee occupied mean temperatures of 23.7-25.2 ^{0}C (Ager 1976). Fitz and Holbrook (1978) reported that walleye in Norris Reservoir, Tennessee appeared to avoid temperatures above 24 °C. Mean temperatures occupied by walleye in Laurel River Lake were very close to the physiological optimum (22.6 °C) reported by Hokanson (1977). The similarity of the mean temperature occupied during each summer month (mean range 22.8-23.2 °C), suggested that walleye preferred temperatures near 23.0 °C.

Most tagged walleye in Laurel River Lake confined their activities to specific areas of the lake and were typically found in the same areas in consecutive weeks during the summer and early fall. The use of specific areas (activity area, activity center, home area, home range) by walleye has been documented in several biotelemetry studies. Ager (1976) found that 9 of the 18 walleye that were monitored in Center Hill Reservoir, Tennessee for more than 10 consecutive days established a home range. Pitlo (1978) stated West Lake Okoboji, Iowa walleye established activity centers from mid-June through mid-October. Einhouse (1981) found that Chatauqua Lake walleye utilized activity centers during summer-early fall. Although most (67%) of the walleye in Laurel River Lake utilized a single activity area, 33% used 2 or more areas. The use of multiple activity areas has also been documented by Pitlo (1978), Einhouse (1981), Hall (1982), and Parks and Kraii (1991). The use of multiple activity areas and nomadic movement have been associated with larger fish in some studies (Einhouse 1981; Hall 1982), although Parks and Kraai (1991) found no significant relationship between fish size and the formation of multiple activity areas.

Laurel River Lake walleye occupied activity areas similar in size (2-590 ha) to those reported in the literature. Ager (1976) found that walleye in Center Hill Reservoir, Tennessee (8,500 ha) occupied areas ranging in size from 11.8-75.6 ha and that winter home range areas were usually twice as large as summer areas. Prophet et al. (1989) found walleye established home range areas of about 10-90 ha in Marion Reservoir, Kansas (2,511 ha). Walleye in West Lake Okoboji, Iowa (1,540 ha) established summertime activity areas of 7-77 ha (Pitlo 1978). Mean size of activity areas for walleyes tracked in the summer at Jamestown Reservoir, North Dakota, was 45.4 ha (Hall 1982). Einhouse (1981) noted most (57%) walleye in Chautauqua Lake, New York (5,324 ha) confined their activities to < 1200 ha areas. Parks and Kraai (1991) found that the majority (79%) of tagged fish occupied areas < 1200 ha in Lake Meredith, Texas (6,447 ha).

Activity areas were typically associated with a group of timbered coves, the primary habitat type utilized by walleye in Laurel River Lake. Walleye have been found in a variety of habitat types that varied throughout the water bodies studied. Walleye have been shown to utilize submerged beds of aquatic vegetation (Pitlo 1978; Einhouse 1981), submerged islands (Summers 1979), mud and rock shorelines with brush or openwater areas (Ager 1976), steep rocky shorelines or openwater areas (Schlagenhaft and Murphy 1985), brushy or rocky shorelines (Parks and Kraai 1991), and standing timber (Wilson 1997). Walleye appear to be very adaptable and typically utilize any available cover. Results from this study indicate that walleye use standing timber where available and anglers may improve their success by concentrating in these areas.

Although walleye are native to Kentucky, they have historically been a minor component of many of Kentucky's fisheries. Native walleye fisheries declined in Kentucky reservoirs following impoundment, and "northern" stock (Lake Erie origin) walleye were used to re-establish fishable populations. Utilization remained low, however, partly because anglers lacked the necessary knowledge to effectively fish for walleye in Kentucky reservoirs. The goal of the walleye telemetry study on Laurel River Lake was to increase the utilization of walleye in Laurel River Lake by informing anglers on their distribution, movement patterns, and habitat use. Angler interest in the project was high throughout the study period and many anglers improved their catches of walleye by using the information relayed to them while the study was ongoing. A report on the findings of the study was provided to anglers in an "angler report" during spring 1997. Walleye harvest is expected to increase in Laurel River Lake as anglers use this information.

The following management recomendations for the walleye fishery in Laurel River Lake are submitted. Information gained from this study should continue to be provided to anglers upon request. Maintenance stockings of fingerling walleye should continue at the current rate of 125 fish/ha (50/ acre), since stocked fish are currently comprising the majority of walleye fishery in the lake. Stocked walleye should be marked with oxytetracycline (OTC) for an additional 2-3 years to monitor the contribution of stocked fish. If stocked fish continue to comprise greater than 50% of the young-of-year walleye captured in fall gillnetting samples, a higher stocking rate should be considered in an effort to produce stronger year classes. Also, timing of stockings coincident with shad spawnings should be considered. Size distribution and relative abundance should be monitored by early spring (March) electrofishing. Additionally, Floy^{R} tagging should be conducted periodically to monitor changes in exploitation rates. Finally, an angler diary program should be considered to supplement creel survey data and to monitor angling success. An angler diary program would capture the night fishery, which has been difficult to sample by conventional creel survey methods.

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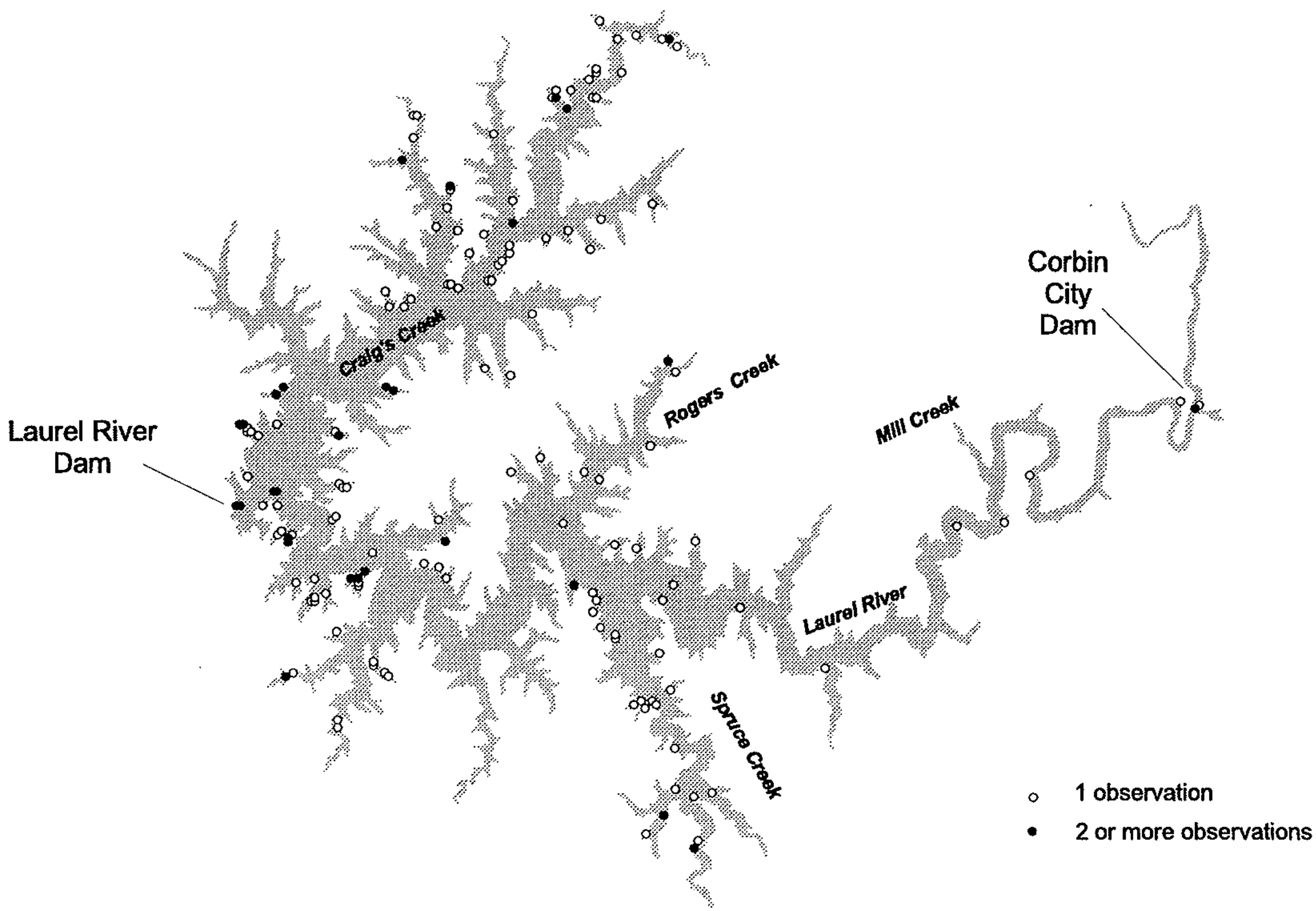

Figure 1. Daytime distribution of walleye during the spring season (March-May) in Laurel River Lake.

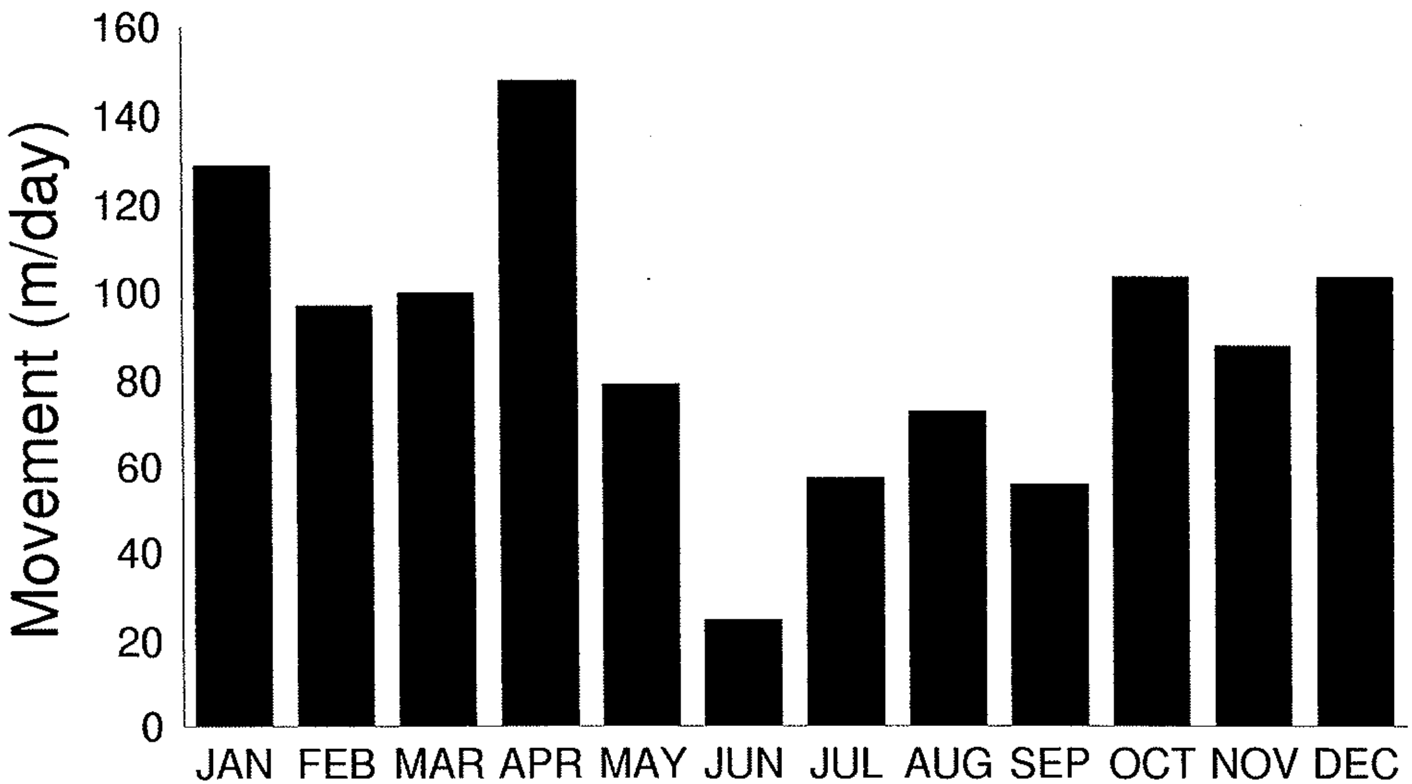

Figure 2. Median monthly walleye movement in Laurel River Lake.

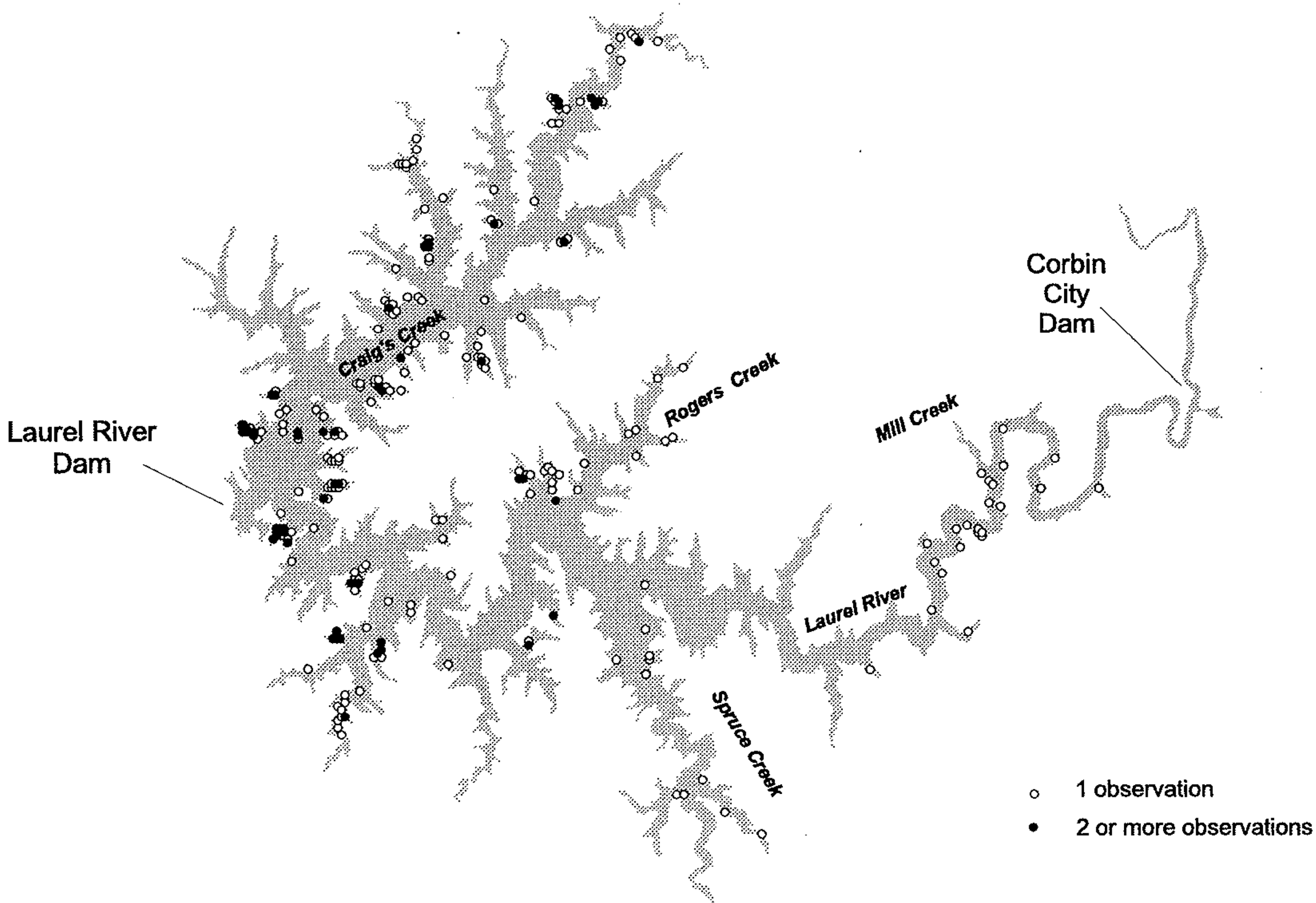

Figure 3. Daytime distribution of walleye during the summer season (June-August) in Laurel River Lake.

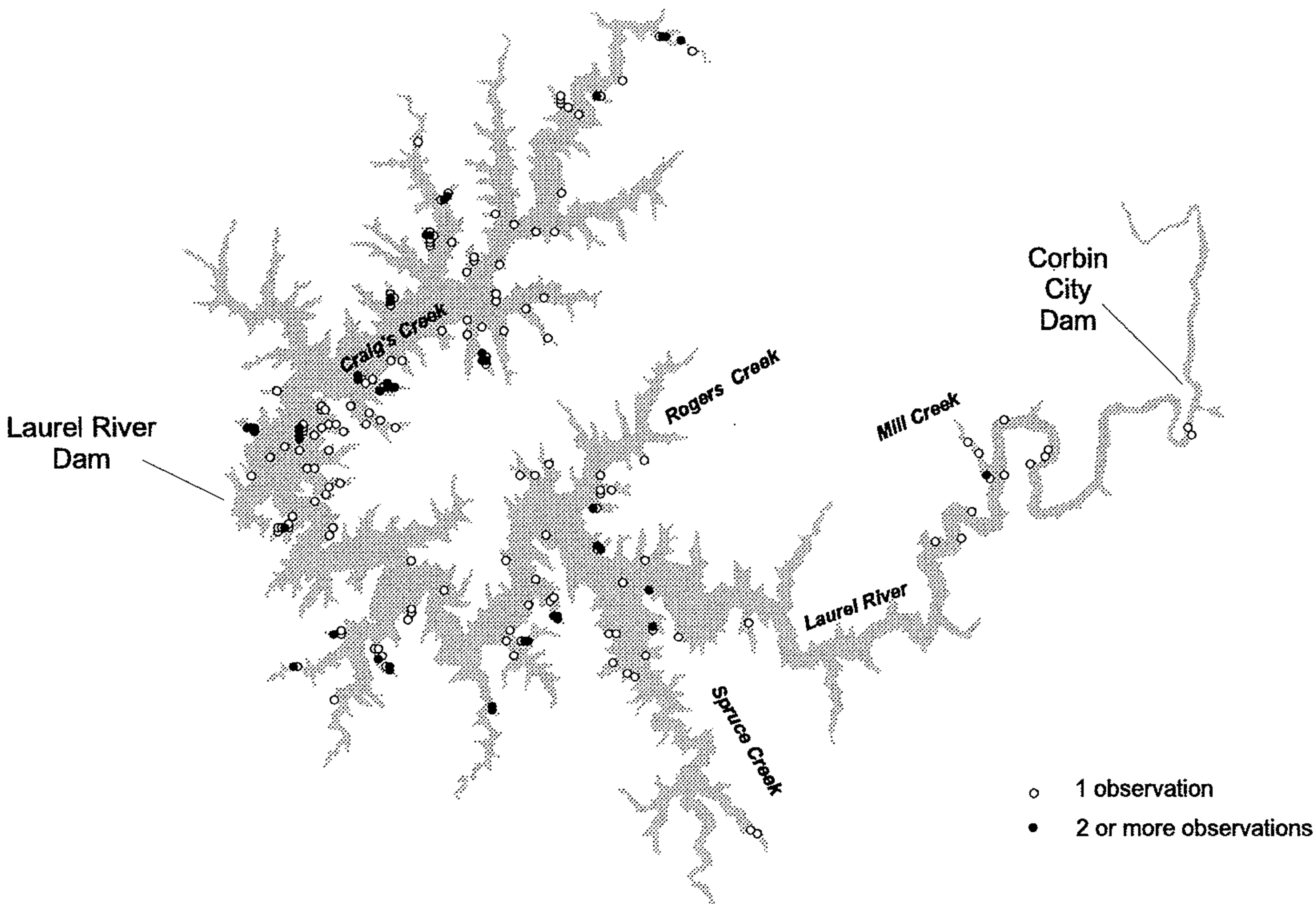

Figure 4. Daytime distribution of walleye during the fall season (September-November) in Laurel River Lake.

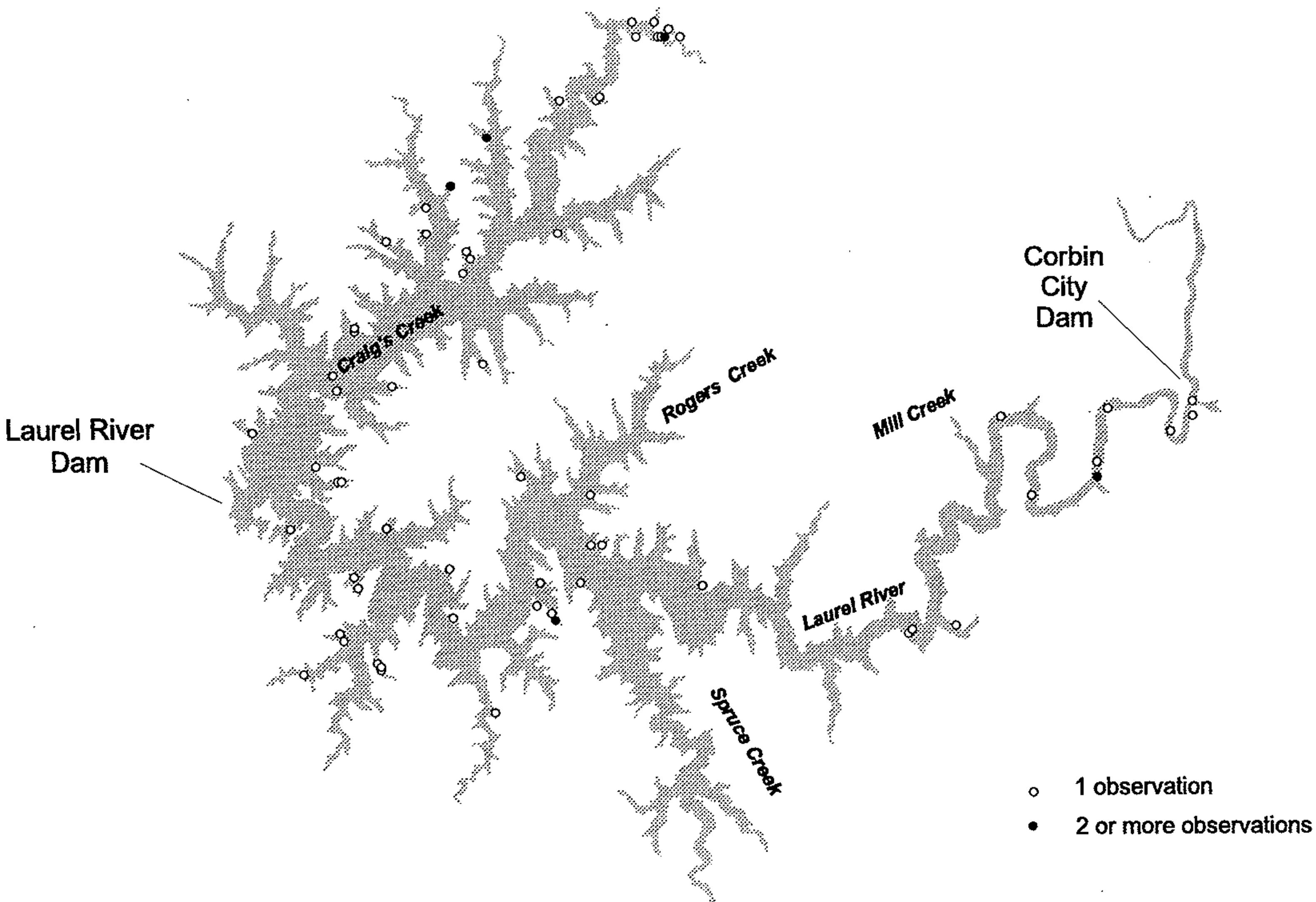

Figure 5. Daytime distribution of walleye during the winter season (December-February in Laurel River Lake.

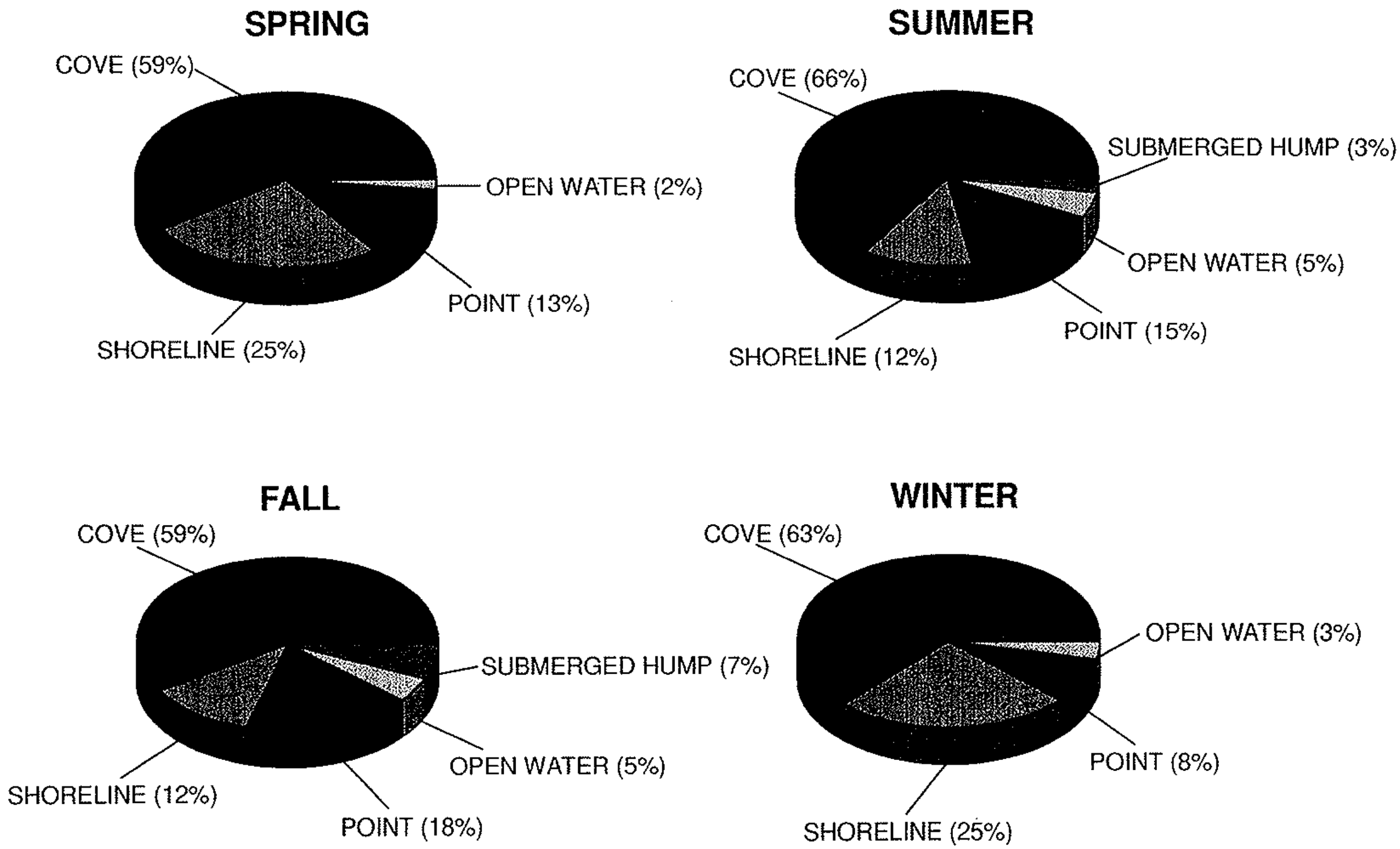

Figure 6. Daytime walleye use of area type by season in Laurel River Lake.

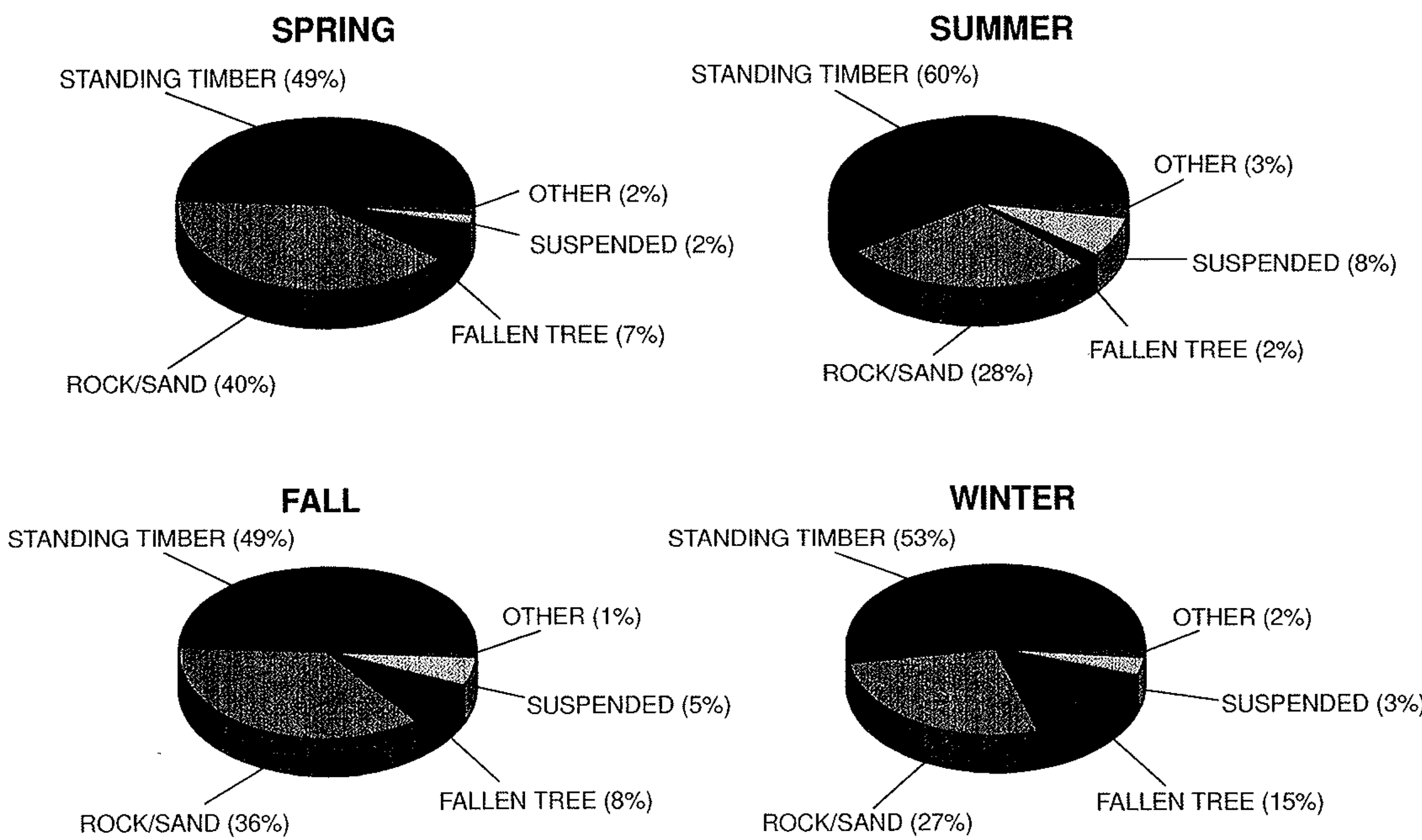

Figure 7. Daytime walleye use of cover type by season in Laurel River Lake.

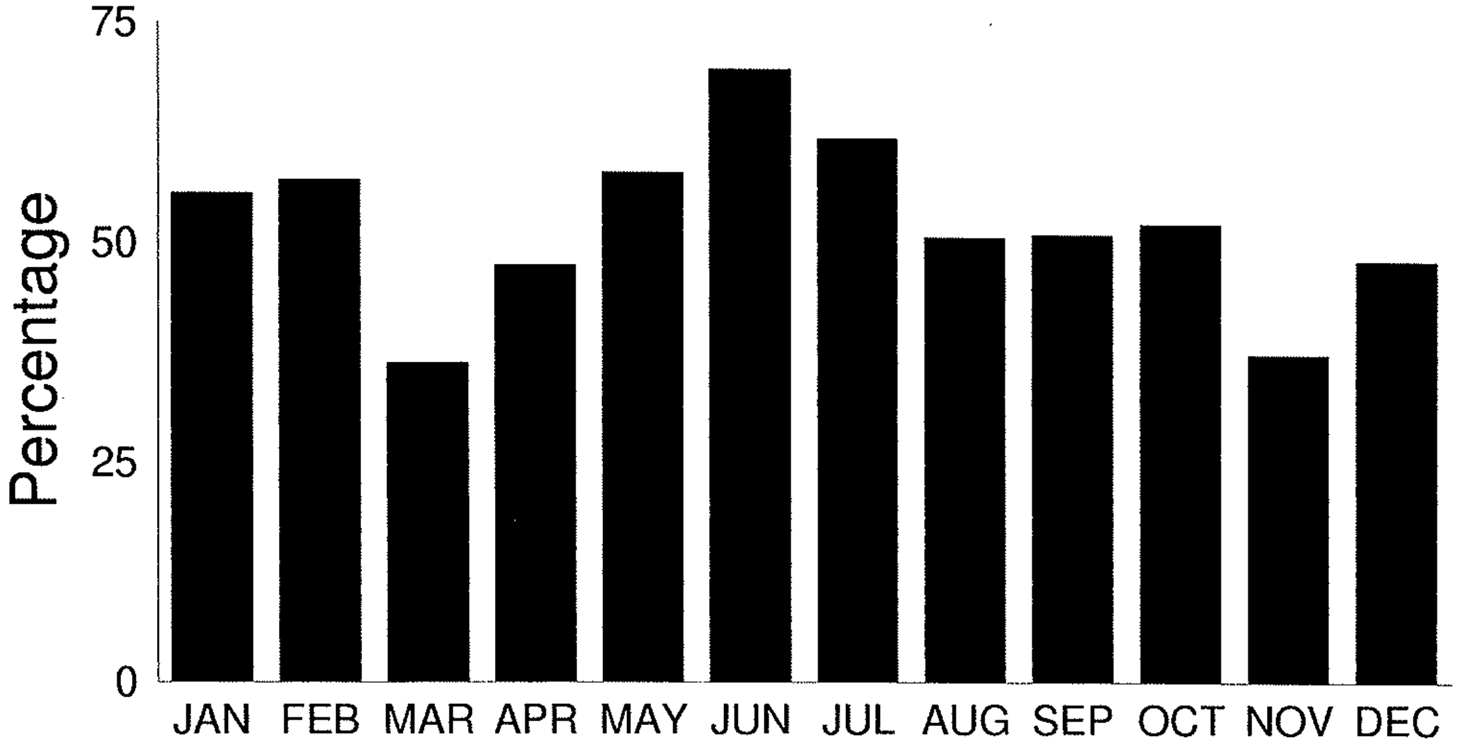

Figure 8. Daytime use (percent) of standing timber by walleye in Laurel River Lake.

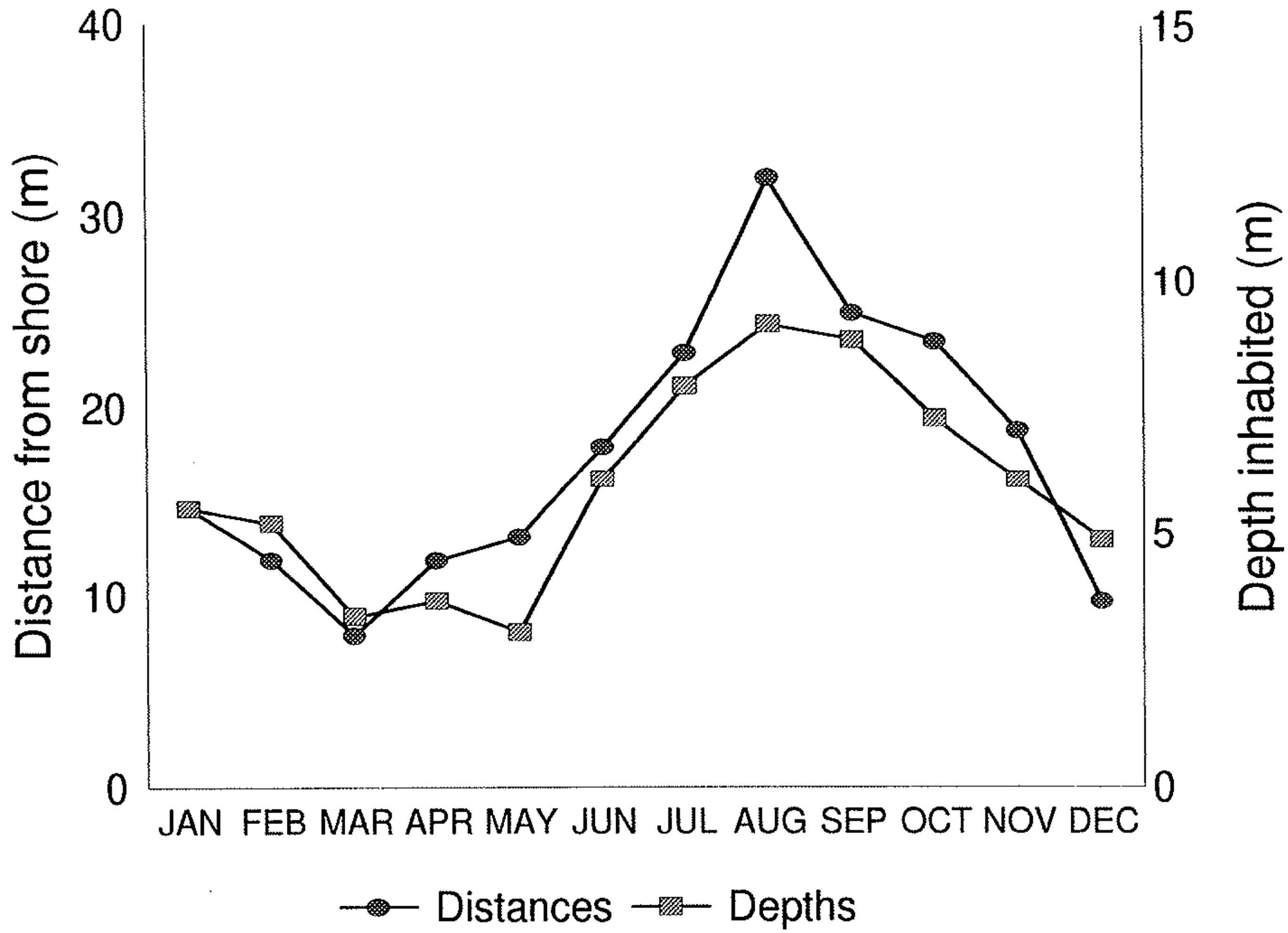

Figure 9. Median monthly depths inhabited and distance from shore of walleye tracked in Laurel River Lake.

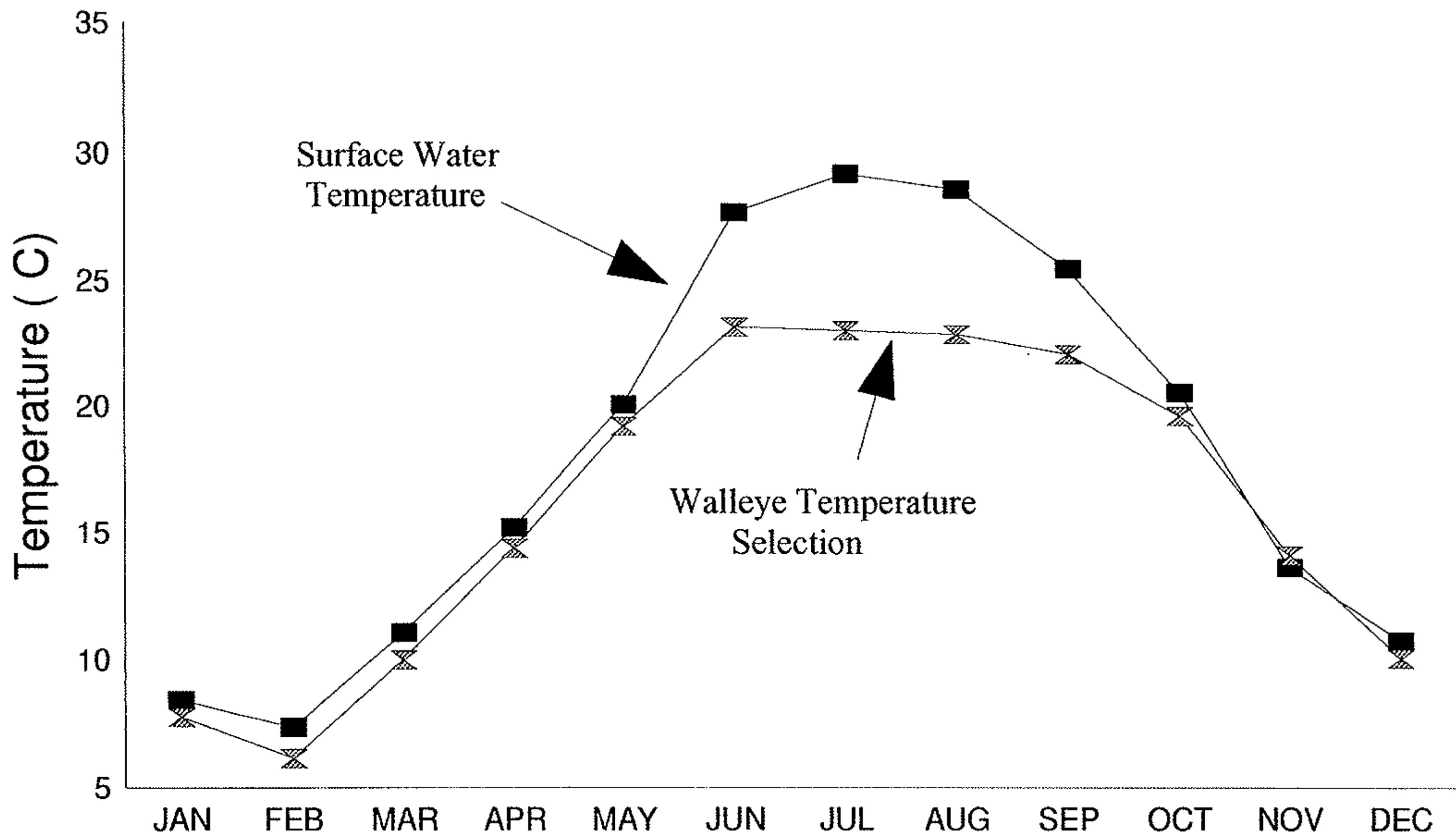

Figure 10. Daytime walleye temperature selection at Laurel River Lake.

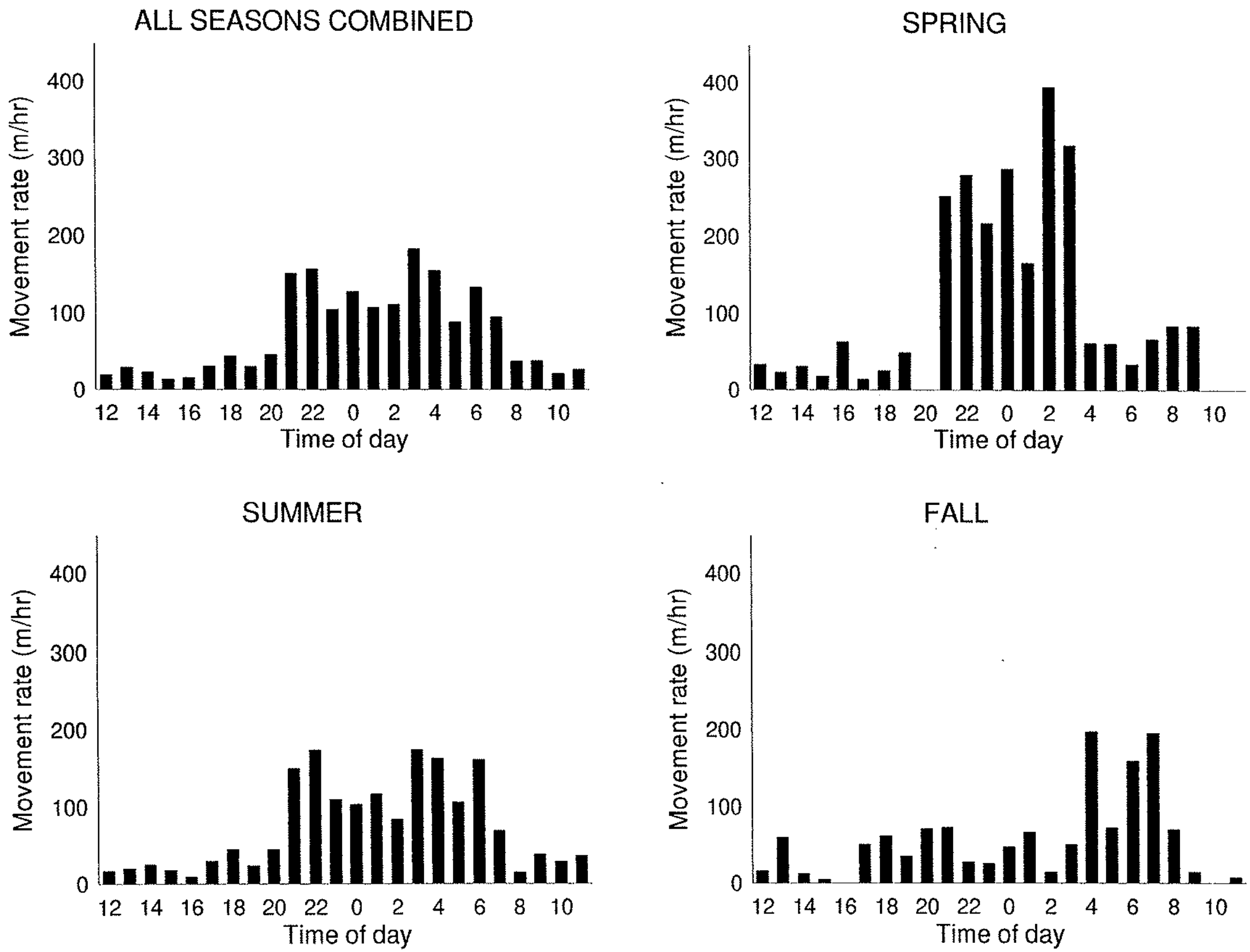

Figure 11. Mean hourly movement for walleye during 24-hour tracks at Laurel River Lake.

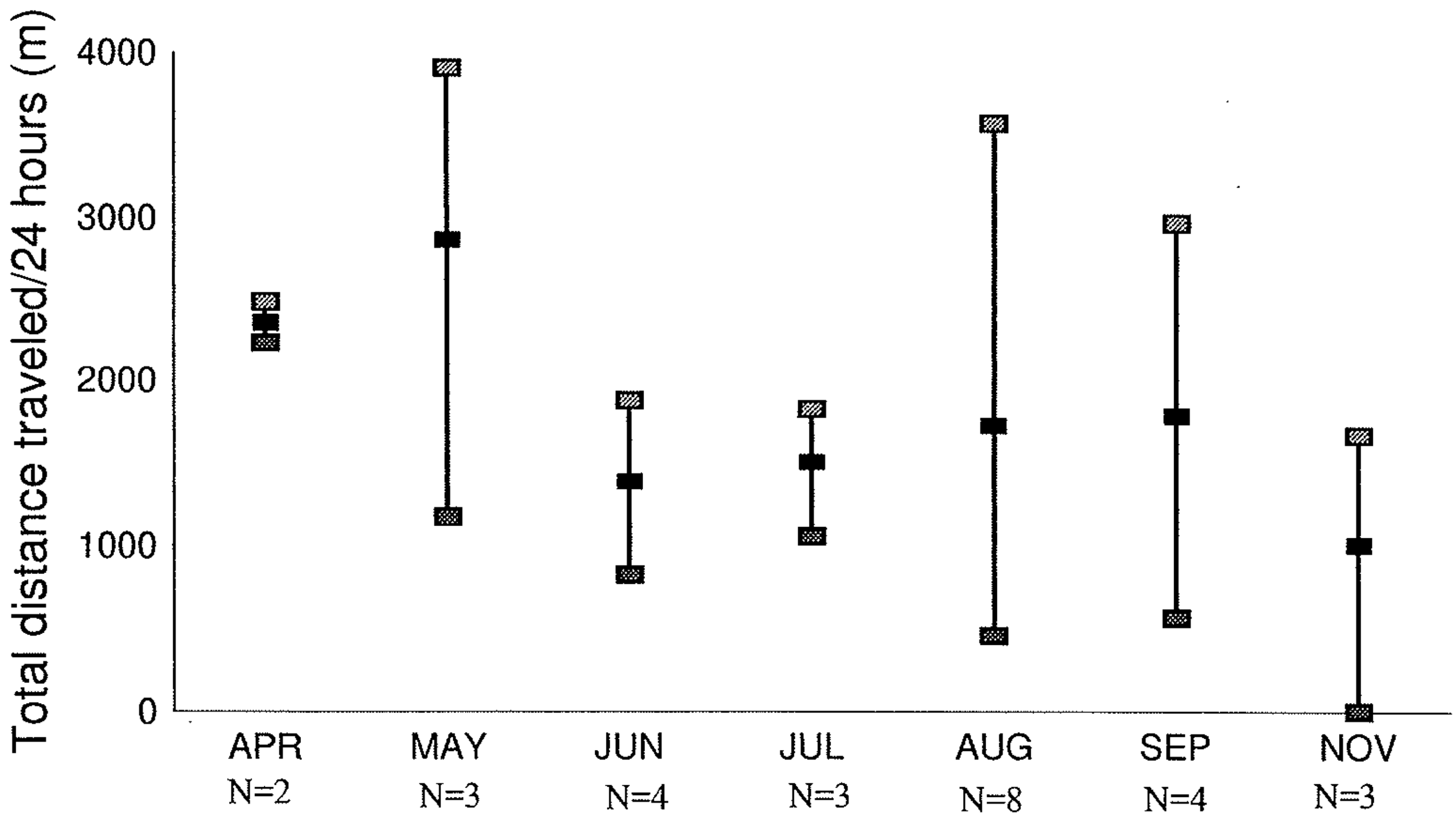

Figure 12. Total distance traveled over 24 hours (range and mean) by walleye in Laurel River Lake.

Table 1. Tagging and tracking data from walleye implanted with radio transmitters in Laurel River Lake, Kentucky (1994-1995).

Tag #	Length (cm)	Weight (kg)	Sex	Capture* Location	Dates Tracked Initial	Dates Tracked Final	Duration (days)	Number of Contacts	Maximum area (ha)	Activity area (ha)	Status***	Date
10	48.5	1.11	F	E	3-22-94	01-09-95	293	36**	733	39	Active	
30	50.5	1.33	F	A	3-18-94	12-21-94	278	27			Inactive	08-09-94
50	50.5	1.25	F	E	3-22-94	11-11-94	234	21	33	33	Active	
70	67.3	3.01	M	D	3-17-94	03-17-94	0	0			Active	
90	49.3	1.11	M	B	3-19-94	03-30-94	11	1			Recaptured	03-27-96
130	52.8	1.65	F	B	3-19-94	01-17-95	304	28	923	97	Active	
150	58.2	2.10	F	A	3-18-94	12-19-94	276	45**	709	31, 60	Active	
170	50.0	1.39	F	B	3-19-94	06-23-94	96	6			Recaptured	03-26-97
190	73.4	4.22	F	C	3-21-95	11-20-95	244	52**	482	2, 108	Active	
210	52.8	1.47	F	A	3-18-94	01-17-95	305	20	710	135	Recaptured	03-26-97
230	54.1	1.65	M	C	3-11-94	09-08-94	181	35**	53	53	Recaptured	03-11-97
231	62.0	2.64	M	C	3-21-95	11-20-95	244	97**	90	90	Active	
250	55.6	1.59	M	D	3-15-94	03-15-95	0	0			Active	
270	51.3	1.59	F	C	3-15-94	03-15-95	0	0			Active	
290	58.4	1.87	M	D	3-15-94	04-04-94	20	1			Active	
310	70.4	3.86	F	A	3-18-94	09-01-95	532	83**	1,075	315	Angled	09-01-95
330	47.8	1.19	F	B	3-14-94	12-19-94	280	75**	353	16,60,104	Angled	05-11-95
350	49.8	1.27	F	B	3-14-94	07-11-94	119	12			Recaptured	03-17-97
370	50.3	1.47	F	B	3-19-94	05-06-94	48	1			Angled	06-06-94
390	54.1	1.56	M	C	3-11-94	09-30-94	203	35**	344	344	Recaptured	03-16-95
410	48.8	1.13	M	A	3-18-94	01-09-95	297	53**	652	78	Active	
430	55.6	1.42	M	E	3-22-94	08-24-94	155	12			Active	
450	62.5	2.58	M	B	3-19-94	10-20-94	215	23	1,419	28, 84	Active	
470	63.8	2.92	M	C	3-11-94	10-04-94	207	30**	498	498	Angled	10-22-94
471	54.4	1.73	F	B	3-10-95	10-06-95	210	15	701	192	Recaptured	03-21-97
490	65.8	3.23	F	B	3-14-94	04-08-94	25	1			Dead	04-16-94
491	74.2	4.08	F	C	3-21-95	11-20-95	244	65**	387	387	Active	
510	56.9	1.84	M	D	3-25-94	03-25-94	0	0			Active	
530	69.6	3.37	M	D	3-15-94	03-15-94	0	0			Tag return	05-03-94
550	74.9	6.25	F	B	3-14-94	10-30-94	230	91**	471	3, 180	Active	
551	56.6	1.53	M	C	3-21-95	10-06-95	199	89**	54	54	Recaptured	03-17-97
570	64.8	2.81	M	C	3-21-95	04-06-95	16	2			Angled	04-10-95
590	51.3	1.31	F	A	12-13-94	05-05-95	143	8			Inactive	05-05-95

Table 1 (continued.)

Tag #	Length (cm)	Weight (kg)	Sex	Capture Location	Dates Tracked Initial	Final	Duration (days)	Number of Contacts	Maximum area (ha)	Activity area (ha)	Status	Date
610	50.0	1.22	F	B	12-20-94	04-19-95	120	8			Dead	07-12-95
630	52.6	1.42	F	E	12-15-94	05-05-95	141	25**			Active	
650	50.8	1.13	M	B	12-21-94	10-25-95	308	24	344	17, 104	Recaptured	03-29-97
670	54.4	1.50	F	E	12-15-94	11-13-95	333	48**	112	43	Active	
690	50.3	1.25	?	C	01-10-95	10-30-95	293	44**	556	171	Active	
710	56.1	1.99	F	A	12-13-94	11-26-95	348	58**	1,509	196	Active	
730	54.4	1.87	?	A	12-13-94	04-19-95	127	9			Dead	07-25-95
750	61.2	1.99	M	D	01-18-95	07-28-95	191	14		3, 76	Angled	08-10-95
770	63.8	2.75	M	C	03-10-95	03-10-95	0	0			Active	
790	56.1	1.67	F	E	12-15-94	11-10-95	330	91**	1,547	80, 143	Active	
830	78.5	6.35	F	D	03-25-94	11-20-95	605	67**	587	587	Active	
850	81.3	6.12	F	D	01-18-95	05-25-95	127	9			Angled	06-10-95
870	70.1	3.97	F	B	1-26-95	11-26-95	304	39**	468	2, 143	Active	
990	66.8	2.92	M	D	03-25-94	11-20-95	605	49	590	590	Recaptured	03-18-96

*Capture location:
- A = upper Laurel River arm (near Corbin City Dam)
- B = middle Laurel River arm
- C = Laurel River Dam area
- D = middle Craig Creek arm
- E = upper Craig Creek arm (near headwaters)

** includes multiple tracks in 1 day

*** Status includes:
- active = alive when last located; present status unknown
- inactive = no movement but unable to recover transmitter
- dead = died or expelled tag; tag recovered
- angled = caught by angler
- recaptured = recaptured by electrofishing; tag recovered
- tag return = tag returned by angler; unknown whether caught or found dead

Table 2. Summary of temperature selection data during summer stratification (June-August) in Laurel River Lake, Kentucky.

Fish	Number of Observations	Mean C	Standard deviation	Minimum	Maximum	95% CI
10	11	23.4	2.4	19.5	26.1	22.4-24.8
50	12	23.9	2.8	20.4	27.0	22.3-25.5
130	12	26.0	0.8	24.6	27.1	25.5-26.5
150	9	25.4	0.7	24.2	26.7	24.9-25.9
170	1	23.2		23.2	23.2	
210	11	25.4	1.5	23.0	27.7	24.5-26.3
230	16	19.4	2.3	15.3	22.9	18.3-20.5
231	12	21.7	1.1	19.3	24.1	21.1-22.3
330	13	24.6	1.5	21.8	26.5	23.8-25.4
350	10	26.3	0.8	24.7	27.6	25.8-26.8
390	14	22.9	1.7	20.4	26.8	22.0-23.8
410	15	23.5	3.2	17.5	27.6	21.9-25.1
430	7	23.0	3.3	19.1	26.9	20.5-25.5
450	12	22.2	1.2	19.9	24.0	21.5-22.9
470	11	22.7	1.7	19.5	25.1	21.7-23.7
471	7	24.0	1.3	22.2	25.4	23.0-25.0
491	10	20.1	0.9	18.9	21.9	19.5-20.7
550	15	21.1	1.9	18.4	23.5	20.1-22.1
551	15	22.4	2.0	18.0	25.2	21.4-23.4
650	8	21.0	2.2	17.3	23.6	19.5-22.5
670	9	22.8	1.9	19.9	25.6	21.6-24.0
690	9	22.0	1.8	20.0	25.9	20.8-23.2
710	9	22.6	1.9	19.8	26.4	21.4-23.8
750	4	23.8	1.0	22.6	24.7	22.8-24.8
790	12	23.7	1.7	20.4	25.8	22.7-24.7
870	7	25.0	0.5	24.4	25.9	24.6-25.4